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# Scoping Workshop on Human Activities and State-of-the-Ecosystem Reporting, February 18 and 19, 1991

Great Lakes Science Advisory Board. State of the Great Lakes Basin Ecosystem Task Force

University of Ottawa. Institute for Research on Economy and Environment

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International Joint Commission's Science Advisory Board

State of the Great Lakes Basin Ecosystem Task Force

# Scoping Workshop on Human Activities and State-of-the Ecosystem Reporting

February 18 and 19, 1991

Hosted by
The Institute for Research on Economy and Enviroment
University of Ottawa
Ottawa, Ontario



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## DISCLAIMER

This report to the Science Advisory Board was carried out as part of the activities of the Task Force on the State of the Great Lakes Basin Ecosystem. Although the Boards supported this work, the specific conclusions and/or recommendations do not necessarily represent the views of the International Joint Commission, the Science Advisory Board or the task force.

# TABLE OF CONTENTS

# TABLE OF CONTENTS (CONTINUED)

# TABLE OF CONTENTS (CONTINUED)

APPENDICES, CONTINUED

# LIST OF TABLES AND FIGURES

TABLE



FIGURE



EXHIBIT

# FOREWORD

A lot is known about the economies and demographics in the states and provinces surrounding the Great Lakes. A fair amount is known about the environment in this same area. But despite the obvious and strong relationship between human activity and environmental degradation in the Great Lakes Basin Ecosystem, little data has been collected which links the two and the data that does exist is rarely collected in a consistent and comparable manner.

In preparing for the State of the Great Lakes Basin Ecosystem report, the Science Advisory Board of the International Joint Commission set out to address this issue by organizing the Scoping Workshop on Human Activities and State of the Ecosystem Reporting. The workshop was hosted by the Institute for Research on Environment and Economy at the University of Ottawa on February 18 and 19, 1991. The workshops 19 United States and Canadian workshop participants were chosen from government, the private sector, non-governmental organizations and the Science Advisory Board.

Two major themes: data and information system problems; and environmental reporting, current programs and practice; were addressed by those making presentations. Other themes emerged from the presentations and discussions that ensued. This report discusses these themes with a view to developing a framework for ecosystem reporting under the Great Lakes Water Quality Agreement which satisfies the needs of the International Joint Commission in relation to the assessment and evaluative functions required under Article VII.

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# 1.0 RAPPORTEUR'S REPORT

## 1.1 Data and Information System Problems

*Prepared by Ms. Laura Stovel and Ms. Carla Nell*

*The Institute for Research on Economy and Environment, University of Ottawa, Ottawa, Ontario*

The Great Lakes Water Quality Agreement (Annex 2) presents a systemic and comprehensive ecosystem approach to the management and restoration of impaired uses of Great Lakes resources. To achieve this objective, a holistic analysis of the state of the Great Lakes is required. Integrating socio-economic behavior variables with ecosystem variables is essential for informed and effective management schemes responding to environmental stress. Traditional ad hoc responses to Great Lakes crisis management must be discarded in favour of a cohesive, long-term strategy.

Computerized databases are important elements in reaching this long-term goal. Unified systems impose a structure and direction for data gathering and assembly. David Allardice of the Federal Reserve Bank in Chicago and Robert Hoffman of Robbert Associates in Ottawa discuss some of the problems of existing data collection and suggest frameworks for data collection in the future.

Discussions about data and information system problems focused on the following questions:

- How can human activities within the Great Lakes basin be linked to the Great Lakes Basin Ecosystem?
- What are the key economic and social indicators that monitor environmental stress within the basin?
- What is the appropriate conceptual framework for linking socio-economic databases with the biophysical databases on the state of the Great Lakes?
- What role should the International Joint Commission (IJC) play in efforts to achieve these objectives?

The workshop attempted to provide a forum through which realistic conclusions to these questions could be reached. Ideally, the proceedings would reveal new management directions and initiatives to be taken by the IJC for the Great Lakes Basin Ecosystem.

### 1.1.1 United States: Too Much or Too Little? **David Allardice**

Some say that the data collection and analysis needed for environmental legislation and policy making in the Great Lakes region have proceeded far enough. We know the basic directions we should go in trying to prevent further environmental degradation. It is time to put policies in place and enforce them.

Other insist that links between human activity and the ecosystem are complex and the data we have does not reveal enough about these linkages. We need to continue monitoring human-environment interrelationships before responsible policy decisions can be made.

In his presentation on human activities affecting the Great Lakes Basin Ecosystem, David Allardice said that both positions are valid. A lot of data on the environment and economy is available and we know enough to make some basic policy decisions, but most available data is not useful because it is not consistent and comparable across the basin.

Aggravating the difficulty of assessing economyu-environment linkages, these interrelationships are not static. Economies evolve and with that evolution comes a change in the environmental problems to be addressed. New environmental str4essors may emerge and add to the legacy of the accumulated stock of environmental degradation. This implies that socio-economic data collection needs to provide relevant information on the economy, environmental stresses and responses to enable flexible environmental assessment and decision-making.

Such a unified database does not yet exist although organizations such as the U.S. Environmental Protection Agency, Statistics Canada, Environment Canada and a number of private agencies are working to that end.

Researchers are also concerned that data collection cannot respond quickly enough to the evolution of human activites and environmental responses. There is an inevitable lag-time in data collection which affects the ability of data to accurately reflect changes.

Many problems have arisen concerning the collection and integration of environmental information into one useful database. The traditional chasm between the physical and social sciences is reflected in the data collection process. This results in the fragmentation and incompatibility of different information sources.

Allardice discussed problems encountered in creating socio-environmental databases. Although abundant data exist, researchers studying socio-environmental conditions in systemically defined (and non-political) regions such as the Great Lakes watershed basin find a paucity of consistent, credible and comparable, socio-environmental data that they have to rely largely on demographic and economic information.

Even this is problematic. The concept of natural regions is absent in socio-economic data collection. Consequently, the activity space is subdivided according to jurisdictional and administrative (political) boundaries which rarely match up with the watershed boundaries desired. Using this data, researchers of the Great Lakes watershed basin can only approximate population, employment and production data within the watershed boundaries.

It was suggested that drainage basin and ecological identifiers could be applied to data collection regimes within the basin region.

There is also a paucity of data on land-use change. This data is key to understanding the relationship between human activities and environmental change. In addition, the lack of relevant information reflects the institutional biases of data collection. Choices of variables and priorities depend upon clients' needs. This institutional bias extends to geographical, ecological and economic perspectives.

If databases are to be used effectively for ecosystem management, these issues must be addressed and priorities established for data collection.

### 1.1.2 Canada: A Framework for Information Management **Robert Hoffman**

Robert Hoffman presented an information management regime and framework designed to organize data on human activities and environmental quality within the Great Lakes basin. In creating this prototype framework, relational components were developed to enhance information content and maintenance.

The framework identified possible modeling relationships to determine and achieve the human behavioral adjustments needed to reduce ecosystem stress. It is based on a conceptual hierarchy for data arrangement[1]. The spatial hierarchy allows users to manipulate information within various spatial dimensions and to analyze and interpret information at different geographic scales. This also helps reveal the level of interdependence of variables

This potential database structure is important because it can maintain multiple histories of data. It can be updated as necessary and can manipulate stored information to allow for data interpolation and extrapolation. Thus, the information base can be used for predictions.

Hoffman discussed the difficulties of creating the database above. Problems predominantly concerned data manageability. Like Allardice, Hoffman encountered a lack of uniformity and compatibility between data sources, especially between American and Canadian ones. Problems arise because of the different scales at which data are collected. Relevant data on human stresses on the environment are also rare.

Brand Niemann of the U.S. Environmental Protection Agency suggested that traditional modeling tools used to address interrelationships between the economy and the environment are no longer useful. Derived relationships collapse during the prediction stage of analysis and interpretation. As a result, past responses to ecosystem issues have been inappropriate and have not addressed the real concerns.

Economic variables must be examined to assess their effects on the environment. These should be targeted as the mechanism for change in natural resource use. In the past, research and data collection have been supply and production oriented. A new emphasis on resource consumption is required to facilitate demand and supply management. A new paradigm must be considered which will allow a new concept of wealth and ecology to emerge.

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[1]For example a hierarchy from general topics to specifics with agriculture at the top, then farm type, then cropping practices, and below that: crop.

The issues involved are complex and goals must be reasonable. The attidue that economies and the environment have competing interests must be discarded. Stress indicators within the ecosystem must occasionally be simplified so that they are manageable and so the essential issues can be dealth with.

In spite of growing demands for environmental databses, too much emphasis on data collection can undermine understanding of the economy-environment relationship. The only effective response to environmental damage is to adjust human activities and behavior which created the stresses. By modifying human resource use, environmental impacts will hopefully lessen.

Comparing the Hoffman and Allardice approaches for creating a database to deal with ecosystem stresses, fundamental differences in conceptual modeling were observed. Hoffman organized data within the realm of software capabilities. Micro data was used to reflect human activity change within a spatial context. Allardice analyzed demographic and economic trends, cycles and structural changes to help interpret the stresses placed on the natural environment of the Great Lakes basin.

The approaches need to be integrated. Historical precedents, communicated through technologically-advanced means, would increase the cpacity of researchers and decision-makers to accurately evaluate ecosystem stress. Only by providing a framework that integrates the many components of the environment-economy relationship can a holistic management approach be achieved.

## 1.2 Environmental Reporting: Current Programs and Practice

The first part of the International Joint Commission Scoping Workshop on Human Activities and State of the Ecosystem Reporting examined problems facing, and needs of, researchers of human-environmental relations in the Great Lakes. The second part looked at the development of environmental statistical databases and state of the environment reporting practices in Canada and the United States. It attempted to answer three questions:

- What information systems are in place in Canada and the United States?
- What is the influence of the political agenda on the development of these systems?
- Do these positions suit the needs of policy-makers and researchers?

Brand Nieman of the United States Environmental Protection Agency, Paul Rump of Environment Canada and Kirk Hamilton of Statistics Canada, outlined their respective agencies approaches to data assembly. In doing so, they reveleased the fact that data collection is not an apolitical act. The effort put into collection, the type of information collected and the organization of this information reveal political attitudes.

David Rapport of the Institute for Research on Environment and Economy and Tony Hodge of McGill University asserted this when they presented two very different assessments of the direction that data collection should be going in trying to help decision-makers meet the environmental challenges facing society.

### 1.2.1 "He Who Pays the Piper, Calls the Tune" — David Rapport

David Rapport opened his assessment with the remark: "He who pays the piper, calls the tune." The political powers that be, don't seem to be serious about environmental improvement and this is the crux of the problem. "Do we need more cud-chewing and science, or more commitment?" With that, he set the tone for the day's discussions.

Compartmentalization of the ecosystem into water, air and solids is dangerous. Stop-gap approaches ignore larger issues like whether the environment can support our current lifestyle or if changes are needed in consumption patterns and attidues toward land development. A holistic approach addresses these issues.

### 1.2.2 United States: U.S. EPA's Approach to Data Collection and Policy Enforcement

**Robert Hoffman**

The U.S. EPA is setting up a Center for Environmental Statistics. This center will act as a centralized repository of databases which will be easily accessible for researchers and decision-makers. In this capacity, the center will be responsible for:

- **Information Management**

Information Management involves data analysis and information dissemination. The centre does not have a mandate for primary data collection but it analyzes and organizes data from federal, state, local and private sector data-collecting organizations. In an uncoordinated state, this pool is "data rich" but "information poor." The Center is therefore trying to develop a framework to assist in compiling, reviewing and updating a core series of "good" data.

To ensure that the data assembled by the Center is useful to environmental researchers, data will have to meet certain criteria. Data will have to be:

a) Validated with quantifiable quality assurance protocols and parameters;
b) Wherever possible, integrated across media (air, water, land);
c) Wherever possible, integrating media information and natural resource data to represent complete ecosystems;
d) Comparable across time and location;
e) Obtained by statistical designs permitting quantifiable inferences and justifiable conclusions; and
f) Unbiased; not influenced by regulatory needs.

(Source: The EPA Statistician, Summer 1990)

- **Transition From Paper to Electronic Reporting**

A Major function of the centre is to make user-friendly computer software with a statistical profile to document data. A bibliography of reliable data is available on disk and can be ordered free of charge. Niemann welcomes a review of this. Some PC versions of data systems available from the centre are:

a) The World Resources Institute Guide to Key National Environmental Statistics in the U.S. Government (1991)
b) The 1991 EPA Guide with Links to Data Results

c) The Prototype Global Change Master Directory of the Interagency Working Group on Data Management for Global Change (1991)

- **Special Analyses and Development of Core Data Base**

The centre will "conduct special analyses of specific environmental issues to promote the development and application of new methods of statistical analysis." It also identifies, refines and promotes the collection of a core data series of environmental indicators for use in future state-of-the-environment reports.

**1.2.3 Environmental Reporting by the Canadian Government**

Although the International Joint Commission was created in 1909 to review transboundary water problems and advise the Canadian and American governments on the cleanup of the Great Lakes, only recently has the Canadian government become involved in environmental issues on any significant scale. The Department of the Environment was not formed until 1972, three years after the creation of the U.S. EPA. Not until 1988, with the passage of the Canadian Environmental Protection Act, was environmental legislation integrated under a single act of parliament.

Environmental reporting by the Canadian government is jointly carried out by Statistics Canada and Environment Canada. These ministries collect their own data and receive information from other federal departments, non-government officials (NGOs), and provincial and territorial governmental sources. Environment Canada and Statistics Canada are also advised by interdepartmental committees and the Public Advisory Committee made up of members from industry, academia and NGOs. Their combined efforts lead to the 1991 publication of the second edition of the "State of the Environment Report" by Environment Canada and a companion report by Statistics Canada called "Human Activity and the Environment."

In December 1990, Environment Canada, released an environmental plan called the Green Plan. Many Canadians hoped that this plan would provide a focus and direction for environmental policy and private action for the next few years. For many, the Green Plan fell short of that goal. Critics said that instead of taking an holistic, preventative approach to environmental management, the plan offered piece-meal remedies.

Paul Rump of Environment Canada expands on this report and explains how the 1991 "State of the Environment Report" and a book on indicators released this year will help the federal government meet its policy objectives.

- **SOE Reporting at Environment Canada** **Paul Rump**

The 1990 Green Plan sees SOE reporting as a fundamental tool for federal environmental decision-making. The plan looks at developing a set of indicators which will then be used as measures of environmental quality. Some indicators will be linked to targets; others will describe environmental trends.

a) Possible indicators of the state of the environment are:

- ph level of rain as a measure of acid rain
- Waterfowl population as a measure of wildlife conditions
- Ambient $CO_2$ to measure climate change

b) Indicators of stress from human activities could include:

- $SO_2$ deposits
- Wetland habitat loss

c) Management response could be measured by examining trends in the rations of, for example:

- $SO_2$ emissions/targets
- Waterfowl population/targets

Desirable properties of indicators are:

- Feasibility
- Reasonable time and cost of collection
- Scientific credibility
- Understandability by the public
- Ability to provide early warnings
- Ability to detect trends

After the indicators are developed and in use, the government may want to develop a set of indices, or packages of indices, which will be easily understandable to the public and decision-makers and useful to researchers. Examples of these would be a water quality index and a household environmental response index. Development of indices, however, is a long-term goal.

Besides the "Green Plan" and the "State of the Environment Report," Environment Canada also produces an annual SOE policy statement, the "environmental equivalent of the budget" (Rump).

In spite of the efforts of Environment Canada and Statistics Canada, there are major gaps in available data such as data on solid waste disposal.

- **Statistics Canada** **Kirk Hamilton**

While collection of physical data is performed by a wide variety of provincial and federal departments, the Canadian government has centralized the collection and dissemination of socio-economic data in the hands of Statistics Canada. Because environmental data is mostly physical, the data compiled by Statistics Canada is mostly collected by environment and natural resource organizations. This poses two problems for Statistics Canada.

a) If Statistics Canada is going to integrate and disseminate physical data in a meaningful way it needs staff equipped with appropriate physical science training.

b) Since Data collection takes place outside Statistics Canada, there may be questions about the quality and statistical validity of the data (Hamilton).

Drawing statistical relationships between environmental stresses and stressors is difficult. Unlike economic data, which is given the system of National Accounts framework, natural systems are inherently complex and physical data are inconsistent in time, space and physical measurement. It is therefore rarely possible to make definite associations between changes in environmental state and inputs to, or pressures on, the system.

Pragmatism and impartiality are needed. A framework for environment statistics should measure stresses on the environment and changes in the state of the environment while making no unwarranted claims about cause and effect.

Statistics Canada has traditionally collected some socio-economic data that is relevant to the environment. These include capital expenditures on pollution control, provision of goods for environmental protection and morbidity and mortality data relating diseases with likely environmental causes. Information like this can be useful for environmental analysis when combined with other environmental data. The use of outlay mapping of socio-economic activity of physical space based on GIS technology is particularly pertinent for macro-level environmental assessment.

This information can become voluminous and cumbersome. Indicators are needed to simplify evaluation. One example of a successful environmental indicator is the Air Pollution Index published by

Environment Canada. This combines data on particulates, hydrocarbons and nitrogen oxides and is designed to indicate threats to people with problems of the pulmonary tract. As opposed to having one, aggragate, environmental index, indicators like the Air Pollution Index need to be designed with a specific audience in mind.

There is a need to bring environmental statistics into the System of National Accounts. According to Hamilton, two problems with the accounts is that they measure "goods," not "bads," and there is no way to determine from the accounts whether economic development is proceeding sustainably. So far there is no satisfactory way of doing this.

Capacity for information organization and reorganization is much better than before. Now a focus is needed. The national accounts were developed from concerns about unemployment in the 1930s. Today's world of overemployed resource and environmental degradation needs new approaches to national accounting.

Some participants felt that organization of information is improving; others see declining commitment to these issues in the federal government. Such deterioration can be seen in the dissolution of the Land Directorate in Environment Canada.

The IJC could provide leadership in this area. It could provide the focus of SOE reporting unhindered by the referee-player problem prevalent in government institutions. Some participants felt that SOE reporting may not be proceeding in an integrated way at Environment Canada and Statistics Canada. There is a lot of relabelling of bottles. An organization such as the IJC could advise what needs to be done and why and encourage the allocation of resources to that end.

Some felt there is a lack of ecological knowledge in Statistics Canada. No one on any of the Statistics Canada advisory councils has ecological expertise, Judy Smith said. There is no integrated approach. Solid environmental criteria must be put in place and the people "can talk about how to manage that," she said. The IJC report on indicators is encouraging in that regard.[2]

Forty years ago, pioneering work on ecological approaches to land use classification was carried out in Ontario by Angus Hill. This work was largely ignored - a missed opportunity. (Caldwell).

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[2] A Proposed Framework for Developing Indicators on Ecosystem Health for the Great Lakes. John Cairns, Paul McCormick and Barbara Niederlehner.

We are not even heading in a unified direction, David Rapport pointed out. In Canada we are moving from a macros (holistic) approach to a micro approach. In the United States, led by the EPA, this trend is being reversed.

### 1.2.4 The Great Lakes/Great Legacy Experience — Tony Hodge

Tony Hodge examined the lessons from years of producing "Great Lakes - Great Legacy."[3] Hodge argued that SOE reporting is not effectively linked to the decision-making process. If environmentalists want politicians to support their policies, they must learn to speak in a language politicians understand.

The reason that an holistic approach to the environmental policy and assessment has not been embraced is political: it does not speak to decision-makers; it only converts the converted - i.e. ecologists. To Hodge, an holistic approach is unrealistic when trying to combine the interests of natural ecosystems and political agendas.

Although biota, land, water and air are integrated, they all operate within different space and time frames. Policymakers have not been able to make effective, long-term management decisions because they operate in a very short time span, or within the electoral period.

An holistic approach is also too complex to be politically acceptable. Decision-makers want compartmentalization of issues. They want issues they can understand quickly and can convey easily to the public. Broadcast media, which convey politician's views to the public demand this speed and simplicity.

The natural system's behavior cannot be changed but human behavior can. Therefore reporting behavior should focus on human behavior to improve harmonization of economic and environmental objectives. Both market and non-market variables have to be examined. An economic approach to environmental management should not be dismissed because the economy will always be in the forefront of decision-maker's concerns. Hodge summarizes by saying that for change to begin, the existing decision-making framework and priorities may have to be used as a foundation.

Hodge's arguments and Environment Canada's search for indicators and eventually, indices, which are understandable by the public, assume that the best way to get responsible environmental legislation is to make science speak to the public and decision-makers in the simplest way possible. It is taken as given that politicians will only act on simple, easy ideas which the public will understand and credit them with. Indicators are a good way of providing symbols for otherwise complex systems.

Some of the participants disagreed with this approach. Symbols like GNP then become ends in themselves and their original intent are lost in the fog of time. Indicators are simply one medium of commmunication. Perhaps scientists have to become better communicators so they can inform the public and decision-makers of the issues at hand or perhaps a whole new profession of scientific media experts needs to be encouraged.

Lynton Caldwell noted that it is wrong to determine scientific practice on the basis of the interests of decision-makers. It wasn't in the interests of big land holders to encourage the work of geographer Angus Hill and his studies of land use, yet this was socially important work.

The environmental issues that politicians are looking at now were brought to the table because of their interest in the issues but because of public and scientific pressure. Scientists and the public took "decision-makers where they are now. Maybe we should be saying what we do want them to be like." (Caldwell).

At the same time, however, there should be some concern about the co-option of powerful interest groups and the political desire to simplify the decision-making model.

Two very different approaches to environmental management were offered above. One deals with handling the stock and flow of natural resources; the other discusses how to deal with the health of the ecosystem.

The EPA takes a cooperative, pragmatic approach to implementing environmental policy. It successfully encourages industrial polluters to voluntarily reduce emissions. This ensures cost-efficient pollution abatement. It may be easier for a company to cut emission in plant A than in plant B. Companies are more likely to cooperate with a quota system because they are given flexibility.

Economists and ecologists each want to approach analysis and reporting problems from their points of view, or at least see that all of their concerns are treated. Common ground needs to be found. One possible starting point suggested by Niemann is toxic emissions inventories. Ecologists would look at the relations between toxic emissions and environmental responses; economists would look at relations between toxic emissions and the industries that produce those emissions. The latter would also look at the options for modifying human activities to reduce toxic emissions (for example, reducing demand for products that involve emissions of toxics in their production).

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[3] Great Lakes - Great Legacy. The Conservation Foundation, Washington, D.C. and The Institute for Research on Public Policy, 1990.

The IJC should develop a pollution prevention plan for the basin that reflects an understanding of the relationship between toxic emissions and human activity/economies and the benefits that will likely accrue to the basin environment from a reduction in those emissions. The pollution prevention plan for the basin would include the information tools for political leaders to implement the plan (Niemann 1991).

# 2.0 ANALYTICAL REPORTS ON HUMAN ACTIVITIES

## 2.1 Analytical Report on Human Activities Related to the State of the Great Lakes Basin Ecosystem

*Prepared by Ms. David R. Allardice, Federal Reserve Bank of Chicago, Chicago, Illinois*

### 2.1.1 Introduction

Economic and environmental events stemming from the 1970s have made society much more aware of the interrelationship between the availability and quality of natural resources and economic prosperity. The relationship between the human economy and the natural resource base has always existed since to create and expand economic output and to sustain life man has had to draw upon the natural resource base.

While there has been an increased public awareness about environmental issues over the past 20 years, a significant portion of the population remains uninformed about the nature of the natural resource base and its role in our modern economy. Environment and energy concerns seem to wax and wane, following the very large and well publicized ecological disasters or energy price shocks. Currently, events in the Middle East have focused public attention on both the long term energy and environmental impacts arising from the conflict.

With the public attention more closely focused on issues of world economic interdependence, the availability and cost of energy resources, and the availability and quality of natural resources, this report attempts to provide a factual basis upon which to further advance the dialogue concerning the relationship of the ecosystem to human economic activity and, in turn, how economic changes impact upon the ecosystem.

In particular, this report focuses on a unique and valuable human and natural ecosystem - the Great Lakes basin. Several features of the basin make it an ideal laboratory for studying the interrelationship between the human and the natural resource dimension. While fresh water is its dominant natural resource (representing about 18% of the world's supply), other resources are present and diverse. In addition the basin has a large binational population. More than one-tenth of the United States and one-quarter of the Canadian populations reside in the basin. Added to the population and natural resource base is one of the world's largest concentrations of industrial capacity. An additional dimension is added by the recognition of agriculture; almost 25% of the Canadian and 7% of the United States production is generated in the basin.

While the basin represents a large geographic region (a total land and water area of about 296,000 square miles) it is sensitive to a wide array of pollutants. The sources of pollution come from industrial discharges, runoff of soils and farm chemicals, waste from municipalities, and leaching from landfill sites. This large surface area also makes it vulnerable to atmospheric pollutants that arise both within and outside the basin.

Another aspect of the basin's ecosystem is that pollutants that enter the system from the various sources, tend to be retained and become more concentrated over time. This is due largely to the fact that outflows from the basin are relatively small - about 1% a year. This aspect alters the time relationship between human impacts and ecological effects. Many of the ecological problems that exist today are the result of human and economic actions taken decades ago. On the other hand, current economic activities may be having impacts on the ecosystem that will not be measureable and identifiable for decades to come.

### 2.1.2 The Need for Information and Analysis

Given the economic and natural resource importance of the Great Lakes basin, it is not surprising that numerous studies, reports, programs, institutions, laws and regulations have been produced to deal with the complex web of economic and ecosystem issues. The question might be asked as to whether we know too much or too little about the nature and extent of the problems of the basin.

Some argue (as they did at the fifth biennial meeting of the International Joint Commission in 1989) that there has been enough scientific research and data collection to support what the environmental dangers are and that what is required are laws to prohibit various practices. Others will contend that there needs to be more analysis and data collection, due to the fact that with more information and improved technology we are inclined to view these problems differently over time. As might be the case with any argument, both parties are correct to some degree.

In the process of preparing this report we have relied upon data from a diverse set of public information sources in an attempt to focus on the extent of human activity in the Great Lakes basin. Reviewing the data sets that are available reveals a wide array of information. Therefore is there a need for more information? The answer is yes for a number of reasons. First, much of the data compiled is done on a geographic basis (such as state level data) that is not comparable with basin boundaries. Some of the data for this study were restructured to make it confirm to the basin boundaries. Other data have been examined that were prepared for particular studies, but lack a historical time series upon which to draw from.

One of the major data problems that exists is the lack of consistent, comparable, and easily accessible data for the Canadian and United States sides of the Great Lakes. While the two nations share a common border and have many of the same concerns over public policy issues relating to the Great Lakes, they maintain separate and distinct data systems. While there are ample explanations for these differences, it does impede the conduct of research and data analysis. A joint US-Canadian center for Great Lakes data and information could serve a useful purpose for both policy makers and researchers.

A question is also raised about the types of data that are collected. The underlying economic structure of the Great Lakes basin is going through a significant transformation. The once dominant industrial base is being restructured toward more of a service economy. This alteration implies changing impacts on the natural resource base. As we generate less of one type of pollutant as industry is altered, we generate more of other types of pollutants arising from human activities, such as municipal waste. Data collection is slow to respond to these changes. Furthermore, in times of fiscal constraints, as both Canada and the United States are experiencing, to add and alter the data collection process is both costly and unlikely. Thus, the data needed to address the questions of human activity impacts on the environment are constrained.

In conjunction with the need for available and enhanced data reflecting human actions and the state of the ecosystem is the need for improved analysis of the impact of human actions on the ecosystem. This improved analysis has both physical and social science dimensions.

Advances in the physical sciences over the past decade have improved our understanding of the effects of human activity on the ecosystem. These scientific advances have also enhanced the ability to deal with the ecological problems that were created due to past actions. It is reasonable to expect that changes in scientific knowledge will be even more startling during the next decade.

A major challenge remains in terms of the development of theories and models that emphasize the relationship of the economic process to the natural resource base. This relationship continues to provide the basis for much debate and disagreement among policy makers and academics.

The role of natural resources has not been central in much of modern economic theory. With natural resources being abundant and cheap relative to labor and capital, there was little reason to include natural resources in economic models. The mainstream theory that evolved was founded on the premise that, in general, resource shortages and reductions in quality cannot be a serious long run problem because technological change responds to resource-related problems by extending the life and quality of resources. During the mid 1970s, this line of reasoning led to research that showed that a constant per capita income could be sustained even with increasing resource scarcity by substituting capital for natural resources. The key assumption in the analysis was that scarcity induced technological change will always correct a scarcity induced economic problem.

Environmental, energy and economic shocks of the 1970s revealed the inability of conventional economic models to deal with these shocks. An outgrowth of this lack of ability to deal with the environmental-economic problem resulted in the expanded use of what is known as biophysical economics. This approach focused on the use of thermodynamic and ecological principles with emphasis on the role of natural resources in the economic process and to focus on the areas of economic theory that had overlooked basic environmental considerations.

While operating under different concepts, the basic ideal of the biophysical or materials balance approach to economic analysis is that economic activity cannot violate the laws of conservation of matter and energy. The economic process by which man transforms raw materials into economic goods neither creates nor destroys matter - it merely alters its form. From an economic accounting point of view, all materials that exist in the economic system at the start of the year plus those extracted over the course of the year will equal those in the system at the end of the year.

The materials balance approach is an identity in that with a given stock of materials in an economy, the increase in the stock of materials must equal the excess of withdrawals from over discharges to the environment during the year. Thus the economic system focuses on all the activities that use materials and contribute to an expansion in the standard of living. As defined by Mills (The Economics of Environmental Quality 1978, p.) human economic activity "includes extraction of materials, production and consumption of goods and services, and the disposal of materials when they are not wanted in the economic system."

Two points are noted. First the materials balance approach, rather than separating, more clearly defines the relationship between human activity and the environment. Human activity has important and controllable effects on the environment. Not all materials returned to the environment need to have adverse effects; however, many do. Thus, the welfare of individuals is influenced by environmental quality variables. The difficult empirical task is to define the nature of the utility function and the extent of the damage.

The second point to consider is that while the overall concept of materials balance is conceptually straight forward, it is most difficult to have a system of accounts that is accurate enough to define the nature of the withdrawals and discharges into the environment. This is even more of a problem in a system such as the Great Lakes where the imports of materials and discharges of other regions and the exports of such materials and discharges are even more difficult to document and identify.

### 2.1.3 Human Activity and the Great Lakes

With the previous sections as background, the Federal Reserve Bank of Chicago undertook an effort to define the nature of human activity within the Great Lakes basin, with the primary focus being on the United States portion of the basin. The document that has been prepared presents an initial report and one that is subject to revision. A few further comments need to be made concerning the nature of the data base.

For the most part, the data presented are from generally available public data sets. Particular efforts were made to collect and utilize county level data so that it would more closely conform to the boundaries of the Great Lakes watershed basin. To facilitate the analysis a set of counties was identified that approximates the boundaries of the Great Lakes basin. In those cases where county level data were not available, state data were employed.

The report identified the sources of data used in the analysis. These sets were used because they were publicly available and are prepared on an on-going basis. Special studies were avoided since the data could not be easily replicated in the future.

The data have been divided into three major sections: Major stressor activities (includes major manufacturing industries, agriculture, water-based transportation and power generation and consumption), demographic factors (with the focus on population and municipal infrastructure spending), and environmental measures.

It should be pointed out that while the data presented tend to represent the product or output of human activity, no attempt in this report is made to link these activities with the state of the Great Lakes ecosystem. While the materials balance approach recognizes that there is a relationship, it is clear that the data presented has not been prepared for a materials balance analysis. All too frequently the economic data reports is reflective of resource inputs (e.g. labor inputs) and little is collected or reported that allows for an analysis of the complete process. That is, no complete data set is available that provides information on material inputs and residual products discharged in to the environment. It is also difficult to define the nature of factor substitution that occurs in the region as relative prices of resources change and one input is substituted for another.

There is definitely a data problem in addressing the issue of the effect of the human activities on the ecosystem. This report is best viewed as a first step toward defining part of the issue.

**Findings of the Study**

The waters of the Great Lakes - Superior, Michigan, Huron, Erie and Ontario - have played an important role in the economic development of the United States and Canada. These vast inland freshwater seas and their connecting rivers and drainage basins have provided water for consumption, transportation, power, recreation and a host of other uses.

On the U.S. side, the basin includes parts of the states of Minnesota, Wisconsin, Illinois, Indiana, Ohio, Pennsylvania, and New York and all of the state of Michigan. In those sections of the report that rely on county level data to approximate basin boundaries the number of counties by state are as follows:

- Four counties in Minnesota, all of which are part of the Lake Superior drainage basin;
- Twenty-nine counties in Wisconsin, which are part of the Lake Superior and Michigan drainage basins;
- Two counties in Illinois, which are in the Lake Michigan drainage basin;
- Ten counties in Indiana, all part of the Lake Michigan drainage basin;
- Eighty-three counties in Michigan, which are part of the drainage basins for Lakes Huron, Superior, Michigan and Erie;
- Twenty-eight counties in Ohio which are part of the Lake Erie drainage basin;
- One county in Pennsylvania which is in the Lake Erie drainage basin;
- Twenty-three New York counties which are part of the Lake Ontario and Lake Erie drainage basins.

**Major Manufacturing Industries**

Much of the Great Lakes basin encompasses a region of the United States that has been known as the Industrial Heartland of the United States. The process of industrialization and human activities added greatly to the wealth of the nation. Obviously, this was not without cost to the ecosystem. Use of inorganic and organic chemicals and metals in various industrial processes found their way into the ecosystem.

In response to economic forces the economy of the region is undergoing significant changes. Some industries are less significant than they once were in that they have either relocated outside the Great Lakes basin or have declined in their overall importance in the economy.

While undergoing significant changes, much of America's steel, paper and chemicals industry is still located within the Great Lakes basin. This conclusion is based on an analysis of employment and establishment data for these industries within the basins.

**Steel** - During the period from 1974-1987 the number of steel establishments in the Great Lakes basin has declined by only 10, from 540 to 530 establishments. This represents a model decline from 22 to 21% of all the steel (SIC 331 and 332) establishments in the nation. The data show that the peak number of establishments occurred around 1978 at 556 establishments.

These establishments are concentrated in the Lake Erie and Michigan drainage basins. As of 1987, 488 of the 530 Great Lakes basin establishments were in the Erie and Michigan sub-basins.

While the number of establishments has declined modestly, employment in the steel industry has contracted significantly. During the period of analysis the industry within the basin contracted from 260,000 to about 116,000 employees, a decline of some 55%. Of the approximately 144,000 jobs lost, 135,000 were lost within the Lake Erie and Lake Michigan basins. It should be pointed out that this contraction in steel industry employment has occurred across the nation. The Great Lakes basin has maintained its 31% share of steel industry employment over the period from 1974 through 1987.

**Paper** - The paper industry has seen a major decline in the numbers of establishments (SIC 26) within the Great Lakes basin, from 982 establishments to 834. This 15% decline in paper establishments translates into a decline from 16% of the nation's establishments to 13%. Thus the industry appears to be locating to other parts of the nation.

Almost two-thirds of the paper establishments in the Great Lakes basin are located in the Lake Michigan drainage basin. The data reveal that the most significant loss in establishments from within the basin has been in the Lake Erie sub-basin where a total of 112 establishments have been lost from 1974-1987.

Employment in the Great Lakes basin paper industry has declined by some 11% over the period. As a result, the basin's paper industry employment has fallen from 17 to 16% of the national total.

As with the establishments, two-thirds of the paper industry employment is found in the Lake Michigan basin. This basin now accounts for about 67,000 jobs. During this period, only the Huron basin has witnessed even a minor increase in the number of establishments and employment.

**Chemicals** - The chemical industry in the Great Lakes basin currently accounts for about 12% of the total establishments in the nation. With 1,490 establishments, this is down from 1,575 in 1974, a decline of some 5% over the period. At the start of the period the basin accounted for some 14% of the national total.

The chemical establishments are concentrated within the Lake Michigan and Erie basins. Only 117 establishments are to be found in the other 3 basins.

Much like other industries, the chemical industry in the Great Lakes basin has seen a significant decline in employment. Some 21,000 jobs were lost within the basin over the period from 1974 to 1987, a decline of some 17%. This translates into a loss of 1% in national share of chemical industry employment to 13%. As with establishments, the dominant part of the employment is to be found in the Lake Michigan and Erie drainage basins.

Combined these three industries have seen their employment in the Great Lakes basin fall some 277,000 jobs from 1974-1987. The translation in terms of human economic stress beyond these industries is expected to be significant in that these industries tend to be ones in which average hourly earnings have been about the overall average. Thus, these losses have spill over effects to other sectors of the basin's economy.

### 2.1.5 Agriculture

Agriculture has long been an important part of the economies of the states bordering on the Great Lakes. This includes not only the land area in the drainage basins but also the rest of the land in the states. The large industrial cities on the Great Lakes have provided ready markets for agricultural products and the major ports have provided a relatively low cost means of transportation of the products to other markets.

Within the Great Lakes basin, farmland represents about one-third of the total land area. In the Lake Erie drainage basin the percentage is much higher, particularly in Canada, where three-fourths of the land area is in farms. In the U.S. portion of the Lake Erie drainage basin, about 54% of the land is farmland. At the other extreme, is the Lake Superior drainage basin where very little of the land is in farms. Here much of the land is forests.

The amount of major farm commodities produced by Great Lakes States illustrates the importance of agriculture in these states and to the nation. Just over one-fifth of the nation's cash receipts from farm marketings comes from these states. Major commodities are corn, soybeans, milk and hogs. About half of the corn, soybeans and milk and two-fifths of the hogs produced in this country come from these eight states.

### 2.1.6 Waterborne Commerce

The Great Lakes serve as a major transportation artery for the states and the industries, including agriculture, along their shorelines. Over two-thirds of the tonnage on the Great Lakes is domestic, primarily lakewise, i.e. from one U.S. port on the Great Lakes to another. The balance is mostly exports to and imports from Canada which represent 26% of the total tonnage. A small percentage (5%) is exports to and imports from overseas through the St. Lawrence Seaway.

The amount of total tonnage shipped on the Great Lakes generally fluctuated with the business cycle up through the end of the 1970s and the back-to-back recessions in the early 1980s. After the sharp decline during those recessions, total tonnage has been increasing slowly but it has not recovered to earlier levels.

The decline in total tonnage since 1969 has been primarily in domestic shipments which were 31% lower in 1988. Canadian shipments, on the other hand, after rising strongly during the 1970s, were only about 4% below the 1969 level in 1988. The strongest gains in Canadian shipments since 1974 have been in exports to Canada which in 1988 were 25% above the 1969 level. Import shipments from Canada to the U.S., however, during this period were down 41%. As a result, Canadian trade expanded slightly from 20% of total tonnage in 1969 to 26% in 1988 while the domestic share of tonnage decreased from 76 to 69%.

Overseas shipments, although the same percentage of total tonnage shipped on the Great Lakes in 1988 as in 1969, have fluctuated substantially during this period. Much of this represents changes in the amount of farm products shipped overseas. As the amount of farm products exported changed, the amount of imports also fluctuated as outgoing ships returned carrying incoming cargo.

Over 90% of domestic tonnage on the Great Lakes during 1988 was iron ore, limestone, and coal, with iron ore half of total domestic tonnage. Most of the iron ore is shipped from ports near the mines on Lake Superior via the Great Lakes to the iron and steel plants in Indiana, Michigan and Ohio. At the same time, limestone and coal are brought from other areas near the Great Lakes, either by water or rail. The balance of the domestic tonnage is primarily petroleum and coal products, stone and concrete and farm products.

Foreign commodity shipments on the Great Lakes are also primarily coal, iron ore, and limestone which are about 70% of the total. Much of this represents trade with Canada. The largest of these is coal (36%) which is largely shipped from ports in Ohio to Canada. Farm products (11.5% of foreign commodity shipments) are much more important for overseas shipments. Much of it is shipped from Duluth-Superior on Lake Superior which is an outlet for the agricultural products of the Great Plains.

The balance of the tonnage is a miscellaneous group of commodities including primary metal and petroleum and coal products, chemicals, stone and concrete, waste and scrap, pulp and paper, transportation equipment, machinery and food and kindred products.

### 2.1.7 Power

Electric utilities generate power using energy inputs. In the Great Lakes states, the major source of energy used at electric utilities is coal which provides 63% of the energy input. This compares with 52% of the energy input at electric utilities in the balance of the United States. The use of nuclear energy for electricity generation has been steadily growing in importance and is now the second major source in both the overall Great Lakes states and the balance of the nation. In 1988, nuclear energy furnished 24% of the energy input in Great Lakes at electric utilities and 18% in the rest of the U.S. Natural gas and hydropower are much more important as a source of energy input at electric utilities in the rest of the U.S. than in the Great Lakes states.

Sources of energy for electricity generation vary widely among the states in the Great Lakes. Almost all of the electricity generated in Indiana and Ohio is based on coal. In Michigan, Minnesota, Pennsylvania and Wisconsin about three-fourths of the electricity depends on coal with the balance primarily nuclear energy. In Illinois 56% of the electricity is generated from nuclear energy and 43% from coal. New York depends on several energy inputs for electricity, with 29% petroleum, 26% hydropower, 18% nuclear energy, 16% coal and 11% natural gas.

The industrial sector consumes the most energy and has experienced the greatest fluctuation in energy use. In 1988, the major sources of the energy for industry in the Great Lakes states were petroleum (29%), natural gas (27%) and coal (26%). The balance was provided by electricity (17%). In the rest of the United States, petroleum and natural gas are much more important as a source of energy to industry, providing in the aggregate almost four-fifths of the total energy consumed. The balance is from electricity (13%) and coal (8%).

While the amount of coal used by industry as a source of energy remained relatively constant from 1960 to 1988 in the rest of the U.S., coal as a source of energy for industry in the Great Lakes states declined substantially during this period. Nevertheless, industries in the Great Lakes states still represented approximately half of the coal consumed by industry in the U.S. in 1988. During this period as coal decreased in importance at industries in the Great Lakes states, the use of electricity and natural gas increased.

### 2.1.8 Demographic Factors

In 1986 the population of the Great Lakes basin was approximately 27.2 million persons. The most populated sub-basin was that of Lake Michigan with 12.2 million persons or about 45% of the Great Lakes basin total population. The next most populated sub-basin is that of Lake Erie, with 11.0 million persons or about 40% of the basin total.

The basin's population in 1986 represented about 11.2% of the total population of the United States. This compares with the 1960 Census that showed the Great Lakes basin with 20.5 million persons or 13.5% of the U.S. population. The basin's population peaked at 13.6% of the U.S. population in 1960 and has declined ever since.

While county level data are not available for the 1990 Census, as yet, state level data provides a preliminary indication that the basin's population continued its decline in 1990. Provisional Census data indicate that the population of the Great Lakes basin states increased by only 0.3% from 1980-1990. This compares with an overall population growth in the U.S. of about 8.5%. All of the major industrial states (Illinois, Michigan, Ohio and Pennsylvania) except for New York lost population over the decade. The smaller states (Indiana, Minnesota and Wisconsin) had population gains.

The most densely populated sub-basin is that of Lake Erie with a population per square mile in 1986 of 448 persons. Erie's population density had grown relatively steadily between the 1920 and 1970 Census. Since 1970 the population density has declined.

In contrast with the slower growth in population density of Erie, the Lake Michigan sub-basin has continued a relatively steady growth in population density since 1920. Currently, the population density of Lake Michigan is 264 persons per square mile. The remaining three lake sub-basins have a population density of less than 150 persons per square mile as of 1986.

### 2.1.9 State and Local Expenditures

Expenditures by state and local governments give some indication of the extent to which state and local governments attempt to manage human incursions into the environment. Such data in isolation may give an incorrect impression as to the extent of the alteration of the ecosystem by human activity. For example, low funding may indicate a lack of financial resources to deal with the problem or it may reflect the lack of a problem.

As of November 1990, the eight states of the basin had a total of 397 sites listed on the National Priority List. The largest concentration of sites was in New York (95), followed by Michigan (78) and Minnesota (42).

National priority sites in the Great Lakes basin tend to have a heavy concentration of landfill sites. Forty nine of the sites in Wisconsin are landfill sites, which compares to the national average of 15% landfill sites. In fact, none of the eight Great Lakes states have less than 15% of their sites in landfill. As expected, large industrial states like Illinois, Michigan, New York and Pennsylvania have a concentration of manufacturing sites greater than the national average of industrial sites (18%). Heavy concentration of industrial waste sites are found in Indiana, Minnesota, Ohio and Pennsylvania. Chemical sites are found to be most heavy in Minnesota, New York and Pennsylvania.

### 2.1.11 Conclusion

The data presented in this report indicates that the Great Lakes basin remains a complex and diverse economic region within the United States. The economic base of the region remains heavily dependent upon and tied to manufacturing activity. However, the last decade has produced a significant amount of economic change to the basic structure of the region's economy. These changes are producing different impacts on the region's ecosystem.

While this report has only scratched the surface of the economic data pertaining to the Great Lakes basin it does provide the basis upon which to better understand the complex and diverse nature of the region's economy.

Much remains to be accomplished. As set forth in the earlier portions of the report there is the need for better modelling of the interaction between the human economic activity and that of the region's ecosystem. Data upon which to do such modelling is from the United States perspective at best limited in scope and detail. There is little basis upon which to expect the publicly provided data sets will improve significantly in the near term. If for no other reason, budget tightness at both the federal and state level will not allow for extra financial resources to fund expanded or modified data collection. The ability to obtain the necessary data will have to be increasingly developed by private sector sources.

The study also revealed the difficulties associated with merging United States and Canadian data for dealing with the issue of the impact of human activities on the environment. Therefore, it is suggested that with respect to both data collection and modelling that efforts focus on a binational approach to more effectively address the issues.

## 2.2 Analysis of Population and Agriculture Census Data

*Prepared by Robert Hoffman, Hoffman Associates, Ottawa, Ontario*

This section of the report provides a descriptive analysis of the data compiled for the purpose of this project and presents selected data in graphical format. It is to be noted that much of the data that would be essential for environmental reporting has never been collected, nor is it likely that such data could be directly measured. Perhaps the only way that these data can be obtained is through the use of process models. For example the agriculture census data is sufficient to calibrate a model that for example might represent the relationships between crops, cultivation practice, fertilizer use by type of nutrient, erosion and nutrient content of run-off. See also points (V) and VI) of Section 7, Concluding Remarks. Consequently, the interpretive analysis is impressionistic and incomplete with respect to the impact of the trends observed in these data on water quality in the basin. At best, potential problems may be identified.

Appendix 2 of the Report contains a list of the variables from the Statistics Canada EIS data base that were loaded in to the data base created by Robbert Associates during the course of this project. Each of the 335 variables is disaggregated by the 104 sub-sub-basins that constitute the Great Lakes basin.

For the purposes of the analysis that follows the Great Lakes basin is considered to be the following drainage areas.

TABLE 2.1 Great Lakes basin drainage areas

| SUB BASIN | AREA (000 km$^2$) |
|---|---|
| Lake Superior Shore | 83.1 |
| Lake Huron Shore | 90.6 |
| Lake Erie and Lake St. Clair Shore | 22.9 |
| Lake Ontario Shore | 28.7 |
| The Ottawa River Basin | 146.0 |
| The Upper St. Lawrence Basin | 122.0 |
| Total Area | 493.0 |

### 2.2.1 Population

Population and population densities are important overall indicators of pressure on water quality. Other things being equal, increased population means more urban run-off and higher levels of discharge from municipal sewage treatment systems that are not fully effective in removing contaminants.

The total population of the basin grew from 15 million in 1971 to over 17 million in 1986 (Chart 1). This represents approximately 70% of the population of Canada. Chart 2 shows population by each of the six sub-basins. Population is concentrated in the Lake Ontario and Upper St. Lawrence basins, approximately two thirds of the population of the basin are in these two areas. Furthermore these areas are growing in population relative to the other four areas. Chart 3 presents population data for selected sub-sub-basins. These sub-sub-basins are identified in terms hydrometric codes in Table 2.2. The two sub-sub-basins containing Toronto and Montreal account for almost one third of the population of the basin. Three of the sub-sub basins report no population at all.

TABLE 2.2 Definitions of selected sub-sub basins

| | SUB-SUB BASIN NAME | CODE | SUB-BASIN |
|---|---|---|---|
| 1. | Kitchener-Waterloo | 2GA | Lake Erie |
| 2. | London-Stratford | 2GD | Lake Erie |
| 3. | Windsor | 2GH | Lake Erie |
| 4. | Niagara | 2HA | Lake Ontario |
| 5. | Hamilton | 2HB | Lake Ontario |
| 6. | Toronto | 2HC | Lake Ontario |
| 7. | Ottawa | 2LA | Ottawa River |
| 8. | Montreal | 2OA | Upper St. Lawrence |
| 9. | Quebec | 2PD | Upper St. Lawrence |

**Population Densities**

Population density measured in persons per hectare increased from 0.3 to 0.35 from 1971 to 1986 for the basin as a whole (Chart 4). However, population densities vary from basin to basin; the most densely populated basin is Lake Ontario at 1.7 persons per hectare in 1986; the least is Lake Superior at 0.05 in 1986 (Chart 5). Chart 6 presents population data for selected sub-sub-basins. The two sub-sub-basins containing Toronto and Montreal are the most densely populated at roughly 10 and 6 persons per hectare respectively. Population density for the Toronto sub-sub-basin is growing most rapidly. Given expected population growth in the Greater Toronto Area, this population density could double again in the next twenty five years.

**Rural-Urban Populations**

Overall the urban population grew more quickly in the period 1971 to 1986 than rural population (Chart 7). The rural share of the population is shown by sub-basin in Chart 8. Given that the total area operated as farms is declined in all sub-basins, data indicate that the non agriculture rural populations are increasing.

### 2.2.2 Agriculture

#### Farm Land

Total farm area operated in the basin fell from about 10.5 million hectares in 1971 to about 8 million in 1985, a decline of almost 25% (Chart 10). In 1971 farm land represented about 22% of the area of land in the basin; by 1986 it was about 17%. These percentages are deceptive; agriculture is concentrated in particular regions in various sub-basins. Charts 11 and 14, which show farm land operated by sub-basin and the farm land share of each sub-basin, indicate that the Lake Erie sub-basin is 80% farm land whereas the Lake Superior basin has very little farm land. In order to facilitate the analysis of agriculture in the basin, eight agriculture regions were defined; each agriculture region is a combination of sub-sub-basins where agriculture is practiced extensively. These regions are defined on Table 2.3; they account for about 16% of the total land in the basin (82,000 $km^2$ of the 439,000 $km^2$ in the basin); Charts 12 and 15 show respectively the farm area operated in each of the eight regions and the farm land share of the total area. These shares are all greater than 50% with the exception of the Western Lake Ontario region which of course is heavily urbanized.

It would appear that two factors account for the decline in agriculture land. A certain amount of land is being lost to urban development, but more importantly agricultural land is being abandoned. For example the decline of 700,000 hectares of land in the St. Lawrence South Shore region is probably attributable to land abandonment. On the other hand, the 300,000 hectares lost in the Western Lake Ontario region is undoubtedly attributable to urban development.

#### Agriculture Land Use

The data indicate that agriculture land is being used more intensively for cropping. Chart 16 shows that the crop land share of agriculture is increasing in all of the agriculture regions with most of the increase occurring in the period 1971 to 1976. Chart 17 shows the decline in the share of agriculture land classified as improved pasture. This, combined with the facts that the number of cattle per hectare of improved pasture doubled or tripled between 1971 and 1986 (Chart 23) and that the population of pigs just about doubled (Chart 19), indicates potential problems of manure management. When animals are concentrated in large numbers, manure is disposed by applying it to the land. Manure, which is rich in both nitrogen (N) and phosphate ($P_2O_5$), is often applied for the purpose of disposal at rates much greater than can be used by plants. These excess nutrients cause environmental damage when phosphorous runs off in surface water or when nitrites contaminate ground water.

TABLE 2.3 Definitions of agriculture regions

1. Huron — 2FA, 2FB, 2FC, 2FD, 2FE, 2FF
Area = 1.48 million hectares

This region includes all the area that drains into Lake Huron between Collingwood on Georgian Bay and Sarnia at the southern end of Lake Huron

2. Essex-Lambton — 2GE, 2GF, 2GG, 2GH
Area = 0.914 million hectares

This region includes all the area that drains into western Lake Erie and Lake St. Clair from Sarnia on the northwest to London on the east to Port Stanley on Lake Erie

3. South-Eastern Lake Erie — 2GB, 2GC
Area = 0.605 million hectares

This region includes all the area that drains into eastern Lake Erie from an area bounded by Port Stanley on the southwest, London on the northwest, Cambridge on the northeast and Beamsville on the southeast

4. Northeast Lake Erie — 2GA, 2GD
Area = 0.775 million hectares

This region includes all the area that drains into eastern Lake Erie from an inland area consisting of the upper Grand River drainage area and the upper Thames River drainage area

5. Niagara — 2HA
Area = .254 million hectares

This region includes all the area that drains into western Lake Ontario from an area bounded by Stoney Creek on Lake Ontario and Beamsville on Lake Erie

6. Western Lake Ontario — 2HB, 2HC
Area = 0.481 million hectares

This region includes all the area that drains into western Lake Ontario from the north bounded by Stoney Creek, Orangeville and Oshawa

7. Eastern Ontario — 2LA, 2LB
Area = 1.02 million hectares

This region includes all the area that drains into the Ottawa River in the Rideau and Nation River drainage basins

8. St. Lawrence River South Shore — 2OA, 2OD, 2OE, 2OF, 2OG, 2OH, 2OJ
Area = 2.59 million hectares

This region includes all the area on the south shore of the St. Lawrence in Quebec that drains into the St. Lawrence River between Beauharnois west of Montreal to Trois Riviere, bounded on the south by the U.S. border

**Crops and Cultivation**

The most important crop grown in the Great Lakes basin is corn. Of the 4.6 million hectares of crop land in 1971, 800,000 hectares was seeded in corn; by 1981, 1.4 million hectares was seeded in corn. The growing of corn is significant from an environmental perspective for several reasons: (1) Corn is a crop that requires large applications of fertilizer; because corn does not fix nitrogen from the air, applications of nitrogen fertilizer are typically 100 or more kg/ha per year; phosphate is usually applied at 40 to 50 kg/ha. (2) Corn is cultivated in wide rows thereby exposing soil to erosion and requiring applications for chemicals for weed control. Some of the potentially harmful impacts of growing corn can be mitigated by interseeding cover crops such as red clover, by practicing no till or conservation tillage cultivation, and by using crop rotations such as three year rotations of corn, soybean and winter wheat as principal crops. It is not known to what extent these mitigating strategies are actually employed. It is not unusual for nitrogen to be applied at rates greater than can be used by the plants. This problem arises because of the volatility of nitrogen with respect to weather events and the lack of a nitrogen test. Corn is grown widely throughout the basin, but is concentrated in the Essex-Lambton and Southern Lake Erie regions where 50% of the crop land is sown in corn.

Soybean is an increasingly important crop, particularly in the Essex-Lambton region where the area seeded in soybean has increased from 140,000 hectares in 1971 to 240,000 in 1986 (Chart 27). Like corn, soybean is a wide row crop and gives rise to the same problems; however, it is to be noted that soybean requires no nitrogen fertilizer.

Chart 28 shows the area of crop land under wide row cultivation in each of the eight agriculture regions. It shows an increase from 1971 to 1981 levelling off to 1986.

**Amendments**

Charts 29 to 34 show amendments in terms of area sprayed with insecticide and herbicide and area fertilized. In all cases, areas amended are increasing from 1971 to 1981 with some levelling off from 1981 to 1986. Note that data was not available for 1976; consequently the 1976 value was imputed by linear interpolation between 1971 and 1981. There is no data on what chemical compounds were being sprayed or on the nutrient content of the fertilizers. A reasonable estimate of fertilizers applied to corn can be made by applying recommended rates for nitrogen and phosphate to acreage seeded. These estimates are reported for each region in Charts 33 and 34.

CHART 1: GLB Total Population)

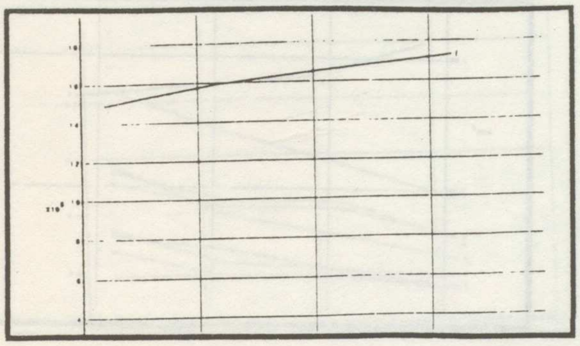


CHART 2: GLB Population by Sub-basin

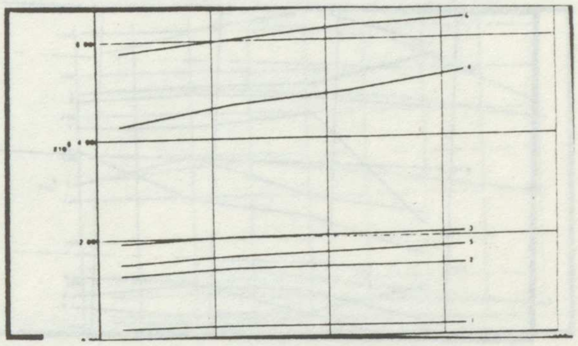


CHART 3: Population for Selected Sub-sub basins

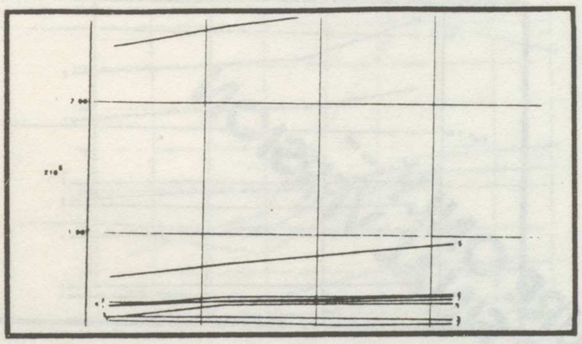


CHART 4: Total Population Density

-- SAMPLE FIGURE ONLY --
TO BE REDRAFTED FOR FINAL VERSION

CHART 5: Sub-Basin Population Density

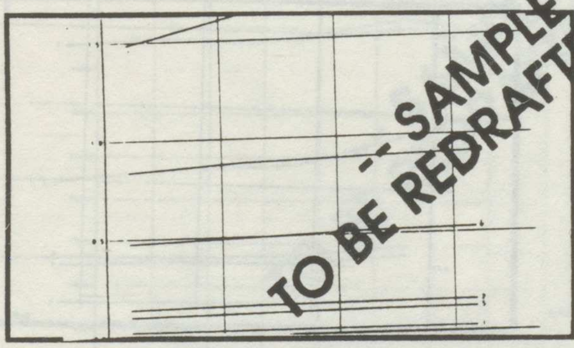


CHART 6: Population Density for Selected Sub-sub basins

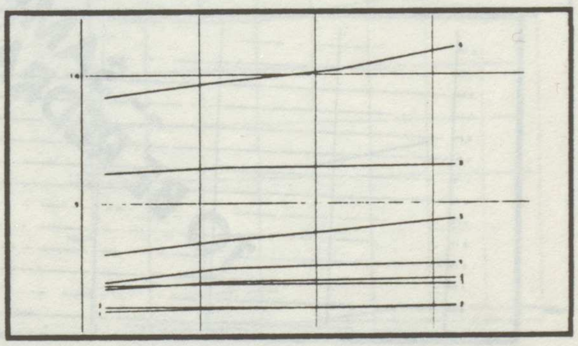


CHART 7: Rural-Urban Population Total

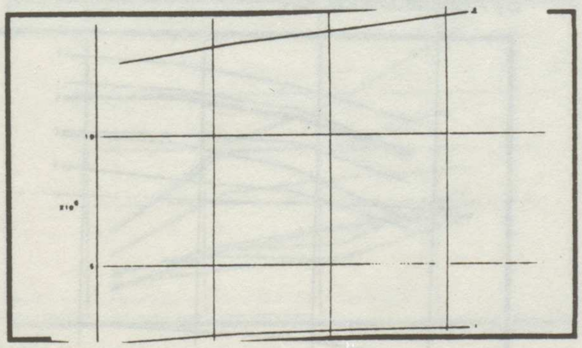


CHART 8: Rural Share by Sub-basin

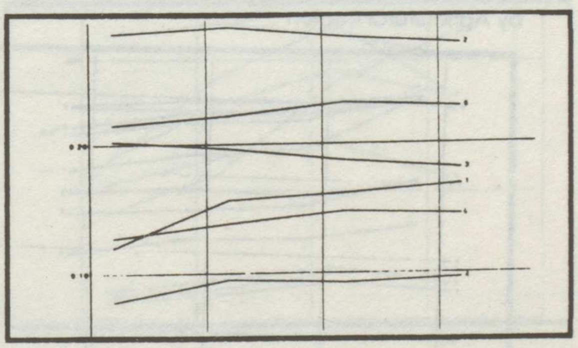


CHART 9: Rural Share for Selected Sub-sub basins

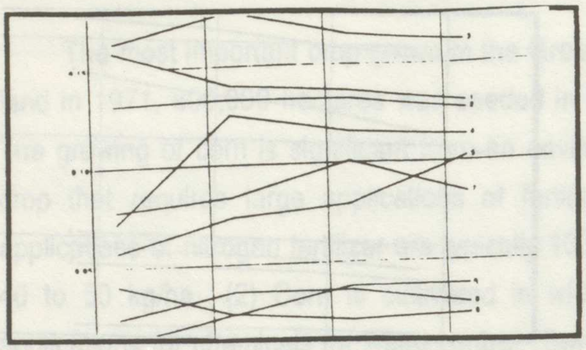


CHART 10: Total Farm Area Operated

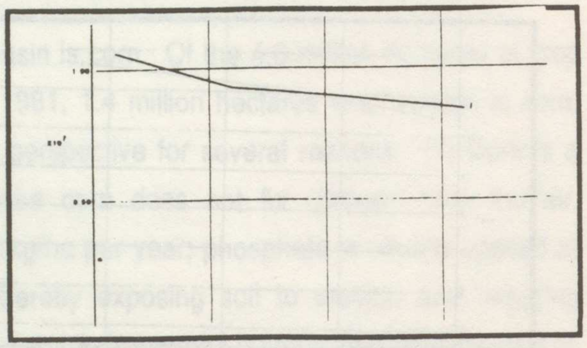


CHART 11: Farm Area Operated by Sub-basin

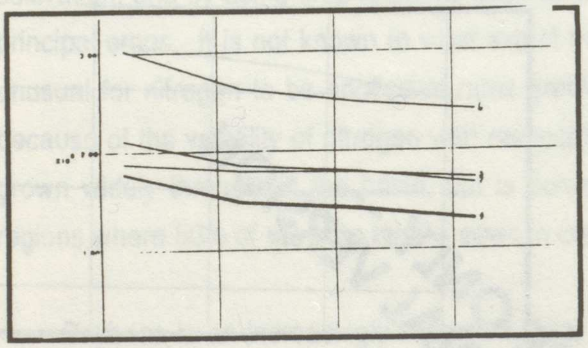


CHART 12: Farm Area Operated by Agricultural Region

-- SAMPLE FIGURE ONLY --
TO BE REDRAFTED FOR FINAL VERSION

CHART 13: Share of Total Land Farm Operated by Sub-basin

CHART 14: Share of Total Land Farm Operated

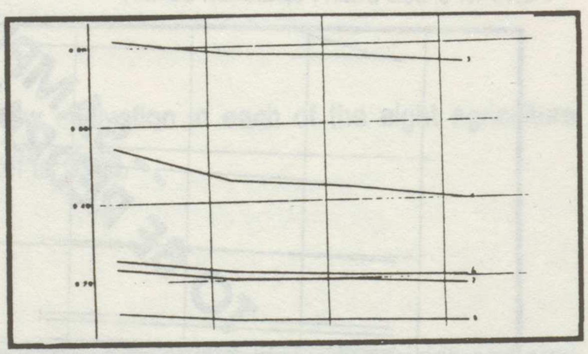


CHART 15: Share of Total Land Farm Operated by Agricultural Region

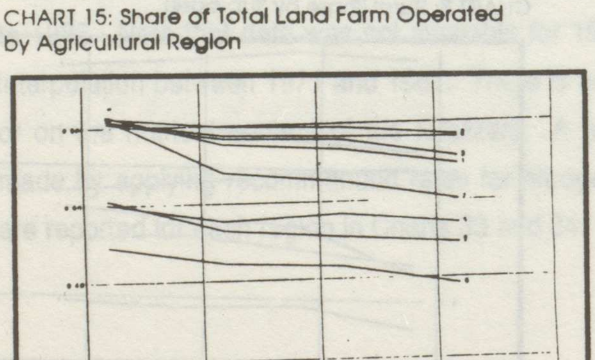


CHART 16: Crop Land Share of Farm Land by Agricultural Region

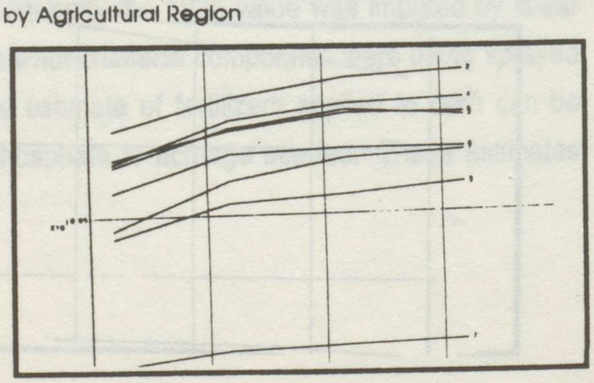


CHART 17: Improved Pasture Land Share of Farm Land by Agricultural Region

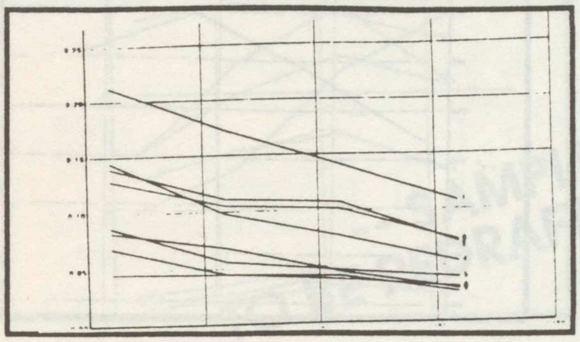


CHART 18: Livestock by Agricultural Region

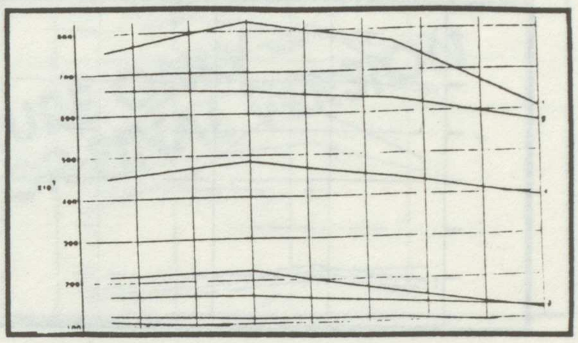


CHART 19: Livestock by Agricultural Region

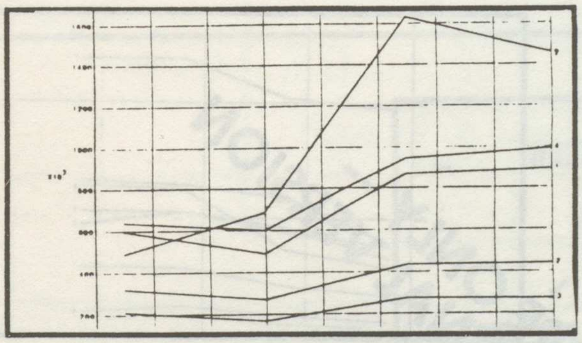


CHART 20: Livestock by Agricultural Region

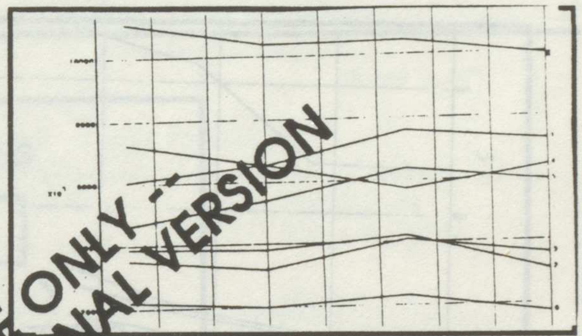


CHART 21: Total Livestock in Agricultural Regions

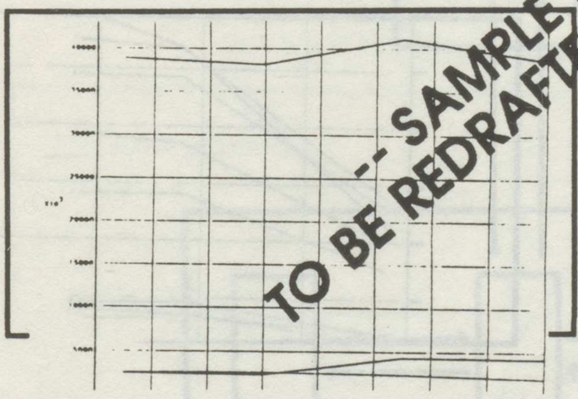


CHART 22: Total Livestock in Sub-sub Basins

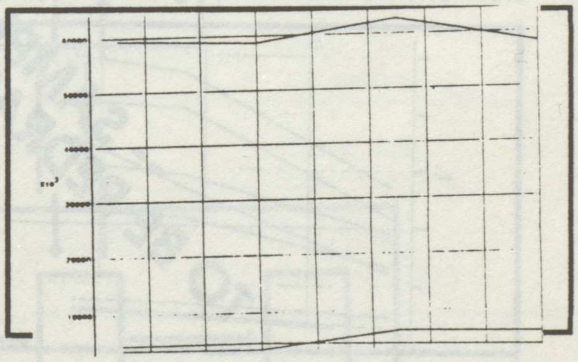


CHART 23: Cattle Per Unit of Improved Pasture Land

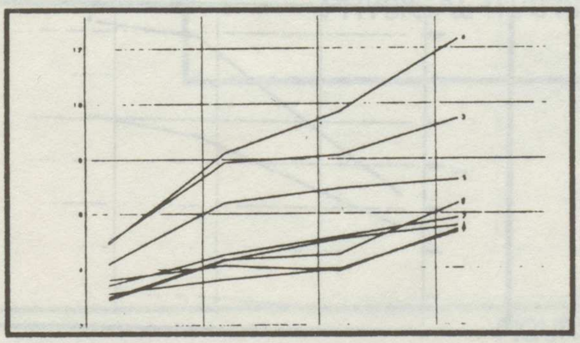


CHART 24: Total Area for Corn by Agricultural Region

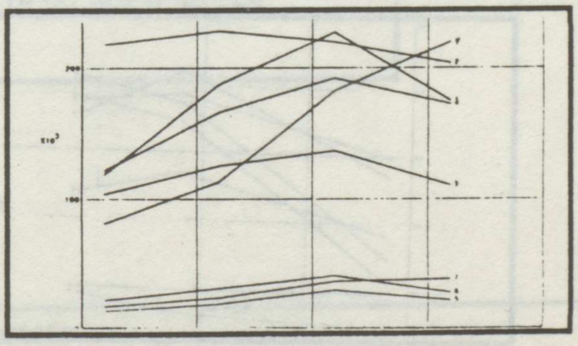


CHART 25: Total Area for Corn in Agricultural Region Basins

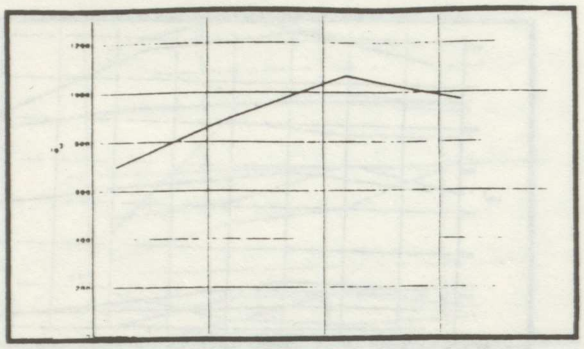


CHART 26: Total Area Seeded for Corn in Sub-sub

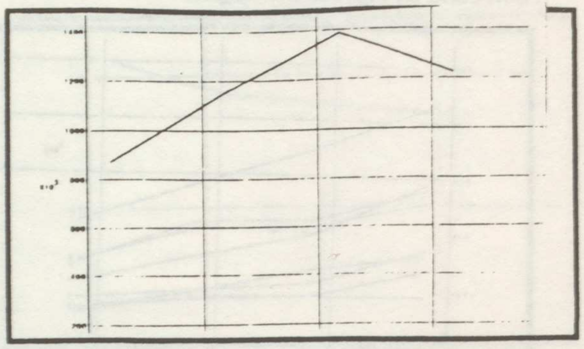


CHART 27: Total Area for Soybeans by Agricultural Region

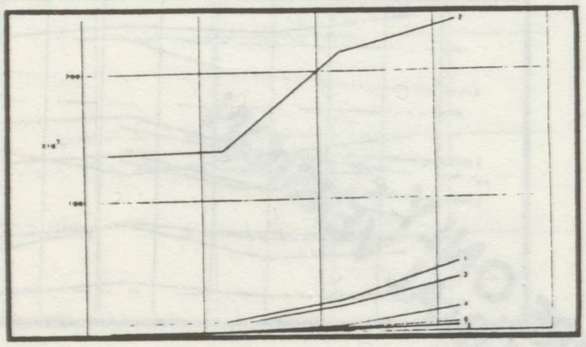
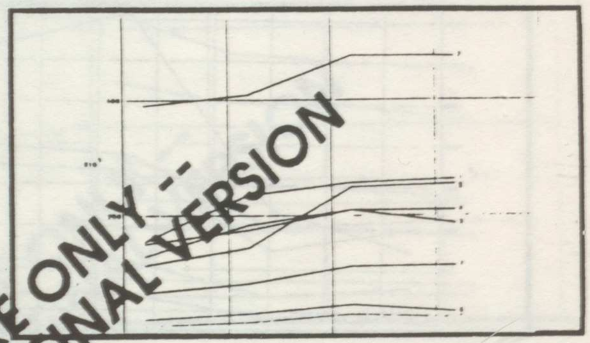


CHART 28: Crop Land under Wide-row Cultivation by Agricultural Region



-- SAMPLE FIGURE ONLY --
TO BE REDRAFTED FOR FINAL VERSION

CHART 29: Area Amended by Agricultural Region

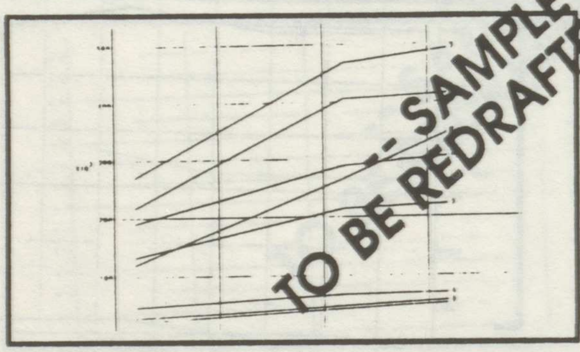


CHART 30: Area Amended by Agricultural Region

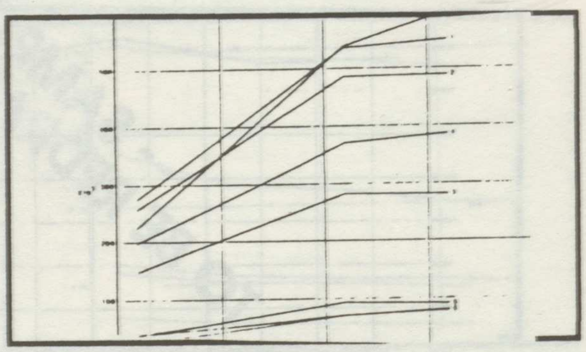


CHART 31: Area Amended by Agricultural Region

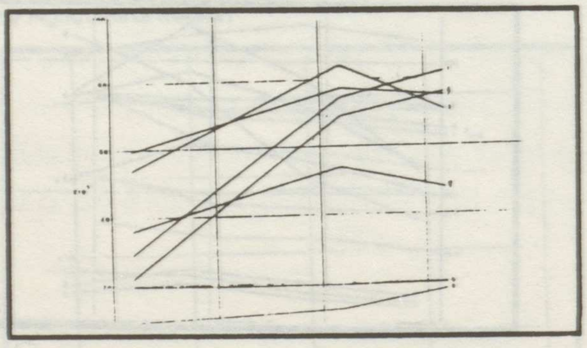


CHART 32: Total Area Amended in Sub-sub Basins

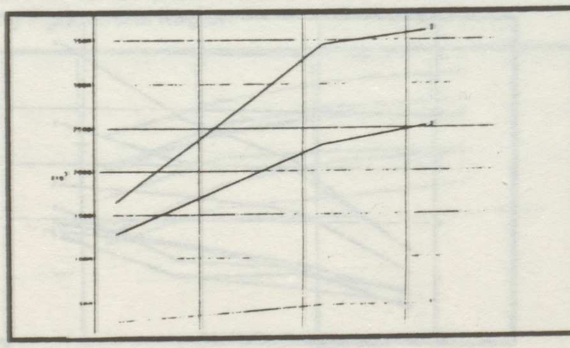
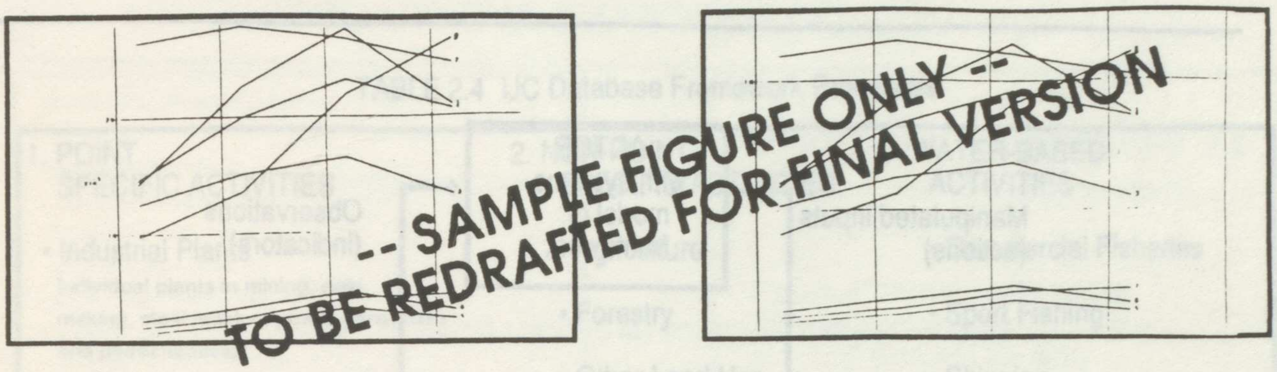


CHART 33: Total Nitrogen (N) Applied to Corn

CHART 34: Total Phosphorus (P) Applied to Corn



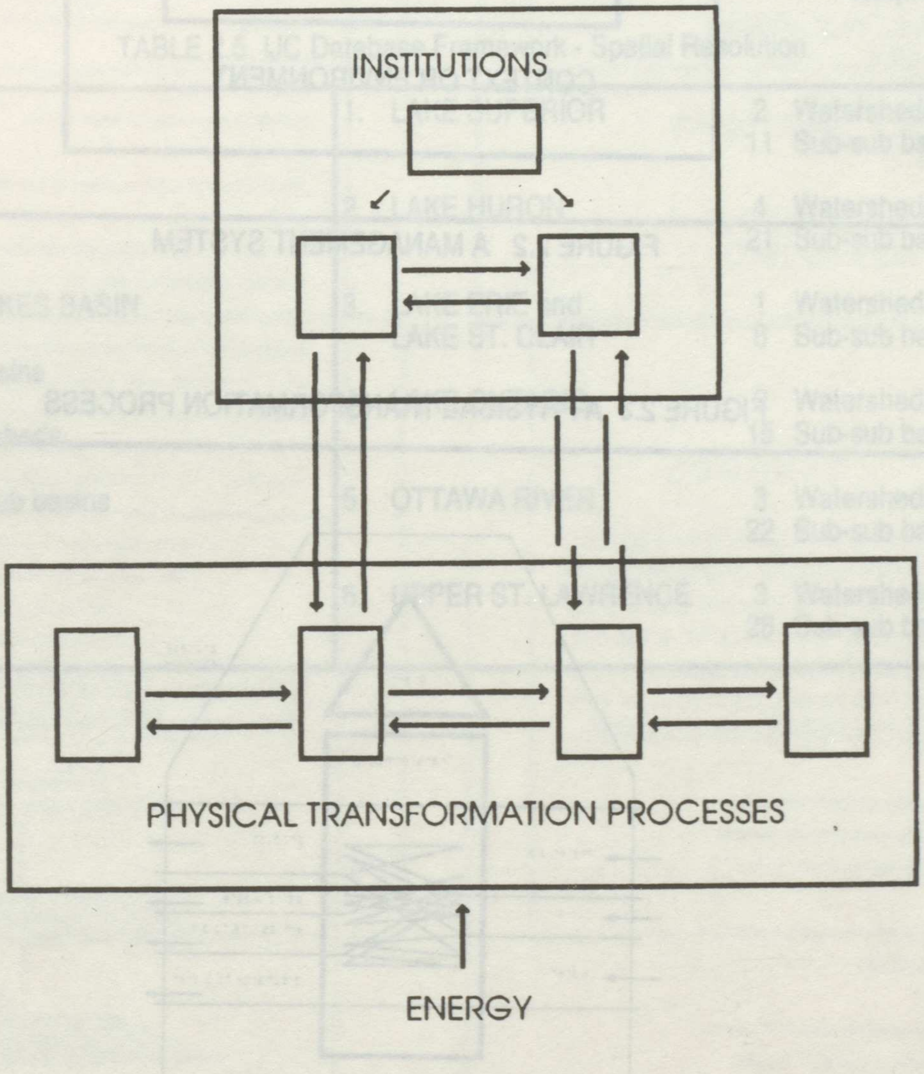




FIGURE 2.1 Processes

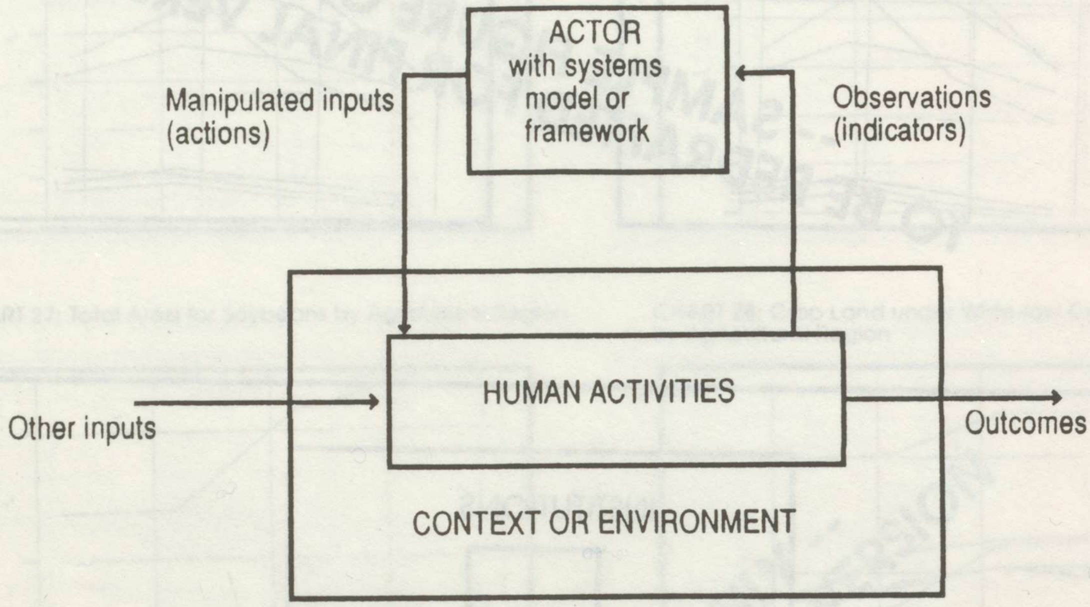



FIGURE 2.2 A MANAGEMENT SYSTEM

FIGURE 2.3 A PHYSICAL TRANSFORMATION PROCESS

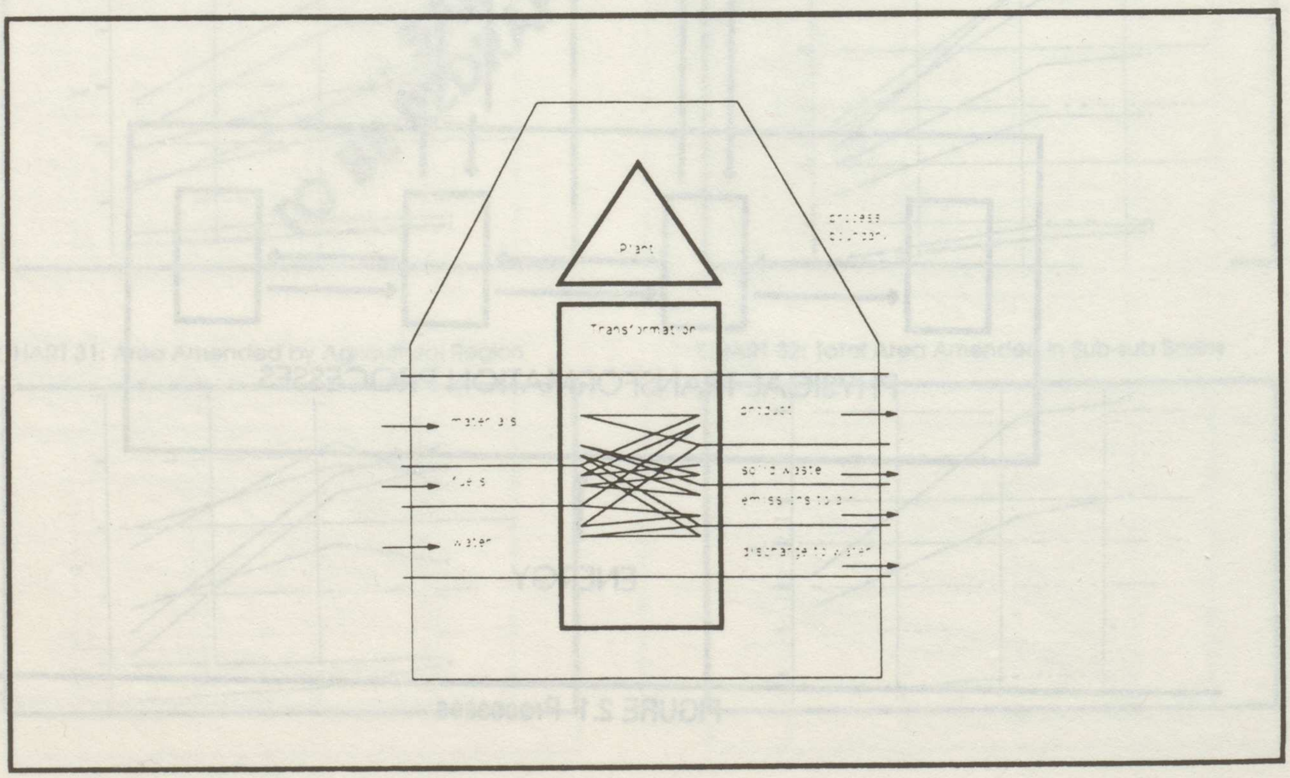


TABLE 2.4 IJC Database Framework Processes

| 1. POINT SPECIFIC ACTIVITIES | 2. NON-POINT SPECIFIC ACTIVITIES | 3. WATER-BASED ACTIVITIES |
|---|---|---|
| • Industrial Plants<br>Individual plants in mining, pulp making, steel making, power generation and petrochemicals | • Agriculture | • Commercial Fisheries |
| | • Forestry | • Sport Fishing |
| • Municipalities<br>Individual municipalities | • Other Land Use | • Shipping |
| | • Shoreline Structuring | • Recreational Boating |

TABLE 2.5 IJC Database Framework - Spatial Resolution

| | | |
|---|---|---|
| GREAT LAKES BASIN<br>6 Sub-basins<br>15 Watersheds<br>104 Sub-sub basins | 1. LAKE SUPERIOR | 2 Watersheds<br>11 Sub-sub basins |
| | 2. LAKE HURON | 4 Watersheds<br>21 Sub-sub basins |
| | 3. LAKE ERIE and LAKE ST. CLAIR | 1 Watersheds<br>8 Sub-sub basins |
| | 4. LAKE ONTARIO | 2 Watersheds<br>15 Sub-sub basins |
| | 5. OTTAWA RIVER | 3 Watersheds<br>22 Sub-sub basins |
| | 6. UPPER ST. LAWRENCE | 3 Watersheds<br>26 Sub-sub basins |

# 3.0 ENVIRONMENTAL REPORTING: CURRENT PROGRAMS AND PRACTICE

## 3.1 United States: Environmental Statistics

*Presented by Brand Neimann, U.S. Environmental Protection Agency, Washington, D.C.*

EXHIBIT 1. The New Environmental Statistics Initiative in the United States

(1)

**THE U.S. EPA CENTER FOR ENVIRONMENTAL STATISTICS**

- EPA Task Force initiative (early 1990)
- Part of EPA Cabinet Agency (mid 1990)
- OMB "Presidential Initiative" in FY 1992 (early 1991)

(2)

**The Development Staff Within EPA Office of Policy, Planning and Evaluation**

- Orderly transition from paper to electronic reporting of environmental data across programs
  Will produce the first comprehensive statistical report on the state of the environment
- Will conduct special analyses of specific environmental issues to promote the development and application of new methods of statistical analysis
- Will sponsor identification, refinement and promotion of necessary data collection for a 'core data series' of environmental indicators for gradual introduction into and use in future state of the environment reports

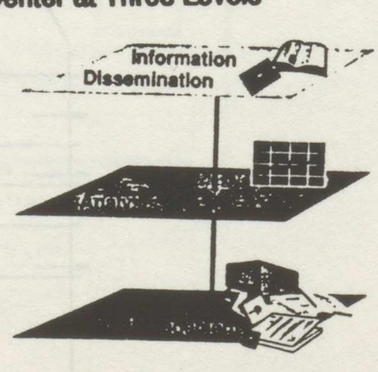
(3)

**MAJOR DELIVERABLES (FY1991)**

- Second edition of the Guide to Key National Environmental Statistics in the U.S. Government (4th Qtr)
- Concept paper on environmental statistics (4th Qtr)
- First comprehensive statistical report on the state of the environment (2nd Qtr, FY 1993)

(4)

**Information Technologies will Support the Center at Three Levels**



(5)

**INFORMATION MANAGEMENT PLANS**

FINDING GOOD DATA

- A person-to-person network
- Compilation of metafiles (data documentation)
- Experienced data analysts
- Selection criteria (guide to metafiles)

ELECTRONIC ACCESS TO DATA

- Search metafiles
- Link data results (tables, graphs, maps)
- Link to actual data tables

PERIODIC REVIEW OF DATA QUALITY

- Internal review
- External advisory committee
- Public access

(6)

**CONCEPT**

Electronic access facilitates the compilation, review and updating of "good" data and the latter evolves into a "core data series" of key environmental indicators

(7)

**CEI/DS IMPLEMENTATION: METAFILES AS INFOBASES**

- WRI Guide to Key National Environmental Statistics in the U.S. Government (March 1990)
- PC Version of WRI Guide (January 1991)
- PC Version of the 1991 EPA Guide with Links to Data Results (April 1991)
- PC Version of the Prototype Global Change Master Directory of the Interagency Working Group on Data Management for Global Change (Jan./91)
- Others in Progress:
  - EPA program offices
  - WRI global
  - State
  - Spatial for GIS

(8)

**CONCEPT**

Multiple infobases can be searched simultaneously and are simple to use and inexpensive to distribute in run-time formats. Our metafile infobases are interim products before the state of the environment report and will become appendices to the report

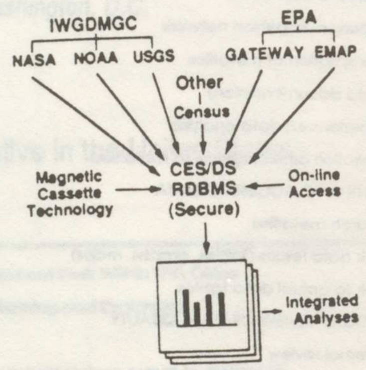
(9)

## ACQUIRING DATA

- Agency Publications (reports
- Agencies with on-line access
- Specialized contractors/consultants
- ADP Tools
  - Mainframe spreadsheet software
  - Client-Server network
  - Mass Storage Devices
  - High-end Workstations
- Work Group Computing

(10)

## FUTURE DATA INTEGRATION NEEDS




(11)

## ABBREVIATIONS

**IWGDMGC** - Interagency Working Group on Data Management for Global Change

**NASA** - National Aeronautics & Space Administration

**NOAA** - National Oceanic and Atmospheric Administration

**USGS** - U.S. Geological Survey

**EMAP** - Environmental Monitoring and Assessment Program

**CES/DS** - Center for Environmental Statistics Development Program

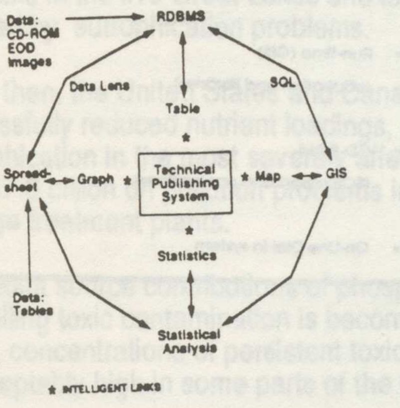
(12)

## DATA INTEGRATION AND REPORTING

- Mock-up of the state of the environment (SOE report)
- Relational database management system (RDMS)
- Geographic Information System (GIS)
- Technical Document Publishing System

(13)

## HOW FUNCTIONS WILL BE ORGANIZED




(14)

## DEFINITIONS

**RDBMS** - Related Database Management System

**CD-ROM** - Compack Disk - Read Only Memory

**EOD** - Erasable Optical Disk

**DataLens** - User-friendly link between spreadsheet and RDBMS

**SQL** - Structured Query Language (English-Like) for communicating requests to the database

**GIS** - Geographic Information System

(15)

**REPORT DESIGN, REVIEW AND PRODUCTION**

- Initial Mock-up of data presentations
- Ad hoc Advisory Committee Review
- Professional layout and writing
- In-House Technical Publishing of Drafts for Review
- Extensive Review and Revision
- Co-Publishing Agreement for Final Production and Distribution

(16)

## CES/DS IMPLEMENTATION: AN "INTELLIGENT DOCUMENT" SOE REPORT

- Database design (relational model, tables, rules, triggers, integrity and security)
- Create views of tables from RDBMS Query data from RDBMS into spreadsheets
- Import data into statistical analysis programs
- Enter data into multiple spreadsheets
- Create graphs from spreadsheet data
- Format spreadsheet data for input to GISs
- Select among multiple desktop GISs for each map display and analysis
- Create layout and text in technical document publishing system
- Link tables, graphs and maps to system
- Work group computing on a local area network

(15)

CEB/DS IMPLEMENTATION: CLIENT SERVER, WORK GROUP COMPUTING

- Stage 1 - Small Unix workstation server and several high-end PCs
- Stage 2 - Medium-sized Unix workstation server and about ten workstations
- Stage 3 - Largest Unix workstation server and about 30 workstations
- Stage 4 - Multi-processor servers and about 50-100 workstations
- Co-Publishing Agreement for Final Production and Distribution

(16)

OTHER REPORTING MEDIA AND ACCESS

- Video (SOE summary)
- Run-time (GIS) (education and libraries)
- CD-ROM (SOE report and appendices)
- On-Line Dial-In system

(17)

CEB/DS IMPLEMENTATION: COOPERATIVE AGREEMENTS

- World Resources Institute (1990-1993)
- Interagency Working Group on Data Management for Global Change
- Canada Centre for Mapping (in process)
- World Bank (under discussion)

EXHIBIT 2. From EPA's Pollution Prevention Strategy

**The Great Lakes Ecosystem**

Two decades ago, a study by the International Joint Commission (IJC) identified nutrients and toxics problems in the five Great Lakes and found that Lake Ontario and Lake Erie, in particular, were afflicted by eutrophication problems.

Since then, the United States and Canada have undertaken cooperative efforts which have successfully reduced nutrient loadings, particularly phosphorus, and helped to reverse eutrophication in the most severely affected areas. Since 1972, the U.S. Government has spent over $7.6 billion on pollution problems in the Great Lakes, mostly for over 1,000 municipal sewage treatment plants.

With point source contributions of phosphorus increasingly under control, the importance of controlling toxic contamination is becoming more evident. Although some progress has been made, concentrations of persistent toxic substances such as mercury, PCBs and lead remain unacceptably high in some parts of the Great Lakes, both in water and sediments.

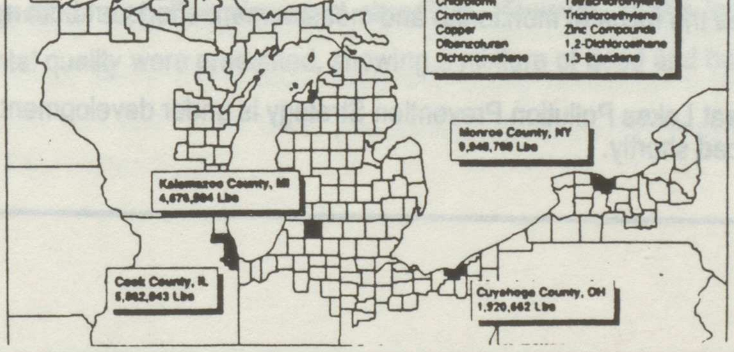
The IJC has found atmospheric deposition to be a major pathway to contamination and has observed airborne sources for 10 of 11 "critical" toxic pollutants. Studies have registered deformities in fish and wildlife exposed to contaminated sediments and other sources of toxic chemicals in the Great Lakes. While the decline in conventional pollutants has encouraged an increase in fish populations in some areas, all Great Lakes states advise residents to limit, or in some cases eliminate, their consumption of popular sportfishing species, such as perch, walleye, brown trout and chinook salmon, due to their contamination by toxics.

Sources: Council on Environmental Trends, Washington D.C. 1989; International Joint Commission, Third Biennial Report, Windsor, Ontario, 1986; Great Lakes National Program Office, U.S. Progress in Implementing the Great Lakes Wakter Quality Agreement, Annual Report to Congress 1988, Chicago, Illinois, July 1989; Great Lakes Water Quality Board, 1989 Report on Water Quality, International Joint Commission, October 1989.

EXHIBIT 3. Air Toxics Releases in the Great Lakes Region (selected TRI data):

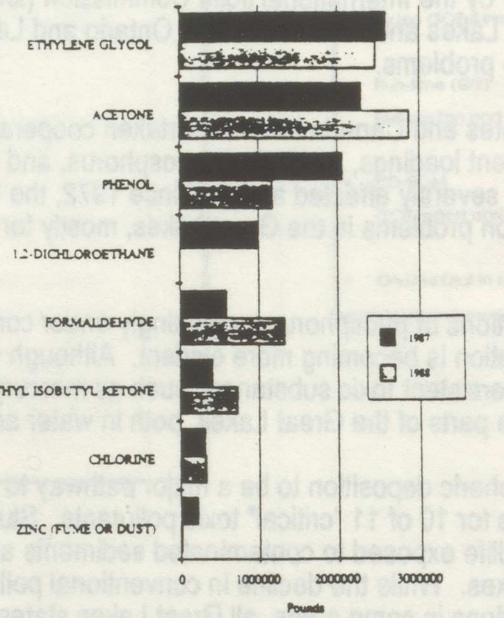
**The Big Hitters**

According to TRI, four of the 176 counties in the Great Lakes watershed released 45% of the following 16 chemicals to the air in 1988. These figures include both fugitive emissions and stack releases. Total releases from all counties equals 48,160,443 lbs. Total releases from the four counties below equals 2,407,977 lbs.



## EXHIBIT 4. From Briefing "Pollutant Loadings to the Great Lakes ..."

TRI Transfers to POTWs in the Great Lakes Watershed for Selected Chemicals
1987-1988




## EXHIBIT 5. Pollution Prevention Targeting

### POLLUTION PREVENTION TARGETING

- As part of EPA's Pollution Prevention Strategy, the Industrial Toxics Project targets 17 toxic substances:

  - 33% reduction of TRI releases of target contaminants by 1992
  - 50% reduction by 1995

- Pollution Prevention Act of 1990 requires companies to report annually on toxic chemical source reduction and recycling

- Increasingly, TRI releases of targeted substances as well as other contaminants identified as priorities will be the focus of monitoring and measurement efforts on both national and regional levels.

- A bilateral Great Lakes Pollution Prevention Strategy is under development and is expected to be announced shortly.

## 3.2 Canada: State of Environmental Reporting Progress on Environmental Indicators and Environmental Accounting

*Prepared by Paul Rump, Environment Canada, Hull, Quebec and*
*Kirk Hamilton, Statistics Canada, Ottawa, Ontario* *(from Canadian Water Watch, Volume 4, No.5)*

We can no longer rely on conventional measures of income and wealth to indicate national well-being. Economic development has entailed costs in environmental and resource degradation that have begun to have an impact on the economy and threaten to limit the development choices available for the future. Accounting systems need to be improved so as to include these costs.

The need for improved accounting systems is highlighted in Canada's Green Plan. *"As the importance of the relationship between the environment and the economy is recognized, there is a growing need for these accounts to be adjusted to show environmental impact and changes in natural resource flows."*

Also in the Green Plan is recognition of the "need to develop a simple set of indicators so that the state of complex environmental systems can be presented concisely and understandably." Interest in environmental indicators stems from growing public concern about the state of the environment and from the need for governments to evaluate the effect of their environmental policies.

### 3.2.1 A Report on Canada's Progress Towards a National Set of Environmental Indicators

Environment Canada has initiated a long-term project to develop a national set of environmental indicators. The Department's first report, released in April 1991, contains a preliminary set of indicators based on existing data and monitoring. In total, 43 indicators in 18 issue areas were presented. Environment Canada hopes to use these as "the basis for further, more widely based consultations to improve, augment and refine this initial set." The report is divided into five sections: atmosphere; water; biota; land and national economic resources. In this summary, our examination is limited to those indicators used to measure water quality and use.

The report concluded, "It was not possible at this time to provide concise, yet comprehensive, national trends for water quality" due to variations in natural water quality and the fact that water quality monitoring is not designed to support environment reporting. However, twelve indicators of fresh-water and marine environmental quality were presented, showing a mixture of good and bad news.

### 3.2.2 Freshwater Quality

- Since 1983, The percentage of the population served by sewage treatment plants has increased, as have secondary and tertiary treatment levels. But, despite these improvements, the discharge of organic wastes measured by Biochemical Oxygen Demand (BOD) and phosphorus has risen.

- While pulp and paper production has grown, discharges of Total Suspended Solids (TSS) and BOD from pulp and paper mills has declined. Discharges of chlorinated organic compounds (such as dioxins and furans) from these mills are not monitored on a regular basis, thus trend data are unavailable. However, an Environment Canada report released in April found dioxins and furans in various concentrations in the vicinity of 95% of the Canadian mills that use chlorine bleaching (see CWW Vol.4, # 4, page 29).

- There has been a steady downward trend in discharge levels of regulated substances from petroleum refineries since 1972. In 1987, the most recent year for which data are available, monthly discharge levels were in compliance 94% of the time.

- Recently, the phosphorous levels in the Lake Ontario mid-region have been below the objective set to restore the lake to a non-eutrophic state. But, many other heavily used lakes and rivers have phosphorous levels in excess of their objectives.

- With the exception of dieldrin, organochlorine residues in herring gull eggs showed a marked decrease from 1974 to the early 1980s, but since then the levels have remained essentially constant.

- Residue levels of PCBs and DDT in lake trout declined between 1977 and 1985, but levels of PCBs in Lake Ontario lake trout still exceed the objective set by the Great Lakes Water Quality Agreement. Since 1985, levels of DDT in Lake Ontario lake trout have remained essentially constant near the Great Lakes Water Quality Agreement objective.

- Changes in migratory game bird populations are related to water quality and availability. The report shows a severe decline in game bird populations since 1955, primarily caused by drainage of waterfowl breeding habitat for agricultural purposes.

### 3.2.3 Marine Environmental Quality

- Municipal discharges into coastal waters measured in terms of BOD and TSS loadings increased on the Pacific Coast between 1983 and 1989, but remained relatively constant on the Atlantic coast.

- Though there have been larger volumes of marine spills in recent years (mostly petroleum), it is difficult to identify a trend as there have been wide fluctuations from 1976 to the present.

- The area closed to shellfish harvesting on the Pacific and Atlantic coasts have increased steadily since 1972.

- Levels of PCBs in eggs of seabirds have generally declined since the early 1970s

- Levels of dioxins and furans in seabird eggs have declined, but current levels in the eggs of great blue herons in the Strait of Georgia are suspected of causing reproductive problems.

### 3.2.4 Water Withdrawals

- Water withdrawal in Canada increased by approximately 75% between 1972 and 1986 compared with a 60% growth in GDP for the same period. In 1986, this withdrawal constituted about 2% of the reliable water supply, but in some regions, such as the southern Prairies, water withdrawal requirements may exceed 50% of the available supply.

- Through activities such as mining and thermal power generation about 90% of the withdrawn water is returned to source, although not necessarily uncontaminated. Agriculture consumes 77% of the water withdrawn and not returned to source. The recirculation of water, although encouraged in some industries, declined by 30% for the three industrial sectors of mining, thermal power and manufacturing.

- Water withdrawal per capita for household use increased by 8% from 1983 to 1989, but comparison with other industrialized countries told a more complete story. Canadian municipal water use is double the European rate and water prices are the lowest compared to five other industrialized countries, including the United States.

### 3.2.5 Forestry

In April, the first annual State of Forestry in Canada report was tabled in Parliament by Forestry Canada. Rather than focusing on the state of the forest environment, the report is oriented toward commercial timber values. This reflects the type of data that is currently available. A chapter on "Forestry and the Environment" discusses the role of the forest in terms of non-timber values including biological diversity, wildlife habitat, aesthetics, wilderness and the forest's role with respect to carbon balance, acid rain and climate change. According to Forestry Canada, environmental values and indicators of environmental qualities are being developed and will be given more prominence in future reports.

The report shows that from 1974 to 1988, the number of hectares treated with chemical pesticides declined, but the area treated with chemical herbicides increased; the area treated with biological insecticides increased, but is still half that treated with chemical pesticides. Since 1978, the area of productive forest land harvested in Canada has risen by 25%, while the area planted almost tripled. The amount of forest successfully regenerated (as a percentage of area harvested) increased from 64% in 1978 to 80% in 1988.

The overall status of Canada's timber resource was presented in a "national forest account." This indicates the forest capital (the productive forest land base plus the timber growing on it) in 1976, the accruals and the withdrawals of capital from 1977 to 1986, and the net balance for the period. From 1976-86, the productive forest land base declined at an annual rate of 474,000 hectares (half the area harvested in 1988). However, additions to the timber volume surpassed depletions on an average of 69 million cubic metres annually, adding .3% to the standing growing stock of timber over the ten-year period. This was due to increased forest growth partly resulting from artificial regeneration.

### 3.2.6 Natural Resources

Statistics Canada is researching two initiatives outlined in the Green Plan; the development of "pilot accounts for two natural resources" and a "draft environmental accounting framework." Research is underway to quantify resource values for the oil and gas, and the forestry sectors with the objective of constructing preliminary national accounts for these sectors over the next year. Also being researched are designs for an overall accounting framework for natural resources. Data bases of environmental information from other federal departments are being gathered by Statistics Canada for eventual consolidation into an on-line data base of environmental information.

### 3.2.7 How Do We Compare?

Early this year, the Organization for Economic Cooperation and Development (OECD) released a preliminary set of 18 environmental indicators, comparing environmental performance among its 24 Member countries. Some of these are illustrated in the table below.

Canada has played a leading role in international efforts to develop better environmental indicators. The OECDs work toward a preliminary set of environmental indicators came largely as a result of Prime Minister Mulroney's initiative at the G7 Paris Summit in 1989. According to the findings presented, we are also one of the countries that has the most to learn from these indicators.

### 3.2.8 Other Developments

- The National State of the Environmental Report, due this fall, will also make extensive use of environmental information and indicators.

- The National Roundtable on Environment and Economy has established a multi-stakeholder working group to develop a set of national energy indicators. The report of a workshop held in March will be available from the National Round Table this summer.

| <u>OECD Environmental Indicators:</u> | *Canada's rank among OECD Countries* |
|---|---|
| • *sulphur dioxide emissions per capita and per unit of GDP* | *1* |
| • *nitrogen oxide emissions per unit of GDP* | *1 (tied with UK)* |
| • *nuclear waste created per unit of energy* | *1* |
| • *total energy requirements per capita* | *1* |
| • *water withdrawal per capita* | *2* |
| • *per capita production of carbon dioxide emissons from energy use* | *2* |
| • *energy intensity (energy requirements per unit of GDP)* | *2* |
| • *greenhouse gas emissions per capita* | *3* |
| • *municipal waste per capita* | *4* |
| • *population growth from 1970* | *4* |
| • *amount of industrial waste generated* | *4* |
| • *passenger cars per capita* | *4* |
| • *industrial waste per unit of GDP* | *6* |
| • *Canada is only slightly above the OECD average in percentage of population served by waste water treatment plants* | |

## 3.3 Indicators of Sustainability: A Framework for Decision-Making Regarding the Natural Ecosystem

*Prepared by Tony Hodge, McGill University, Montreal, Quebec*

### 3.3.1 General Purpose and Specific Objectives

Nourished by a growing concern for the environment and coupled with the recognition of vast and threatening inequitities that exist between developed and developing parts of the world, the idea of sustainability has reemerged as a mainstream concept. The contemporary discussion has centered on the vage notion of "sustainable development," a topic popularized in 1987 with publication of the Burndtland Commission's report "Our Common Future" (World Commission on Environment and Development 1987). As a result of this discussion, the relationship between human activities and well-being, and ecosystem well-being is now being addressed from both the perspectives of economic health and long-term environmental integrity.

### 3.3.2 Working Hypothesis

A *generalized framework* for assessing sustainability based on placing human activities as the link between human and ecosystem well-being is found in Figure 3.1.

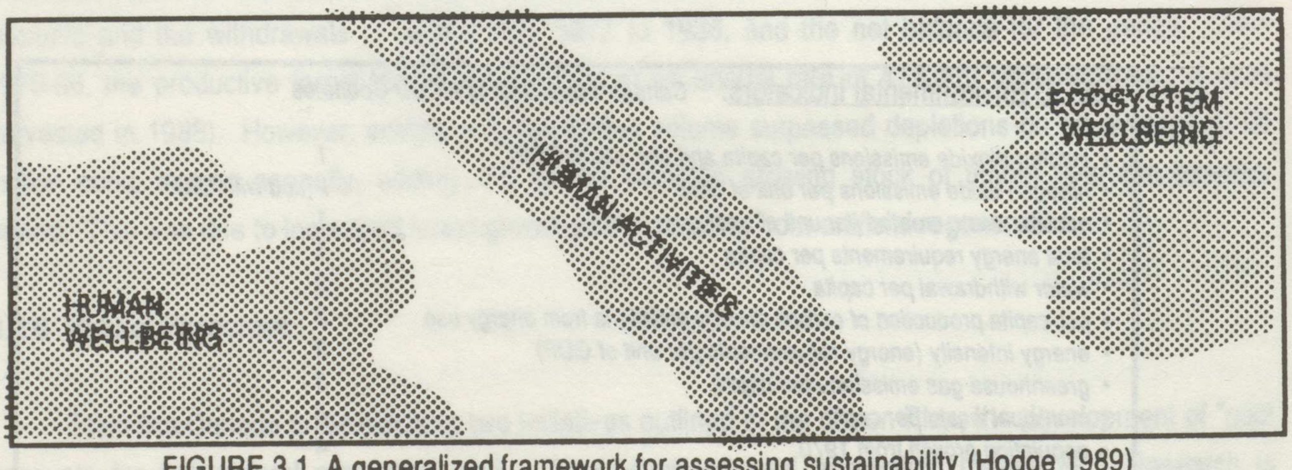



FIGURE 3.1 A generalized framework for assessing sustainability (Hodge 1989)

Historically, sets of indicators relating to each of the three components shown in Figure 1, human wellbeing, human activities (described most completely through our system of economic accounting) and ecosystem well-being, have been developed in isolation ffrom each other. The double-ended arrows in Figure 3.1 represent both the flow of life support contributed by the environment and the physical, chemical and biological stresses imposed by human activity on the environment. To date, attempts to establish a integrated set or system of "Indicators of Sustainability" linking all three components, have met with only limited success.

The following four assertions comprise a *working hypothesis* for the generalized framework:

1. An integrated system of indicators of sustainability can best be derived through a careful reassessment and characterization of natural and human-induced stresses on the environment.

2. Characterization of the stress elements will allow recognition of "streams" of interdependenty data that lie along a spectrum linking the components shown in Figure 3.1. Continuity along these streams will allow identification of key points of data and information. Using a time horizon appropriate to the particular stress and ecosystem elements being considered, a rationalization of data and information will be possible.

3. This systematic approach to identification of indicators is value driven in that it is based on a overal belief that society must move to minimize the stresses it imposes on the environment. However, the rate and extent of stress minimization will depend on values operating at any point in time. The system of indicators to be developed will be able to respond to such alternative goals and objectives for stress minimization and in that sense, it will be value independent.

4. The proposed system will be built on traditional professional strengths, linking easily and clearly to the range of existing systems of governance.

### 3.3.3 The Idea of Sustainabilty

The idea of sustainability dates at least as far back as the ancient Greeks who linked their vision of Gaia, the Goddess of the Earth, with natural replenishment (Hughes 1983). However, as noted previously, contemporary interest focuses on the notion of "sustainable development" defined by the Brundtland Commission as a kind of development that "... meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987). The general nature of this description has led to heated academic debate, the elements of which are important to understand for setting a context for this projecty.

At this stage of analysis, I draw the following conclusions. First, I concur with Daly's (in press) observation that the vague notion of sustainability has been key in developing an important consensus that we must factor in future needs with current decision-making. This conclusion sets a new time horizon for planning and decision-making. Second, Robinson et al. (1990) have rightly pointed out that the concept of sustainability is, in fact, a normative ethical princple. They define sustainability as "the persistence over an apparently indefinite future of certain necessary and desired characteristics of the socio-political system and its natural environment."

environmental factors only implicity, if at all. An essential paradix is that most costs attributed to degraded environments contribute to the growth of the GNP.

The MEBSS approach focused on a structual model of human activity where "economic transactions" were seen as physical processes rather than "economic instiutional transactions." It permitted, for example, an accounting of waste residual generation and provided a basis for measurement of national wealth in terms of physical assets (accumulated infrastructure) and natural resources. With development, this approach was seen as a potential replacement methodology for construction of input/output models.

A subset of this work led to the development of the "Stress-Response Environmental Statistical System" (S-RESS; Rapport and Friend, 1979). Within this work, Rapport and Friend recognized the difficulty of specifying appropriate indicators that would act as danger signals of ecosystem instability and eventual collapse. Their database development was motivated by three concerns (page 74):

1. the need to protect and conserve environmental assets for future generations
2. the need to maintain and enhance the quality of the ambient environment for quality of life objects
3. the need to make explicit the closing of potential options by man-initiatid permanent restructuring of the environment, i.e. ecosystem destruction

Through the 1970s and 1980s, state of environment (SOE)reporting slowly evolved as a recognized monitoring instrument in countries throughout the world. Over 200 such reports have now been written from global through national and regional to local. Though every SOE report team is faced with the task of portraying environmental conditions through the use of "indicators," to this day, no set recipe has emerged that has become the standard, either in terms of specific indicators or in terms of an overall approach to SOE reporting.

The Canadian-developed stress-response approach, combined with capability in physical-based modeling of human activity, together provide the most complete framework for addressing environmental indicators that is currently available. A specific application of this approach is given in Rapport (1983) and examples of SOE reports organized to some extent on the stress-response conceptual model include: at the international level, *The State of the Environment in OECD Member Countries* (OECD 1979); at the national level, *The State of the Environment Report for Canada* (Bird and Rapport, 1986); and at the municipal level, *The State of Environment Report - Regional Municipality of Waterloo* (Elkin 1987).

In spite of these advances and for a variety of reasons, an accepted conceptual "indicator" framework that links across the spectrum shown in Figure 1, remains elusive. The issue is a primary element of this dissertation and will be examined in detail. However, it is evident that a major limitation of work to date is the difficulty encountered in linking the results with existing systems of policy and decision-making.

### 3.3.5 Stress and Stress-Assessment Framework

The stress-response framework described by Rapport and Friend (1979) is analgous to the stress-strain approach of classical mechanicals where concepts of force, stress, deformation and strain are linked through idealized relationships between stress and strain. Stress is defined as the force per unit area acting at a given point and strain is the resulting deformation. In the natural ecosystem, properties are orders-of-magnitude more complex than those of a steel beam, a concrete wall or subsurface rock. In spite of this difference, the rigorous approach used to understand and characterize forces and resulting stresses in the study of mechanics stands as an example in considering the natural and man-induced stresses acting to cause environmental change.

The range of stresses experienced by the ecosysem can be grouped into the six distinct human and natural activities listed and described in Table 3.1. While these stresses are often imposed simultaneously and in an interlinked manner making identification of specific causes and effectis impossible, isolating specific stresses induced by human activity is possible. Furthermore, subsequent reduction of those stresses is equally possible through specific action on the part of society. This relationship betwen stress reduction and explicit societal decision-making is the practical link that provides a focus of this work.

The concepts embodied in Table 3.1 have evolved over the past decade and are regrouped by categorizing stresses as physical, chemical or biological in Table 3.2.

Whereas Table 3.1 is useful for understanding the various types of human activities that stress the environment, Table 3.2 focuses on the nature of potential stresses that any human activity might induce. It is this reassessment, based on an evaluation of induced stress that allows the "universe" of indicators to be developed from which an appropriate choice can be made. Historically there has been a preoccupation with chemical "pollution" and most government environmental programs, past and present, are driven by this issue. However, human-induced stresses on the environment are significantly broader. Further, it is an alternative perspective on human activities, one that recognizes the broad range of stresses outlined in Tables 3.1 and 3.2, that is required if the ideas of sustainability are to be brought from theory to practice.

TABLE 3.1 Naturally occurring and human-induced stresses experienced by the ecosystem (modified from Colborn et al. 1990; Regier 19988; Bird and Rapport, 1986; Rapport and Friend, 1979)

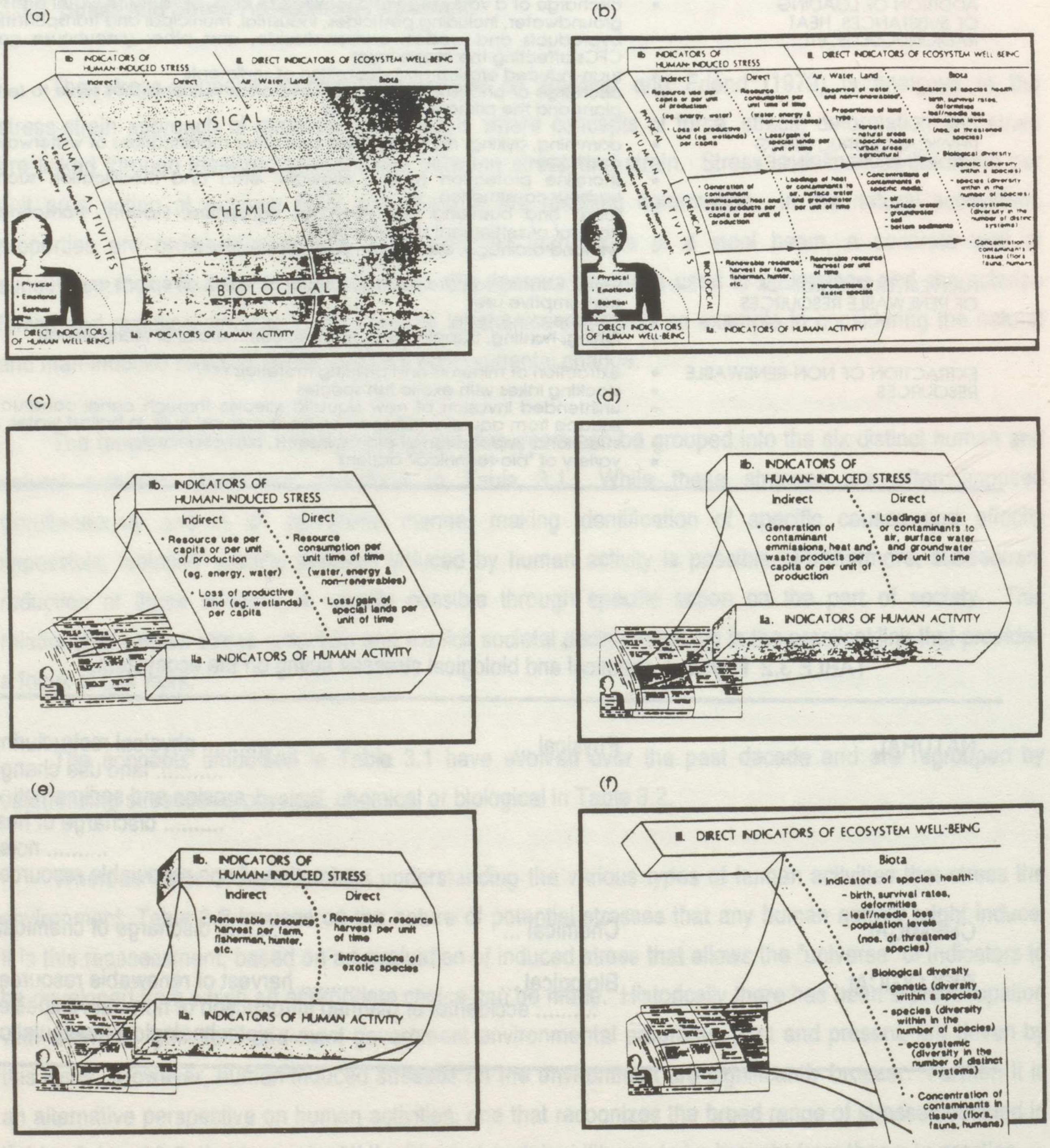
| STRESS CATEGORY | EXAMPLE ACTIVITY |
|---|---|
| NATURAL PROCESSES | • Weather related; wind, storms, rain, flooding, drought, freeze-thaw cycles<br>• natural fires in forest, grasslands and marsh areas<br>• disease, parasites and other causes leading to natural population shifts |
| ADDITION OF LOADING OF SUBSTANCES, HEAT RADIONUCLIDES, ETC. | • discharge of a vast range of chemicals to land, air, surface water and groundwater, including pesticides, industrial, municipal and transportation byproducts and wastes, carbon-dioxide, and other greenhouse gases, CFCs affecting the ozone layer<br>• man-induced erosion and deposition of sediments<br>• discharge of phosphorus, nitrogen and other nutrients that serve to fertilize plans and the primary tropic levels |
| PHYSICAL RESTRUCTERING AND LAND USE CHANGE | • damming, dyking, dredging, filling and other modifications of waterways and lakes<br>• shoreline protection (groins, seawalls, etc.) and modification such as harbour construction<br>• forest and bushland clearance for agriculture, industry, transportation corridor or settlement development<br>• wetland drainage, excavation and development |
| HARVEST/EXTRACTION OF OF RENEWABLE RESOURCES | • water withdrawals (from surface water or wells), diversions and consumptive uses<br>• commercial forestry<br>• fishing, hunting, trapping (subsistence, commercial or recreational) |
| EXTRACTION OF NON-RENEWABLE RESOURCES | • extraction of minerals and building materials<br>• stocking lakes with exotic fish species<br>• unintended invasion of new aquatic species through canal construction, escape from aquaria, transport on boat or ships' hulls, in ballast water, etc.<br>• intentional importation of plants, insects, bird or animals<br>• variety of "bio-technical" actions |

TABLE 3.2 Physical, chemical and biological stresses acting on the ecosystem

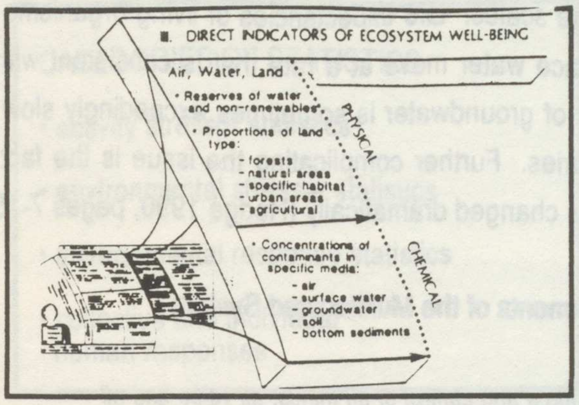
| | | |
|---|---|---|
| NATURAL | Physical ... | .......... physical restructuring<br>.......... land use change<br>.......... erosion and sedimentation<br>.......... discharge of heat<br>.......... noise<br>.......... extraction of non-renewable resources |
| CHEMICAL | Chemical ... | .......... discharge of chemicals |
| BIOLOGICAL | Biological ... | .......... harvest of renewable resources<br>.......... accidental or planned introduction of non-native species<br>.......... biotechnological manipulation |

Figure 3.2 (a through g) are a preliminary attempt to show "streams" of indicators organized within the general framework of figure 3.1 and grouped according to physical, biological and chemical stresses. To further develop this approach, each human activity as identified in (1) the standard industrial classification, (2) characterizations of settlemen development and (3) other classifications not captured in (1) and (2) should be assessed according to the stresses induced on the natural ecosystem. In this project, an arbitrary limit to the range of human activities has been established through choice of those related to water and energy use.

FIGURE 3.2 Streams of indicators organized within the general framework of Figure 3.1



(g)




Utilization of the stress assessment in this way is particularly powerful because it can relate directly to the system of policy and decision-making that governs human activity. However, in itself, the stress-related monitoring and assessment will give only part of the state-of-environment picture. Ultimately, all of the linked categories of data and information shown on Figure 3.2 are required to provide an assessment of the state of the environment. These are listed in Table 3.3.

TABLE 3.3 Categories of data and information required in state of the environment assessment

| | | |
|---|---|---|
| 1. | | Direct indicators of human well-being |
| 2. | a. | Indicators of human activity |
| | b. | Direct and indirect indicators of human-induced stress on the environment |
| 3. | | Direct indicators of ecosystem well-being |

The complexities in the above categories cause a significant data management challenge that is a key element of this dissertation. While a data/information accounting framework will be designed and tested, no attempt will be made to model and/or project future conditions.

### 3.3.6 Boundaries in Space and Time

Odum (1983, page 17) defines an ecosystem as "an organized system of land, water, mineral cycles, living organisms and their programmatic behavioral control mechanisms." While the breadth of the concept of ecosystem is captured in this definition, the difficulty in defining ecosystem boundaries is not. Rapport (1989, page 121) points out that "drawn" ecosystem boundaries are always to some extent arbitrary. In reality, ecosystems are "open systems with important linkages to neighboring systems via energy transfers and nutrient flows mediated by physical, chemical and biological processes."

A second characteristic that Odum's definition does not explicitly capture is that different components of the ecosystem operate on dramatically different time scales. Life expectancies of living organisms vary froma few hours to centuries. Similarly, air and surface water move at a rate that is consistent with the human sense of time and space while the movement of groundwater is sometimes exceedingly slow with discernable change best measured in terms of centuries. Further complicating the issue is the fact that over the centuries, humankind's perception of time has changed dramatically (Hodge 1990, pages 7-15).

### 3.3.8 Human Use of Energy and Water - Two Key Elements of the Multifaceted System

> *Everything is based on energy. Energy is the source and control of all things, all value and all actions of human beings and nature. This simple truth, long known to scientists and engineers, has generally been omitted from most education in this century.*
>
> Odum and Odum, 1976, page 1

> *Water commands a unique place among our natural resources. It supports other resources such as fish and forests; it provides an important medium of transportation and energy production; it governs our settlement patterns; it is a major recreational resource; it inspires artistic and cultural expression; and, of course, it is essential for all life.*
>
> Pearse et al. 1985, page 7

in the broadest sense, components of energy are necessary for the action of all the processes of the universe. In a like sense, energy use touches on every aspect of human life and is a major cause of human-induced stress on the environment. Odum and Odum (1976) point out that, from a human viewpoint, throughout history when energy is secure and adequate to meet needs, quality of life improves and conversely, when needs exceed available energy supplies, quality of life decreases. Thus, from any perspective, energy is a central element of sustainability.

Similarly, the critical importance of water to humankind ensures its place also as a cenmtral drainage-basin boundary provides an initial ecosystem limit that usefully bounds a study area for examining human-ecosystem interactions.

Together, detailed examinations of water and energy provide a broad test of approaching the issue of indicators of sustainability through the stress-assessment framework.

EXHIBIT 6

(1)

KEY ELEMENTS

- is value based
- VALUE SHIFT 1: environmental studies
- VALUE SHIFT 2: time horizon shift

(2)

SOE REPORTING PERSPECTIVES

- issues of concern
- industrial sectors
- ecosystem components
- combination

(Sheehy 1989)

(3)

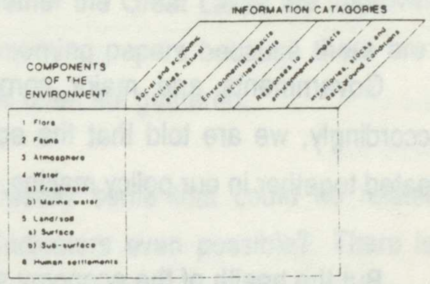
CATEGORIES OF STATISTICS

- activity stressor statistics
- environmental stressor statistics
- environmental response statistics
- collective and individual human responses

(Rapport and Friend, 1979)

(4)

UN FRAMEWORK FOR ENVIRONMENTAL STATISTICS (1984)




(5)

DATA CLASSIFICATION

- STOCKS
  - Population - Capital
  - Natural assets
- PROCESSES
  - Population - Natural
  - Socio-economic
- INTERACTIONS
  - Socio economic process with population
  - Natural assets with population
  - Natural assets with socio-economic processes
  - Population with natural assets
  - Socio-economic processes with natural assets

(Hamilton 1990)

(6)

INDICATORS OF SUSTAINABILITY -- SOE REPORTING --

- Direct indicators of human well being
- Indicators of human activities
- Direct and indirect indicators of human-induced environmental stress
- Direct indicators of ecosystem well-being

(Hodge 1991)

## 3.4 Better Environmental Indicators are Needed

*Prepared by Al T. Davidson, Royal Canadian Geographic Society, Vanier, Ontario*

*Canadian Geographic, February/March 1991*

Governments and major corporations in Canada are committed to sustainable development. Accordingly, we are told that the economy and the environment are closely related, that they must be treated together in our policy making, and that a healthy economy depends upon a health environment.

But the health of the economy seems much better understood and better analysed than the health of the environment. Thousands of our country's best pore over the financial pages of newspapers each morning analysing economic indicators: Gross National Product, unemployment, prime rate, housing starts, stock exchange indexes, the consumer price index, and the inflation rate. There are analyses of where these indicators have been and where they are going, and many relating one indicator to others. As indexes, they may have important shortcomings; the weaknesses of the GNP index, for example, are well known. But they are based on masses of data collected over many years, and are widely accepted.

Ideal indicators are those that are used to guide action. When the speedometer in your car registers over 100 km/hr in an 80 km/hr zone, you consider taking your foot off the gas pedal. When the thermometer outside registers - 30°C, you consider donning your parka before going out. Most economic indicators are not as clear cut as these, but important individual, government and corporate decisions, which greatly affect general well-being, are based on their analysis. Moreover, "state of the economy" reports by the Economic Council of Canada and the Organization for Economic Co-operation and Development are eagerly studied as a guide to public policy.

When we turn to the other side of the coin - the environment - the picture is much poorer.

"State of the environment" reports are issued by governments and private organizations, but most contain little solid analysis. It is difficult to tell from them whether the environment is getting better or worse. We may read that ozone levels, in city air are going up; that sulphur dioxide is going down; that nitrous oxides are increasing; that a toxic contaminant is found in parts per billion in the nearby harbour; that one species is flourishing while another is threatened; that so many million trees have been cut and so many million planted.

We may be left in confusion and uncertainty stemming from weak, unrelated and uninformative data.

Great Lakes environmental issues have been studied by hundreds of experts over many years. Arguably, greater strides have been made there in environmental management than in any other region on earth. But these same experts have difficulty saying precisely whether the Great Lakes are improving or getting worse. We do not read environmental indicators in our morning papers because there are few accepted indicators in general use and therefore the relevant data is often not gathered.

It seems clear we need better environmental indicators, ideally some that could be related to economic indicators. Is the development of a series of useful indicators even possible? There is no question it is a difficult task, but success would be a great step forward in environmental analysis.

In the past decade; a number of agencies have recognized the importance of the idea and are giving it renewed attention. In 1989 the G7 Economic Summit, attended by the World's foremost economic decision makers, called on the OECD to examine the development of environmental indicators.

Such indexes would need a framework within which they could be related. One possible framework would relate the health of the natural environment to the stresses put on it, which in turn are a result of man's economic activities.

In measuring the health of the natural environment, we are concerned with the integrity of natural systems, their productive capacity, their resilience. These do not have exact definitions, but neither do some aspects of the economy, and workable definitions might be arrived at. We know that these attributes are affected by non-natural stresses - the dumping and pouring of contaminants, and structural changes like roads, bridges, dams and buildings - and these in turn are related to economic development. It should be possible to find meaningful indicators at each of these levels. Lake trout have been selected as an indicator of the health of natural systems in Lake Superior; the ability of certain species like eagles to reproduce can be one indicator of the environmental health of some regions; tons of certain contaminants dumped are an important stress measurement and can be linked to economic activities; hectares of wetland drained or filled (or restored) can be linked to road and housing development, and then to numbers of automobiles and human population.

Beach closings or openings (an annual phenomenon in many Canadian cities) appear to be a good indicator of some aspects of water quality and in turn of the quality of sewage management. A trick would be to find single indicators that represent a number of trends in the same way that the Dow Jones Industrial Average reflects changes in the value of many stocks.

My own view is that good single indicators can be selected - certain fish, birds at the top of the food chain, sensitive plants - which can be related to stresses and economic activity.

Once such indicators are determined, the investment must be made to collect data as assiduously as we do for the economy. To achieve this will be costly, for nature is certainly far more complex than the economy.

No doubt we will need to monitor the ecology at a large number of sites over many decades. For a century and a half, the Geological Survey of Canada has done a marvelous job. Today, an Ecological Survey is needed on an equally ambitious scale.

Such a survey would be a great boon in promoting more informed understanding of environmental issues, predicting the impact of man's activities, and making sustainable development policy. If this issue gets more attention, we may look forward to reading meaningful "state of the environment" reports and sound environmental analysis over our morning coffee.

# 4.0 CONCLUSIONS

**Problems**

- the use of models tends to magnify uncertainty
- the effect of Technology and regulation confounds the ability to predict and forecast
- important aspects of Great Lakes problems are external to the basin and require data that is greater than the current regional scope
- Great Lakes problems cannot be addressed solely in terms of water quality
- data is inherently static, however, the problems are dynamic. The use of structural statistics related to commodities is of limited value because the economy is moving to services. The most important indicators are perhaps related to the three R's. Reduction of raw material input, reuse, recycling. Energy efficiency is one way of measuring the impact from human activities.
- there is a need for more science to address cleanup after damage, in some cases the ecosystem will not heal itself - what information is needed that can indicate the type of intervention that is required?
- passive observations about how a system is working is insufficient - there is a need for controlled interventions to determine what is necessary for integrity.

**Opportunities**

- the ecosystem approach connects human activities and links the economic system and water quality under the Agreement
- focus on consumption/demand data rather than production/supply data and avoid the end of pipe approach when defining environment/economy linkages
- work from the "middle" i.e.

TOXIC EMISSIONS
↓
ECONOMY - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - IMPACT

- the most relevant indicators are not post mortem but risk assessment
- there is a need for indicators of healthiness rather than indicators of pathology

- there is a lack of a framework to support SOE reporting, and a lack of understanding of processes; there is a lack of seminal work and direction to address this problem. The IJC could play a leadership role in developing the original work to move beyond managing data and coordinating information. The IJC role would be to focus on the thinking behind a State of the Ecosystem Report.

**Other Relevant Comments**

- There is a need to move beyond Great Lakes/Great Legacy; from risk assessment to risk management. Three questions need to be addressed:

  1. What are the relationships of toxics and effects inside and outside of the basin?

  2. What is the relationship of toxics to the economy?

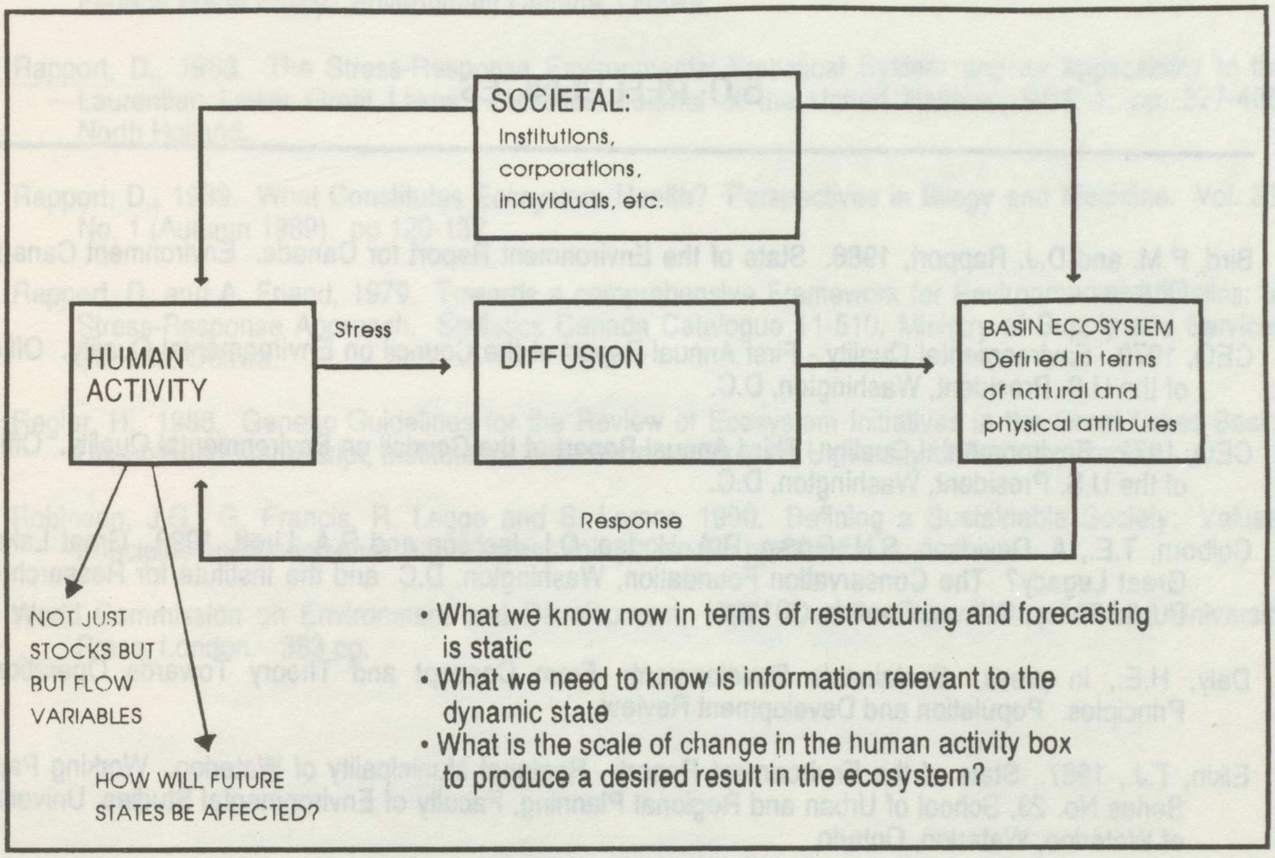
  3. What are the options for modifying the human activities?

- Economic efficiency reduces redundancy and as efficiency increases vulnerability increases. In nature the opposite occurs as the ecosystem diversifies.

- When assessing the impact of human activities data is most relevant in terms of the specific industry or sector. The most important of these can be identified from working from the general to the specific, i.e., 72% of the energy is used by 4% of the industries; from Toxic Release Inventory data - four of the 176 counties in the U.S. basin released 16 of the toxic substances in greatest quantity.

- In terms of indicators it is necessary to consider more than one suite, i.e. there are at least three that are important: compliance, early warning and diagnostic.

- Other relevant comments continued .......


SOCIETAL:
Institutions, corporations, individuals, etc.
HUMAN ACTIVITY
Stress
DIFFUSION
BASIN ECOSYSTEM
Defined in terms of natural and physical attributes
Response
NOT JUST STOCKS BUT BUT FLOW VARIABLES
HOW WILL FUTURE STATES BE AFFECTED?
• What we know now in terms of restructuring and forecasting is static
• What we need to know is information relevant to the dynamic state
• What is the scale of change in the human activity box to produce a desired result in the ecosystem?

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# APPENDICES

A. Glossary of Acronyms and Phrases

B. List of Participants

C. The Development of a Database to Support Reporting on Human Activities Related to the State of the Great Lakes Basin Ecosystem
*Robert Hoffman, Robbert Associates, Ottawa, Ontario (February 1991)*

D. Manual for the Prototype Database: State of the Great Lakes Basin Ecosystem
*Robert Hoffman, Robbert Associates, Ottawa, Ontario (February 1991)*

E. Analytical Report on: Human Activities Related to the Great Lakes Basin Ecosystem
*David R. Allardice and E. Erderig*
*Federal Reserve Bank of Chicago, Chicago, Illinois (February 1991)*

# APPENDIX A: GLOSSARY OF ACRONYMS AND PHRASES

| | |
|---|---|
| BOD | Biological Oxygen Demand |
| CD-ROM | Compact Disk - Read Only Memory |
| CEQ | Council of Environmental Quality |
| CES/DS | Center for Environmental Statistics Development Program |
| DDT | dichlorodiphenyltrichloethane |
| DataLens | User-friendly link between spreadsheet and RDBMS |
| EMAP | Environmental Monitoring and Assessment Program |
| EOC | Erasable Optical Disk |
| GDP | Gross Domestic Production |
| GIS | Geographical Information System |
| GNP | Gross National Product |
| IJC | International Joint Commission |
| IWGDMGC | Interagency Working Group on Data Management for Global Change |
| MEBS | Material-Energy Balance Statistical System |
| NASA | National Aeronautics and Space Administration |
| NEPA | National Employment Policy Act |
| NGOs | Non goverment organizations |
| NOAA | National Oceanic and Atmospheric Administration |
| OECD | Organization for Economic Cooperation and Development |
| RDBMS | Related Database Management System |
| SAMM | Scenario and Model Manager |
| S-RESS | Stress-Response Environmental Statistical System |
| SNA | System of National Accounts |
| SOE | State of the Environment |
| SQL | Structured Query Language |
| TOOL | Tool Kit for Data Analysis |
| TRI | Toxic Release Information ???? |
| TSS | Total Suspended Solids |
| U.S. EPA | United States Environmental Protection Agency |
| USGS | United State Geological Survey |

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## APPENDIX C: THE DEVELOPMENT OF A DATABASE TO SUPPORT REPORTING ON HUMAN ACTIVITIES RELATED TO THE STATE OF THE GREAT LAKES BASIN ECOSYSTEM

(insert)

DRAFT
revised 22-Feb-91

# The Development of a Data Base to Support Reporting on Human Activities Related to the State of the Great Lakes Basin Ecosystem

prepared for the

International Joint Commission

by

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February, 1991

Contents

# 1. Introduction

This report is intended to serve as a background document for the Scoping Workshop on Human Activities and the State of the Great Lakes Basin Ecosystem, scheduled for February 18 and 19, 1991. It presents the findings from a project carried out by ROBBERT Associates in the period November 1990 to January 1991. The purposes of the project were:

1. To develop a framework within which data relating human activities to Great Lakes water quality can be identified and compiled.
2. To identify and assess data sources and to assess the the comparability of data from Canadian and U.S. sources.
3. To develop procedures for managing the acquisition and maintenance of the data base.
4. To compile a prototype data base which will serve to:
   a. illustrate concepts, methods, procedures, and data management techniques; and,
   b. support the preparation of the forthcoming State of the Great Lakes Report.

# 2. The Need for a Framework

All too often, there is a sequence that runs like this

1. a problem is identified
2. it is determined that there is a need for data
3. data collection and compilation activities are initiated
4. large amounts of data are stuffed into a 'data base' on the grounds that they seem to be relevant
5. users of the data base find that "90% of the data they require is not in the data base and 90% of the data in the data base is not relevant"
6. it is then determined that what was needed was a "framework" to ensure that the data base was both comprehensive and relevant

Fortunately, in the case of a data base to support reporting on the state of the Great Lakes Ecosystem, the need for a framework was identified at the outset. It is the objective of this section of the report to stimulate the development of such a framework by putting forward some tentative ideas.

Unfortunately, the word framework, as appealing as it is, is rather abstract and has different meanings for different people. In what follows, the word framework will be used in the following sense:

A *framework* is the understanding of a system that is required if effective action is to be taken with respect to that system.

A *system* is a part of the real world that we single out for observation distinguished from its surroundings by a boundary. A system consists of a set of processes. The concept of process is fundamental; it is a dynamic concept concerned with the transformation of streams of input flows into streams of output flows within arbitrary boundaries. Interactions among processes give rise to the properties of the system. Quantitative description of a system makes use of the *properties* which are simply the quantities identified by well-defined measuring operations. The *state* of a system is defined, or prescribed, by a particular set of property numbers. According to Capra (1985), the concept of process is primary; the observed states of a system are a manifestation of the underlying processes.

*Effective action* is the means by which an actor can influence an object or system to behave in a desired way. An actor is an individual, a group of individuals, an institution, or a group of institutions. Action is effective if the actor meets his objective, if the system is influenced in such a way that it behaves in the desired way or produces the desired outcomes. The actor bases its decisions on observations of the state of the controlled system and on its understanding of the controlled system. The observations of the state of the system are the system *indicators*; the understanding is referred to as the *framework* or *systems model*. The understanding embodied in the systems model serves both as a framework for delineating the possible outcomes from which the desired outcome must be chosen and for defining the system indicators.

To summarize, effective management has three necessary ingredients : a well defined objective, an understanding of how the system-to-be managed works, and continuing observations of the state of the managed system that provide feedback to the system manager.

In the application of these concepts to the issue of the Great Lakes Basin Ecosystem, the following difficulties are apparent:

(a) The Great Lakes Basin ecosystem is characterized by complexity: it is made up of human activities and naturally occuring processes. Together they constitute an entire socio-economic system in the context of its environment; the environment serves both as a source of and a sink for materials and energy used to support human activities.

(b) In this case, the actor or manager is not monolithic. Rather, the actor is society itself composed of individuals and the institutions of society that have been delegated responsibility for managing various aspects of human activities, including the IJC, state and provincial governments, two national governments, and local governments. Clearly, individuals, corporations, and non-governmental organizations, through their actions, impact the ecosystem.

(c) The understanding of the system is both incomplete to the extent that specific processes are not understood and fragmented in that understanding exists in narrowly defined disciplines. Consequently, there is inadequate understanding of the system as a whole; furthermore what understanding there is is not necessarily held by the relevant institutions nor is it sufficiently broad-based.

(d) Societal objectives with respect to the ecosystem are not well-defined. They are couched in phases such as "sustainable development" or "harmony between human populations and the environment that sustains them". Furthermore, the objectives of various actors in the system may well be incompatible.

(f) The feedback loop from observations of the ecosystem to the actors is weak and indirect. The IJC state of the ecosystem reporting mechanisms are an important part of that feedback loop.

## 3. The Development of a Framework

The first step in the development of a framework is the designation of the boundary of the Great Lakes Basin Ecosystem. Since the focus of the IJC mandate is the Great Lakes and water quality, we take the boundary of the ecosystem to be the Great Lakes basin drainage area. We include in this the Ottawa River and Upper St. Lawrence drainage areas. This geography is defined on the hydrometric maps produced by Environment Canada (Map References 1 and 2). The drainage area of the Great Lakes and Upper St. Lawrence basin consists of 6 Minor basins. These are further subdivided into 104 sub-sub basins, each of which is distinguished by a unique hydrometric code. The list of hydrometric codes is appended.

The next step is to identify the processes that constitute the system. Bearing in mind that the concept of process primary, it is incumbent upon us to identify processes at a level of resolution that is commensurate with management possibilities. The rule of parsimony should apply.

Three sets of processes can be identified:

1. **Human Activities**: Processes that are purposeful in that they are designed and used by humans to meet their needs for food, shelter, etc. It is useful to focus on those activities that have consequences for water quality. These processes are both the source term for the discharges the affect water quality and the means by which water quality can be ameliorated.

2. **Diffusion Processes**: Processes that move contaminants from point of discharge to the lakes.

3. **Naturally-Occuring Processes:** Biological and chemical processes that occur within the lake that are affected by the materials entering the water body.

This report is concerned only with the first category of processes, namely human activities.

Two kinds of human activities may be distinguished: those that transform materials and energy and those that transform information. The former constitute (a part of) the physical substrate of a socio-economic system; the latter the institutional or behaviorial space . This separation serves to make human behaviour explicit as processes in institutional space, in such a way that the influence or outcomes of decisions are registered in the physical substrate. Certain physical transformation processes occur within human-created artifacts or plants. These processes are influenced by two levels of decisions: decisions to build plants or artifacts according to particular designs, and decisions with respect to their operation. Other processes which occur naturally, such as plant growth, are directly influenced to meet human objectives. While it is customary to think of a process as transforming raw materials and energy into products, the concept applies equally to consumption activities. For example, a house may be thought of as artifact that is intended to provide conditioned space to its occupants.

It is clear that the processes of most interest from the perspective of reporting on the state of the ecosystem are physical transformation processes, particularly those that affect water quality either by direct discharge to water bodies or indirectly by through run-off. Two other factors must be taken into consideration in the designation of processes: the first is geographical resolution. It is important that the processes be specific to locations in the drainage area. It seems appropriate to use hydrometric codes, of which there are 104 in the Great Lakes Basin, as the target level of geographical resolution. Second, it is important that the processes chosen have sufficient resolution that the effects of ameliorative action can be registered, ie, it important there be sufficient resolution to monitor the effective of recommended actions on the quantity of discharges and ultimately on the quality of lake water.

## 3.1 Industrial Point-Specific Processes

There are a relatively small number of individual plants or processes, approximately 500 in the Canadian part of the basin, that are transform relatively large quantities of materials and energy and water. Often, these plants discharge waste water containing effluents directly into water bodies. It would desirable that a data base contain information indicating the states of each of these plants individually. Theses plants are engaged in the following activities:

mining, milling, and refining

pulp making

petroleum refining

manufacture of industrial chemicals

generation of electricity

cement making

steel making

The states of these processes might be indicated by the following variables:

capacity of the plant

throughput or production

volume of water discharged by sink

quality of water discharged

temperature of water discharged

quantity of solid waste

accumulated solid waste stored on site by quality of storage

emissions to air

### 3.2 Municipalities or Urban Areas

It is proposed that each municipality or urban area be treated as a process. It is recognized, of course, that each urban area has a rich and diverse set of human activities. However, it is usually the case that there is usually a single source and a single sink for water used in each community.

The states of these processes might be indicated by the following variables:

urban population

number of dwellings by type

employment by sector

area of developed land residential, industrial, commercial and institutional

capacity of water treatment facilities

capacity of sewage treatment facilities

quantity of water discharged from sanitary system after treatment

quality of water discharged from sanitary system after treatment
quantity of water discharged from sanitary system not treated
quality of water discharged from sanitary system not treated
quantity of water discharged from storm system
quality of water discharged from storm system
air quality
solid waste generated
solid waste accumulated in landfill by quality of the landfill site

## 3.3 Non Point-Specific Processes

### 3.3.1 Agriculture

The state of agriculture in each geographical area might be indicated by the following variables:

number of farms
farmland by type: cropland, pasture, woodland, etc.
area of cropland by type of crop seeded
area by kind of cultivation: wide-row, close row
area by tillage practice
area fertilized by nutrient
area sprayed by chemical compound
quantity of fertilizer applied by nutrient and type of fertilizer
quantity of chemical spray applied
area irrigated by kind of equipment
quantity of irrigation water by source
livestocks
manure generated
disposal of manure

### 3.3.2 Forests and Forestry

The state of forestry in each geographical area might be indicated by the following variables:

area of forest land
volume of forest inventory by age class and species
area clear cut by year of cut
area managed by year seeded
volume of wood harvested by species
logging roads constructed
wild life populations by species

### 3.3.3 Other Land Use

area of parkland
area of wetlands
area for transportation corridors: road, rail, pipeline, power transmission

### 3.3.4 Shore line structuring

length of shore line by type of use: urban, recreational, wetland, etc.

## 3.4 Water Based Activities

### 3.4.1 Commercial Fisheries

The state of commercial fishing activities might be indicated by the following variables:

catch by species and average size
fish quality
fleet size
fishing effort
number of fishermen

### 3.4.2 Sport Fishing

The state of commercial fishing activities might be indicated by the following variables:

catch by species and average size
fish quality
fishing effort
number of fishermen

### 3.4.3 Shipping

The state of shipping activities might be indicated by the following variables:

registered fleet by tonnage
port activity in tonnage
ton-miles carried
canal traffic

### 3.3.4 Recreational Boating

The state of recreational boating might be indicated by the following variables:

number of boats by type of boat
number and capacity of marinas
hours of use

## 4. Process Data

Thus far the framework has been elaborated in terms of the designation of the processes that it should encompass and the variables that indicate the state of each process. Two points should be made here: interpretation of the state data or changes in the state data requires an understanding of how each process works; this information cannot in general be derived from observations of state variables. What is required, then, is a data base of process descriptions. In the early 1980's, the Structural Analysis Division of Statistics Canada developed concepts, methods and a prototype data base of industrial process descriptions. It was suggested that three sets of data could combine to form a process description: a representation of the topography of the process which defined the process in terms of a boundary and the names of the flows that cross the boundary; the functional form or forms of the transformation occuring inside the process which serves to define the parameters of the relationships between input flows and output flows, and; sets of values of the parameters identified above. In essence, what was proposed was a data base of process models. Process data for many of the industrial processes identified above is readily available in the engineering literature.

# 5. Data Sources

This section of the report describes a number of data sources that were identified during the course of the project. The list of data sources is, of course, not exhaustive, nor were all the of topics suggested in the framework covered. However, from the sources that were identified and evaluated, some conclusions can be drawn with respect to the feasibility of compiling a data base in accordance with the framework whose rough outline has been described in the preceding sections of the report. These conclusions are presented in the following section.

## 5.1 Statistics Canada Environmental Information System (EIS)

Statistics Canada is in the process of establishing an Environmental Information system using the geographic information system software package Arc Info. This system is intended to support geographically disaggregated data so that it can be retrieved according to different geographical criteria. Data from this data base will be used to prepare the tables to be published in a forthcoming edition of Human Activities and the Environment. In this case, the two main spatial aggregations will be hydrometric areas and ecozones. At the present time, the data base contains about 835 variables, where a variable is a set of values, by geographical area, for a single time period. For example, "population 1986" is a single variable containing population counts for the 44,042 enumeration areas (EAs) that constitute Canada for 1986; "population 1981" is a separate variable consisting of 41,197 population counts corresponding to the EAs in 1981. At the present time, the variables for EIS are mostly drawn from the 1971, 1976, 1981 and 1986 censuses of population and agriculture. Accordingly, the data base contains approximately 200 time series for each geographical area, each time series consisting of four data points. The data base also contains some data on power generation facilities such as the installed capacity and the kind of fuel burned for thermal plants. For the most part, sample surveys, such as the labour force survey or the household surveys will not support geographic dissagregation because the samples are not large enough. Statistics releases data from the data base on a cost recovery basis. Statistics Canada is in the process of adding more variables to the data base, in the area of forestry and mining.

### 5.2 Environment Canada Water Use Survey Data.

Environment Canada has conducted industrial and municipal water use surveys for the years 1972, 1976, 1981, and 1986. Each survey year, data is collected from approximately 5000 industrial establishments and municipalities by means of mail questionnaire. A two page overview of scope and methodology is attached. Summary results are published. The data is being entered into an Oracle data base in such a way that it can be retrieved according to hydrometric geography. The source data can be released to the IJC on IBM compatible diskettes at no cost.

### 5.3 Canadian Forestry Service, Forest Inventory Data

The Petawawa National Forestry Institute, a branch of the Canadian Forestry Service, maintains a Canadian forest inventory data base for 1986 in a GIS system (Arc-Info). The inventory contains information for 43,156 geographical areas called cells. At the present time the cells vary in size. The smallest is 100 $km^2$; the ultimate objective is to standardize at that scale. The information recorded for each cell is area in hectares and wood volume in cubic metres per hectare by ownership (crown, private); status (reserved, available for harvest); land class (water, forest, non-forest); stocking class for forest land (non-stocked, fully stocked); cause of disturbance for non-stocked forest land (cutover, burn, pest), age class in 20 year age classes; maturity class (even aged regeneration, immature, mature, overmature, uneven aged); forest type (hardwood, softwood, mixed); predominant species (13 species). These data can be retrieved in the river basin geography if the appropriate digital map file is provided to PNFI. Such a file exists at Statistics Canada. There may be a problem with Quebec as Quebec has asked PNFI not to release data below the level of the province. An estimate of cost has been requested.

The Canadian Forestry Service publishes information on area and volume cut, but the most detailed data is at the provincial level.

## 5.4 Ontario Ministry of Natural Resources, Forest Management Data Base

The Ontario Ministry of Natural Resources, the agency responsible for forest management, maintains information on area and volume cut at the level of forest management areas. A map showing forest management areas was made available by MNR. (Map Reference 3). MNR indicated willingness to provide data at that level. Some work would be required to transform the data from forest management areas to hydrometric areas.

## 5.5 Energy Mines and Resources Data on Mining Operations

EMR publishes a list of mine operators and provides information on location of mill/mine/refinery, year mill started operations, mill capacity in tonnes/day, process, products, and descriptive information. Production data for each mine is published separately.

## 5.6 Environment Canada - Air Emissions Inventory

Environment Canada maintains an emissions data base and has published summary data for the period 1970 to 1986. Air quality data for selected urban centres is published as well.

## 5.7 Ontario Ministry of the Environment - Industrial Discharge Data

Information on approximately 350 industrial plants is published for the year 1986. The data include plant name, industry, location, volume of water discharged, receiving water body, actual loadings by element measured in kg/day, and guidelines.

### 5.8 Ontario Ministry of the Environment - Municipal Discharge Data

Information for each municipality operating sewage treatment plants is published for the year 1986. The data include plant name, type of treatment, location, volume of water discharged, receiving water body, actual loadings by element measured in kg/day, and guidelines.

### 5.9 Fisheries and Oceans - Sport Fishing Surveys

Fisheries and Oceans Canada in conjunction provincial and territorial government agencies conduct periodic surveys of sport fishing activities. Data include catch by species by area, number of fishermen, fishing effort, etc.

## 6. Prototype Data Base

A part of the project consisted of the compilation of a prototype data base which would serve to:

a. illustrate concepts, methods, procedures, and data management techniques; and,

b. support the preparation of the forthcoming State of the Great Lakes Report.

Approximately 335 variables from the Statistics Canada Environmental Information System were loaded into a prototype data base. Each variable is geographically referenced at the level of the 104 hydrometric codes in the Great Lakes Basin. Thus, about 34,000 data points were loaded into the data base.

The prototype data base was implemented using the ROBBERT Associates suite of software tools, TOOL, SAMM, and Documenter.

The data base was designed as a hierarchical structure shown on the first page of the Manual. This structure is used to navigate through the data base. The shaded boxes in the hierarchy are the nodes, or calculators, that contain data.

Each node or calculator is documented in the Manual in terms of a diagram showing the variables stored at the node and the relationships among the variables, a calculator description section that contains a description of the calculator, a list of the variables, a listing of the TOOL code representing the programs that implement the relations among the variables, and references to data sources.

The diagrams use special symbols to represent variables and procedures. 'Barrels', 'pipes', and 'hexagons' are used to represent stock, flow, and ratio variables respectively; 'rectangles' are used to represent procedures. The arrows connecting variables to procedures designate variables as inputs or outputs of the procedure.

The variables are multi-dimensioned arrays. For example the variable population is population count by time (1971, 1976, 1981, 1986), by sub-sub basin. TOOL is a language that manipulates multi-dimensioned arrays, using a syntax that resembles sub-scripted algebra. It also displays variables in tabular and graphic format. The shapes of the variables associated with each calculator node are documented in the Manual. By shape is meant information on the dimensions over which the variable is defined, units of measure, and entity. TOOL does its arithmetic using standard international units of measure and full dimensional analysis over units of measure and entity. The section of the Manual entitled, Informants, lists the titlesets associated with each dimension or informant.

The procedures calculations registered at each node in the data base framework take as input the data obtained from Statistics Canada and perform operations such as aggregation, interpolation, extrapolation. They may also take data from other calculators in order to calculate intensities or densities.

The data base is managed by SAMM which is a system that keeps track of the hierarchical structure and the linkages among calculators. SAMM also keeps track of different versions (perhaps revisions) of data. When data are revised, all of the derived or output variables can be calculated. Because the derived variables can always be derived from the input variables from the information stored in SAMM, it is not necessary to provide permanent disk storage for them. SAMM also provides the facility to store "views" at each node in the hierarchy. A view is a file of TOOL code which may be used to display a variable or a combination of variables according to the preference of the user. For example, views may be used to calculate and display growth rates.

The program, Documenter, is used to create the diagrams and other components of the Manual. The files created by Documenter are used to structure the data base; this assures that the Manual is always a reflection of the data base.

Facilities exist to import and export into and out of the data base in different formats such as ASCII, DIF, and spreadsheet formats. For example the Statistics Canada data was imported using the DIF format. The Macintosh system can read and create IBM compatible disks.

At this time TOOL does not support cartographic display. However, cartographic display can be achieved by using the export channel to transfer data to a cartographic system such as SPANNS or MAP II.

Appendix 3 provides an overview of the functionality of the ROBBERT Associates software tools.

## 7. Concluding Remarks

(i) This report presents a first attempt at developing a framework for organizing a data base to support reporting the state of the Great Lakes Basin ecosystem. The proposed framework identifies the human activities or processes that are pertinent to the issue of water quality in the Great Lakes. It is suggested that the data base contain observations of the variables that indicate the state of these processes. The spatial resolution of the processes that is recommended is the 104 hydrometric codes or areas that constitute the Great Lakes, Ottawa River, and Upper St. Lawrence drainage areas.

(ii) The report focused exclusively on human activities. It was recognized that a comprehensive framework would have to consider two additional sets of processes: those concerned with the diffusion of substances from the point of discharge to the recipient water bodies, and; naturally ocuring chemical and biological transformations that take place in the environment.

(iii) A key suggestion is that the data base contain information on individual plants engaged in the following activities: mining, milling, and refining, pulp making, petroleum refining, manufacture of industrial chemicals, generation of electricity, cement making, and steel making. This raises the question of the availability of data as it is clear that Statistics Canada cannot release data on individual plants because of the confidentiality provisions of the Statistics Act. It should be noted that data on individual plants is published by EMR for the mining sector and by Statistics Canada for power generation. As well, the Ontario Ministry of the Environment publishes data on discharges from individual plants. It is the opinion of the author that sufficient information can be found from non Statistics Canada sources to make reporting for selected individual plants feasible.

(iv) A source of data not evaluated is the process for developing Remedial Action Plans (RAPS). It would appear that the RAP process might be an invaluable data source.

(v) A problem common to many areas of the data base is lack of sufficiently detailed or reliable data on the quality of water discharged from point sources. The same holds true for emissions to air and solid waste. In many instances, measurements of concentrations properly sampled have not been taken. Even when samples are tested, the range of chemical elements whose presence is to be determined is not comprehensive. Furthermore, there is tendency not to disclose the results of testing especially if the results show a problem. Perhaps the only way to estimate these flows is build process models which take as input the level of activity of the plant, the process configuration of the plant, the properties of the materials being processed where relevant, and calculate as output waste flows. In the longer term, these estimates can be calibrated to water quality measures in the receiving water bodies.

(vi) The census of agriculture data provides a relatively rich data set on the state of agriculture. However, from the perspective of linking agriculture to water quality, several pieces of data are missing: nutrient content of fertilizers applied, chemical composition of pesticides applied, tillage technique (conventional or conservation tillage), and the use crop rotations or cover crops.

(vii) This report touched only briefly on the need for process data. The feasibility of developing such a data base and the software systems needed to support it need to be established.

(viii) If it is decided to proceed with the development of a data base of the kind addressed by this report, questions of support and access arise. It is the opinion of the author, that some agency, perhaps the IJC, house the activities associated with the data base. Because of the diversity of data sources and the degree to which data must be messaged and manipulated, it is not feasible to rely on envision a distributed data base.

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# WATER USE DATA

## DESCRIPTION

The way we use water has an important bearing on how it is managed. To assist with the wise management of this resource, Environment Canada is developing a water use database which will include information on all major water users.

## COVERAGE

Data are currently available on municipal water use, and industrial water use in four sectors - manufacturing, mineral extraction, thermal and hydro power. A more detailed list of the type of information available is on the back of this sheet.

## SOURCES

Municipal water use data were originally obtained from a federal and provincial inventory of municipal water works and waste treatment facilities published in 1975. It was updated by Environment Canada through 1983, 1986 and 1989 surveys of municipalities with over 1,000 population.

Industrial water use data are obtained from over 5,000 industrial companies through periodic surveys conducted in co-operation with Statistics Canada. Such surveys have been undertaken for 1972, 1976, 1981 and 1986.

## ACCESS

Until the database is developed, data is available in the following publications of Environment Canada:

. *Manufacturing Water use Survey, 1972 - A Summary of Results* by D.M. Tate (Social Science Series #17)
. *Water Use in the Canadian Manufacturing Industry, 1976* by D.M. Tate (Social Science Series #18)
. *Municipal Water Use in Canada, 1976* by D.M. Tate and D. Lacelle
. *Water Use in Canadian Industry, 1981* by D.M. Tate and D.N. Scharf (Social Science Series #19)
. *Municipal Water Use in Canada, 1983* by D.M. Tate and D. Lacelle (Social Science Series #20)
. *Water Use in Canadian Industry, 1986* by D.M. Tate and D.N. Scharf (Social Science Series #24)
. *Municipal Water Rates in Canada, 1986 - Current Practices and Prices* by D.M. Tate

These publications can be obtained from the Editorial and Publications Division, Inland Waters Directorate, Environment Canada, Ottawa, Ontario, K1A 0H3

Inquiries should be addressed to the Manager.

## MANAGER

Water Planning and Management Branch
Inland Waters Directorate
Environment Canada
Ottawa, Ontario, K1A 0H3 Tel.: (819) 953-3478

## TYPE OF INDUSTRIAL WATER USE DATA AVAILABLE

1) water intake by source
   . public
   . freshwater self-supplied (surface, ground other)
   . brackish water self-supplied (ground, tide, other)

2) water intake by type of intake treatment
   . filtration . chlorination & disinfection
   . hardness and alkalinity control . screening
   . corrosion & slime control . other

3) water intake by purpose
   . processing . sanitary
   . cooling, condensing & stream . other

4) water discharge by point of discharge
   . public sewer . ground . artificial body
   . freshwater body . transferred to other uses . tidewater body
   . tailings pond transfer

5) water discharge by type of treatment
   . primary . tertiary
   . secondary . none

6) water use
   . total water intake . total gross use . total water discharge
   . recirculation . consumption (imputed)

7) water costs by cost component
   . water acquisition . recirculation
   . intake treatment . discharge treatment

8) water recirculation by purpose
   . processing . cooling & condensing . other

9) use rates and consumption rates

## TYPE OF MUNICIPAL WATER DATA AVAILABLE

1) population served by municipal utilities
   . water supply . waste collection . waste treatment

2) municipal water pumpage
   . average daily flow by source (surface, ground, per capita served, % of water supply)

3) municipal water use
   . domestic . system losses & accounted . water use indicators
   . industrial . commercial & institutional

4) waste treatment (# persons, % of pop served)
   . no treatment . waste stabilization ponds
   . primary treatment . secondary treatment . tertiary treatment

## Appendix 2
## Statistics Canada EIS Data in The Prototype Data Base

Farms (1971,1976, 1981, 1986)
- number of farms

Agricultural land measured in hectares (1971,1976, 1981, 1986)
- barley for grain
- barley for feed
- buckwheat
- total wheat
- corn for silage
- corn for grain
- millet for grain
- mixed grains
- total oats
- total rye
- mustard seed
- canary seed
- forage seed
- canola
- caraway seed
- safflower
- soybeans
- sunflowers
- total oilseeds
- dry field peas
- lentils
- total dry beans
- potatoes
- sugarbeets
- root crops for feed
- total hay
- other fodder crops
- tobacco
- nursery products
- sod grown for sale
- cultivated grapes
- total other field crops
- total fruit tree orchards
- total small fruits
- total vegetables
- summerfallow
- total area of cropland
- total area under drainage
- improved pasture
- other improved land
- total improved land
- unimproved pasture
- woodland
- other unimproved land
- total unimproved land
- total area of land operated

Irrigated land (1986)
- area irrigated by wheel roll
- area irrigated by volume gun
- area irrigated by hand moved water
- area irrigated by pivot
- area irrigated by flood
- other irrigated area

Livestock (1971,1976, 1981, 1986)
- total sheep
- pigs
- total poultry
- total cattle

Areas amended (1971,1976, 1981, 1986)
- total area fertilized
- area sprayed for insects
- area sprayed for weeds

Amendments (1986)
- dry granular fertilizer
- fertilizer suspensions
- non pressurized liquid fertilizer
- pressurized liquid fertilizer
- total fertilizer

Cropping practice (1971,1976, 1981, 1986)
- close-row crop area on close-row mono farms
- close-row crop area on non-cropping farms
- close-row crop area on rotational farms
- close-row crop area on speciality farms
- close-row crop area on wide-row mono farms
- wide-row crop area on close-row mono farms
- wide-row crop area on non-cropping farms
- wide-row crop area on rotational farms
- wide-row crop area on speciality farms
- wide-row crop area on wide-row mono farms

Population and employment (1971,1976, 1981, 1986)

- total population
- population in rural areas
- number of persons employed

Dwelling Stock (1971,1976, 1981, 1986)

- total single detached houses
- total apartments
- total movable dwellings
- total other dwellings
- total dwellings

Labour Force (1986 )

agriculture labour force
fishing and hunting labour force
forestry labour force
mining labour force
manufacturing labour force
construction labour force
communication labour force
transport and storage labour force
public utilities labour force
wholesale and retail labour force
finance labour force
services labour force
public administration labour force
not defined labour force
total labour force

Electric Power Generation (1988 )

name of power generating plant
station type
plant power generating capacity
fuel type if plant is not hydro
hydrographic system if plant is hydro

# ROBBERT Associates
# Decision Support Tools

## Functionality

A Complete Software Environment for
Large Scale Simulation Models and Decision Support Systems

- design
- documentation
- implementation
- calibration
- scenario creation
- *ad hoc* data analysis

# ROBBERT Associates
# Decision Support Tools

### Components

**TOOL**
**Tool Kit for Data Analysis**
interactive language for manipulating multi-dimensional data arrays

**SAMM**
**Scenario and Model Manager**
supports the creation of scenarios and linkages among sub-models

**Documenter**
supports the preparation of design diagrams and documentation for manuals and model implementation

# ROBBERT Associates

## TOOL
### Tool Kit for Data Analysis

- self-documented multi-dimensional arrays
- control structures
- syntax of stylized subscripted algebra
- mathematical and statistical operators
- titlesets for dimensions including sets and sequences
- standard international units of measure, entity identification and inheritance rules
- interactive graphical display of arrays with selective highlighting
- data input from graphics using digitization
- interactive tabular display with scrolling
- data import/export channels to ASCII files and Excel spreadsheets
- data representation in character and packed binary format
- open-ended with respect to the creation of custom operators

# ROBBERT Associates

## SAMM

### Scenario and Model Manager

- documentation of scenarios at time of creation
- comparative display of scenarios with selective highlighting
- management of "views" or scripts for creating and displaying data arrays
- lazy evaluation - computation as required
- use of a conceptual hierarchy for navigating through model structure
- management of linkages among model components through the use of a dependency structure
- scenario management - facilities for maintaining the integrity of multiple scenarios including creation, modification, and deletion
- command-oriented user interface with on-line help facilities

# ROBBERT Associates

## Documenter

- supports the creation of structural diagrams using special symbols to designate variables, procedures and connective structure
- uses pop-down menus and dialogue boxes to capture information concerning variables, procedures and connective structure
- manual preparation - produces a detailed and comprehensive hard-copy document describing model structure
- provides files required by SAMM for model implementation
- assures that documentation is accurate and up-to-date as documentation is an integral and necessary part of implementation
- based on Design OA™ Open Architecture system developed and distributed by Meta Software Corporation of Cambridge, Massachusetts

# ROBBERT Associates Decision Support Tools

## Hardware/Software Environment

The current version of the **ROBBERT Associates Decision Support Tools** is implemented as a single user system. SAMM and TOOL run on a Macintosh computer under the A/UX operating system (Apple's implementation of UNIX). The system must be configured with sufficient memory, at least 4 megabytes, and sufficient disk storage capacity, at least 80 megabytes, to support A/UX. Documenter runs under the native Macintosh operating system. The preferred hardware environment is a Macintosh IIfx system with 4 mb memory, 80 mb internal disk, 160 mb external, and A/UX 2.0.

The **ROBBERT Associates Decision Support Tools** are designed to support multiple user systems. Future versions of the software will incorporate this capability. In this case, the data base and data manipulation functionality will reside on a host computer running UNIX, for example a Digital Equipment Corporation VAX running ULTRIX or a SUN Workstation; the user interface and graphical display functionality will reside on workstations which may be Macintosh computers or PC's equiped with Windows software.

# APPENDIX D: MANUAL FOR THE PROTOTYPE DATABASE STATE OF THE GREAT LAKES BASIN ECOSYSTEM

(insert)

# MANUAL

# for the

# PROTOTYPE DATA BASE

# STATE OF THE GREAT LAKES ECOSYSTEM

prepared for the

International Joint Commission

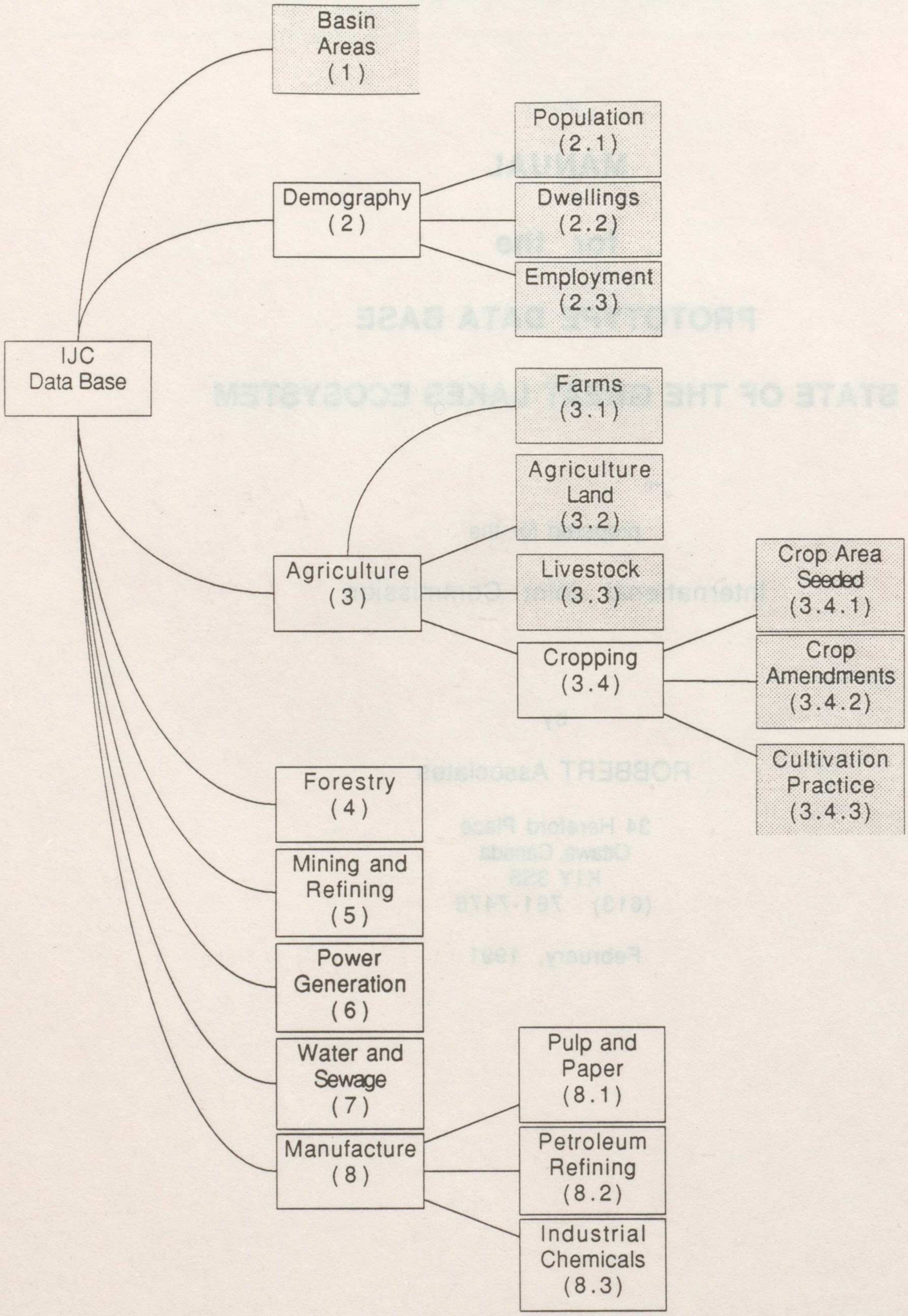
by

ROBBERT Associates

34 Hereford Place
Ottawa, Canada
K1Y 3S5
(613) 761-7478

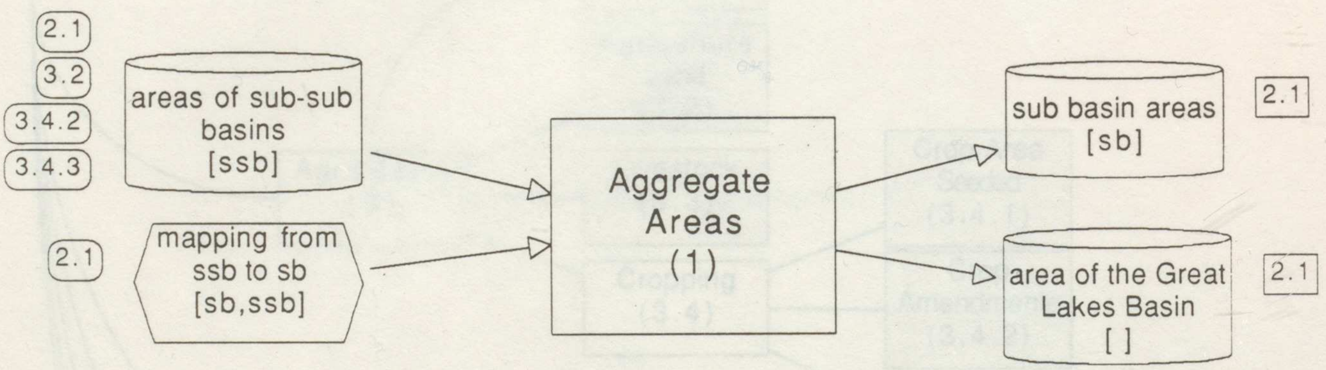
February, 1991

# IJC Data Base Hierarchy Structure



# CALCULATOR DESCRIPTIONS

# 1 Basin Areas




ssb subSubBasin
sb subBasin

# 1 Basin Areas

## Description

This calculator contains basic information on the hydrometric geography including aggregation parameters and areas.

## Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| basinArea[ssb] | s | F | S | areas of sub-sub basins |
| ssbTosb[sb,ssb] | s | F | P | mapping from ssb to sb |
| subBasArea[sb] | f | O | S | sub basin areas |
| glbArea[] | f | O | S | area of the Great Lakes Basin |

## Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| subBasin | sb | set | sub basins for the Great Lakes |

## Procedures

! (1) Aggregate Areas

subBasArea[sb] = map (basinArea[ssb],ssbTosb[sb,ssb])

glbArea[] = sum (basinArea[ssb])

## References

Maps

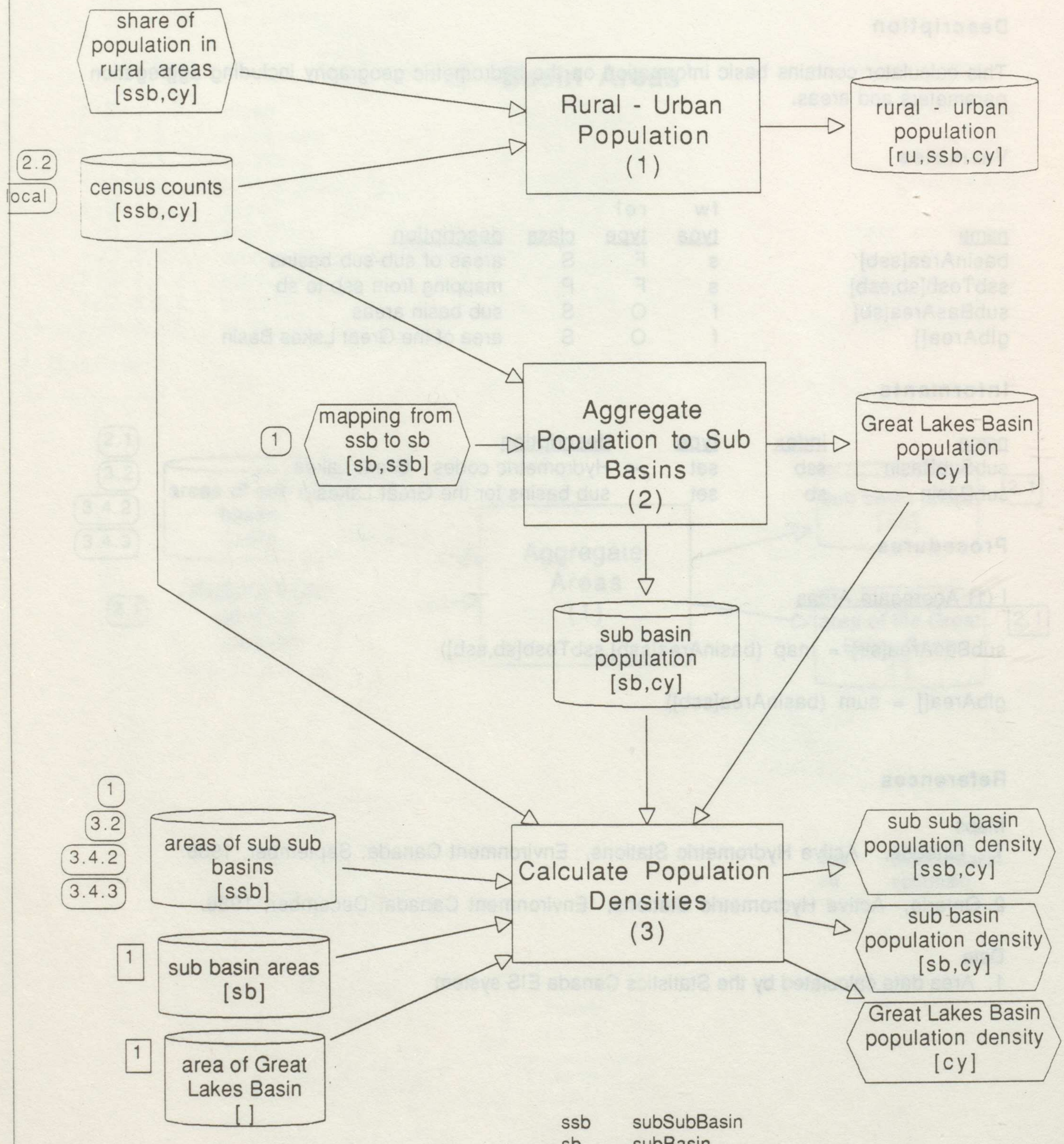
1 Quebec, Active Hydrometric Stations, Environment Canada, September, 1988.

2. Ontario, Active Hydrometric Stations, Environment Canada, December, 1986.

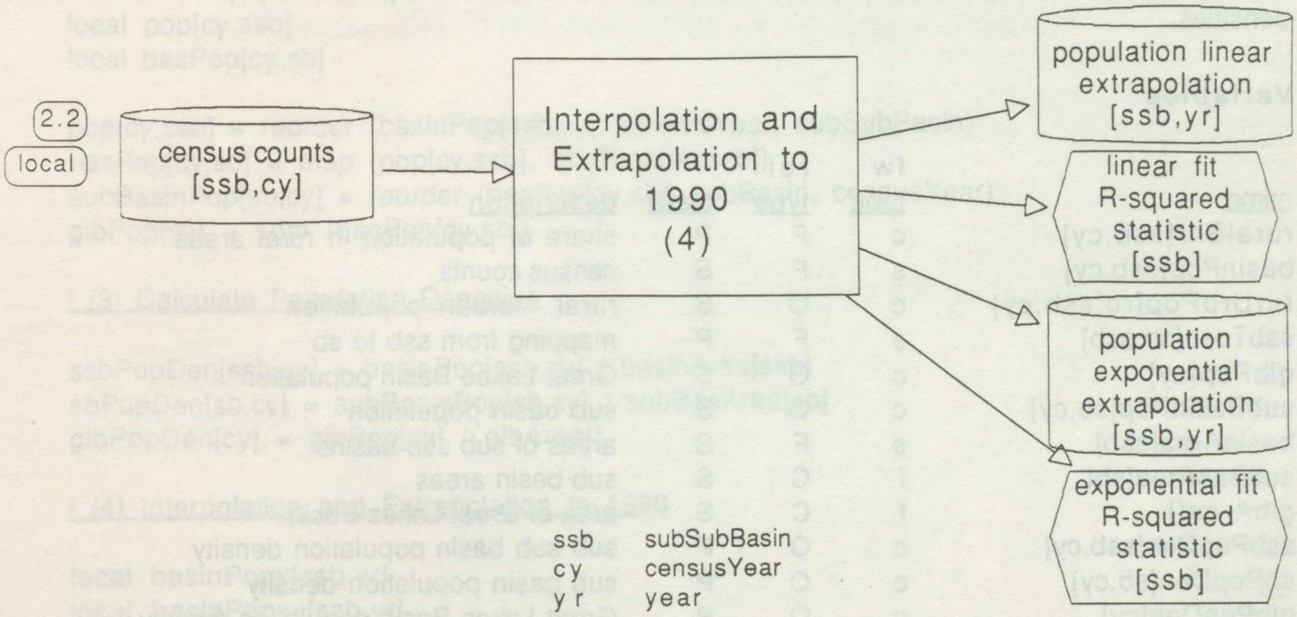
Data

1. Area data calculated by the Statistics Canada EIS system

# 2.1 Population




ssb subSubBasin
sb subBasin
cy censusYear
ru rurUrban


2.2
local
census counts
[ssb,cy]
Interpolation and
Extrapolation to
1990
(4)
population linear
extrapolation
[ssb,yr]
linear fit
R-squared
statistic
[ssb]
population
exponential
extrapolation
[ssb,yr]
exponential fit
R-squared
statistic
[ssb]
ssb subSubBasin
cy censusYear
yr year

# 2.1 Population

## Description

This calculator contains census population counts, rural shares, and produces population densities.

## Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| ruralShr[ssb,cy] | c | F | P | share of population in rural areas |
| basinPop[ssb,cy] | s | F | S | census counts |
| rurUrbPop[ru,ssb,cy] | c | O | S | rural - urban population |
| ssbTosb[sb,ssb] | s | F | P | mapping from ssb to sb |
| glbPop[cy] | c | O | S | Great Lakes Basin population |
| subBasinPop[sb,cy] | c | O | S | sub basin population |
| basinArea[ssb] | s | F | S | areas of sub sub basins |
| subBasArea[sb] | f | C | S | sub basin areas |
| glbArea[] | f | C | S | area of Great Lakes Basin |
| ssbPopDen[ssb,cy] | c | O | P | sub sub basin population density |
| sbPopDen[sb,cy] | c | O | P | sub basin population density |
| glbPopDen[cy] | c | O | P | Great Lakes Basin population density |
| linPop[ssb,yr] | c | O | S | population linear extrapolation |
| linRSqStat[ssb] | c | O | P | linear fit R-squared statistic |
| expPop[ssb,yr] | c | O | S | population exponential extrapolation |
| expRSqStat[ssb] | c | O | P | exponential fit R-squared statistic |

## Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| subBasin | sb | set | sub basins for the Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |
| rurUrban | ru | set | rural urban |
| year | yr | seq | single years from 1971 to 1990 |

## Procedures

```
! (1) Rural - Urban Population

local urbShr[ssb,cy]
local urbanPop[ssb,cy]
local ruralPop[ssb,cy]

urbShr[ssb,cy] = 1 - ruralShr[ssb,cy]
urbanPop[ssb,cy] = urbShr[ssb,cy] * basinPop[ssb,cy]
ruralPop[ssb,cy] = basinPop[ssb,cy] - urbanPop[ssb,cy]

rurUrbPop[ru,ssb,cy] = insert (expand (urbanPop[ssb,cy]); \
```

```
                                        expand->rurUrban:urban)
rurUrbPop[ru,ssb,cy] = insert (expand (ruralPop[ssb,cy]); \
                                        expand->rurUrban:rural)
```

! (2) Aggregate Population to Sub Basins

```
local pop[cy,ssb]
local basPop[cy,sb]

pop[cy,ssb] = reorder (basinPop[ssb,cy]; censusYear, subSubBasin)
basPop[cy,sb] = map (pop[cy,ssb], ssbTosb[sb,ssb])
subBasinPop[sb,cy] = reorder (basPop[cy,sb]; subBasin, censusYear)
glbPop[cy] = sum (basPop[cy,sb])
```

! (3) Calculate Population Densities

```
ssbPopDen[ssb,cy] = basinPop[ssb,cy] / basinArea[ssb]
sbPopDen[sb,cy] = subBasinPop[sb,cy] / subBasArea[sb]
glbPopDen[cy] = glbPop[cy] / glbArea[]
```

! (4) Interpolation and Extrapolation to 1990

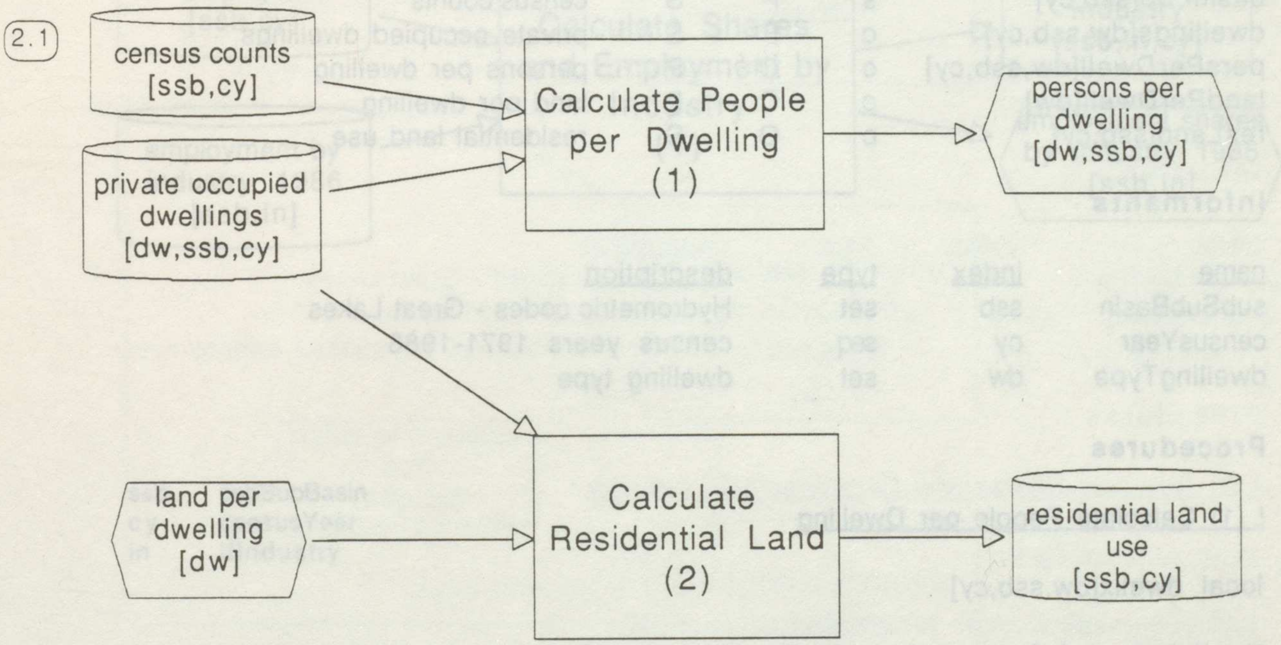
```
local basinPopx[ssb,yr]
local basinPopxx[ssb,yr]

say (" ..doing linear interpolation in history")
create (basinPopx[ssb,yr]; dim=subSubBasin, \
    dim="SEQ;year:1971:1986:1;year", ent=person, data=0)
basinPopx[ssb,yr] = insert (basinPop[ssb,cy]; \
                    censusYear->year:+0@5)
basinPopxx[ssb,yr] = linint (basinPopx[ssb,yr])


say (" ..doing linear extrapolation")

local linTrend[ssb,yr]
local linProj[ssb,yr]
local linStat[ssb]

linTrend[ssb,yr], linProj[ssb,yr] = lintrend (basinPopxx[ssb,yr]; \
year=1990, join=on, stats= §tat[ssb,sc])
linPop[ssb,yr] = basinPopxx[ssb,yr] | linProj[ssb,yr]
linRSqStat[ssb] = shrink (extract (linStat[ssb,sc];2:-0))

say (" ..doing exponetial extrapolation")

local lnBasPop[ssb,yr]
local lnTrend[ssb,yr]
local lnProj[ssb,yr]
local expStat[ssb]
```

```
setenv ("entityChk","off")
setenv ("uomChk","off")
lnBasPop[ssb,yr] = loge (basinPopxx[ssb,yr])
lnTrend[ssb,yr], lnProj[ssb,yr] = lintrend (lnBasPop[ssb,yr]; \
year=1990, join=on, stats=expStat[ssb,sc])
expPop[ssb,yr] = changeshape (exp (
        lnBasPop[ssb,yr]   |   lnProj[ssb,yr]);   ent=person)
setenv ("entityChk","on")
setenv ("uomChk","on")
expRSqStat[ssb] = shrink (extract (expStat[ssb,sc];2:-0))
```

## References

1. Source: Statistics Canada EIS system

# 2.2 Dwellings




| | |
|---|---|
| ssb | subSubBasin |
| cy | censusYear |
| dw | dwellingType |

# 2.2 Dwellings

## Description

## Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| basinPop[ssb,cy] | s | F | S | census counts |
| dwellings[dw,ssb,cy] | c | F | S | private occupied dwellings |
| persPerDwell[dw,ssb,cy] | c | O | P | persons per dwelling |
| landPerDwell[dw] | c | C | P | land per dwelling |
| resLand[ssb,cy] | c | O | S | residential land use |

## Informants

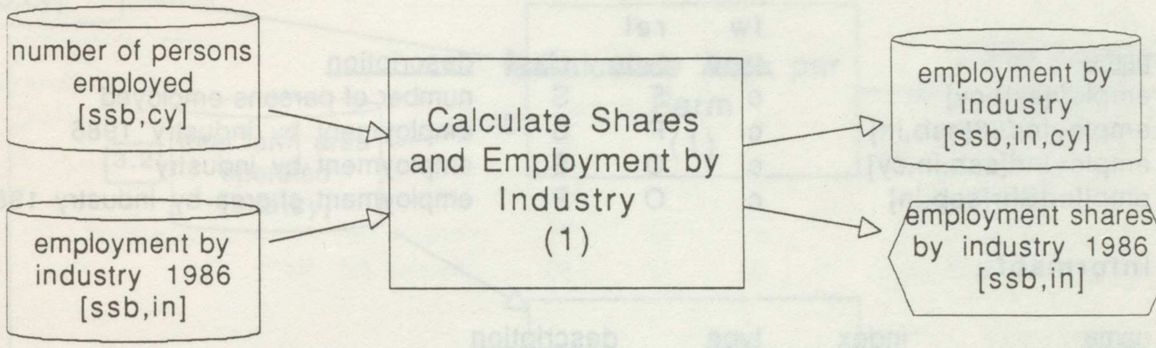
| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |
| dwellingType | dw | set | dwelling type |

## Procedures

```
! (1) Calculate People per Dwelling

local dwellx[dw,ssb,cy]

dwellx[ssb,cy,dw] = reorder (dwellings[dw,ssb,cy]; \
                    subSubBasin, censusYear, dwellingType)

persPerDwell[dw,ssb,cy] = reorder (basinPop[ssb,cy] /
      dwellx[ssb,cy,dw]; dwellingType, subSubBasin, censusYear)

! (2) Calculate Residential Land

resLand[ssb,cy] = sum (reorder (landPerDwell[dw] * \
      dwellings[dw,ssb,cy]; subSubBasin, censusYear, dwellingType))
```

## References

# 2.3 Employment




| | |
|---|---|
| ssb | subSubBasin |
| cy | censusYear |
| in | lfIndustry |

# 2.3 Employment

## Description

## Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| employ[ssb,cy] | c | F | S | number of persons employed |
| employInd86[ssb,in] | c | F | S | employment by industry 1986 |
| employInd[ssb,in,cy] | c | O | S | employment by industry |
| emplIndShr[ssb,in] | c | O | P | employment shares by industry 1986 |

## Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |
| lfIndustry | in | set | industry classification for census employment |

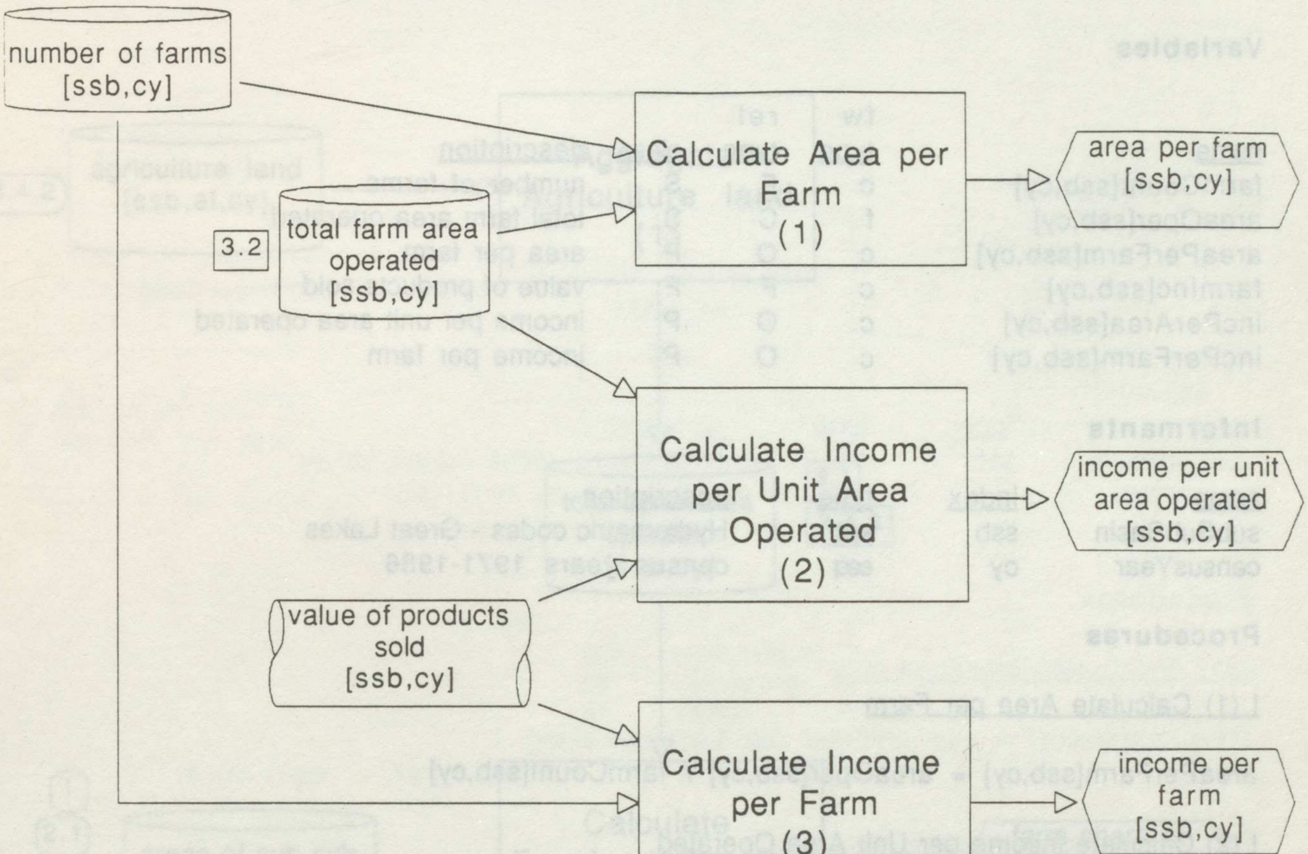
## Procedures

! (1) Calculate Shares and Employment by Industry

```
local totEmp86[ssb]

totEmp86[ssb] = sum (employInd86[ssb,in])
emplIndShr[ssb,in] = employInd86[ssb,in] / totEmp86[ssb]
employInd[ssb,in,cy] = outer (emplIndShr[ssb,in], employ[ssb,cy])
```

## References

# 3.1 Farms




ssb subSubBasin
cy censusYear

# 3.1 Farms

## Description

## Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| farmCount[ssb,cy] | c | F | S | number of farms |
| areaOper[ssb,cy] | f | C | S | total farm area operated |
| areaPerFarm[ssb,cy] | c | O | P | area per farm |
| farmInc[ssb,cy] | c | F | F | value of products sold |
| incPerArea[ssb,cy] | c | O | P | income per unit area operated |
| incPerFarm[ssb,cy] | c | O | P | income per farm |

## Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |

## Procedures

! (1) Calculate Area per Farm

areaPerFarm[ssb,cy] = areaOper[ssb,cy] / farmCount[ssb,cy]

! (2) Calculate Income per Unit Area Operated

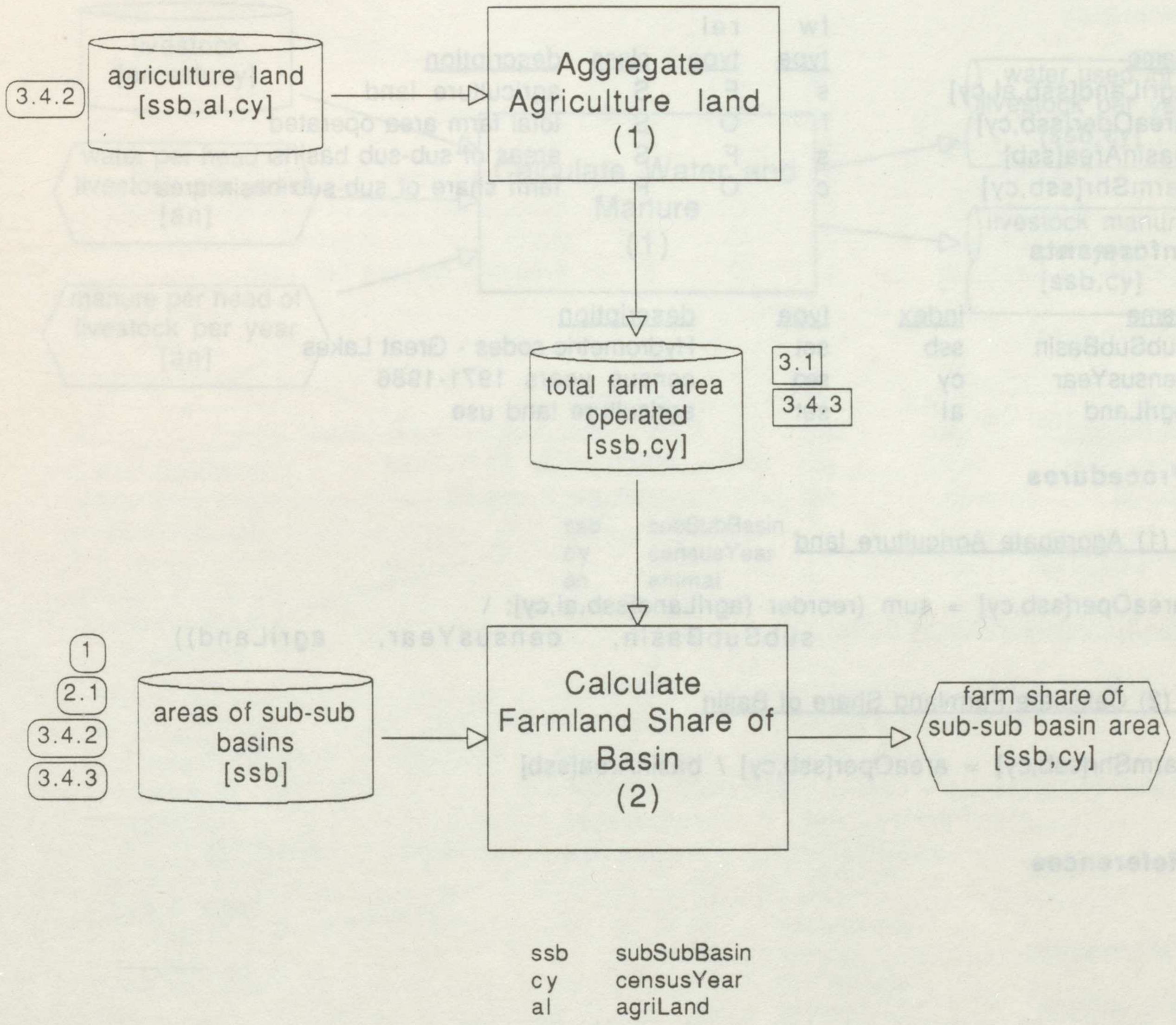
incPerArea[ssb,cy] = farmInc[ssb,cy] / areaOper[ssb,cy]

! (3) Calculate Income per Farm

incPerFarm[ssb,cy] = farmInc[ssb,cy] / farmCount[ssb,cy]

## References

# 3.2 Agriculture Land



# 3.2 Agriculture Land

## Description

## Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| agriLand[ssb,al,cy] | s | F | S | agriculture land |
| areaOper[ssb,cy] | f | O | S | total farm area operated |
| basinArea[ssb] | s | F | S | areas of sub-sub basins |
| farmShr[ssb,cy] | c | O | P | farm share of sub-sub basin area |

## Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |
| agriLand | al | set | agriculture land use |

## Procedures

! (1) Aggregate Agriculture land

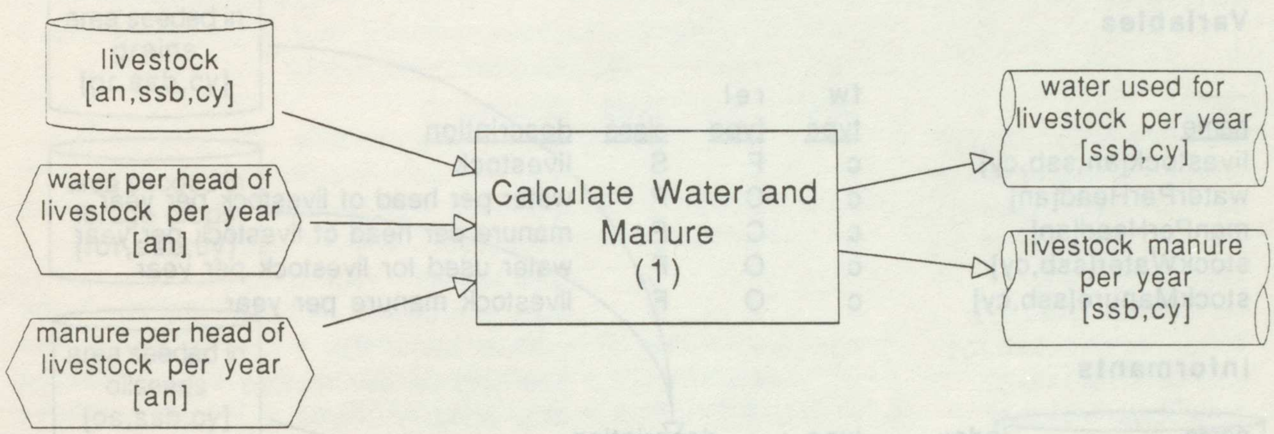
```
areaOper[ssb,cy] = sum (reorder (agriLand[ssb,al,cy]; \
                     subSubBasin, censusYear, agriLand))
```

! (2) Calculate Farmland Share of Basin

```
farmShr[ssb,cy] = areaOper[ssb,cy] / basinArea[ssb]
```

## References

# 3.3 Livestock




| | |
|---|---|
| ssb | subSubBasin |
| cy | censusYear |
| an | animal |

# 3.3 Livestock

## Description

The livestock takes census counts for livestock herds and calculates water used for livestock and manure benerated in each sub-sub basin.

## Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| livestock[an,ssb,cy] | c | F | S | livestock |
| waterPerHead[an] | c | C | P | water per head of livestock per year |
| manPerHead[an] | c | C | P | manure per head of livestock per year |
| stockWater[ssb,cy] | c | O | F | water used for livestock per year |
| stockManure[ssb,cy] | c | O | F | livestock manure per year |

## Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |
| animal | an | set | agriculture livestock |

## Procedures

! (1) Calculate Water and Manure

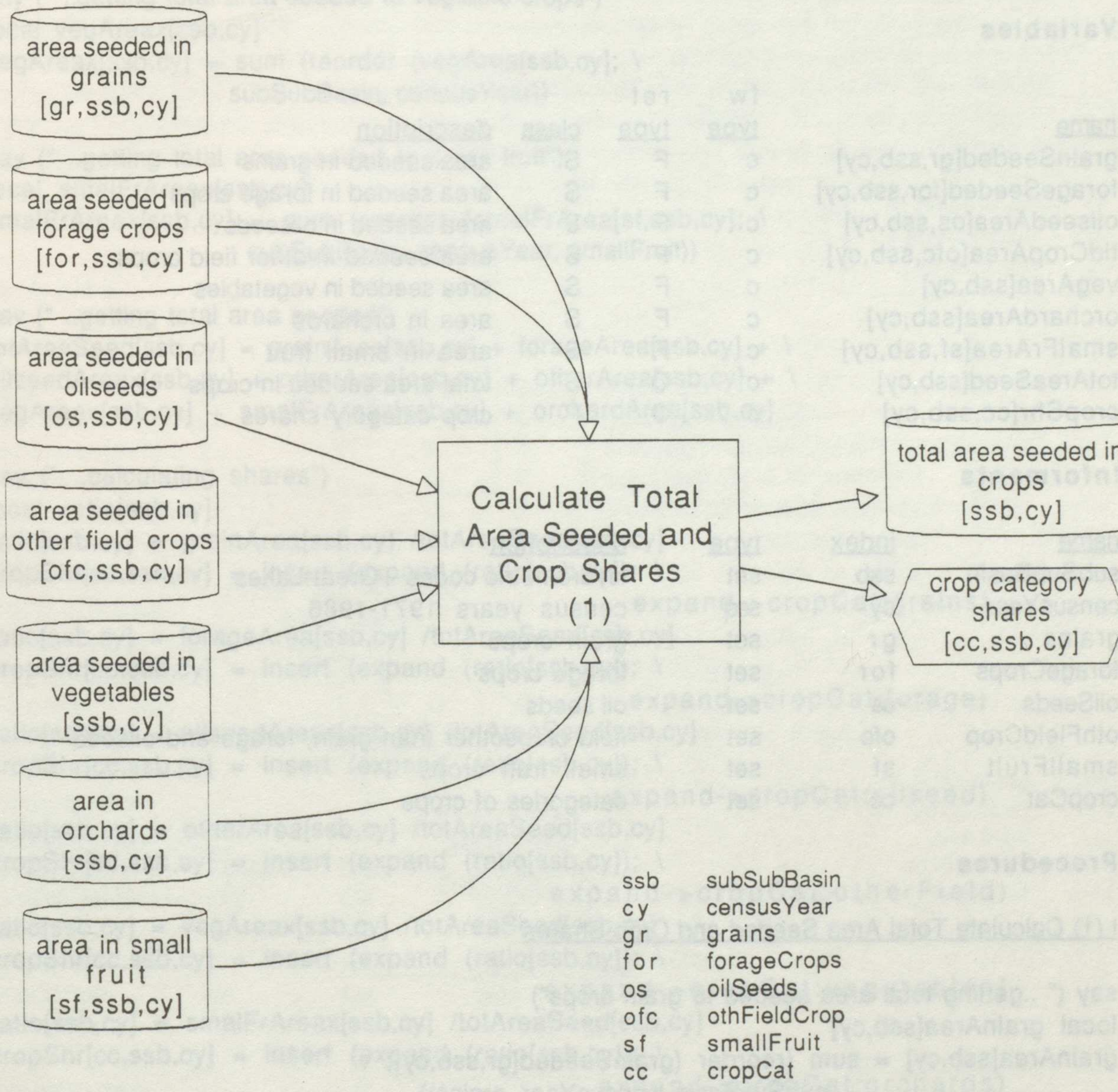
```
stockWater[ssb,cy] = changeshape (sum (reorder ( \
          waterPerHead[an]  *  livestock[an,ssb,cy];  \
               subSubBasin,  censusYear,  animal));  lowerEnt)
stockManure[ssb,cy] = changeshape (sum (reorder ( \
          manPerHead[an]  *  livestock[an,ssb,cy];  \
               subSubBasin,  censusYear,  animal));  lowerEnt)
```

## References

Data sources

1. livestock herds from the census of agriculture and the EIS
2. water per anaimal from the Great Lakes Basin Framework
3. manure per animal " " " " "

# 3.4.1 Crop Area Seeded



## 3.4.1 Crop Area Seeded

### Description

This calculator contains data from the EIS which breaks cropland area down by crop area seeded.

### Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| grainSeeded[gr,ssb,cy] | c | F | S | area seeded in grains |
| forageSeeded[for,ssb,cy] | c | F | S | area seeded in forage crops |
| oilseedArea[os,ssb,cy] | c | F | S | area seeded in oilseeds |
| fldCropArea[ofc,ssb,cy] | c | F | S | area seeded in other field crops |
| vegArea[ssb,cy] | c | F | S | area seeded in vegetables |
| orchardArea[ssb,cy] | c | F | S | area in orchards |
| smalFrArea[sf,ssb,cy] | c | F | S | area in small fruit |
| totAreaSeed[ssb,cy] | c | O | S | total area seeded in crops |
| cropShr[cc,ssb,cy] | c | O | P | crop category shares |

### Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |
| grains | gr | set | grain crops |
| forageCrops | for | set | forage crops |
| oilSeeds | os | set | oil seeds |
| othFieldCrop | ofc | set | field cropsother than grain, forage and oilseed |
| smallFruit | sf | set | small fruit crops |
| cropCat | cc | set | categories of crops |

### Procedures

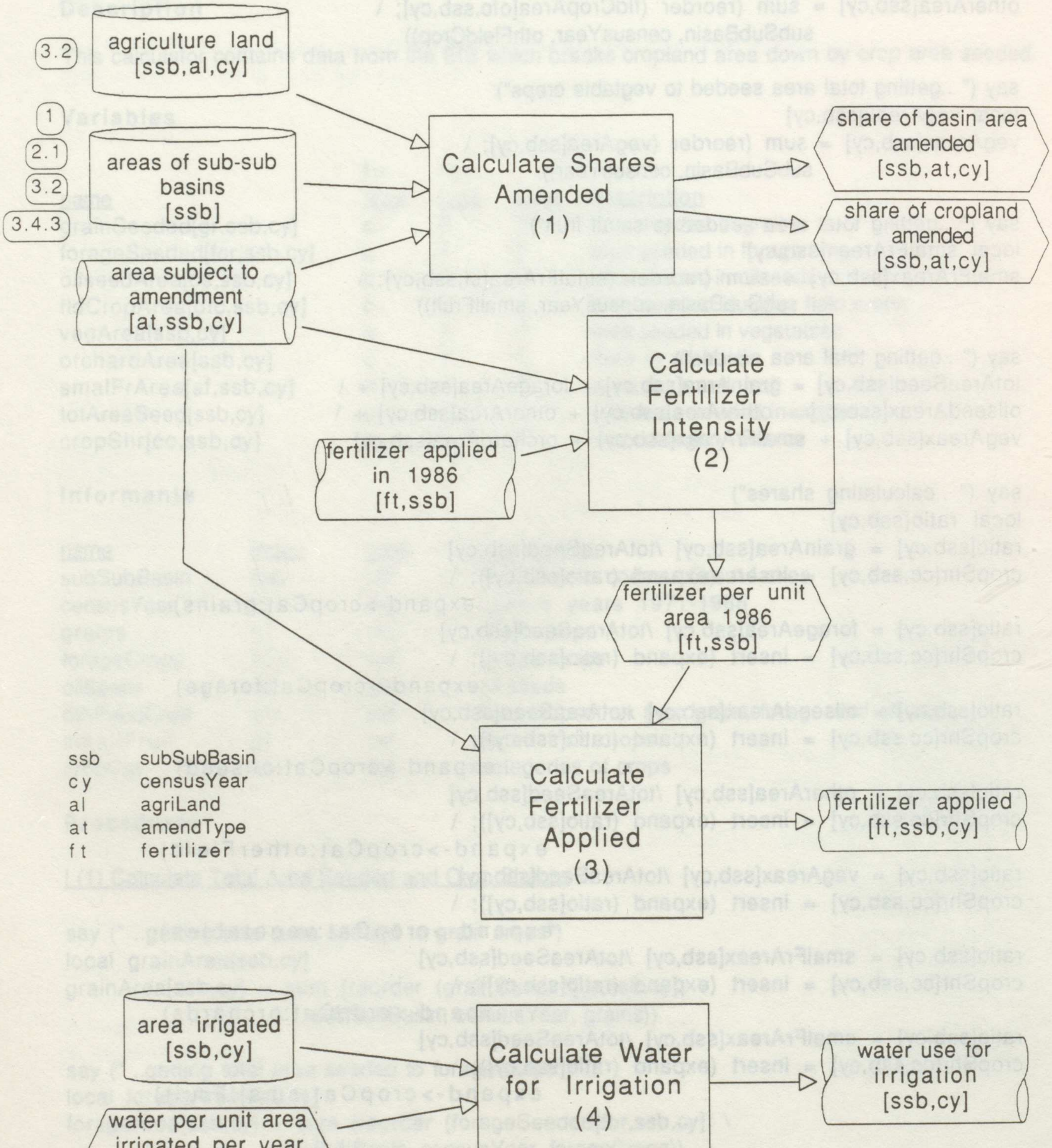
! (1) Calculate Total Area Seeded and Crop Shares

```
say (" ..getting total area seeded to grain crops")
local grainArea[ssb,cy]
grainArea[ssb,cy] = sum (reorder (grainSeeded[gr,ssb,cy]; \
                    subSubBasin, censusYear, grains))

say (" ..getting total area seeded to forage crops")
local forageArea[ssb,cy]
forageArea[ssb,cy] = sum (reorder (forageSeeded[for,ssb,cy]; \
                    subSubBasin, censusYear, forageCrops))

say (" ..getting total area seeded to oilseed crops")
local oilseedAreax[ssb,cy]
oilseedAreax[ssb,cy] = sum (reorder (oilseedArea[os,ssb,cy]; \
                    subSubBasin, censusYear, oilSeeds))
```

```
say (" ..getting total area seeded to other field crops")
local otherArea[ssb,cy]
otherArea[ssb,cy] = sum (reorder (fldCropArea[ofc,ssb,cy]; \
                    subSubBasin, censusYear, othFieldCrop))

say (" ..getting total area seeded to vegtable crops")
local vegAreax[ssb,cy]
vegAreax[ssb,cy] = sum (reorder (vegArea[ssb,cy]; \
                    subSubBasin, censusYear))

say (" ..getting total area seeded to small fruit")
local smalFrAreax[ssb,cy]
smalFrAreax[ssb,cy] = sum (reorder (smalFrArea[sf,ssb,cy]; \
                    subSubBasin, censusYear, smallFruit))

say (" ..getting total area seeded")
totAreaSeed[ssb,cy] = grainArea[ssb,cy] + forageArea[ssb,cy] + \
oilseedAreax[ssb,cy] + otherArea[ssb,cy] + otherArea[ssb,cy] + \
vegAreax[ssb,cy] + smalFrAreax[ssb,cy] + orchardArea[ssb,cy]

say (" ..calculating shares")
local ratio[ssb,cy]
ratio[ssb,cy] = grainArea[ssb,cy] /totAreaSeed[ssb,cy]
cropShr[cc,ssb,cy] = insert (expand (ratio[ssb,cy]); \
                    expand->cropCat:grains)
ratio[ssb,cy] = forageArea[ssb,cy] /totAreaSeed[ssb,cy]
cropShr[cc,ssb,cy] = insert (expand (ratio[ssb,cy]); \
                    expand->cropCat:forage)
ratio[ssb,cy] = oilseedAreax[ssb,cy] /totAreaSeed[ssb,cy]
cropShr[cc,ssb,cy] = insert (expand (ratio[ssb,cy]); \
                    expand->cropCat:oilseed)
ratio[ssb,cy] = otherArea[ssb,cy] /totAreaSeed[ssb,cy]
cropShr[cc,ssb,cy] = insert (expand (ratio[ssb,cy]); \
                    expand->cropCat:otherField)
ratio[ssb,cy] = vegAreax[ssb,cy] /totAreaSeed[ssb,cy]
cropShr[cc,ssb,cy]= insert (expand (ratio[ssb,cy]); \
                    expand->cropCat:vegetables)
ratio[ssb,cy] = smalFrAreax[ssb,cy] /totAreaSeed[ssb,cy]
cropShr[cc,ssb,cy] = insert (expand (ratio[ssb,cy]); \
                    expand->cropCat:orchards)
ratio[ssb,cy] = smalFrAreax[ssb,cy] /totAreaSeed[ssb,cy]
cropShr[cc,ssb,cy] = insert (expand (ratio[ssb,cy]); \
                    expand->cropCat:smallFruit)
```

**References**

## 3.4.2 Crop Amendments



## 3.4.2 Crop Amendments

### Description

This calculator keeps track of areas of land subject to the following amendments: sprying for insects, spraying for weeds, fertilization, and irrigation. The only data for quantities of fertilizer used are for 1986. These data are used to impute quantities for other census years by making the assumption that the quantity of fertilizer per unit land fertilized is constant for each sub-sub basin. The 1986 data distinguishes the form of the fertilizer: dry granular, non-pressurized liquid, pressurized liquid, fertilizer suspensions. The calculator also calculates share of the basin area subject to amendment. This serves as indicator of intensity. Finally, the fourth procedure calculates the annual volume of water withdrawn for irrigation assuming an annual rate of cubic metres of water per unit area irrigated.

### Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| agriLand[ssb,al,cy] | s | F | S | agriculture land |
| basinArea[ssb] | s | F | S | areas of sub-sub basins |
| areaAmend[at,ssb,cy] | c | C | F | area subject to amendment |
| basShrAmend[ssb,at,cy] | c | O | P | share of basin area amended |
| cropShrAmend[ssb,at,cy] | c | O | P | share of cropland amended |
| fertAppl86[ft,ssb] | c | F | F | fertilizer applied in 1986 |
| fertDen[ft,ssb] | c | O | P | fertilizer per unit area 1986 |
| fertAppl[ft,ssb,cy] | c | O | F | fertilizer applied |
| areaIrrig[ssb,cy] | c | F | S | area irrigated |
| waterPerArea[] | c | C | P | water per unit area irrigated per year |
| irrigWater[ssb,cy] | c | O | F | water use for irrigation |

### Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |
| agriLand | al | set | agriculture land use |
| amendType | at | set | type of crop amendment |
| fertilizer | ft | set | type of fertilizer |

### Procedures

! (1) Calculate Shares Amended

```
local cropLand[ssb,cy]
cropLand[ssb,cy] = shrink (extract (agriLand[ssb,al,cy]; \
                        agriLand:cropland); 2)
local areaAmendx[at,ssb,cy]
areaAmendx[ssb,cy,at] = changeshape (reorder (areaAmend[at,ssb,cy]; \
            subSubBasin, censusYear, amendType); ent="-")
local cropShrAmendx[ssb,cy,at]
```

```
cropShrAmendx[ssb,cy,at] = areaAmendx[ssb,cy,at] / cropLand[ssb,cy]
cropShrAmend[ssb,at,cy] = reorder (cropShrAmendx[ssb,cy,at]; \
        subSubBasin, amendType, censusYear)
local basShrAmendx[ssb,cy,at]
basShrAmendx[ssb,cy,at] = areaAmendx[ssb,cy,at] / basinArea[ssb]
basShrAmend[ssb,at,cy] = reorder (basShrAmendx[ssb,cy,at]; \
        subSubBasin, amendType, censusYear)
```

! (2) Calculate Fertilizer Intensity

```
local area86[ssb]
area86[ssb] = shrink (extract (areaAmend[at,ssb,cy]; \
        amendType:fert, censusYear:1986))
local fertAppl86x[ssb,ft]
fertAppl86x[ssb,ft] = reorder (fertAppl86[ft,ssb]; \
        subSubBasin, fertilizer)
local fertDenx[ssb,ft]
fertDenx[ssb,ft] = fertAppl86x[ssb,ft] / area86[ssb]
fertDen[ft,ssb] = reorder (fertDenx[ssb,ft]; fertilizer, subSubBasin)
```

! (3) Calculate Fertilizer Applied

```
local areaAmendxx[ssb,cy]
areaAmendxx[ssb,cy] = shrink (extract (areaAmend[at,ssb,cy]; \
        amendType:fert))

local fertDenxx[ssb,ft]
fertDenxx[ssb,ft] = reorder (fertDen[ft,ssb]; \
        subSubBasin, fertilizer)

fertAppl[ft,ssb,cy] = reorder (outer ( \
        fertDenxx[ssb,ft], areaAmendxx[ssb,cy]); \
        fertilizer, subSubBasin, censusYear)
```

! (4) Calculate Water for Irrigation

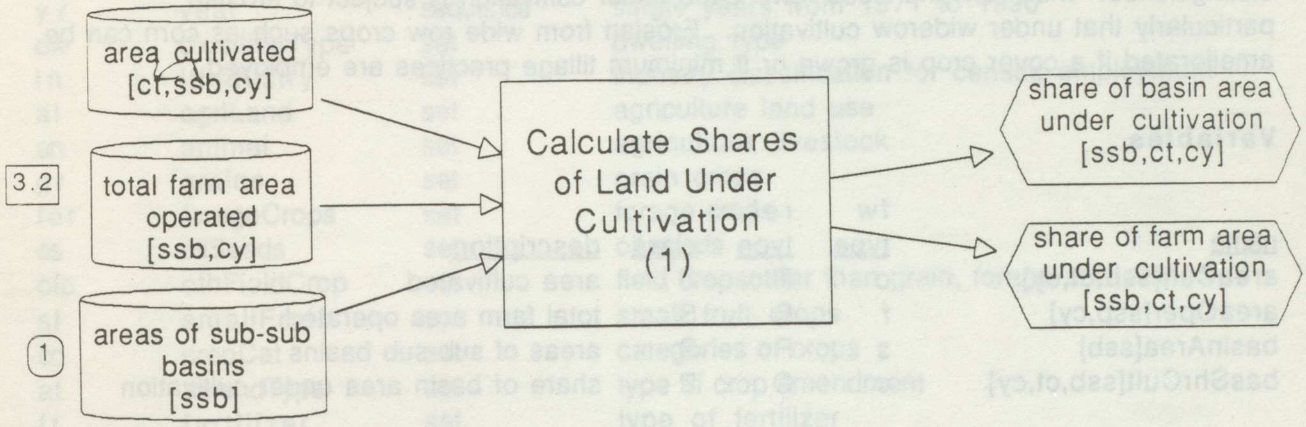
```
irrigWater[ssb,cy] = waterPerArea[] * areaIrrig[ssb,cy]
```

**References**

Data Sources

1. Agriculture census data maintained in the Statistics Canada EIS system.

# 3.4.3 Cultivation Practice




ssb subSubBasin
cy censusYear
ct cultivate

# 3.4.3 Cultivation Practice

## Description

This calculator keeps track of the area under cultivation by type of cultivation and calculates the share of land in each sub-sub basin under cultivation. Two kinds of cultivation are distinguished: wide row and close row. Land under cultivation is subject to erosian particularly that under widerow cultivation. Erosian from wide row crops such as corn can be ameliorated if a cover crop is grown or if minimum tillage practices are employed.

## Variables

| name | fw type | rel type | class | description |
|---|---|---|---|---|
| areaCult[ssb,ct,cy] | c | F | S | area cultivated |
| areaOper[ssb,cy] | f | C | S | total farm area operated |
| basinArea[ssb] | s | F | S | areas of sub-sub basins |
| basShrCult[ssb,ct,cy] | c | O | P | share of basin area under cultivation |

## Informants

| name | index | type | description |
|---|---|---|---|
| subSubBasin | ssb | set | Hydrometric codes - Great Lakes |
| censusYear | cy | seq | census years 1971-1986 |
| cultivate | ct | set | cultivation practice |

## Procedures

```
! (1) Calculate Shares of Land Under Cultivation
local  areaCultx[ssb,cy,ct]
local  basShrCultx[ssb,cy,ct]

basShrCult[ssb,ct,cy] = areaCult[ssb,ct,cy] / basinArea[ssb]
areaCultx[ssb,cy,ct] = reorder (areaCult[ssb,ct,cy]; \
        -        subSubBasin, censusYear, cultivate)
basShrCultx[ssb,cy,ct] = areaCultx[ssb,cy,ct] / areaOper[ssb,cy]
basShrCult[ssb,ct,cy] = reorder (basShrCultx[ssb,cy,ct]; \
                 subSubBasin, cultivate, censusYear)
```

## References

Data Sources

1. Agriculture census data maintained in the Statistics Canada EIS system

# INFORMANTS

| Index | Name | Type | Description |
|---|---|---|---|
| ssb | subSubBasin | set | Hydrometric codes - Great Lakes |
| sb | subBasin | set | sub basins for the Great Lakes |
| cy | censusYear | sequence | census years 1971-1986 |
| ru | rurUrban | set | rural - urban |
| yr | year | sequence | single years from 1971 to 1990 |
| dw | dwellingType | set | dwelling type |
| in | lfIndustry | set | industry classification for census employment |
| al | agriLand | set | agriculture land use |
| an | animal | set | agriculture livestock |
| gr | grains | set | grain crops |
| for | forageCrops | set | forage crops |
| os | oilSeeds | set | oil seeds |
| ofc | othFieldCrop | set | field cropsother than grain, forage and oilseed |
| sf | smallFruit | set | small fruit crops |
| cc | cropCat | set | categories of crops |
| at | amendType | set | type of crop amendment |
| ft | fertilizer | set | type of fertilizer |
| ct | cultivate | set | cultivation practice |
| sc | statChar | set | |
| ws | watShed | set | water sheds |

**subSubBasin**

Index: ssb

Type: set

Description: Hydrometric codes - Great Lakes

2AA
2AB
2AC
2AD
2AE
2BA
2BB
2BC
2BD
2BE
2BF
2CA
2CB
2CC
2CD
2CE
2CF
2CG
2DA
2DB
2DC
2DD
2EA
2EB
2EC
2ED
2FA
2FB
2FC
2FD
2FE
2FF
2GA
2GB
2GC
2GD
2GE
2GF
2GG
2GH
2HA
2HB
2HC
2HD
2HE
2HF
2HG

2HH
2HJ
2HK
2HL
2HM
2MA
2MB
2MC
2JA
2JB
2JC
2JD
2JE
2KA
2KB
2KC
2KD
2KE
2KF
2KG
2KH
2KJ
2LA
2LB
2LC
2LD
2LE
2LF
2LG
2LH
2NA
2NB
2NC
2ND
2NE
2NF
2NG
2OA
2OB
2OC
2OD
2OE
2OF
2OG
2OH
2OJ
2PA
2PB
2PC
2PD
2PE

2PF
2PG
2PH
2PJ
2PL

**subBasin**
Index: sb
Type: set
Description: sub basins for the Great Lakes

| | |
|---|---|
| superior | Lake Superior drainage area |
| huron | Lake Huron drainage area |
| erie | Lakes Erie and St Clair drainage area |
| ontario | Lake Ontario drainage area |
| ottawa | Ottawa River drainage area |
| stLawrence | Upper St. Lawrence drainage area |

**censusYear**
Index: cy
Type: sequence
Description: census years 1971-1986

**rurUrban**
Index: ru
Type: set
Description: rural - urban
rural
urban

**year**
Index: yr
Type: sequence
Description: single years from 1971 to 1990

**dwellingType**
Index: dw
Type: set
Description: dwelling type

| | |
|---|---|
| single | single detached houses |
| apartments | apartments |
| movable | movable dwellings |
| other | doubles, duplexes, rows and other dwellings |

**lfIndustry**
Index: in
Type: set
Description: industry classification for census employment

| | |
|---|---|
| agriculture | |
| forestry | |
| fishHunt | fishing and hunting |
| mining | |

| | |
|---|---|
| manufacturing | |
| construction | |
| publicUtil | public utilities |
| communication | |
| trade | wholesale and retail trade |
| transport | transport and storage |
| finance | |
| services | other services |
| publicAdmin | public administration |
| notDefined | not defined |

**agriLand**

Index: al
Type: set
Description: agriculture land use

| | |
|---|---|
| cropland | cropland |
| summerfallow | summerfallow |
| improvedPast | improved pasture |
| otherImproved | other improved land |
| unimprPasture | unimproved pasture |
| woodland | woodland |
| otherUnimpr | other unimproved land |

**animal**

Index: an
Type: set
Description: agriculture livestock

| | |
|---|---|
| cattle | cattle, beef and dairy |
| pigs | |
| poultry | chickens, turkeys and other poultry |

**grains**

Index: gr
Type: set
Description: grain crops

| | |
|---|---|
| barley | barley for grain |
| buckwheat | |
| wheat | |
| rye | |
| oats | oats for grain |
| corn | corn for grain |
| mixedGrain | mixed grains |

**forageCrops**

Index: for
Type: set
Description: forage crops

| | |
|---|---|
| cornSilage | corn for silage |
| oatsFeed | oats for feed |
| tameHay | alfalfa and other tame hay |
| otherFodder | other fodder crops |

**oilSeeds**

Index: os

Type: set

Description: oil seeds

| | |
|---|---|
| canola | rapeseed or canola |
| flaxseed | |
| soybeans | |
| safflower | |
| mustard | mustard seed |
| sunflower | sunflower seed |

**othFieldCrop**

Index: ofc

Type: set

Description: field cropsother than grain, forage and oilseed

| | |
|---|---|
| dryPeas | dry field peas |
| dryBeans | dry field beans |
| potatoes | potatoes |
| sugarBeets | sugar beets |
| tobacco | tobacco |
| canarySeed | canary seed |
| caraway | caraway seed |
| fababeans | |
| forageSeed | forage seed |
| lentils | |
| millet | |
| triticale | |
| otherField | other field crops |

**smallFruit**

Index: sf

Type: set

Description: small fruit crops

| | |
|---|---|
| grapes | cultivated grapes |
| othSmallFruit | other small fruit |

**cropCat**

Index: cc

Type: set

Description: categories of crops

grains
forage
oilseed
otherField
vegetables
orchards
smallFruit

**amendType**

Index: at
Type: set
Description: type of crop amendment

| | |
|---|---|
| insect | insecticide |
| weed | herbicide |
| fert | fertilizer |

**fertilizer**

Index: ft
Type: set
Description: type of fertilizer

| | |
|---|---|
| dryGran | dry granular fertilizer |
| npLiquid | non-pressurized liquid fertilizer |
| pressLiquid | pressurized liquid fertilizer |
| suspension | fertilizer suspensions |

**cultivate**

Index: ct
Type: set
Description: cultivation practice

| | |
|---|---|
| wideRow | wide row cultivation |
| closeRow | close row cultivation |

**statChar**

Index: sc
Type: set
Description:

slope
yIntercept
slopeWt
yInterceptWt
chiSquare
RSquare

**watShed**

Index: ws
Type: set
Description: water sheds

2A
2B
2C
2D
2E
2F
2G
2H
2J
2K
2L
2M

2N
2O
2P

# VARIBLE SHAPES

# 1 Basin Areas

**basinArea[]**- areas of sub-sub basins
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
Sluom = m**2
altUom = hectare

**ssbTosb[]**- mapping from ssb to sb
Framework type: specified (s)
Relational type: Fixed (F)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subBasin
dim2 = subSubBasin

**subBasArea[]**- sub basin areas
Framework type: framework (f)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subBasin
Sluom = m**2
altUom = hectare

**glbArea[]**- area of the Great Lakes Basin
Framework type: framework (f)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
Sluom = m**2
altUom = hectare

## 2.1 Population

**ruralShr[]**- share of population in rural areas
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year

**basinPop[]**- census counts
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
entity = person

**rurUrbPop[]**- rural - urban population
Framework type: calculator (c)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = rurUrban
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
entity = person

**ssbTosb[]**- mapping from ssb to sb
Framework type: specified (s)
Relational type: Fixed (F)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subBasin
dim2 = subSubBasin

**glbPop[]**- Great Lakes Basin population
Framework type: calculator (c)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = SEQ; censusYear: 1971:1986:5; 5-year
entity = person

**subBasinPop[]**- sub basin population
Framework type: calculator (c)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
entity = person

**basinArea[]**- areas of sub sub basins
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
SIuom = m**2
altUom = hectare

**subBasArea[]**- sub basin areas
Framework type: framework (f)
Relational type: Control (C)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subBasin
SIuom = m**2
altUom = hectare

**glbArea[]**- area of Great Lakes Basin
Framework type: framework (f)
Relational type: Control (C)
Class: Stock (S)
Shape:
object = array
data type = real
SIuom = m**2
altUom = hectare

**ssbPopDen[]**- sub sub basin population density
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**-2
altUom = /(hectare**2)
entity = person

**sbPopDen[]**- sub basin population density
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**-2
altUom = /(hectare**2)
entity = person

**glbPopDen[]**- Great Lakes Basin population density
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**-2
altUom = /(hectare**2)
entity = person

**linPop[]**- population linear extrapolation
Framework type: calculator (c)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; year: 1971:1990:1; year
entity = person

**linRSqStat[]**- linear fit R-squared statistic
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin

**expPop[]**- population exponential extrapolation
Framework type: calculator (c)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; year: 1971:1990:1; year
entity = person

**expRSqStat[]**- exponential fit R-squared statistic
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin

## 2.2 Dwellings

**basinPop[]**- census counts
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
entity = person

**dwellings[]**- private occupied dwellings
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = dwellingType
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
entity = dwelling

**persPerDwell[]**- persons per dwelling
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = dwellingType
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
entity = person/dwelling

**landPerDwell[]**- land per dwelling
Framework type: calculator (c)
Relational type: Control (C)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = dwellingType
SIuom = m**2
altUom = hectare
entity = /dwelling

**resLand[]**- residential land use
Framework type: calculator (c)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

## 2.3 Employment

**employ[]**- number of persons employed
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | subSubBasin |
| dim2 | = | SEQ; censusYear: 1971:1986:5; 5-year |
| entity | = | person |

**employInd86[]**- employment by industry 1986
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | subSubBasin |
| dim2 | = | lfIndustry |
| entity | = | person |

**employInd[]**- employment by industry
Framework type: calculator (c)
Relational type: Output (O)
Class: Stock (S)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | subSubBasin |
| dim2 | = | lfIndustry |
| dim3 | = | SEQ; censusYear: 1971:1986:5; 5-year |
| entity | = | person |

**emplIndShr[]**- employment shares by industry 1986
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | subSubBasin |
| dim2 | = | lfIndustry |

## 3.1 Farms

**farmCount[]**- number of farms
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
entity = farm

**areaOper[]**- total farm area operated
Framework type: framework (f)
Relational type: Control (C)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
SIuom = m**2
altUom = hectare

**areaPerFarm[]**- area per farm
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
SIuom = m**2
altUom = hectare
entity = /farm

**farmInc[]**- value of products sold
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Flow (F)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
entity = dollar/year

**incPerArea[]**- income per unit area operated
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m** - 2
altUom = /(hectare**2)
entity = dollar/year

**incPerFarm[]**- income per farm
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
entity = dollar/(year farm)

## 3.2 Agriculture Land

**agriLand[]**- agriculture land
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = agriLand
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**areaOper[]**- total farm area operated
Framework type: framework (f)
Relational type: Output (O)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**basinArea[]**- areas of sub-sub basins
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
Sluom = m**2
altUom = hectare

**farmShr[]**- farm share of sub-sub basin area
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year

## 3.3 Livestock

**livestock[]**- livestock

Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | animal |
| dim2 | = | subSubBasin |
| dim3 | = | SEQ; censusYear: 1971:1986:5; 5-year |
| entity | = | animal |

**waterPerHead[]**- water per head of livestock per year

Framework type: calculator (c)
Relational type: Control (C)
Class: Parameter (P)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | animal |
| Sluom | = | m**3 |
| altUom | = | gallon |
| entity | = | (/year)/animal |

**manPerHead[]**- manure per head of livestock per year

Framework type: calculator (c)
Relational type: Control (C)
Class: Parameter (P)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | animal |
| Sluom | = | kg |
| altUom | = | tonne |
| entity | = | (/year)/(animal) |

**stockWater[]**- water used for livestock per year

Framework type: calculator (c)
Relational type: Output (O)
Class: Flow (F)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | subSubBasin |
| dim2 | = | SEQ; censusYear: 1971:1986:5; 5-year |
| Sluom | = | m**3 |
| altUom | = | gallon |
| entity | = | /year |

**stockManure[]**- livestock manure per year

Framework type: calculator (c)

Relational type: Output (O)

Class: Flow (F)

Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | subSubBasin |
| dim2 | = | SEQ; censusYear: 1971:1986:5; 5-year |
| SIuom | = | kg |
| altUom | = | tonne |
| entity | = | /year |

# 3.4.1 Crop Area Seeded

**grainSeeded[]**- area seeded in grains
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = grains
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**forageSeeded[]**- area seeded in forage crops
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = forageCrops
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**oilseedArea[]**- area seeded in oilseeds
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = oilSeeds
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**fldCropArea[]**- area seeded in other field crops
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = othFieldCrop
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**vegArea[]**- area seeded in vegetables
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**orchardArea[]**- area in orchards
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**smalFrArea[]**- area in small fruit
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = smallFruit
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**totAreaSeed[]**- total area seeded in crops

Framework type: calculator (c)
Relational type: Output (O)
Class: Stock (S)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | subSubBasin |
| dim2 | = | SEQ; censusYear: 1971:1986:5; 5-year |
| SIuom | = | m**2 |
| altUom | = | hectare |

**cropShr[]**- crop category shares

Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:

| | | |
|---|---|---|
| object | = | array |
| data type | = | real |
| dim1 | = | cropCat |
| dim2 | = | subSubBasin |
| dim3 | = | SEQ; censusYear: 1971:1986:5; 5-year |

## 3.4.2 Crop Amendments

**agriLand[]**- agriculture land
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = agriLand
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**basinArea[]**- areas of sub-sub basins
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
Sluom = m**2
altUom = hectare

**areaAmend[]**- area subject to amendment
Framework type: calculator (c)
Relational type: Control (C)
Class: Flow (F)
Shape:
object = array
data type = real
dim1 = amendType
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare
entity = /year

**basShrAmend[]**- share of basin area amended
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = amendType
dim3 = SEQ; censusYear: 1971:1986:5; 5-year

**cropShrAmend[]**- share of cropland amended
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = amendType
dim3 = SEQ; censusYear: 1971:1986:5; 5-year

**fertAppl86[]**- fertilizer applied in 1986
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Flow (F)
Shape:
object = array
data type = real
dim1 = fertilizer
dim2 = subSubBasin
Sluom = kg
altUom = tonne
entity = /year

**fertDen[]**- fertilizer per unit area 1986
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = fertilizer
dim2 = subSubBasin
Sluom = m**-2 kg
altUom = tonne/hectare

**fertAppl[]**- fertilizer applied
Framework type: calculator (c)
Relational type: Output (O)
Class: Flow (F)
Shape:
object = array
data type = real
dim1 = fertilizer
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = kg
altUom = tonne
entity = /year

**arealrrig[]**- area irrigated
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2
altUom = hectare

**waterPerArea[]**- water per unit area irrigated per year
Framework type: calculator (c)
Relational type: Control (C)
Class: Parameter (P)
Shape:
object = array
data type = real
Sluom = m
altUom = (m**3)/hectare
entity = /year

**irrigWater[]**- water use for irrigation
Framework type: calculator (c)
Relational type: Output (O)
Class: Flow (F)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**3
entity = /year

## 3.4.3 Cultivation Practice

**areaCult[]**- area cultivated
Framework type: calculator (c)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = cultivate
dim2 = subSubBasin
dim3 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2

**areaOper[]**- total farm area operated
Framework type: framework (f)
Relational type: Control (C)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = SEQ; censusYear: 1971:1986:5; 5-year
Sluom = m**2

**basinArea[]**- areas of sub-sub basins
Framework type: specified (s)
Relational type: Fixed (F)
Class: Stock (S)
Shape:
object = array
data type = real
dim1 = subSubBasin
Sluom = m**2

**basShrCult[]**- share of basin area under cultivation
Framework type: calculator (c)
Relational type: Output (O)
Class: Parameter (P)
Shape:
object = array
data type = real
dim1 = subSubBasin
dim2 = cultivate
dim3 = SEQ; censusYear: 1971:1986:5; 5-year

# CONCEPTUAL HIERARCHY TREE DEFINITION

| | |
|---|---|
| IJCDB : | basin demography agriculture |
| demography : | population dwellings employment |
| agriculture : | farms agriLand livestock cropping |
| cropping : | cropSeeded cropAmend cultivation |

# DEPENDENCY STRUCTURE EQUIVALENCE RULES

| | |
|---|---|
| basinArea : | basin population agriLand cropAmend cultivation |
| ssbTosb : | basin population |
| subBasArea : | basin population |
| glbArea : | basin population |
| basinPop : | population dwellings |
| areaOper : | farms agriLand cultivation |
| agriLand : | agriLand cropAmend |

# APPENDIX E: HUMAN ACTIVITIES RELATED TO THE GREAT LAKES BASIN ECOSYSTEM

(insert)

Analytical report on:

# Human Activities Related to the Great Lakes Basin Ecosystem


**International Joint Commission on the Great Lakes**
Ottawa, Ontario
February 18, 1991

David R. Allardice
*Vice President and Assistant Director of Research*

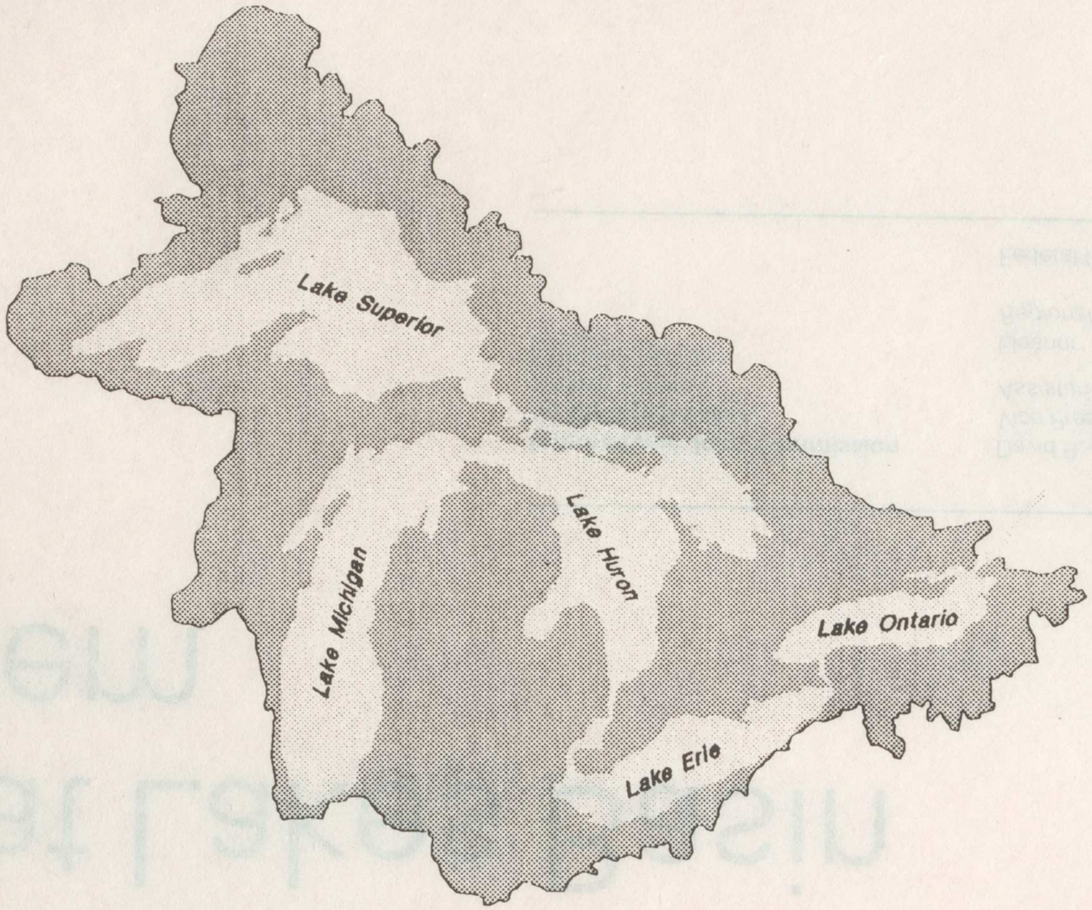
Eleanor Erdevig
*Regional Economist*

Federal Reserve Bank of Chicago



FEDERAL RESERVE BANK OF CHICAGO

# The Great Lakes basin

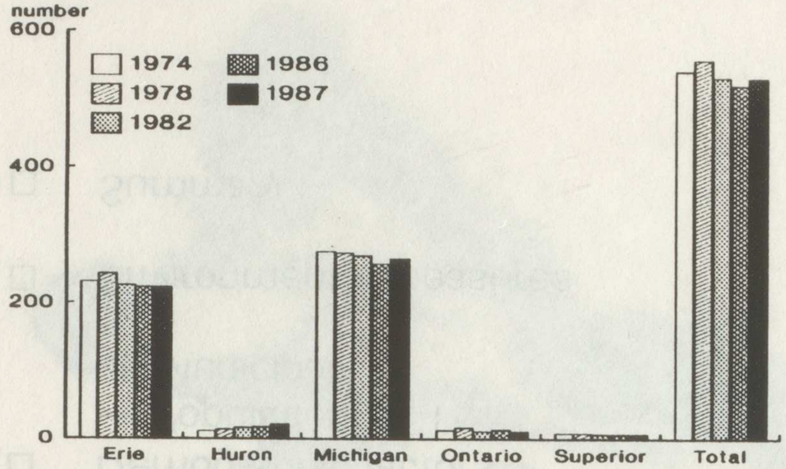


# Outline

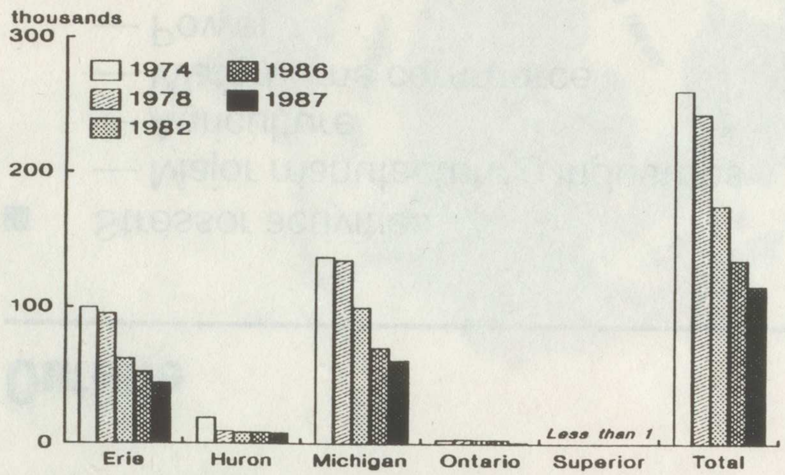
- ■ Stressor activities
  - — Major manufacturing industries
  - — Agriculture
  - — Waterborne commerce
  - — Power
- □ Demographic factors
  - — Population
  - — Municipal
- □ Environmental measures
- □ Summary

## Steel industry: 1974 – 87

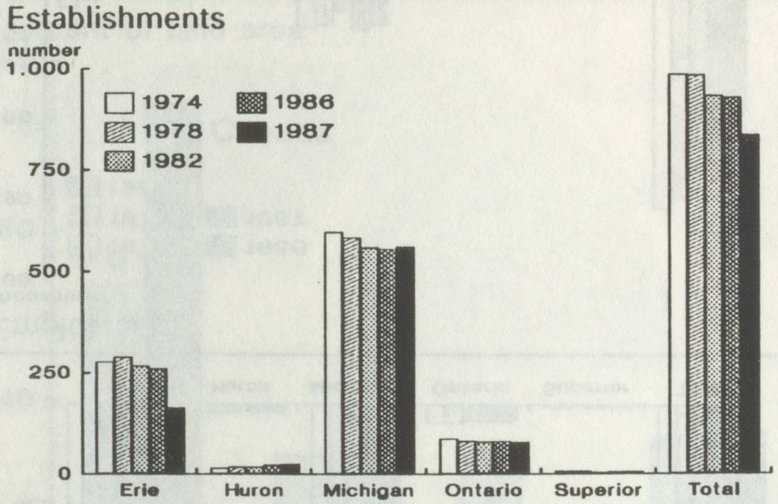
Establishments

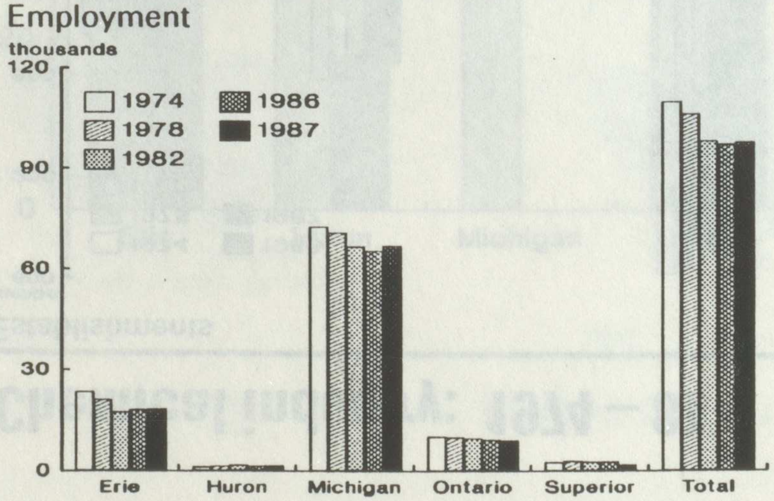



Employment



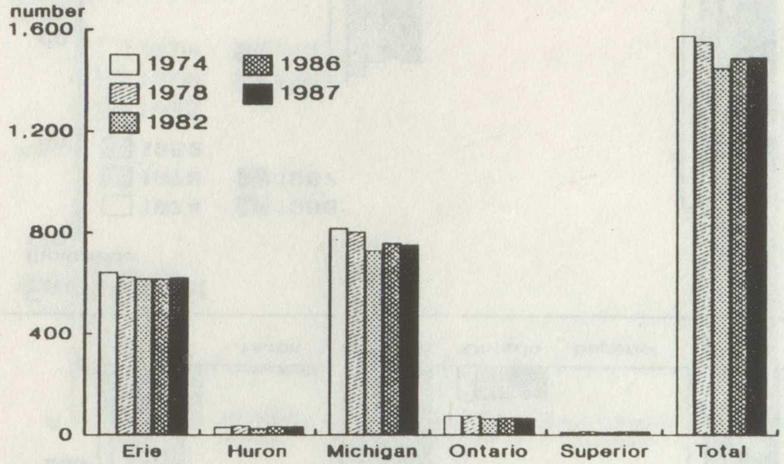
# Pulp and paper industry:  1974 – 87



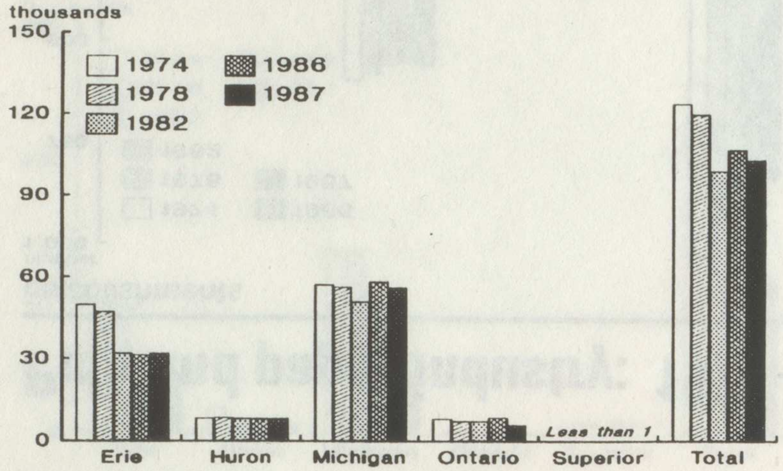



# Chemical industry: 1974 – 87

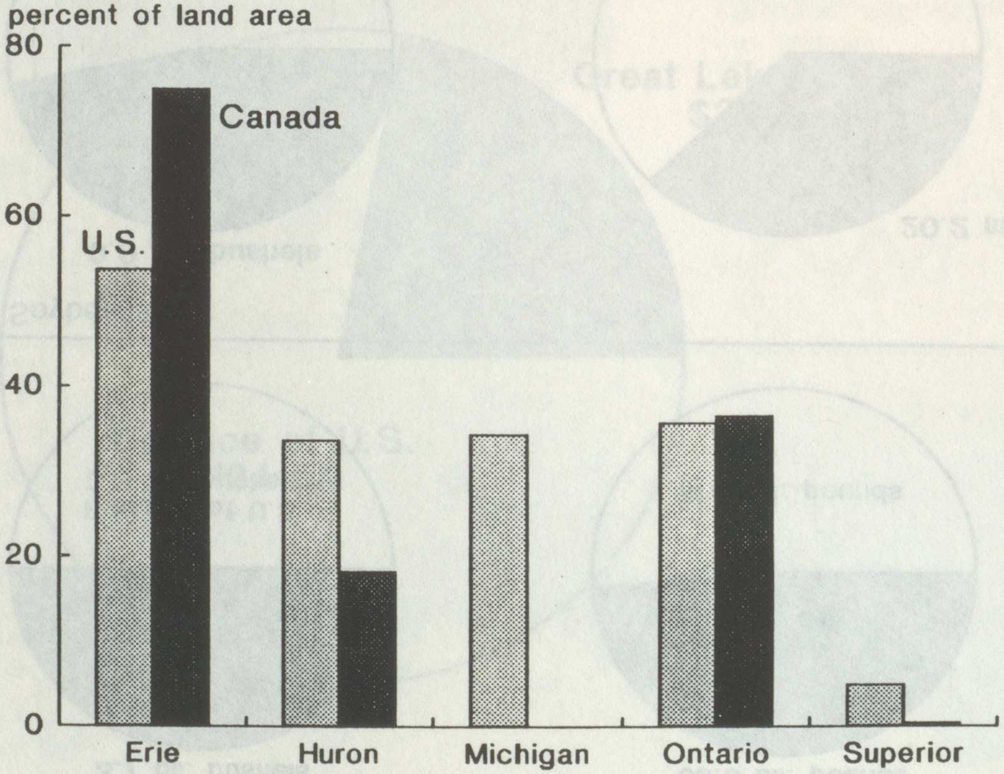
Establishments




Employment

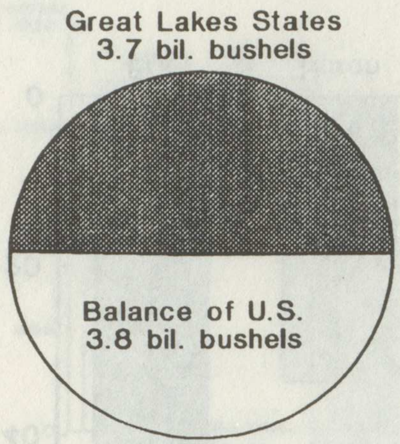


# Farmland in the Great Lakes basin: U.S. – 1987 and Canada – 1986

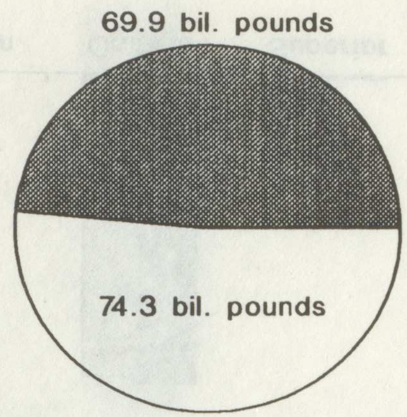


# Farm production of major commodities: 1989

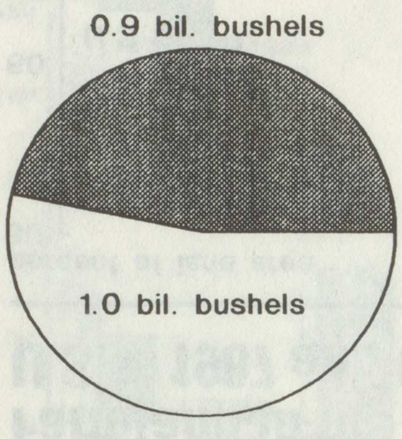
Corn



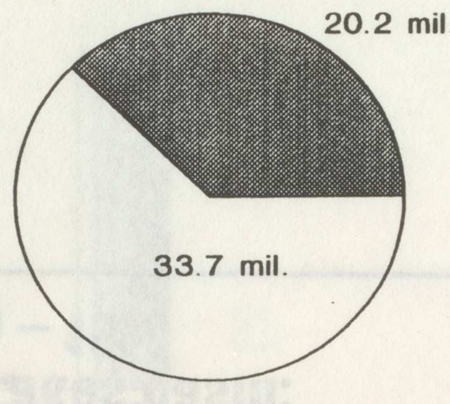

Milk



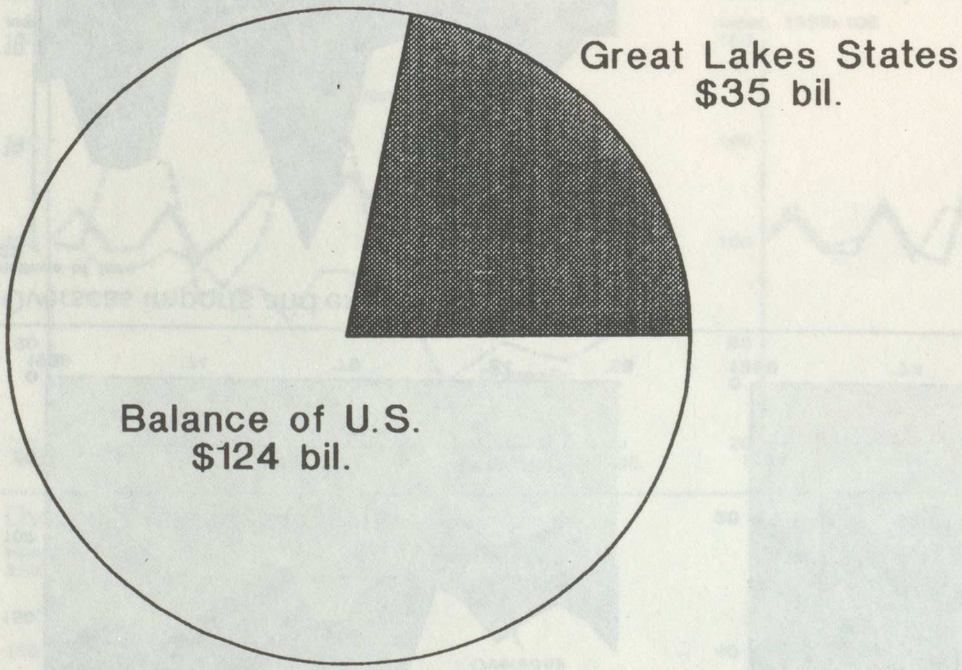

Soybeans




Hogs

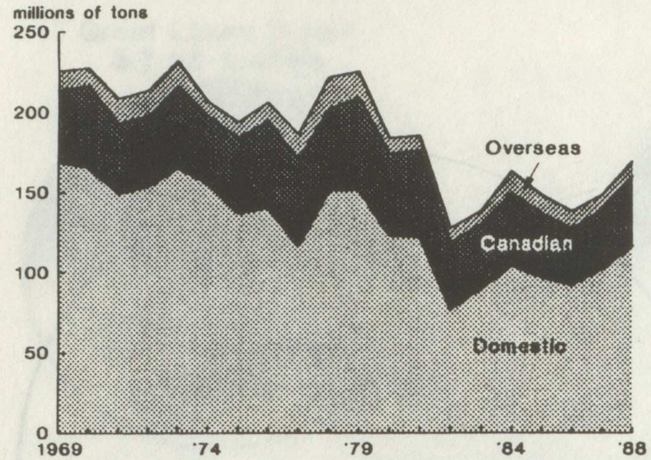


# Cash receipts from farm marketings: 1989

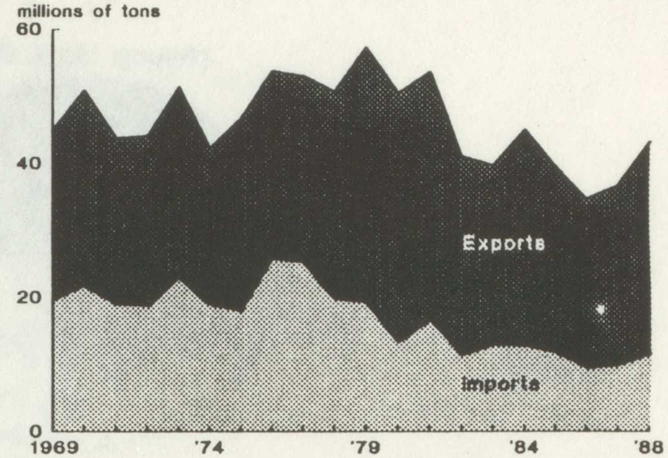


# Waterborne commerce on the Great Lakes (tons): 1969 – 88

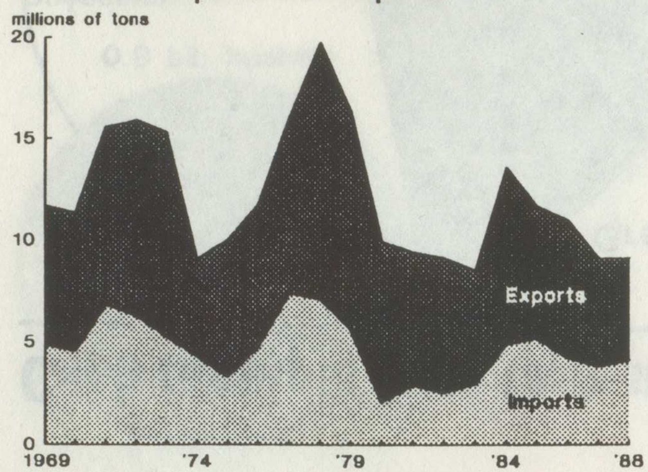
Domestic, Canadian, and overseas




Canadian imports and exports

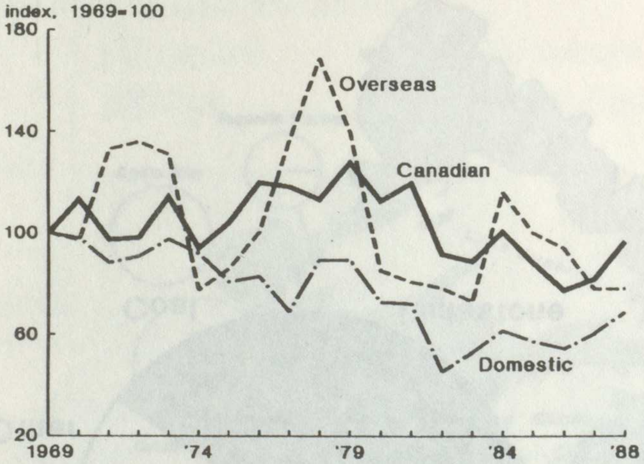



Overseas imports and exports

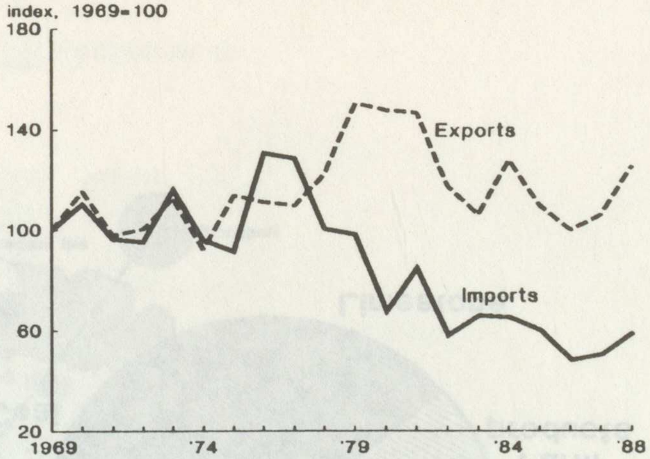


# Waterborne commerce on the Great Lakes (indexed): 1969 – 88

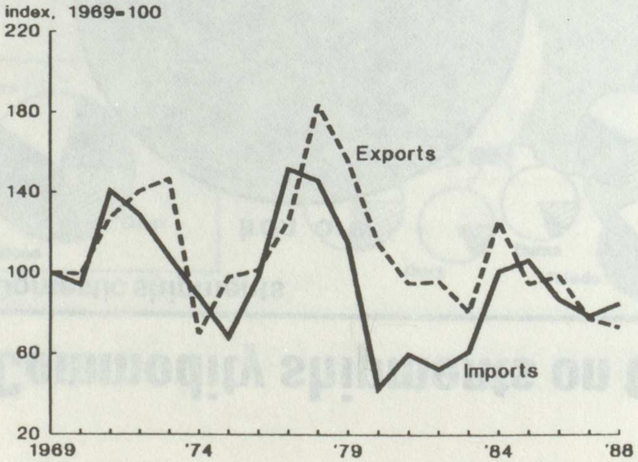
Domestic, Canadian, and overseas




Canadian imports and exports

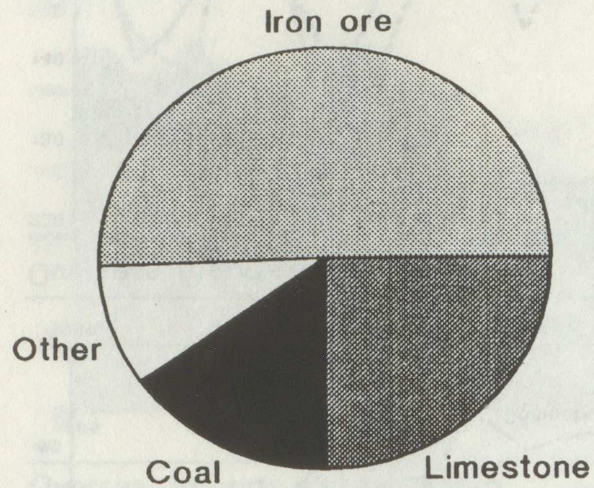



Overseas imports and exports

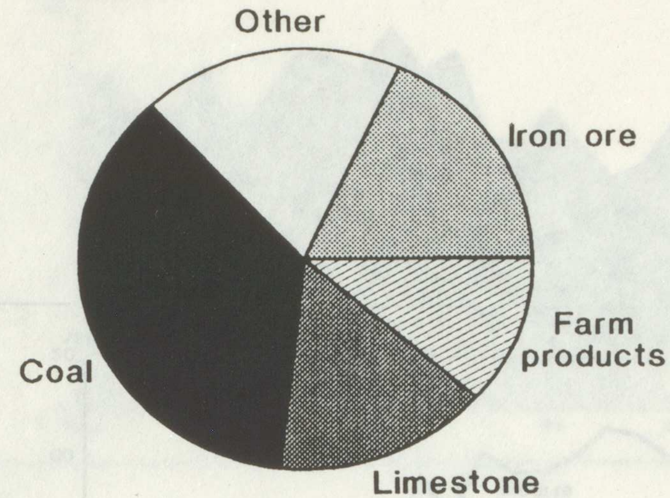


# Commodity shipments on the Great Lakes: 1988

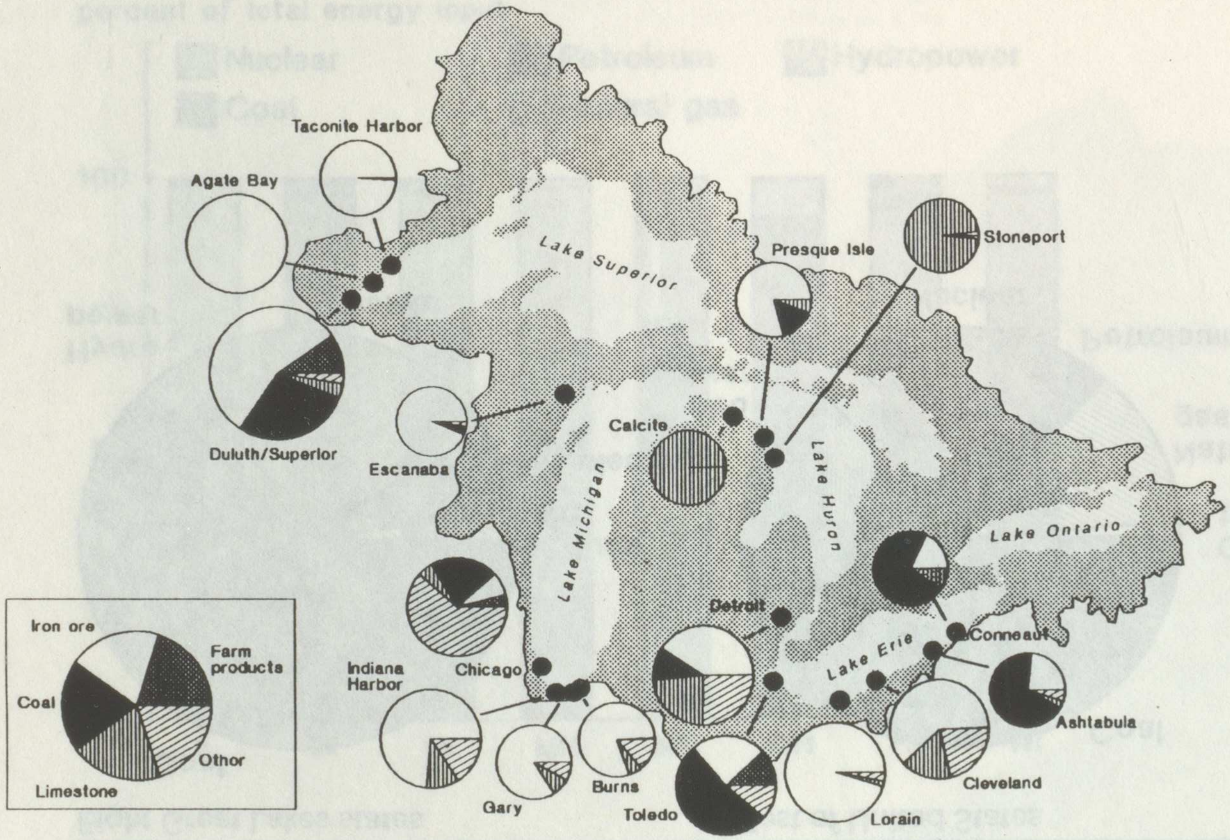
Domestic shipments




Foreign imports and exports

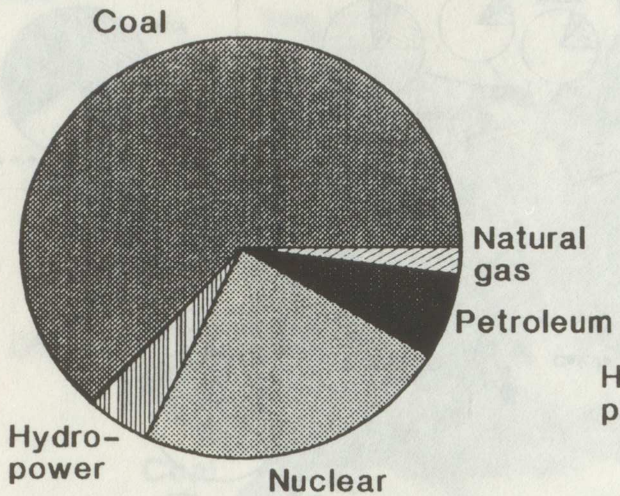


# Great Lakes waterborne commerce

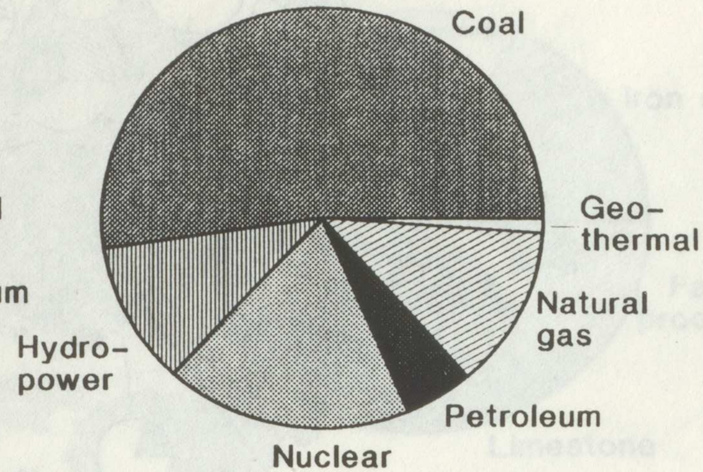


# Energy input at electric utilities: 1988

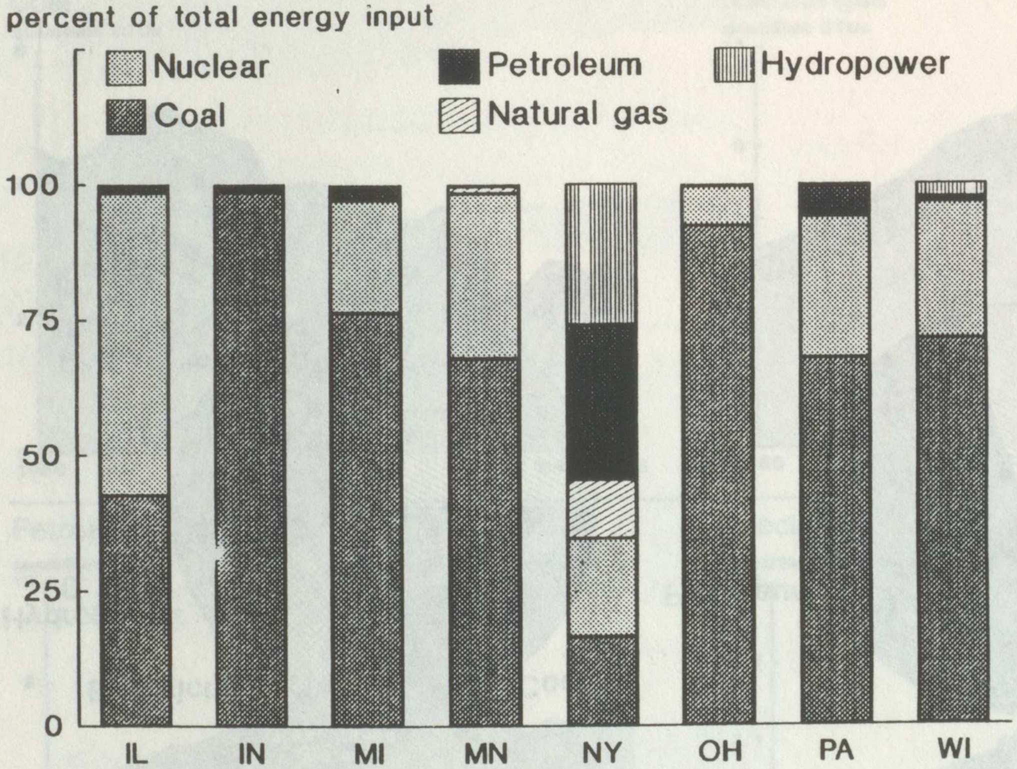
Eight Great Lakes states



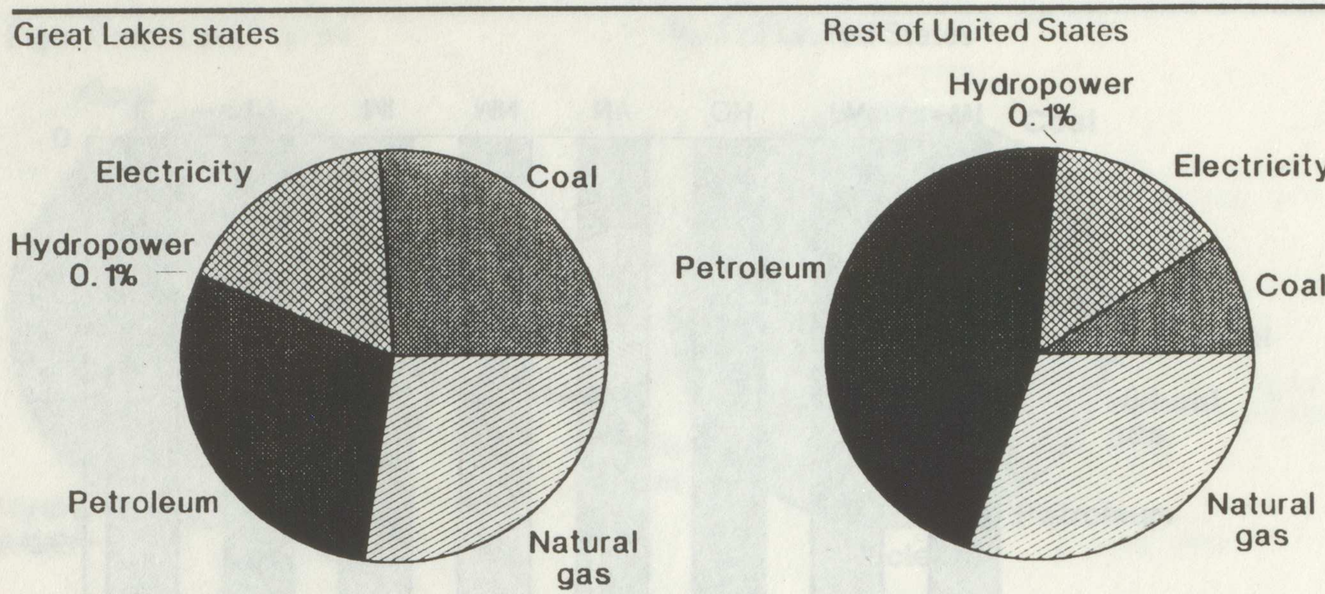

Rest of United States



# Energy input at electric utilities: 1988

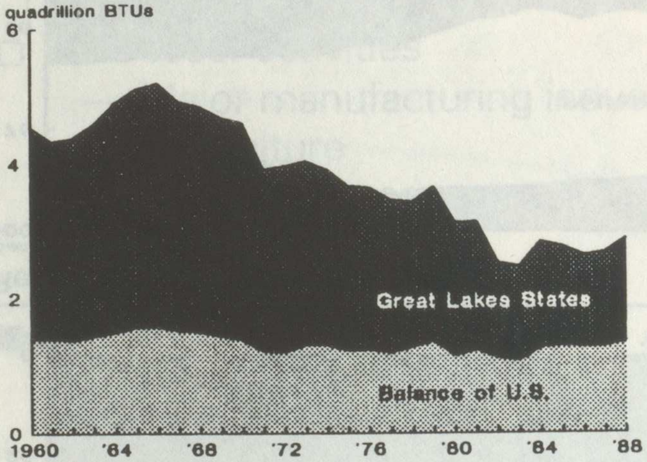


# Industrial energy consumption: 1988

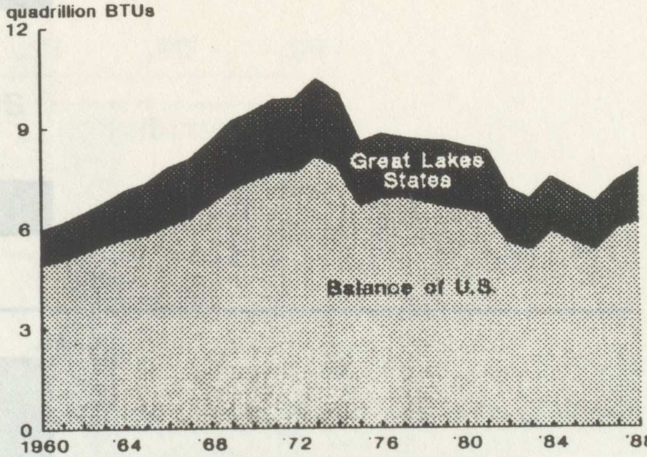


# Industrial energy consumption: 1960 – 88

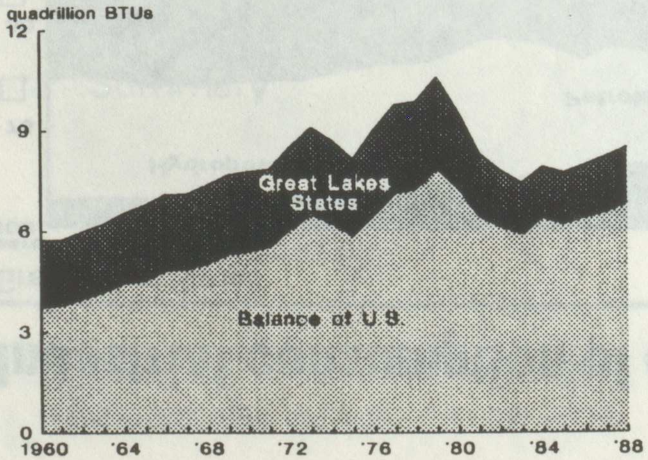
Coal



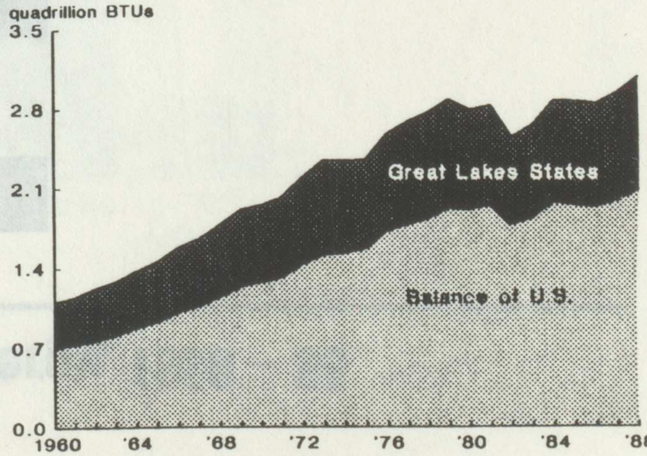

Natural gas




Petroleum

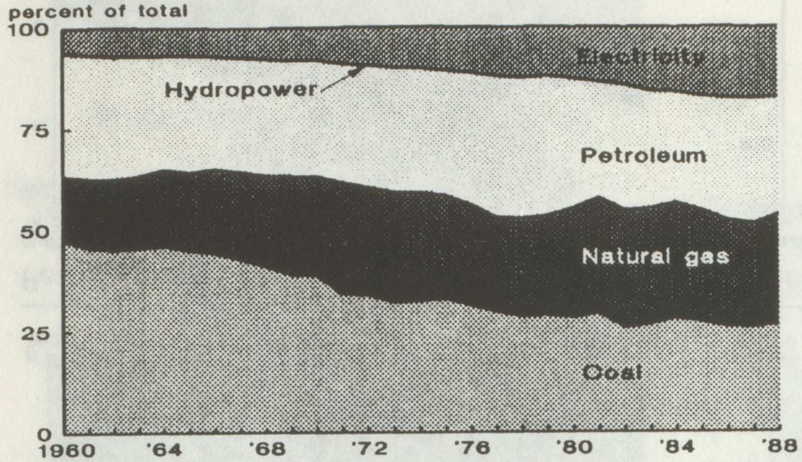



Electricity

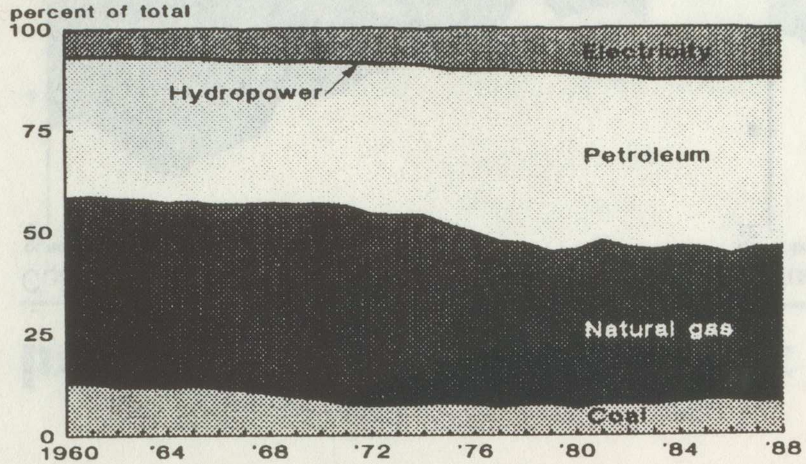


# Industrial consumption of energy, 1960 – 88

Great Lakes States




Rest of United States

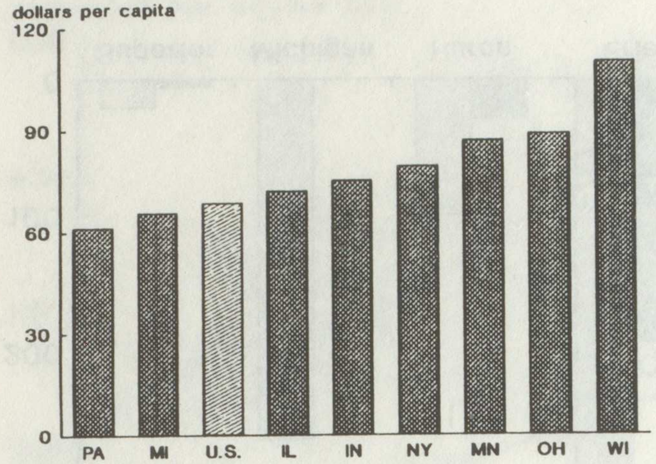


## Outline

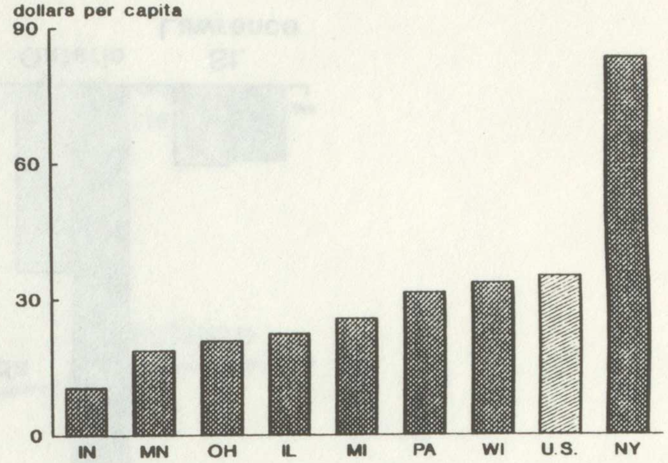
- □ Stressor activities
  - — Major manufacturing industries
  - — Agriculture
  - — Waterborne commerce
  - — Power
- ■ Demographic factors
  - — Population
  - — Municipal
- □ Environmental measures
- □ Summary

# State and local government expenditures: 1988 – 89

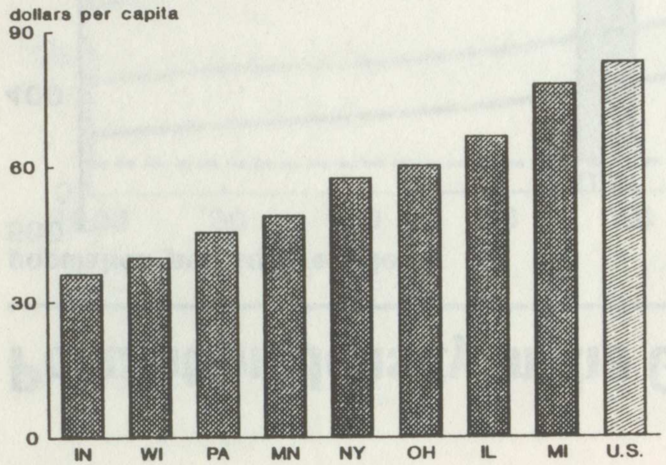
Sewerage



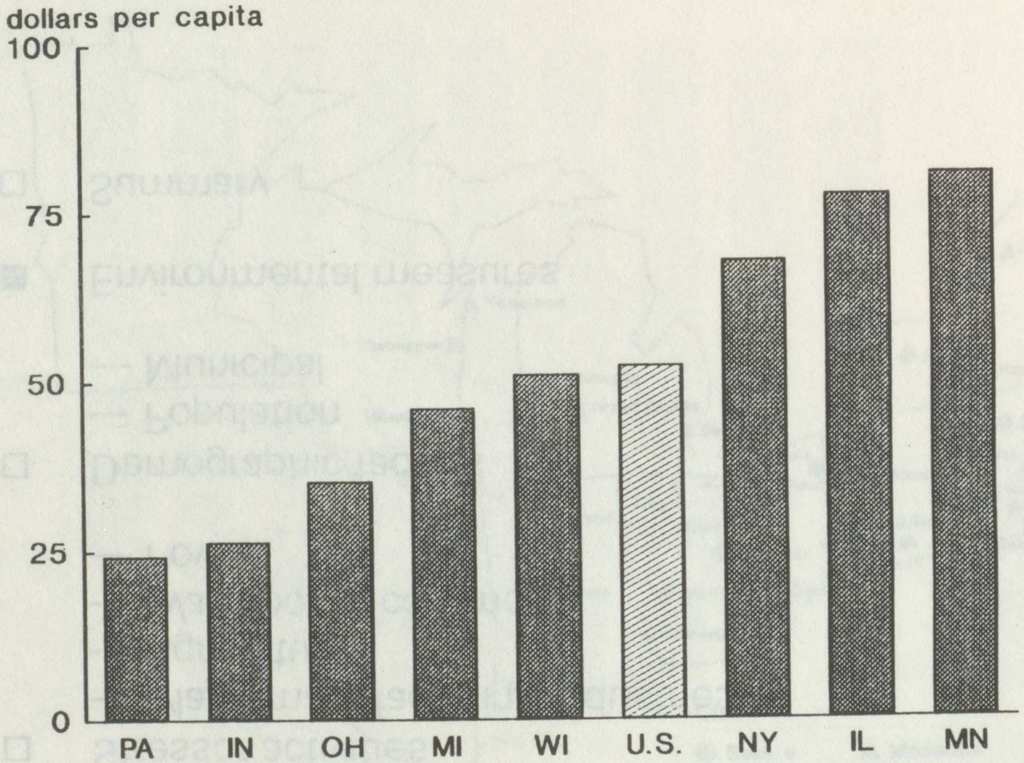

Solid waste management




Water supply



## State and local government expenditures on parks and recreation: 1988 – 89



## Outline

- ☐ Stressor activities
  - — Major manufacturing industries
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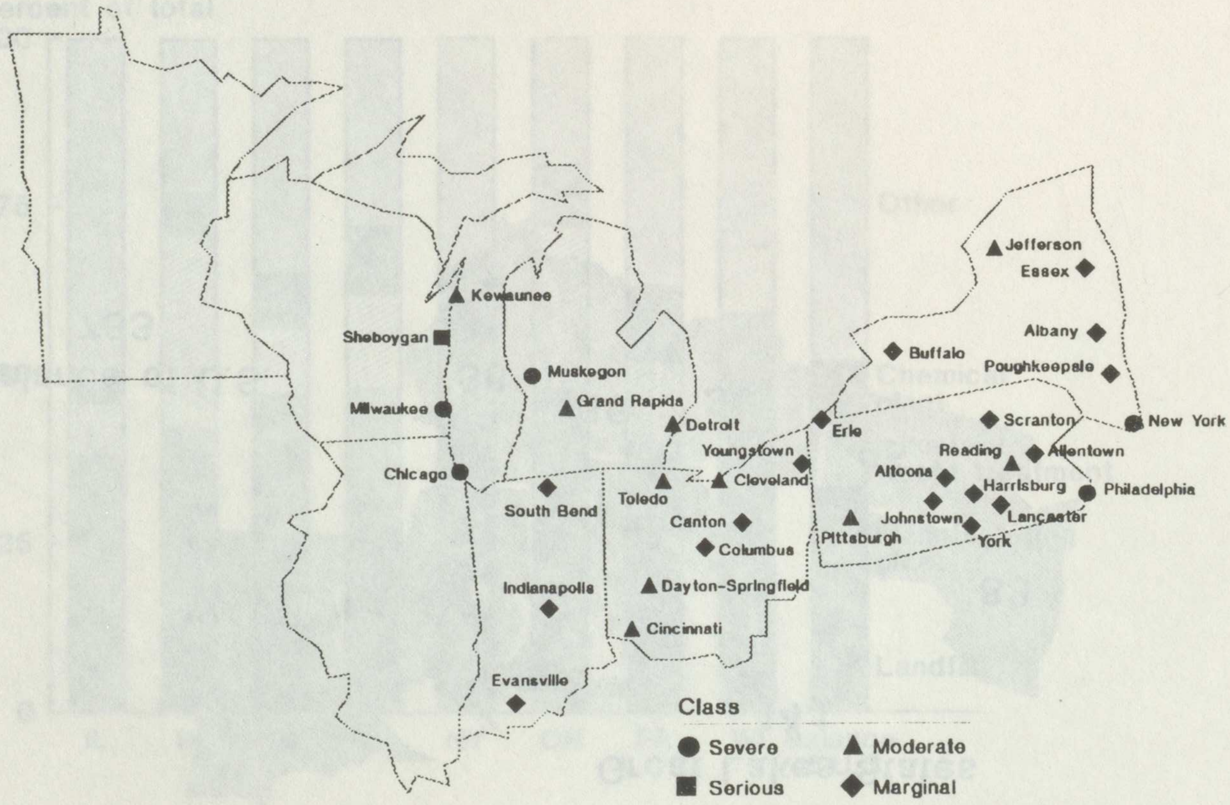
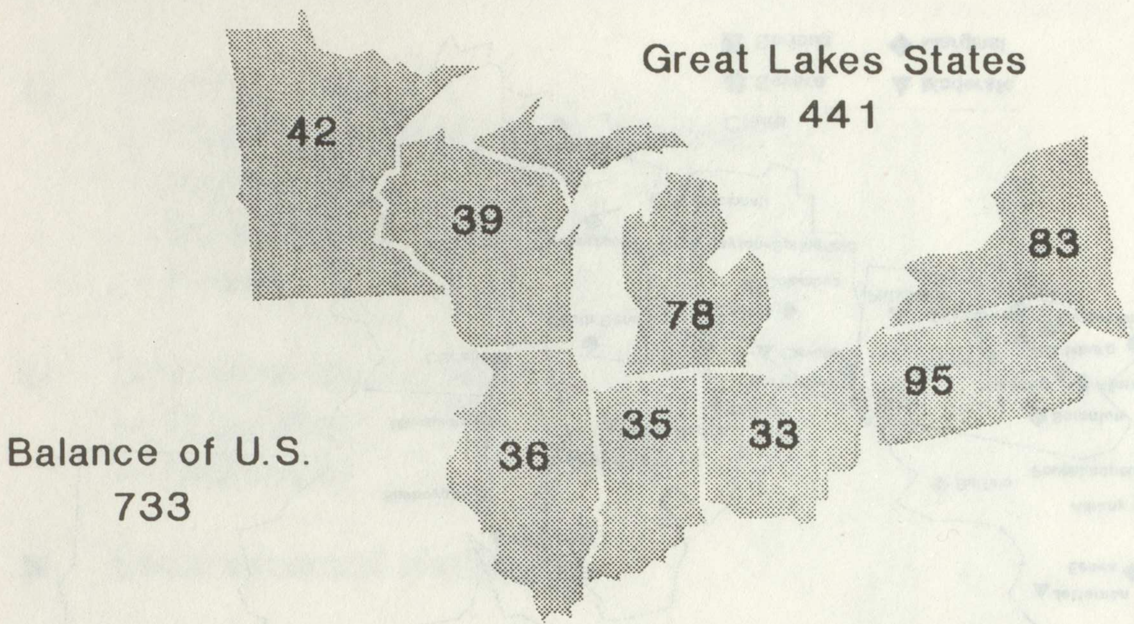
- ☐ Summary

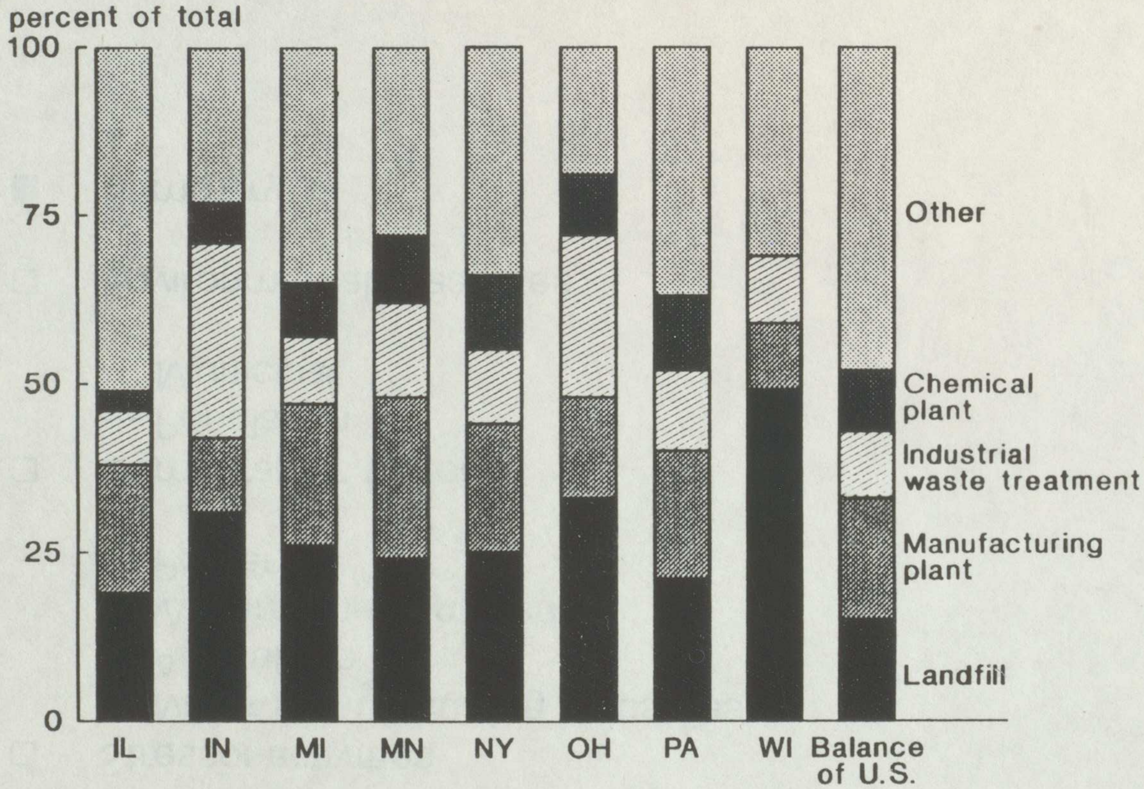
# Clear Air Act target cities



# National Priority List sites



# National Priority List sites



## Outline

- □ Stressor activities
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