State of the Lakes Ecosystem Conference

Selection of Indicators for Great Lakes Basin Ecosystem Health

Version 4

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Notice to Readers

This is the fourth version of the SOLEC report ***Selection of Indicators for Great Lakes Basin Ecosystem Health*** *released by the SOLEC steering committee. The four versions of this report represent a continuum of work on indicators for determining Great Lakes ecosystem health - continuing the development, refinement and acceptance of a suite of Great Lakes indicators.*

The concepts and ideas contained in this paper were first assembled for discussion at SOLEC 98 (October 21-23, 1998). The SOLEC deliberations were an important step in the process. Participants reviewed the SOLEC 98 document prior to SOLEC and provided comments, specific information and / or references during the breakout sessions, on the comment forms or directly to the authors. These comments were considered during the preparation of the revised post-conference SOLEC Indicator List (Version 3). Major changes included the deletion of a few indicators, additions of a few others, revisions to the indicator descriptors of all, summary of a criteria assessment and the inclusion of a section of the different ways the SOLEC indicators may be sorted and organized.

In Version 4 of ***Selection of Indicators for Great Lakes Basin Ecosystem Health****, a few indicators have been dropped, added or moved to another category, the short descriptions of each indicator have been modified and individual indicators have been refined.*

The Parties to the GLWQA want to establish a consistent, easily understood suite of indicators that will objectively represent the state of major ecosystem components across all Great Lakes basins, and which the Parties can use to report status and trends every two years. This suite of indicators will also be used to assess the Parties progress toward achievement of the purpose and general objectives of the GLWQA.

SOLEC

Selection of Indicators For Great Lakes Ecosystem Health

1.0 Introduction

1.1 History of SOLEC

The State of the Lakes Ecosystem Conferences (SOLEC) are hosted by the U.S. Environmental Protection Agency and Environment Canada, every two years on behalf of the two countries in response to the Great Lakes Water Quality Agreement (GLWQA). Canada and the United States are known as the Parties to the GLWQA. SOLEC conferences are intended to focus on the condition of the Great Lakes ecosystem and the major factors impacting it, and to provide a forum for exchange of this information. These conferences are not intended to discuss the status of programs needed for its protection and restoration. Another goal of the conferences is to reach a large audience of people in all levels of the government, corporate, and not-for-profit sectors who make decisions that affect the Lakes.

The conferences are the focal point of a process of gathering information from a wide range of sources and engaging a variety of organizations in bringing it together. In the year following each conference the Governments have prepared a report on the state of the Lakes based in large part upon the conference process.

The first conference, held in 1994, addressed the entire system with particular emphasis on aquatic community health, human health, aquatic habitat, toxic contaminants and nutrients in the water, and the changing Great Lakes economy. The 1996 conference focused on the nearshore lands and waters of the system where biological productivity is greatest and humans have had maximum impact. Emphasis was placed on nearshore waters, coastal wetlands, land by the Lakes, the impact of changing land use, and information availability and management. For both conferences indicators were chosen and, based on expert opinions, subjective assessments were provided as to the conditions in terms of good, fair, poor, etc.

In planning for SOLEC 98 the organizers wanted to support further development of easily understood indicators which objectively represent the condition of the Great Lakes ecosystem components. These would be used every two years to inform the public and report progress in achieving the purpose of the GLWQA: *to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Ecosystem*. The SOLEC indicators would reflect conditions of the whole Great Lakes basin and its major components (a general system-wide overview), and they would draw upon and complement indicators used for more specific purposes such as Lakewide Management Plans (LaMPs) or Remedial Action Plans (RAPs) for Areas of Concern.

Beginning with SOLEC 2000 and continuing for at least the next decade, progressively more indicators will be reported at each conference until the entire suite is included. The indicators presented in this report comprise the SOLEC indicators list for SOLEC 2000. The list should be considered dynamic, and modifications and adjustments can be expected as the list evolves to reflect better understanding of Great Lakes ecosystem functioning and human interactions with and within the ecosystem.

2.0 Indicators

2.1 What is an Indicator?

The concept of indicators is quite familiar. They can be thought of as pieces of evidence, or clues, that tell us something about the condition of something of interest. For example, doctors use blood pressure and weight to gauge human health, and economists use interest rates and housing starts to assess the health of economies. Similarly, environmental indicators provide bits of information that are useful to us to assess our surroundings. Indicators, when tracked over time, provide information on trends in the condition of the surroundings.

> Indicators can be thought of as pieces of evidence that help us assess the condition of something of interest.

During the organization of a set of indicators for SOLEC, it became apparent very quickly that a number of related terms and concepts could be confusing. Some basic definitions are presented here to provide the context for the SOLEC indicators project.

Vision A general description of the desired state of a lake, geographical area, etc., as expressed by a group of stakeholders.

Goal A condition or state desired to be brought about through a course of action. Goals are usually qualitative statements that provide direction for plans and projects.

Objective Specific descriptions of the state or condition that must be met in order to achieve goals and the vision.

Indicator A parameter or value that reflects the condition of an environmental (or human health) component, usually with a significance that extends beyond the measurement or value itself. Indicators provide the means to assess progress toward an objective.

Data Point A single measurement of an environmental feature. Data points may be combined to serve as an indicator.

Endpoint Specific, attainable, quantitative target or reference values for an indicator that provides the context for assessing whether or not an objective is being met.

An indicator is more than a data point. It consists of both a value (which may be a direct environmental measurement or may be derived from measurements) and an endpoint or reference

value. The indicator is intended to be used, alone or in combination with other indicators, to assess progress toward one or more objectives. For SOLEC purposes, the objectives may be expressed in the Great Lakes Water Quality Agreement, LaMPs, RAPs, Fish Community Objectives, or other generally accepted Great Lakes planning documents. In addition, to be widely used by decision-makers and others, indicators should be readily understood by a broad audience.

2.2 Types of Indicators

There are several classification schemes for indicators, which encompass everything from human actions (e.g., the number of participants in public hearings) to environmental measurements (e.g., the number of bald eagle fledglings per breeding pair). SOLEC has adopted the State—Pressure—Human Activities (Response) indicator model. This framework is considered one of the most widely accepted classification schemes for environmental indicators because of its simplicity and broad applicability. The SOLEC indicators can be classified according to the following types:

> **State (of the Environment):** These indicators address the state of the environment, the quality and quantity of natural resources, and the state of human and ecological health. They reflect the ultimate objective of environmental policy implementation. The indicators are chosen by considering biological, chemical and physical variables and ecological functions.
>
> **Pressure:** These indicators describe natural processes and human activities that impact, stress or pose a threat to environmental quality.
>
> **Human Activities (Response):** These indicators include individual and collective actions to halt, mitigate, adapt to, or prevent damage to the environment. They also include actions for the preservation and the conservation of the environment and natural resources. Examples of actions include education, regulation, market incentives, technology changes, etc.

These three indicator types are closely linked. For example, the *pressure* (or stressor) of a particular pollutant entering a system may cause a change of *state* of some species (i.e. population declines) which may, in turn, cause a *response* of (additional) restrictions on the discharge of the pollutant. The additional restrictions reduce the *pressure* which improves the *state*. Most SOLEC indicators will be of types State or Pressure, reflecting the focus of the Conference.

2.3 Scale

Indicators may be selected to reflect environmental conditions on a variety of scales in both space and time. From a satellite, one can obtain an image of the entire Great Lakes basin. From an airplane, one can view an entire lake or lake basin. From a canoe, one can view a single turtle. Indicators identified for SOLEC are intended to be generally applicable on a basin-wide or lake basin scale. Lake-by-lake differences may exist in endpoints or reference values for some indicators, but the indicators themselves should be relevant across lakes. Indicators of local

conditions, as might be presented in Remedial Action Plans for Areas of Concern, are not the focus for SOLEC. In addition, the indicators identified for SOLEC should reflect changes in conditions in the short, medium, and long-term.

2.4 The Need for an Indicator List

One way to determine the status of the health of the Great Lakes ecosystem is to use indicators, which address a spectrum of conditions ranging from the health of humans and other living components of the system to the stressors and the activities that cause them. Ecosystem health indicators reflect ecosystem quality or trends in quality that are useful to managers and scientists. However, ecosystems are inherently complex so that any single indicator (or even suites of indicators) cannot be completely representative of all possible conditions.

The Parties to the GLWQA want to establish a consistent, easily understood suite of indicators that will objectively represent the state of major ecosystem components across all Great Lakes basins, and which the Parties can use to report status and trends every two years. This suite of indicators will also be used to assess the Parties progress toward achievement of the purpose and general objectives of the GLWQA.

> The goal of this project is to assemble a basin-wide suite of scientifically valid indicators that will be most useful and understandable in determining and reporting the health of the Great Lakes ecosystem to the interested public.

The SOLEC process has assembled a set of indicators that reflects the state of major ecosystem components for the Great Lakes, including open and nearshore waters, coastal wetlands, nearshore terrestrial environments, human health, stewardship, and socio-economics/land use. The indicators nominated for the SOLEC list were extracted primarily from existing Great Lakes documents (see Appendix 7), (e.g., Lakewide Management Plans, Fish Community Goals and Objectives, and International Joint Commission (IJC) proposed indicators of desired outcomes).

2.5 Why Should There be Agreement on Indicators?

The demand for high quality, relevant data concerning the health of various components of the Great Lakes ecosystem has been escalating rapidly for the past decade or so. The U.S. and Canada have spent billions of dollars and uncounted hours attempting to reverse the effects of cultural eutrophication, toxic chemical pollution, over-fishing, habitat destruction, introduced species, etc. Environmental management agencies are being asked to demonstrate that past programs have been successful and that the success of future or continuing programs will be proportional to the resources expended (financial and personnel time). At the same time, in both countries, the amount of taxpayers dollars being devoted to Great Lakes environment issues is decreasing. The demand for high quality data, while operating with limited resources, is forcing environmental and natural resource agencies to be more selective and more efficient in the collection and analysis of data.

The most efficient data collection efforts will be those that are cost-effective and relevant to multiple users. An understanding by stakeholders about what information is necessary and sufficient to characterize the state of Great Lakes ecosystem health through the use of indicators, and to measure progress toward ecosystem goals, would facilitate efficient monitoring and reporting programs. Common databases would provide easier access to relevant supporting data, and the relative strengths of the agencies could be utilized to improve the timeliness and quality of the data collection.

The International Joint Commission (IJC) has a responsibility to evaluate progress toward achieving the goals and objectives of the GLWQA. A set of indicators that is relevant to both the IJC and the Parties will prevent a dilution of monitoring effort for competing purposes, and will foster cooperation between the Parties and the IJC for the common good of the Great Lakes ecosystem. Data will be collected for pre-determined applications, and they will be available on a timely basis. This system of a core set of indicators will be flexible enough to expand to take into account new emerging issues.

Access by non-government organizations (NGOs) to environmental data should become easier, and the data should be more timely and more relevant to a wide variety of stakeholders. Results of government programs for environmental protection and restoration (or lack thereof) would be easier to identify.

Achieving consensus on a set of core indicators means that individual programs and jurisdictions may continue to maintain their own unique indicators. Individual user groups may need to retain certain indicators or other data requirements that are not shared by other groups. The SOLEC process will not attempt to impose a uniform set of indicators onto all user groups, nor will it discourage new indicator development work. However, the SOLEC Indicators List is expected to influence future monitoring and data gathering efforts for a common broad scale set of indicators. An understanding by multiple stakeholders about what information is necessary and sufficient to characterize the health of the Great Lakes ecosystem should foster cost-efficient, standardized, and relevant monitoring programs.

…the SOLEC Indicators List is expected to influence future monitoring and data gathering efforts…

3.0 The Process for Selecting SOLEC Indicators

3.1 Pre-SOLEC 98

In preparation for SOLEC 98, a SOLEC Indicators Group was established by the SOLEC Steering Committee and asked to identify a set of indicators that reflects the state of all major Great Lakes ecosystem components. The Indicators Group consisted of volunteers from government, industry, academics, plus contracted writers/coordinators, each an expert in some aspect of the Great Lakes ecosystem. Because of the high degree of interest in this project, representatives from the LaMP work groups, IJC, and other government agencies participated as their time permitted.

The enormous task of finding indicators applicable to the Great Lakes basin ecosystem was originally divided into seven Core Groups, each lead by experts in the respective fields:

Open waters;
Nearshore waters;
Coastal wetlands;
Nearshore terrestrial (land by the Lakes);
Human health;
Socio-economics/Land use; and
Stewardship

Each of the seven groups proceeded to select a set of indicators for its domain that would be proposed as part of the SOLEC list. The Indicators Group coordinated the work, setting out guidelines for the process (outlined below), arranging conference calls, etc. The groups worked largely independently, but each group followed a process somewhat similar to that listed below. Alternative and/or additional steps in the process followed by some groups are presented in the specific group sections of this report.

The following is a list of activities that each group undertook to select a list of proposed SOLEC Indicators:

1. Assembled a group of experts. Each group identified and invited additional experts to assist in the selection or review of the proposed indicators. Efforts were made to include both Canadian and U.S. representatives on the expert panels, but representation from every agency was not attempted.

2. Reviewed and extracted proposed indicators from Great Lakes documents. An initial list of 55 documents was identified early in the process, and this list was the starting point for each group. The documents included reports from previous SOLEC conferences, the LaMP work groups, the IJC, the Great Lakes Fishery Commission, the Great Lakes Water Quality Agreement, and others. Each group was also encouraged to find and use other sources for Great Lakes indicators. See Appendix 7 for a list of documents used by the Core Groups.

3. Identified potential indicators from non-Great Lakes documents. Some groups found that few indicators had been proposed for the Great Lakes for their domain or that other, non-Great Lakes sources provided relevant indicators or approaches. As time permitted or need required, these additional sources were consulted, and indicators not previously proposed for the Great Lakes were identified. Appendix 7 also includes these documents.

4. Entered information about potential indicators into a database. A relational database was created specifically to assist the Indicator Group assemble, maintain and sort through the potential indicators for the SOLEC list. Each indicator extracted from (or mined out of) the documents was entered into the electronic database. See Section 3.7 and Appendix 5 for a detailed description of the database, the information retained about each indicator, and its potential usefulness to other user groups. In addition, see Appendix 2 for a full listing of all indicators entered into the database.

5. Screened the indicators using a broad set of SOLEC criteria. There were three general criteria that had to be met for an indicator to be put forward as a candidate for a SOLEC indicator:

Necessary - Do we really need to monitor a particular indicator? We want to gather information that is necessary to assess ecosystem health.

Sufficient - Will the suite of indicators give us enough information to assess the health of the Great Lakes ecosystem? We don't want to make an overall assessment of ecosystem health from too few indicators.

Feasible - Can the information reasonably be gathered, considering budgetary and monitoring constraints? The ideal situation would be if a monitoring program is already in place to gather the needed information.

6. Selected a subset (short list) of indicators from the database to be proposed for the SOLEC Indicators List based on expert opinion. The groups varied considerably in their approach to this critical task. For some groups (e.g., coastal wetlands, nearshore terrestrial), an active expert panel reviewed the entire list of indicators related to their domain, provided advice about the selection of an appropriate subset, and/or were involved in the combining or modification of indicators to create a subset more suitable for SOLEC needs. For other groups, the group leaders provided most of the energy for identifying the subset, and the expert panel was consulted during the process or provided review comments. Consultation with the expert panels has continued beyond SOLEC 98.

7. Screened the short list of indicators with a comprehensive set of SOLEC criteria. A set of selection criteria were adapted from an EPA document, *Process for Selecting Environmental Indicators and Supporting Data*, and modified slightly to better fit this project. These 21 criteria fall under seven categories: validity, understandibility, interpretability, information richness, data availability, timeliness, and cost considerations. These criteria will continue to be the basis for the review, selection and refinement of the indicators proposed for the SOLEC list. Reviewers of the SOLEC list have been encouraged to refer to these criteria when suggesting improvements, additions or deletions from the list. These criteria can be found in Appendix 4.

8. Sent the short list (Version 1) out for review. During the review process of the selected indicators, stakeholders were invited to provide advice on what indicators would be useful and interesting - June, 1998

9. Comments from review considered and revisions made. A draft report and SOLEC Indicator List (Version 2) were prepared for discussions at SOLEC 98 in October 1998.

10. Identify ecosystem components for which additional indicator development is needed. This step has been and will continue to be considered throughout the process.

3.2 SOLEC 98

Many discussions about the Indicators List were held at SOLEC 98. The conference workshops looked at the individual core group suites of indicators as well as the total suite of indicators (basin-wide overview). Many comments, concerns, suggestions and plain old-fashioned good advice were garnered from these sessions. A more detailed description of the SOLEC 98 indicator workshops can be found in the "SOLEC 98 Conference Proceedings" document (available on-line at www.cciw.ca/solec/ or www.epa.gov/glnpo/solec/).

3.3 SOLEC Indicators List - Version 3

The majority of the comments from the SOLEC 98 workshops were thoroughly discussed at a meeting of the core group leaders in January 1999. As a result of these discussions a few indicators were deleted or combined with others, a few new indicators were added and the remainder were revised as appropriate.

After the revisions were made, each indicator was subjected to a clarification and consistency check. The purpose of this was to ensure that the indicators are clear and understandable and that they all follow a similar format. This process resulted in a much better indicator descriptor (see Appendix 1) and also helped to identify gaps in information as well as identifying future research needs.

For each indicator in Version 3 of the *Selection of Indicators for Great Lakes Basin Ecosystem Health*, a third party assessment against the SOLEC criteria was also undertaken. The results of this assessment can be found in Appendix 4 of Version 3.

In addition, and as a result of comments heard at SOLEC 98, the indicators have been categorized in several ways, in order to meet the needs of SOLEC and other interested stakeholders. The indicators can now be sorted and organized for many different means. For example, you may be interested in seeing a list of all the SOLEC indicators that relate to the GLWQA Annex 12, Persistent Toxic Substances. These can then be sub-categorized by state, pressure, and human activity. For more details on many indicator sorting possibilities please see Appendix 3.

Version 3 of the *Selection of Indicators for Great Lakes Ecosystem Health* was distributed for broad review to a wide variety of stakeholders. It was reviewed from both a technical standpoint and a policy standpoint in order to generate an understanding of the project, as well as getting buy-in and commitment. Comments received from the review were used to generate Version 4 of the indicator list and report. The majority of these comments, along with responses formulated by the core groups, can be found in Appendix 9.

3.4 State of the Great Lakes 1999

The State of the Great Lakes reports are produced in an effort to tie together all the information discussed at the SOLEC conferences. These reports are released about a year after the respective conference. The 1999 State of the Great Lakes report was released in November 1999 and not only discussed the indicator process but also reported on 19 of the 80 indicators.

3.5 SOLEC Indicators List - Version 4

The major changes to the Indicator List are:

< Indicator 72, Fish Entrainment, was removed from the list. This indicator has been incorporated into indicator 6, Aquatic Habitat.

- Indicator 9001, Atmospheric Visibility: Prevention of Significant Deterioration, was removed from the list. This indicator was removed as it was not widely viewed as "*necessary*" in order to determine the health of the Great Lakes basin ecosystem.
- Indicator 9002, Exotic Species, was added. This indicator has been added as a placeholder at this time to fill a gap in the previous indicator list. A more fleshed out indicator is anticipated to be presented at SOLEC 2000.
- A list of contaminants of common concern to most Great Lakes regions and ecosystem components has been determined. These were derived from the priority or critical contaminant lists from GLWQA, IADN, BNS, and the LaMPs. The list is intended to reflect contaminants of a basin-wide concern.
- The "Purpose" statements for each indicator have been modified to more correctly reflect the intent of each indicator.
- Some of the indicators have been revised based on comments received from the last review - the most significantly revised indicators are included in the Nearshore and Open Waters group.
- The spreadsheet in Appendix 3 has been modified to better reflect the relevant links to other works and environmental issues.
- Some indicators have re-categorized within different SOLEC core groups, and some have changed indicator types (pressure, state or human activity)

3.6 Where Do We Go From Here?

We've only just begun the journey! It is anticipated that there may be continual adjustments, refinements and revisions either to individual indicators or to the list as a whole. The SOLEC Indicators List is a living list. New emerging issues must be considered as they arise and potentially the list expanded to include indicators of the issues.

The SOLEC Indicators List currently contains 79 indicators that together can be used to assess the health of the major ecosystem components of the Great Lakes basin ecosystem. However, for many of the indicators more research or information is needed before the indicator can be used and data collected for it. Buy-in and commitment to the process by the various Great Lakes agencies and stakeholders is also necessary. This includes a commitment to monitoring and data collection.

Data gathering efforts for some of the indicators are underway in order to assess and report on as many indicators as is possible at SOLEC 2000 and in future State of the Great Lakes reports. However, the 79 indicators are not organized to answer the questions most frequently asked by the public: How is the water - is it safe to drink? How is the air - is it safe to breathe? How are the fish - are they safe to eat? Therefore, for SOLEC 2000, the 79 indicators may be grouped and reported on within environmental compartments and issues, such as: air, water, land, persistent toxic chemicals, exotic species...

3.7 The SOLEC Indicators Database

To assist the Indicator Group collect and sort indicators from existing documents, a database was designed to retain two main types of information about each indicator: 1) information useful for sorting the indicators according to various user perspectives, and 2) a detailed description of each

indicator. Because the database contains information about indicators, but does not contain any of the environmental measurements, the information is more appropriately described as meta-data.

Within the database, each indicator under consideration for the SOLEC list was designated "Under Consideration." After a decision about an indicator had been reached regarding its inclusion on the SOLEC list, its status was changed to "Selected," "Not Selected," or "Concept Retained." See Appendix 5 for more details about these designations.

The "sorting" part of the database contains fields whose elements are selected by pull down pick lists. For example, information is stored concerning the type of indicator (i.e. state, pressure or human activity) and applicable SOLEC group (i.e. open waters, nearshore waters, coastal wetlands...). Nearly all of the indicators entered into the database are associated with some or all of these fields.

The "description" part of the database contains text fields that provide details about the indicator itself. This information is provided, to the best extent possible, for each of the indicators that make up the SOLEC list. For many of the other indicators in the database, this information was either not available or remains within the source documents but was not transferred to the database. The text fields include: indicator purpose, ecosystem objective, indicator features, desired endpoint (or range, outcome or other reference value), indicator limitations, indicator interpretation, additional comments, and a list of other groupings for which the indicator is relevant.

Originally conceived as an organizing and sorting tool for the SOLEC Indicator Group, the database may have value to other user groups. Therefore, an explanation and/or rationale for each of the database fields is provided in Appendix 5. Since SOLEC 98, work has proceeded on the database to make it more useable to a broader audience as well as making it more user friendly. An interactive on-line version is expected to be available by fall 2000. Please check the SOLEC websites frequently.

4.0 Indicator Core Groups

Please note: the following sub-sections have been substantially edited for brevity. If you require further details on the process of each core group then please refer to the October 1998 draft of "Selection of Indicators for Great Lakes Basin Ecosystem Health," or contact one of the Core Group leaders.

4.1 Nearshore and Open Waters

Definition of Nearshore and Open Waters
For the purposes of SOLEC 98 the nearshore and open waters are defined as in the SOLEC 96 background paper "Nearshore Waters of the Great Lakes." The definitions may be paraphrased as follows:

The nearshore waters largely occupy a band of varying width around the perimeter of each lake between the land and deeper offshore waters of the lake. The band begins at the shoreline or the lakeward edge of the coastal wetlands and extends offshore to the deepest lake-bed depth contour at which the thermocline typically intersects with the lake bed in late summer or early fall. Also included as nearshore waters are the Great Lakes connecting channels and the reaches of tributaries that are subject to seiche activity. Offshore Waters, as the name implies, are all of the waters beyond the lakeward edge of the nearshore waters.

Scale
An attempt was made to develop individual indicators that could be used to provide basin-wide status and trend information for the aquatic resources and habitats of the Great Lakes. Whenever possible, reference values have been provided specific to each lake to reflect significant natural differences between lakes, whether those differences occurred historically or are found currently.

4.1.1 The Indicator Selection Process

The Open Waters (OW) and Nearshore Waters (NSW) Core Groups proceeded independently during the initial phases. However, many of the indicators in one group were duplicated by the other. The two groups and their lists were consolidated for reconsideration and elimination of duplicative entries.

The groups' philosophical approach was to present the minimum number of indicators needed to address the important environmental issues of concern. The indicators needed to have solid scientific underpinnings yet be presented in terms that could be easily understood by a non-technical audience.

> …present the minimum number of indicators needed to address the important environmental issues…

Currently, the Nearshore and Open Waters indicator list contains 20 indicators (of which one indicator, 8142, is also grouped with the Nearshore Terrestrial group).

4.1.2 Open and Nearshore Waters Indicators

Note: The numbers preceding the indicator name (here and in all the following Core Group sections) are a means of identifying the indicator in the database.

STATE
Fish Habitat (Indicator #6)

This indicator will assess the quality and amount of aquatic habitat in the Great Lakes ecosystem, and it will be used to infer progress in rehabilitating degraded habitat and associated aquatic communities.

Salmon and Trout (Indicator #8)

This indicator will show trends in populations of introduced trout and salmon populations, and it will be used to evaluate the potential impacts on native trout and salmon populations and the preyfish populations that support them.

Walleye and *Hexagenia* (Indicator #9)

This indicator will show the status and trends in walleye and *Hexagenia* populations, and it will be used to infer the basic structure of warm-coolwater predator and prey communities; the health of percid populations; and the health of the Great Lakes ecosystem.

Preyfish Populations (Indicator #17)

This indicator will assess the abundance and diversity of preyfish populations, and it will be used to infer the stability of predator species necessary to maintain the biological integrity of each lake.

Native Unionid Mussels (Indicator #68)

This indicator will assess the population status of native Unionid populations, and it will be used to infer the impact of the invading Dreissenid mussel on the Unionid mussel.

Lake Trout and Scud (*Diporeia hoyi*) (Indicator #93)

This indicator will show the status and trends in lake trout and scud populations, and it will be used to infer the basic structure of coldwater predator and prey communities and the general health of the ecosystem.

Deformities, Eroded Fins, Lesions and Tumors (DELT) in Nearshore Fish (Indicator #101)

This indicator will assess the combination of deformities, eroded fins, lesions and tumors (DELT index) in nearshore fish, and it will be used to infer areas of degraded habitat within the Great Lakes.

Benthos Diversity and Abundance (Indicator #104)

This indicator will assess species diversity and abundance in the aquatic oligochaete community, and it will be used to infer the relative health of the benthic community.

Phytoplankton Populations (Indicator #109)

This indicator will assess the species and size composition of phytoplankton populations in the Great Lakes, and it will be used to infer the impact of nutrient enrichment, contamination and invasive exotic predators on the Great Lakes ecosystem.

Zooplankton Populations (Indicator #116)

This indicator will assess characteristics of the zooplankton community, and it will be used to infer over time changes in vertebrate or invertebrate predation, system productivity, energy transfer within the Great Lakes, or other food web dynamics.

Sediment Available for Coastal Nourishment (Indicator #8142) - *this indicator is also a Nearshore Terrestrial indicator*

This indicator will assess the amount of water and suspended sediment entering the Great Lakes through major tributaries and connecting channels, and it will be used to estimate the amount of sediment available for transport to nourish coastal ecosystems.

PRESSURE

Sea Lamprey (Indicator #18)

This indicator will estimate sea lamprey abundance and assess their impact on other fish populations in the Great Lakes.

Phosphorus Concentrations and Loadings (Indicator #111)

This indicator will assess the total phosphorus levels and loadings in the Great Lakes, and it will be used to support the evaluation of trophic status and food web dynamics in the Great Lakes.

Contaminants in Young-of-the-Year Spottail Shiners (Indicator #114)

This indicator will assess the levels of PBT chemicals in young-of-the-year spottail shiners, and it will be used to infer local areas of elevated contaminant levels and potential harm to fish-eating wildlife.

Contaminants in Colonial Nesting Waterbirds (Indicator #115)

This indicator will assess chemical concentration levels in a representative colonial waterbird, and it will be used to infer the impact of these contaminants on colonial waterbird physiology and population characteristics.

Atmospheric Deposition of Toxic Chemicals (Indicator #117)

This indicator will estimate the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes, and it will be used to infer potential impacts of toxic chemicals from atmospheric deposition on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Toxic Chemical Concentrations in Offshore Waters (Indicator #118)

This indicator will assess the concentration of priority toxic chemicals in offshore waters, and it will be used to infer the potential impacts of toxic chemicals on the Great Lakes aquatic ecosystem, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Concentrations of Contaminants in Sediment Cores (Indicator #119)

This indicator will assess the concentrations of toxic chemicals in sediments, and it will be used to infer potential harm to aquatic ecosystems by contaminated sediments, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Contaminant Exchanges between Media: Air to Water and Water to Sediment (Indicator #120)

This indicator will estimate loadings of priority pollutants to the Great Lakes, and it will be used to infer the potential harm these contaminants pose to human, animal and aquatic life within the Great Lakes, as well as to infer the progress of various Great Lakes programs toward virtual elimination of toxics from the Great Lakes.

Wastewater Pollution (Indicator #7059)

This indicator will assess the loadings of wastewater pollutants discharged into the Great Lakes basin, and it will be used to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

4.2 Coastal Wetlands

Coastal Wetlands Definition
The extent of Great Lakes coastal wetlands fluctuates greatly with natural lake processes which can particularly affect the lake-side boundary. For SOLEC, the inland boundary is the extent of wetlands as far as the 100-year floodline of the Lakes (as described in the SOLEC 96 background paper "Coastal Wetlands of the Great Lakes").

Coastal wetlands differ from inland wetlands in that they are shaped by large-lake processes, including waves, wind tides, seiches, and especially seasonal and long-term fluctuations in water levels. They include emergent marshes, strand communities, wet meadows, submergent communities, swamps, and peatlands. They occur in a number of geomorphological settings: open shoreline, unrestricted bays, shallow sloping beaches, river deltas, restricted riverine settings, Lake-connected inlands, barrier beaches, and diked wetlands. The SOLEC 96 background paper "Coastal Wetlands of the Great Lakes" provides a detailed description of the types of coastal wetlands and the geomorphological settings in which they occur.

Indicating Health and Integrity
To select indicators of the health and integrity of coastal wetlands, the following definition of coastal wetland health was used:

- capability to self-maintain assemblages of organisms that have a composition and functional organization comparable to natural habitat;
- resiliency to natural disturbances; and
- risk factors or human-induced pressures at an "acceptable level".

Scale
For the purpose of SOLEC, the recommended indicators should be applicable basin-wide. The IJC suggests that an understanding of a system at any scale requires indicators of at least three scales: a) the level in question; b) the level above for context; and c) the level below for mechanisms. In the case of coastal wetland indicators we are considering indicators at the following scales: individual Lake basins, the Great Lakes basin, and a set of sites. Monitoring at sites will require a choice of representative sites.

Representative Wetland Sites
Representative sites have yet to be chosen for monitoring the recommended indicators. Ideally, sites should represent wetland distribution among the Lakes, and take into account influencing pressures, wetland types, and geomorphological settings. In part, the selection will be based on the representative reaches identified through the "Coastal Wetlands Biodiversity Investment Areas" paper. They should also include high quality (i.e., relatively pristine) reference sites to serve as baselines for comparison to the more degraded sites. It should be recognized, of course, that some parts of the Great Lakes basin no longer have any reference sites of this quality, and reference sites themselves will be degraded to some degree. This is particularly true of Lake Ontario, which has had regulated water levels for about 40 years.

4.2.1 The Indicator Selection Process

Potential coastal wetlands indicators were "mined" from eleven documents. Reviewing the documents and listing information for indicators related to wetland health yielded 330 potential

indicators for further consideration. These were grouped into eleven categories: Area, Habitat, Vegetation, Community/Diversity, Benthos, Fish, Contaminants, Nutrients, Human/Land Use/Terrestrial, Species, and Physical Factor in order to identify and remove duplication. Because SOLEC primarily focuses on pressures and the state of the ecosystem, and does not make recommendations on programs, the coastal wetlands group did not actively seek out human activities indicators.

Based on the SOLEC criteria (Appendix 4), the indicators were ranked by the Coastal Wetlands expert panel and those that ranked low were no longer considered. The expert panel made recommendations of the best indicators, but in some cases additional indicators were suggested.

Currently there are 12 indicators in the Coastal Wetlands indicator list (one of which, 4861, is also grouped in the Nearshore Terrestrial core group).

4.2.2 Problems / Unresolved Issues

Difficulties Encountered with the Process
For SOLEC purposes, indicators need to have specific measures that can either utilize data being provided by an existing monitoring program or provide sufficient detail that a new monitoring program can be designed. However, few of the documents contained any significant information beyond the name of the indicator, and most of the indicator names were vague (e.g., quantity and quality of wetlands).

However, indicators clearly could not have been developed without first reviewing what others had done. With the indicators grouped into broad classes, they could be easily compared, modified, or combined. Thus, the process involved an additional step, but produced a proposed suite of indicators that the coastal wetlands group feels will allow an adequate assessment of the ecological health of Great Lakes coastal wetlands.

Unresolved Issues
Protocols for monitoring several of the indicators still need to be refined. The wide natural fluctuations associated with many features of Great Lakes coastal wetlands complicate the setting of desired endpoints. Some may require modifications. The method to select representative sites for monitoring also needs refinement.

The segregation of coastal wetlands from the other groups was necessary for a manageable process. This organization, however, hindered some broader ecosystem considerations. Positioned between the lakes and upland, and affected by processes in each, healthy coastal wetlands depend on healthy lake and watershed ecosystems. As such, coastal wetlands could be considered indicators of the health of the whole basin ecosystem (and so all that would be needed); or conversely, the health of the Land Use, Nearshore Terrestrial and Open and Nearshore Waters could indicate coastal wetland health (and wetland indicators would not be needed). These links and their implications for what is necessary and sufficient have not been explored.

In general, if there is broad agreement among the Great Lakes constituency on SOLEC indicators for coastal wetlands, organizations at all levels may be responsive to sharing monitoring expertise among themselves without any one organization taking an undue burden.

There are few existing monitoring programs for Great Lakes coastal wetlands. Efforts were made in the coastal wetlands group to select indicators for which there are existing data and monitoring programs, particularly for the pressure indicators. Many of the indicators will require new or improved monitoring programs. For the new programs to attain SOLEC's feasibility criterion, it is suggested that:

- Monitoring be conducted by volunteers, where possible. Volunteers would require training and adherence to monitoring protocols and quality assurance plans; however, this is true for professionals as well.
- Monitoring frequencies for each indicator will also need to be determined. While some indicators may need to be monitored several times a year, the more intensive (and expensive) monitoring may only need to be conducted every few years.
- Different organizations may be able to incorporate new protocols into their ongoing monitoring programs, without an inordinate increase in costs.

4.2.3 Coastal Wetland Indicators

STATE

Coastal Wetland Invertebrate Community Health (Indicator #4501)

This indicator will assess the diversity of the invertebrate community, especially aquatic insects, and it will be used to infer habitat suitability and biological integrity of Great Lakes coastal wetlands.

Coastal Wetland Fish Community Health (Indicator #4502)

This indicator will assess the fish community diversity, and it will be used to infer habitat suitability for Great Lakes coastal wetland fish communities.

Deformities, Eroded Fins, Lesions and Tumors (DELT) in Coastal Wetland Fish (Indicator #4503)

This indicator will assess the combination of deformities, eroded fins, lesions and tumours (DELT index) in fish of Great Lakes coastal wetlands, and it will be used to infer ecosystem health of Great Lakes coastal wetlands.

Amphibian Diversity and Abundance (Indicator #4504)

This indicator will assess the species composition and relative abundance of frogs and toads, and it will be used to infer the condition of coastal wetland habitat as it relates to the health of this ecologically important component of wetland communities.

Wetland-Dependent Bird Diversity and Abundance (Indicator #4507)

This indicator will assess the wetland bird species composition and relative abundance, and it will be used to infer the condition of coastal wetland habitat as it relates to the health of this ecologically and culturally important component of wetland communities.

Coastal Wetland Area by Type (Indicator #4510)

This indicator will assess the periodic changes in area (particularly losses) of coastal wetland types, taking into account natural variations.

Presence, Abundance and Expansion of Invasive Plants (Indicator #4513)

This indicator will assess the decline of vegetative diversity associated with an increase in the presence, abundance, and expansion of invasive plants, and it will be used as a surrogate measure of the quality of coastal wetlands which are impacted by coastal manipulation or input of sediments.

PRESSURE

Contaminants in Snapping Turtle Eggs (Indicator #4506)

This indicator will assess the accumulation of organochlorine chemicals and mercury in snapping turtle eggs, and it may be used to infer the extent of organochlorine chemicals and mercury in food webs of Great Lakes coastal wetlands.

Sediment Flowing into Coastal Wetlands (Indicator #4516)

This indicator will assess the sediment load to coastal wetlands and its potential impact on wetland health.

Nitrate and Total Phosphorus Into Coastal Wetlands (Indicator #4860)

This indicator will assess the amount of nitrate and total phosphorus flowing into Great Lakes coastal wetlands, and it will be used to infer the human influence on nutrient levels in the wetlands.

Water Level Fluctuations (Indicator #4861) - *this is also a Nearshore Terrestrial indicator*

This indicator will assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and it will be used to infer the effect of water level regulation on emergent wetland extent.

HUMAN ACTIVITY

Gain in Restored Coastal Wetland Area by Type (Indicator #4511)

This indicator will assess the amount of restored wetland area, and it will be used to infer the success of conservation and rehabilitation efforts.

4.3 Nearshore Terrestrial

4.3.1 The Indicator Selection Process

A process similar to the Coastal Wetlands group was followed to develop a proposed set of indicators of the health of the nearshore environment.

First, potential indicators were mined from reports and documents, most of which related to the Great Lakes, but a few reports had broader applications (see Appendix 7). With the help of an expert panel the initial list of 145 indicators was winnowed down by assessing against the basic criteria (necessary, sufficient and feasible), removing duplication, and combining or creating new indicators where necessary. This reduced the list quite considerably. Then each of the potential nearshore terrestrial indicators was described more fully.

Currently, there are 14 indicators in the Nearshore Terrestrial indicator list, 2 of which are also grouped in other core groups - 8142 is also grouped with the Nearshore and Open Waters indicators, and 4861 is also grouped with the Coastal Wetlands group.

The Indicator Framework
Indicators are provided to highlight physical, biological, and chemical stressors. Within the state categories, indicators are proposed both for habitat status, and for the health and stability of ecological communities/species. Human activities (responses) consider direct actions, such as recovery plans written or habitats protected.

Issues and Next Steps
A protocol will need to be developed for each of the selected indicators which will establish such details as:

- whether monitoring should take place across the entire nearshore area or in "sentinel sites" only;
- whether indicator results should be reported as trends over time, or in comparison to historical conditions or a defined target (such as RAP habitat targets);
- the degree to which existing monitoring programs and databases can be adapted to each indicator.

4.3.2 **Nearshore Terrestrial Indicators** (within 1 kilometre of shore)

STATE
Indicators related to habitats:
Extent and Quality of Nearshore Natural Land Cover (Indicator #8136)

This indicator will assess the amount of natural land cover that falls within 1 km of the shoreline, and it will be used to infer the potential impact of artificial coastal structures, including primary and secondary home development, on the extent and quality of nearshore terrestrial ecosystems in the Great Lakes.

Indicators related to health and stability of ecological communities/species:
Area, Quality, and Protection of Special Lakeshore Communities (Indicator #8129)

This indicator will assess the changes in area and quality of the twelve special lakeshore communities, and it will be used to infer the success of management activities associated with the protection of some of the most ecologically significant habitats in the Great Lakes terrestrial nearshore.

Nearshore Land Use (Indicator #8132)

This indicator will assess the types and extent of major land uses within 1 km from shore, and it will be used to identify real or potential impacts of land use on significant natural features or processes, particularly on the twelve special lakeshore communities.

Nearshore Species Diversity and Stability (Indicator #8137)

This indicator will measure the composition and abundance of plant and wildlife species over time within the nearshore area and indirectly measure adverse effects on the nearshore terrestrial ecosystem due to stresses such as climate change and/or increasing land use intensity.

Sediment Available for Coastal Nourishment (Indicator #8142) - *this is also a Nearshore Waters Indicator*

This indicator will assess the amount of water and suspended sediment entering the Great Lakes through major tributaries and connecting channels, and it will be used to estimate the amount of sediment available for transport to nourish coastal ecosystems.

PRESSURE

Indicators related to physical stressors:

Water Level Fluctuations (Indicator #4861) - *this is also a Coastal Wetland indicator*

This indicator will assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and it will be used to infer the effect of water level regulation on emergent wetland extent.

Extent of Hardened Shoreline (Indicator #8131)

This indicator will assess the amount of shoreline habitat altered by the construction of shore protection, and it will be used to infer the potential harm to aquatic life in the nearshore as a result of conditions (i.e., shoreline erosion) created by habitat alteration.

For the purposes of applying these indicators, the nearshore terrestrial environment was defined as those lands within approximately one kilometer of the Great Lakes shoreline.

Artificial Coastal Structures (Indicator #8146)

This indicator will assess the number of artificial coastal structures on the Great Lakes, and it will be used to infer potential harm to coastal habitat by disruption of sand transport.

Indicators related to biological stressors:

Nearshore Plant and Animal Problem Species (Indicator #8134)

This indicator will assess the type and abundance of plant and wildlife problem species in landscapes bordering the Great Lakes, and it will be used to identify the potential for disruption of nearshore ecological processes and communities.

Indicators related to chemical stressors:

Contaminants Affecting Productivity of Bald Eagles (Indicator #8135)

This indicator will assess number of fledged young, number of developmental deformities, and the concentrations of organic and heavy metal contamination in Bald Eagle eggs, blood, and feathers. The data will be used to infer the potential harm to other wildlife and human health through the consumption of contaminated fish.

Contaminants Affecting the American Otter (Indicator #8147)

This indicator will assess the contaminant concentrations found in American otter populations within the Great Lakes basin, and it will be used to infer the presence and severity of contaminants in the aquatic food web of the Great Lakes.

HUMAN ACTIVITIES (RESPONSE)

Community / Species Plans (Indicator #8139)

This indicator will assess the number of plans that are needed, developed, and implemented to protect, maintain or restore high quality, natural nearshore communities

and federally listed endangered, threatened, and vulnerable species. This indicator will be used to infer the degree of human stewardship toward these communities and species.

Shoreline Management Under Integrated Management Plans (Indicator #8141)

This indicator will assess the amount of Great Lakes shoreline managed under an integrated management plan, and it will be used to infer the degree of stewardship of shoreline processes and habitat.

Protected Nearshore Areas (Indicator #8149)

This indicator will assess the kilometers/miles of shoreline in six classes of protective status. This information will be used to infer the preservation and restoration of habitat and biodiversity, the protection of adjacent nearshore waters from physical disturbance and undesirable inputs (nutrients and toxics), and the preservation of essential habitat links in the migration (lifecycle) of birds and butterflies.

4.4 Land Use

4.4.1 The Indicator Selection Process

Poor land use by humans is the predominant cause of environmental problems in the ecosystems of the Great Lakes basin. In spite of considerable evidence of the significant disadvantages of urban sprawl, this development form continues to be the most commonly applied approach to new development. Clearly, as was concluded in SOLEC 96, there is a need for better ways of influencing decision-makers in the Great Lakes basin to make environmentally informed development decisions. The land use indicators are intended to meet that need.

Several documents and reports were consulted to develop an initial list of Land Use indicators (see Appendix 7). Using the basic criteria of necessary, sufficient and feasible, the list was then shortened. An expert panel was formed to review, revise and add further detail to these indicators.

Currently, there are eight indicators grouped in the Land Use core group.

> Poor land use is a major source of environmental stress in the Great Lakes basin ecosystem.

4.4.2 Land Use Indicators

STATE

Urban Density (Indicator #7000)

This indicator will assess the human population density in the Great Lakes basin, and it will be used to infer the degree of inefficient land use and urban sprawl for communities in the Great Lakes ecosystem.

Habitat Adjacent to Coastal Wetlands (Indicator #7055)

This indicator will provide an index of the quality of adjoining upland habitat which can have a major effect on wetland biota, many of which require upland habitat for part of their life cycle.

Habitat Fragmentation (Indicator #8114)

This indicator will assess the amount and distribution of natural habitat remaining within Great Lakes ecoregions, and it will be used to infer the effect of human land uses such as housing, agriculture, flood control, and recreation on habitat needed to support fish and wildlife species.

PRESSURE

Land Conversion (Indicator #7002)

This indicator will assess the changes in land use within the Great Lakes basin, and it will be used to infer the potential impact of land conversion on Great Lakes ecosystem health.

Mass Transportation (Indicator #7012)

This indicator will assess the percentage of commuters using public transportation, and it will be used to infer the stress to the Great Lakes ecosystem caused by the use of the private motor vehicle and its resulting high resource utilization and pollution creation.

HUMAN ACTIVITIES (Response)

Brownfield Redevelopment (Indicator #7006)

This indicator will assess the acreage of redeveloped brownfields, and it will be used over time to evaluate the rate at which society rehabilitates and reuses former developed land sites that have been degraded by poor use.

Sustainable Agriculture Practices (Indicator #7028)

This indicator will assess the number of Environmental and Conservation farm plans, and it will be used to infer environmentally friendly practices in place, such as integrated pest management to reduce the unnecessary use of pesticides, zero tillage and other soil preservation practices to reduce energy consumption, and prevention of ground and surface water contamination.

Green Planning Process (Indicator #7053)

This indicator will assess the number of municipalities with environmental and resource conservation management plans in place, and it will be used to infer the extent to which municipalities utilize environmental standards to guide their management decisions with respect to land planning, resource conservation and natural area preservation.

4.5 Human Health

4.5.1 The Indicator Selection Process

There is interest in having indices or indicators for monitoring progress or changes in human health as it relates to the Great Lakes environment. These can be either changes over time or comparisons between geographic regions. The premise is that as environmental conditions change in the Great Lakes basin, so does the state of the health of the population in that region. Such indicators are also needed to assess the effectiveness of health and environment policies and actions in protecting or improving the health of the Great Lakes basin population.

With our present knowledge, it is clear that no single indicator is adequate to establish associations and trends between human health and the environment. Consequently, indicators were chosen which, as a whole, serve to monitor human health as it relates to the Great Lakes environment. The indicators chosen are by no means exhaustive but represent an initial effort at establishing health-related indicators for the Great Lakes population. As research progresses in this area, other indicators can be added to the current suite of indicators, or may replace them altogether.

…it is clear that no single indicator is adequate to establish associations and trends between human health and the environment.

For practical purposes, this effort to develop health indicators for SOLEC has focused primarily on indicators of human exposure to environmental contaminants along with some geographic patterns and trends in disease incidence. The indicators of exposure are either contaminant levels measured in human tissues, such as breast milk or blood, estimates of daily intake of persistent contaminants by the Great Lakes population, or contaminant levels in air, drinking water and recreational water. The contribution of these exposures as causative factors in disease, such as cancer and birth defects, can be difficult to identify. However, the analysis of geographic patterns and trends in incidence rates can serve to identify potential areas of concern and may lead to testable hypotheses regarding the correlation of environmental exposure with human disease.

The extensive initial list of indicators identified by the Human Health Core Group was reduced by eliminating those indicators that were thought not to be informative, either because 1) specific exposure media were unlikely to make a relatively significant contribution to overall contamination exposure levels, 2) some contaminants were unlikely to be detected in specific media, or 3) difficulties in obtaining information in a comprehensive manner. A greater weight was given to those indicators that represented data available from current monitoring programs, to those indicators that were supported by an existing database, and to those indicators that were more likely to provide information that could be used to evaluate the relationships between contaminant exposures and health. Currently, there are nine indicators in the Human Health indicators list.

Although there exist many other indicators of health such as life expectancy, birth weight and well being, these were not included in the final list because the impact of current environmental conditions on these indicators is either not well understood or not well developed. In many cases, improvements in these indicators have occurred even during times of changing environmental quality due to population growth and industrialization in the Great Lakes basin. Advances in public health, medicine, access to health care, education, and economy contributed greatly to improvements in the health of the population. However, as we gain more information on the relationships between these parameters and the environment, their inclusion as future indicators may be warranted.

4.5.2 Human Health Indicators

STATE

Geographic Patterns and Trends in Disease Incidence (Indicator #4179)

This indicator will assess geographical and temporal patterns in disease incidences in the Great Lakes basin population, and it will also b e used to identify areas where further investigation of the exposure and effects of environmental pollutants on human health is needed.

PRESSURE (Indicators of Exposure)

Contaminants in Recreational Fish (Indicator #0113)

This indicator will assess the levels of PBT chemicals in fish, and it will be used to infer the potential harm to human health through consumption of contaminated fish.

E. coli and Fecal Coliform Levels in Nearshore Recreational Waters (Indicator #4081)

This indicator will assess coliform contaminant levels in nearshore recreational waters, acting as a surrogate indicator for other pathogen types, and it will be used to infer potential harm to human health through body contact with nearshore recreational waters.

Contaminants in Edible Fish Tissue (Indicator #4083)

This indicator will assess the concentration of persistent, bioaccumulating, toxic (PBT) chemicals in Great Lakes fish, and it will be used to infer the exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing.

Chemical Contaminant Intake From Air, Water Soil and Food (Indicator #4088)

This indicator will estimate the daily intake of PBT chemicals from all sources, and it will be used to evaluate the potential harm to human health and the efficacy of policies and technology intended to reduce PBT chemicals.

Drinking Water Quality (Indicator #4175)

This indicator will assess the chemical and microbial contaminant levels in drinking water, and it will be used to evaluate the potential for human exposure to drinking water contaminants and the efficacy of policies and technologies to ensure safe drinking water.

Air Quality (Indicator #4176)

This indicator will monitor the air quality in the Great Lakes ecosystem, and it will be used to infer the potential impact of air quality on human health in the Great Lakes basin.

Chemical Contaminants in Human Tissue (Indicator #4177)

This indicator will assess the concentration of PBT chemicals in human tissues, and it will be used to infer the efficacy of policies and technology to reduce PBT chemicals in the Great Lakes ecosystem.

Radionuclides (Indicator #4178)

This indicator will assess the concentrations of artificial radionuclides in cow's milk, surface water, drinking water, and air, and it will be used to estimate the potential for human exposure to artificial radionuclides.

4.6 Societal

In the period between SOLEC 98 and Spring 1999 the decision was made to broaden the scope of the Stewardship Core Group to include socio-economic and other societal indicators. Since this group now housed the indicators of society, it was renamed "Societal" in order to reflect this change.

Stewardship and Sustainability
A "steward" is someone who manages the affairs of a household or estate on behalf of an employer, owner, or beneficiary. "Stewardship" is a process requiring competence, vigilance, and an ethic of responsibility for the condition of that which is being looked after.

Stewardship is not sustainability, but sustainability provides the conceptual structure for which the process of stewardship is pursued. That is, stewardship activities are intended to achieve a sustainable future — *a balance between environmental integrity, economic viability, and social well-being.* In this regard, stewardship is closely related to ecosystem-based management which seeks to sustain ecosystem integrity across time. Thus, *sustainability* is the expression of the overall "desirable end state" and *ecosystem management* describes the basic strategy employed in *the process of stewardship*.

For SOLEC, sustainability is implicit within the entire set of proposed indicators, and a separate set of indicators for sustainability would be redundant. A comprehensive set of indicators to assess human activities, or "program responses," however, would reflect our collective stewardship of the Great Lakes ecosystem - our individual and collective actions to halt, mitigate, adapt to, or prevent damage to the environment.

The initial process to identify indicators of stewardship for SOLEC 98 was similar to that for the other groups, but with inconclusive results. Few documents were found that contained indicators for stewardship in the Great Lakes. Although many ideas had been generated, there were very few appropriate stewardship indicators, and they were quite general.

> …stewardship activities are intended to achieve a sustainable future — a balance between environmental integrity, economic viability, and social well-being.

The approach described in Section 4.6.1 was developed just prior to SOLEC 98. Due to the late change in emphasis, *neither the approach nor the proposed indicators had received extensive review from an expert panel or other stakeholders prior to SOLEC 98.* It is anticipated that a full suite of Societal indicators will be presented at SOLEC 2000. Some of these indicators will include examples of their applications.

Socio-Economics and Other Aspects of Society
The health of the environment is closely tied to a regions' economy and societal values. In the case of the Great Lakes region, an international border separates distinct political traditions and national cultures, but despite this, an integrated economy has developed - one with a strong resource base and manufacturing complex. However, increased competition from both domestic and global economies, a maturing industrial infrastructure, continued urbanization and the

environmental impacts of economic and social activity are forcing a new development path - one that both supports the economy and preserves the environment.

Integrated management of society as part of the ecosystem requires organization of human activities consistent with the need to respect other ecosystem components. For example, the callous creation and discharge of waste materials may impact on the habitat of other species, result in contamination and other health problems.

4.6.1 The Indicator Selection Process

Stewardship Indicators
This approach assumes that the existence of partnerships, their coverage of the Great Lakes basin, their organizational capacities, and the "richness" of their memberships, will lead to improvements in the state of the environment and to reductions of environmental pressures or threats. In addition, local partnerships are framed and supported by citizen interest and involvement in stewardship initiatives, as well as governmental adoption and endorsement of ecosystem management and sustainability principles. These proposed stewardship indicators would track the development and capacities of partnerships engaged in ecosystem management activities in the Great Lakes basin, but not the underlying motivations or other reasons for actions and responses, nor the actual environmental changes brought about by these actions.

Socio-Economic and Other Society Indicators
Some of the indicators (such as economic prosperity, dollars allocated to Great Lakes programs and societal values (like aesthetics)) did not fit very well in their original core group but belonged in a group looking at indicators of society. This resulted in the expansion of the Stewardship group to a Societal group. The socio-economic section of the suite of Great Lakes indicators is in the early stages of development and further work is needed. It is hoped that in the future an indicator for social well being can be included here.

4.6.2 Societal Indicators

STATE
Aesthetics (Indicator #7042)

> This indicator will assess the amount of waste and decay around human activities in the Great Lakes basin, and it will be used to infer the degree to which human activities are conducted in an efficient and ordered fashion consistent with ecosystem harmony and integrity.

Economic Prosperity (Indicator #7043)

> This indicator will assess the unemployment rates within the Great Lakes basin, and it will be used in association with other Societal indicators to infer the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem.

PRESSURE

Water Withdrawal (Indicator #7056)

This indicator will assess the amount of water used in the Great Lakes basin per capita, and it will be used to infer the amount of wastewater generated and the demand for resources to pump and treat water.

Energy Consumption (Indicator #7057)

This indicator will assess the amount of energy consumed in the Great Lakes basin per capita, and it will be used to infer the demand for resource use, the creation of waste and pollution, and stress on the ecosystem.

Solid Waste Generation (Indicator #7060)

This indicator will assess the amount of solid waste generated per capita per capita in the Great Lakes basin, and it will be used to infer inefficiencies in human economic activity (i.e., wasted resources) and the potential adverse impacts to human and ecosystem health.

HUMAN ACTIVITIES (Response)

Capacities of Sustainable Landscape Partnerships (Indicator #3509) - *unchanged from SOLEC 98*

This indicator assesses the organizational capacities required of local coalitions to act as full partners in ecosystem management initiatives. It includes the enumeration of public-private partnerships relating to the pursuit of sustainable ecosystems through environmental management, staff, and annual budgets.

Organizational Richness of Sustainable Landscape Partnerships (Indicator #3510) - *unchanged from SOLEC 98*

This indicator assesses the diversity of membership and expertise included in partnerships. Horizontal integration is a description of the diversity of partnerships required to address local issues, and vertical integration is the description of federal and state/provincial involvement in place-based initiatives as full partners.

Integration of Ecosystem Management Principles Across Landscapes (Indicator #3511) - *unchanged from SOLEC 98*

This indicator describes the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted ecosystem management guiding principles in place-based resource management programs.

Integration of Sustainability Principles Across Landscapes (Indicator #3512) - *unchanged from SOLEC 98*

This indicator describes the extent to which federal, state/provincial, and regional governments and agencies have endorsed and adopted sustainability guiding principles in place-based resource management programs.

Citizen/Community Place-Based Stewardship Activities (Indicator #3513) - *unchanged from SOLEC 98*

Community activities that focus on local landscapes/ecosystems provide a fertile context for the growth of the stewardship ethic and the establishment of a “a sense of place.” This indicator, or suite of indicators, will reflect the number, vitality and effectiveness of citizen and community stewardship activities.

Financial Resources Allocated to Great Lakes Programs (Indicator #8140)

This indicator will measure the amount of dollars spent annually on Great Lakes programs and indirectly measure the responsiveness of Great Lakes programs by determining the adequacy of annual funding focused on research, monitoring, restoration, and protection of Great Lakes ecosystems by federal and state/provincial agencies and non-governmental organizations.

4.7 Unbounded Indicators

Several proposed indicators do not fit neatly into any of the seven SOLEC ecological categories (open waters, nearshore waters, coastal wetlands, nearshore terrestrial, land use, human health, and societal). These categories were selected to be consistent with the themes and papers of the two previous SOLECs, and they provide an organizational framework for selecting and reviewing indicators. The indicators could have been organized differently (for example, "fish, fauna, flora, water, land, air" - and, in fact, they have been sorted this way in Appendix 3, Relevancies), however, it is likely that some indicators would still transcend the group boundaries. For example, indicators related to issues such as climate change will affect all the groups yet truly belong in none of them.

Throughout the selection process these indicators were recognized and discussed. In some cases they were kept with the Core Group that originally nominated them, but in other cases they were transferred to another group that appeared to be more relevant. The Indicators Group avoided the creation of the category "miscellaneous" so that each indicator would receive the attention of at least one group, and none would become orphans.

However, for clarity of organization and presentation of the proposed indicators, the creation of an additional category called "Unbounded" was found to be useful. These indicators may have application to more than one of the organizing categories, or they may reflect issues that affect the Great Lakes but have global origins or implications.

Reviewers please note that the indicators in the Unbounded group have yet to receive an intensive review. We welcome your comments and suggested improvements for these indicators.

STATE

Breeding Bird Diversity and Abundance (Indicator #8150)

This indicator will assess the status of breeding bird populations and communities, and it will be used to infer the health of breeding bird habitat in the Great Lakes basin.

Threatened Species (Indicator #8161)

This indicator will assess the number, extent and viability of threatened species, which are key components of biodiversity in the Great Lakes basin, and it will be used to infer the integrity of ecological processes and systems (e.g., sand accretion, hydrologic regime) within Great Lakes habitats.

PRESSURE

Acid Rain (Indicator #9000)

This indicator will assess the pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin, and it will be used to infer the efficacy of policies to reduce sulphur and nitrogen acidic compounds released to the atmosphere.

Global Warming: Number of Extreme Storms (Indicator #4519)

This indicator will assess the number “extreme storms” each year, and it will be used to infer the potential impact on ecological components of the Great Lakes of increased numbers of storms due to climate change.

Global Warming: First Emergence of Water Lilies in Coastal Wetlands (Indicator #4857)

This indicator will assess the change over time in first emergence dates of water lilies as a sentinel of climate change affecting the Great Lakes.

Global Warming: Ice Duration on the Great Lakes (Indicator #4858)

This indicator will assess the temperature and accompanying physical changes to each lake over time, and it will be used to infer potential impact of climate change on wetlands.

Exotic Species (Indicator #9002)

This indicator will assess the presence, abundance and distribution of invasive exotic species in the Great Lakes basin ecosystem and their impacts on ecosystem functioning. *This indicator is under development. It has been added to the SOLEC list in response to suggestions from multiple reviewers of the Version 3 list of SOLEC indicators.*