

Great Lakes Indicator Review: Findings and Future Direction

June 2011

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Introduction

Context

The purpose of the Great Lakes Water Quality Agreement (GLWQA) is “to restore and maintain the physical, chemical and biological integrity of the water of the Great Lakes Basin Ecosystem.” The State of the Lakes Ecosystem Conferences (SOLEC) were established by the governments of Canada and the United States (the Parties to the GLWQA) in 1992 to provide coordinated, consistent and science-based reporting on the state of the Great Lakes ecosystem. Between 1994 and 2008 a conference and corresponding *State of the Great Lakes* report was released every two years, now continuing on a three cycle.

The objectives of the SOLEC and corresponding *State of the Great Lakes* reports are:

- To assess the state of the Great Lakes ecosystem based on accepted indicators
- To strengthen decision-making and environmental management concerning the Great Lakes
- To inform local decision makers of Great Lakes environmental issues
- To provide a forum for communication and networking amongst all the Great Lakes stakeholders

A suite of Great Lakes indicators has been developed to support delivery of the SOLEC and *State of the Great Lakes* reporting. An indicator is a piece of evidence or clue about broader conditions. An indicator provides information about conditions at a particular point in time, and information about trends over time. Reporting on a suite of Great Lakes indicators produces a big picture perspective on the condition and trends of the complex ecosystem.

No single organization has the resources or mandate to examine the conditions of the entire Great Lakes ecosystem. The *State of the Great Lakes 2009* report was prepared by 139 individual authors from forty-three government and non-government organizations. An additional 111 contributors were formally recognized by the authors in the report.

In 2010, the Great Lakes indicator suite was reviewed. The purpose of the review was to deliver an improved, updated and representative indicator suite that reports on the state of the Great Lakes in a comprehensive, understandable and scientific manner and allows for well-informed decision making in the Great Lakes basin. The review also aimed to build consensus on indicators among federal, state, provincial and local management organizations, which is necessary to ensure that all related data are being collected, analyzed, and reported in an effective manner.

Process

The review of Great Lakes indicators was undertaken in three steps, described below. The process was designed to facilitate input from the diverse expertise found in the Great Lakes community. Staff from over thirty government and non-governmental organizations provided input. A list of contributors and their organizations are found in Appendix One.

Step 1: Taking Stock

The history of the Great Lakes indicator suite is getting longer, the information is vast, and the products are thick.

- Each indicator underwent an analysis, comparing what the indicator description requested with what the actual indicator report delivered. It allowed for easy reference and assessment of the indicator's purpose, measures and endpoints.
Product: *Indicator Assessment Tables*
- The strength of the existing suite of indicators was analyzed based on eight different criteria, including whether or not the indicator report provided status and trend, appropriate geographic scales, and an end-point. This analysis allowed for an understanding of the strengths and weaknesses of the 2009 State of the Lakes reporting information.
Product: *Great Lakes Indicator Suite: Strengths and Weaknesses Report 2009.*

Step 2: Review

The review was open to the Great Lakes community, and participation was promoted in various ways, including meetings, teleconferences and web-based information and submissions. Specific questions were asked of different groups in order to optimize the time people spent reviewing the indicators.

- An independent panel was convened to review the Great Lakes indicators. The panel provided recommendations on indicator gaps and redundancies, framework options and other suggestions to improve the suite and reporting.
Product: *Review Report of the SOLEC Independent Expert Panel.*
- Three other distinct groups were specifically engaged to review different aspects of the indicator suite: 1) indicator authors; 2) workgroups of the Lakewide Management Plans/ binational lake action plan; and 3) other targeted members of the Great Lakes community. All responses were recorded and incorporated into extensive indicator worksheets used in Step 3 below.

Step 3: Future Direction

- A Great Lakes indicator review team, consisting of the SOLEC organizers and volunteers from the SOLEC Steering Committee met regularly starting in July 2010 to assess all of the review input and to set the future direction of the SOLEC and *State of the Great Lakes* reporting. The indicators were reviewed using best professional judgment including factors such as:
 - Contribution to the framework
 - Redundancies and gaps
 - Service to GLWQA decision-makers
 - Applicable spatial scales
 - Relevancy, usability, achievability, and reliability

- The review findings were organized into six categories:
 - Purpose of *State of the Great Lakes* reporting
 - Indicator Framework and Categories
 - The Indicators
 - Indicator Descriptions and Reporting
 - Monitoring, Data Analysis and Sponsorship
 - SOLEC 2011 and Beyond

Future Direction

Section 1: Purpose of State of the Great Lakes Reporting

Clarity of purpose and geographic scope of SOLEC and *State of the Great Lakes* reporting sets bounds and expectations on what will (and will not) be delivered. See Appendix Two for more information about geographic scope.

- 1a) The SOLEC and *State of the Great Lakes* reporting will continue to provide environmental indicators and data in a meaningful way for the decision-makers working to improve and protect the health of the Great Lakes ecosystem in support of the Great Lakes Water Quality Agreement.
- 1b) The SOLEC and *State of the Great Lakes* reporting will continue to answer the following questions:
 - How are the Great Lakes doing (status and trends)?
 - How are humans impacting the Great Lakes?
- 1c) The SOLEC and *State of the Great Lakes* reporting will continue to contribute to, but not aim to answer the following questions:
 - Are the Parties to the GLWQA achieving their program commitments?
 - What achievements can be attributed to agency investments?
 - Are the Great Lakes basin resources being used sustainably?
- 1d) Conditions of the Great Lakes themselves will continue to be the focus of reporting. Watershed related indicators (e.g. land use) will continue to be included to explain how human activities are related to the conditions in the Great Lakes. Reports will continue to be on a basinwide and individual lake basin scale. A recent endeavour to report, wherever applicable, on the scale of lake's open waters and the lake's nearshore waters will be enhanced.

Great Lakes Basinwide → Individual Lake Basin → Open Waters & Nearshore Waters

Section 2: Indicator Framework and Categories

Using a framework to select, evaluate and report on indicators minimizes redundancies, highlights information gaps, and ultimately supports delivery of the purpose of SOLEC and *State of the Great Lakes* reporting. Changes to the framework are outlined below. The rationale for changes to the framework is provided in Appendix Three.

2a) SOLEC organizers will adopt the *Driving Force – Pressure – State – Impact – Response* (DPSIR) framework for Great Lakes indicators. This replaces the existing issue-category framework.

2b) SOLEC organizers will adopt the ten following top-level reporting categories.

Driving Force	Pressure		
Economic & Social	Pollution & Nutrients	Invasive Species	Resource Use & Physical Stressors

State			Impact		Response
Water Quality (chemical integrity)	Aquatic-dependent life (biological integrity)	Landscapes & Natural Processes (physical integrity)	Human	Fish & Wildlife	Restoration & Protection

These replace the existing nine issue-categories or bundles: Coastal Zones, Aquatic Habitats, Invasive Species, Contamination, Human Health, Biotic Communities, Resource Utilization, Land Use-Land Cover, and Climate Change.

2c) SOLEC organizers will place work priority on pressure, state and impact indicators when constrained by resources.

Section 3: The Indicators

The decisions summary for keeping, shelving, or adopting new indicators is found in Appendix Four. Detailed changes will first be recorded in the indicator descriptions prepared for the authors of SOLEC 2011 reports. A comprehensive paper discussing the changes to the Great Lakes indicator suite will be prepared.

3a) The Great Lakes indicator suite has been modified.

- 47 (of 87) indicators from the 2008 suite have been kept, although in most cases adjustments will still be made.
- 30 new indicators have been adopted
- In some cases, data from the 40 indicators being shelved (see 3b) may be incorporated into other active indicators.

The tables below (and Appendix Five) present the indicators within the new DPSIR framework.

Legend:
 The ' ■ ' symbol marks a new indicator
 The number in brackets (e.g. 7043) represents an existing indicator reference

DRIVING FORCE
<p style="text-align: center;">Social & Economic</p> <ul style="list-style-type: none"> ■ Human population - Economic prosperity (7043) - Energy consumption (7057) ■ Value of Great Lakes ■ Greenhouse gas emissions

PRESSURE		
<p style="text-align: center;">Pollution & Nutrients</p> <ul style="list-style-type: none"> - Contamination in sediment (119) - Atmospheric deposition (117) ■ Inland water quality index <ul style="list-style-type: none"> ■ Nutrients in tributaries ■ Pesticides in tributaries ■ Bacterial loadings from tributaries ■ Municipal wastewater loadings ■ Industrial loadings 	<p style="text-align: center;">Invasive Species</p> <ul style="list-style-type: none"> - Aquatic non-native species, including a watch-list of high risk species (9002) - Terrestrial non-native Species (9002) - Sea lamprey (18) ■ <i>Dreissenid</i> mussels 	<p style="text-align: center;">Resource Use & Physical Stressors</p> <ul style="list-style-type: none"> ■ Watershed stressor index - Forest disturbance (8501) - Artificial coastal structures (8146) - Hardened shorelines (8131) ■ Surface water temperature <ul style="list-style-type: none"> ■ Air temperature ■ Extreme precipitation events

STATE		
<p>Water Quality (chemical integrity)</p> <ul style="list-style-type: none"> - Toxic chemicals in offshore waters (118) - Contaminants in whole fish (121) - Contaminants in waterbirds (115) <ul style="list-style-type: none"> - Groundwater quality (7100) <ul style="list-style-type: none"> - Nutrients in lakes (111) <ul style="list-style-type: none"> ▣ Water clarity ▣ Major Ions ▣ Water chemistry 	<p>Aquatic-Dependent Life (biological integrity)</p> <ul style="list-style-type: none"> - Wetland fish (4502) - Wetland plants (4862) - Wetland birds (4507) - Wetland invertebrates (4501) <ul style="list-style-type: none"> - Wetland amphibians (4504) <ul style="list-style-type: none"> - Walleye (9) - Lake Trout (93) - Preyfish (17) - Benthos (104) - <i>Diporeia</i> (123) - Zooplankton biomass (116) <ul style="list-style-type: none"> ▣ Zooplankton health - Phytoplankton (109) <ul style="list-style-type: none"> - Threatened species (8161) - Bald eagle (8135) - Sturgeon (125) <ul style="list-style-type: none"> ▣ Piping Plover 	<p>Landscapes & Natural Processes (physical integrity)</p> <ul style="list-style-type: none"> - Land cover (7002) <ul style="list-style-type: none"> ▣ Aquatic habitat connectivity - Fish habitat (6) - Base flow due to groundwater (7102) - Water levels (4861) - Ice duration (4858) - Forest diversity (8500) <ul style="list-style-type: none"> - Sediment coastal nourishment (8142) <ul style="list-style-type: none"> ▣ Tributary flashiness - Wetland landscape extent and composition (4510)

IMPACT		RESPONSE
<p>Human</p> <ul style="list-style-type: none"> - Drinking water (4175) - Beach advisories (4200) - Fish consumption restrictions (4201) <ul style="list-style-type: none"> ▣ Harmful algae blooms <ul style="list-style-type: none"> ▣ <i>Cladophora</i> 	<p>Fish & Wildlife</p> <ul style="list-style-type: none"> ▣ Botulism outbreaks ▣ Fish disease occurrences ▣ Endocrine disruption 	<p>Restoration & Protection</p> <ul style="list-style-type: none"> - Withdrawing water sustainably (7056) <ul style="list-style-type: none"> ▣ Stocking native fish - Treating wastewater (7065) <ul style="list-style-type: none"> ▣ Protecting and restoring of habitats and species - Protecting special lakeshore areas (8149) - Conserving forest land (8503) <ul style="list-style-type: none"> - Enhancing wildlife and conserving soil and water on agricultural lands (7028) - Implementing industrial efficiency measures (3514) ▣ Remediating contaminated sediment ▣ Educating Great Lakes basin residents

3b) The SOLEC and *State of the Great Lakes* reporting will no longer pursue or report on 40 of 87 Great Lakes indicators found in the 2008 suite. These indicators will be “shelved” in a database for future reference. Note that in some cases some of the data from these indicators are being incorporated into new indicators; please see Appendix Four for details.

- Salmon and Trout
- Native Freshwater Mussels
- Contaminants in Young-of-the-Year Spottail Shiners
- *Hexagenia*
- External Anomaly Prevalence Index for Nearshore Fish
- Biological Markers of Human Exposure to Persistent Chemicals
- Contaminants in Snapping Turtle Eggs
- Urban Density
- Brownfields Redevelopment
- Ground Surface Hardening
- Solid Waste Disposal
- Nutrient Management Plans
- Integrated Pest Management
- Vehicle Use
- Groundwater and Land: Use and Intensity
- Ground Dependant Plant and Animal Communities
- Islands - Area, Quality and Protection of Special Lakeshore Communities
- Air Quality
- Maintenance of Forest Ecosystem Health
- Alvars - Area, Quality and Protection of Special Lakeshore Communities
- Cobble Beaches - Area, Quality and Protection of Special Lakeshore Communities
- Sand Dunes - Area, Quality and Protection of Special Lakeshore Communities
- Population Monitoring and Contaminants Affecting the American Otter
- Biodiversity Conservation Sites
- Acid Rain
- Household Stormwater Recycling
- Geographic Patterns in Diseases
- Coastal Wetlands Restored Area by Type
- Sediment Flowing into Coastal Wetlands
- Human Impact Measures
- Habitat Fragmentation
- Nearshore Land Use
- Extent and Quality of Nearshore Landcover
- Nearshore Species Diversity and Stability
- Breeding Bird Diversity and Abundance
- Health of Terrestrial Plant Communities
- Status and Protection of Special Places
- Climate Change Crop Heat Units
- Phosphorus and Nitrogen Levels
- Land-use Adjacent to Coastal Wetlands

3c) Final indicator names will be confirmed with the finalization of the indicator descriptions in 2011. Existing indicator names will remain the same wherever possible. Indicator names will be a simple reflection of what the indicator is measuring.

Section 4: Indicator Descriptions and Reporting

An indicator achieves its purpose through appropriate collection, interpretation and display of the data. The future direction on a number of issues related to indicator descriptions and reporting are provided below.

4a) Endpoints and Reference Values

- SOLEC organizers will collaborate with authors to establish endpoints or reference values for most pressure, state and impact indicators.

4b) Metrics

- The metric used in each indicator report will preferably be a simple and representative measure of the issue (e.g. number of sites).
- The metric can also be an established peer-accepted index (e.g. Index of Biotic Integrity).
- In some cases, some indicator reports can continue to provide multiple comparable and related data sets (e.g. concentration of mercury, PCBs, and PBDEs in fish).

4c) Status and Trend Definitions

- Pressure, state and impact indicators, will report on both status and trend.
- Driving force and response indicators will report on trend only.
- New definitions will be adopted (see tables below).

Table 1: New “Status” Definitions, for Pressure, State and Impact Indicators

STATUS Term	New Definitions: Pressure, State and Impact Indicators	Previous (2009) Definitions (for reference)
GOOD	The metrics show that the ecosystem component is meeting the ecosystem objectives (or endpoints) or is otherwise in an acceptable condition.	The ecosystem component is presently meeting ecosystem objectives or otherwise is in acceptable condition.
FAIR	The metrics show that the ecosystem component is not meeting some ecosystem objectives (or endpoints), but is exhibiting minimally acceptable conditions.	The ecosystem component is currently exhibiting minimally acceptable conditions, but it is not meeting established ecosystem objectives, criteria, or other characteristics of fully acceptable conditions.
POOR	The metrics show that the ecosystem component is not displaying minimally acceptable conditions and is severely impacted.	The ecosystem component is severely negatively impacted and it does not display even minimally acceptable conditions.
UNDETERMINED	Data are not available or are insufficient to assess the status for	<i>(The Same)</i> Data are not available or are insufficient to assess the

MIXED	the ecosystem component. - <i>Mixed will no longer be a status designation</i>	status of the ecosystem component. The ecosystem component displays both good and degraded features.
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Table 2: New “Trend” Definitions, for Pressure, State and Impact Indicators

TREND	New Definitions: Pressure, State and Impact Indicators	Previous (2009) Definitions (for reference)
IMPROVING	The metrics show a change toward more acceptable conditions.	Information provided shows the ecosystem component to be changing toward more acceptable conditions.
UNCHANGING	The metrics show no change.	Information provided shows the ecosystem component to be getting neither better nor worse.
DETERIORATING	The metrics show a change away from acceptable conditions.	Information provided shows the ecosystem component to be departing from acceptable conditions.
UNDETERMINED	Data are not available to report on a trend.	Data are not available to assess the ecosystem component over time, so no trend can be identified.

Table 3: Trend Definitions: Driving Force and Response Indicators

TREND Term	Definition for Driving Force and Response Indicators
Increasing	Indicator metric is increasing
Decreasing	Indicator metric is decreasing
No Change	Indicator metric has not changed over time
Undetermined	Data are not available to report on a trend

4d) Trend Timeline

- Trend reporting will now include both a long-term trend (i.e. since the start of the data set) AND a short-term trend (i.e. since the indicator was last reported) where possible. This replaces the existing approach of reporting a trend since the previous SOLEC (i.e. two years), which was not always adhered to.

4e) Trend line Reliability

- In the indicator report writing guidelines, authors will be newly advised to use the most appropriate trend line(s) to illustrate the data set, such as linear and/or logarithmic.
- The *State of the Great Lakes* report’s section “Assessing Data Quality” will be revised to also include information on trend line reliability.

4f) Traditional Ecological Knowledge (TEK)

- TEK information will be continually pursued as a part of each applicable Great Lakes indicator.

4g) Indicator Report Description Headings

- Indicator report descriptions will be revised to reflect the new indicator framework. See table below.

Table 4: Indicator Report Descriptions

Previous Indicator Report Description Headings (for reference)	New Headings for Pressure, State and Impact Indicators	New Headings for Driving Force, and Response Indicators
Overall assessment ➤ Status ➤ Trend ➤ Rationale	Overall assessment ➤ Status ➤ Trend ➤ Rationale	Overall assessment ➤ Trend
Lake-by-Lake assessment ➤ Status ➤ Trend ➤ Rationale	Lake-by-Lake assessment, where applicable ➤ Status ➤ Trend ➤ Rationale	Lake-by-Lake assessment, where applicable ➤ Status ➤ Trend ➤ Rationale
	Open Lake, Nearshore and other spatial scale assessment, where applicable ➤ Status ➤ Trend ➤ Rationale	Open Lake, Nearshore and other spatial scale assessment, where applicable ➤ Status ➤ Trend ➤ Rationale
Purpose	Purpose	Purpose
Ecosystem Objective	Ecosystem Objective	Ecosystem Objective
State of the Ecosystem	Ecological Condition	Ecological Condition
	Traditional Ecological Knowledge	Traditional Ecological Knowledge
Pressures	Linkages	Linkages
Management Implications	Management Implications	Management Implications
Comments from author(s)	Comments from author(s)	Comments from author(s)
Assessing Data Quality	Assessing Data Quality	Assessing Data Quality
Acknowledgements	Acknowledgements	Acknowledgements
Sources	Sources	Sources
Last Updated	Last Updated	Last Updated

4h) Indicator Numbering

- Indicators will be assigned a letter corresponding to the DPSIR framework and a number (e.g. D1).
- Existing indicator numbers, where applicable, will be added in brackets (e.g. D1 [7043])

Section 5: Monitoring, Data Analysis and Sponsorship

The SOLEC organizers face data collection, analysis and sponsorship challenges. The SOLEC organizers will play the following role in overcoming these challenges.

5a) SOLEC Monitoring Priorities

- The SOLEC organizers will continually develop, in consultation with the LaMPs, a list of ongoing monitoring priorities that aim to fill data gaps in Great Lakes indicator reports.

5b) SOLEC Data Analysis Priorities

- The SOLEC organizers will develop, in cooperation with the LaMPs, a list of data analysis priorities that aim to fill data gaps in Great Lakes indicator reports.

5c) Indicator Report Sponsorship

- The SOLEC organizers will seek applicable agency or organizational commitment to sponsor (co-author) indicator reports.
- Following the completion of each Great Lakes indicator reporting cycle, the SOLEC organizers will report to Binational Executive Committee on Great Lakes indicator report sponsorship successes and challenges.

Section 6: SOLEC 2011 and Beyond

The SOLEC and the *State of the Great Lakes* reporting will continue to respond to evolving management needs, technologies and information. The future direction set out in this report will guide preparations for SOLEC 2011 and 2012 *State of the Great Lakes* reporting. The SOLEC organizers do not anticipate that all indicators can be fully reported at SOLEC 2011. Future indicator development will include:

- 6a) Following the adoption of a new GLWQA, systematically integrate GLWQA's purpose, ecosystem objectives, environmental targets, endpoints, and environmental issues into the suite of Great Lakes indicators.
- 6b) Use the DPSIR framework in 2011, while educating the SOLEC audience on its utility.
- 6c) Continue to refine the suite of indicators within the DPSIR framework and in context of the GLWQA post SOLEC 2011, including
 - Evolve top level categories (e.g. water quality), into top level indices.
 - Strengthen relationships within the DPSIR framework. In other words, pressure indicators are related to state indicators, related to impact indicators, related to response indicators.
 - Continue to simplify indicator report metrics and remove indicator redundancies as they become apparent.
- 6d) Vital to the future relevancy and utility of *State of the Great Lakes* reporting, SOLEC organizers will continue to promote and pursue opportunities for a user-friendly, web-based reporting and mapping system to replace static hard-copy *State of the Great Lakes* technical reporting.

Appendix One - Great Lakes Indicator Review Participants

SOLEC organizers

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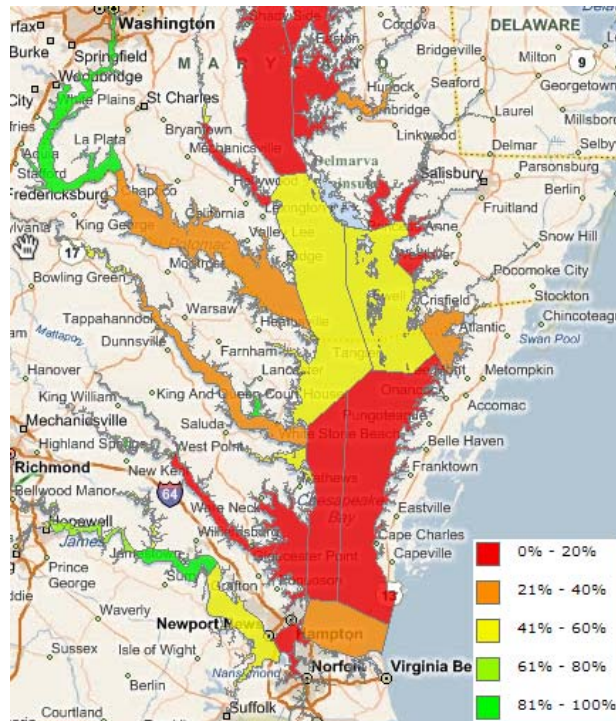
Janette Anderson, Environment Canada
Greg Mayne, Environment Canada

Appendix Two - Geographic Scope & Web-Based Reporting

The State of the Lakes Ecosystem Conference (SOLEC) reporting is limited by the absence of a web-based reporting system. A web-based reporting system would replace the existing “technical report” and allow for Great Lakes indicator data to be more accessible and easily displayed at additional scales for various audiences. There has been a long-recognized need for utilization of a web-based reporting system for SOLEC’s Great Lakes indicators. Opportunities and options for web-based reporting are currently being explored, including the possible utilization of the Great Lakes Observing System.

Below is an example of a web-based display of the threshold concentrations of chlorophyll a that are acceptable to underwater bay grasses, used by the Chesapeake Bay Program.

Figure 1: Example of Web-based Indicator Data Display



Appendix Three - Framework Considerations

Table 1: Other Framework Considerations

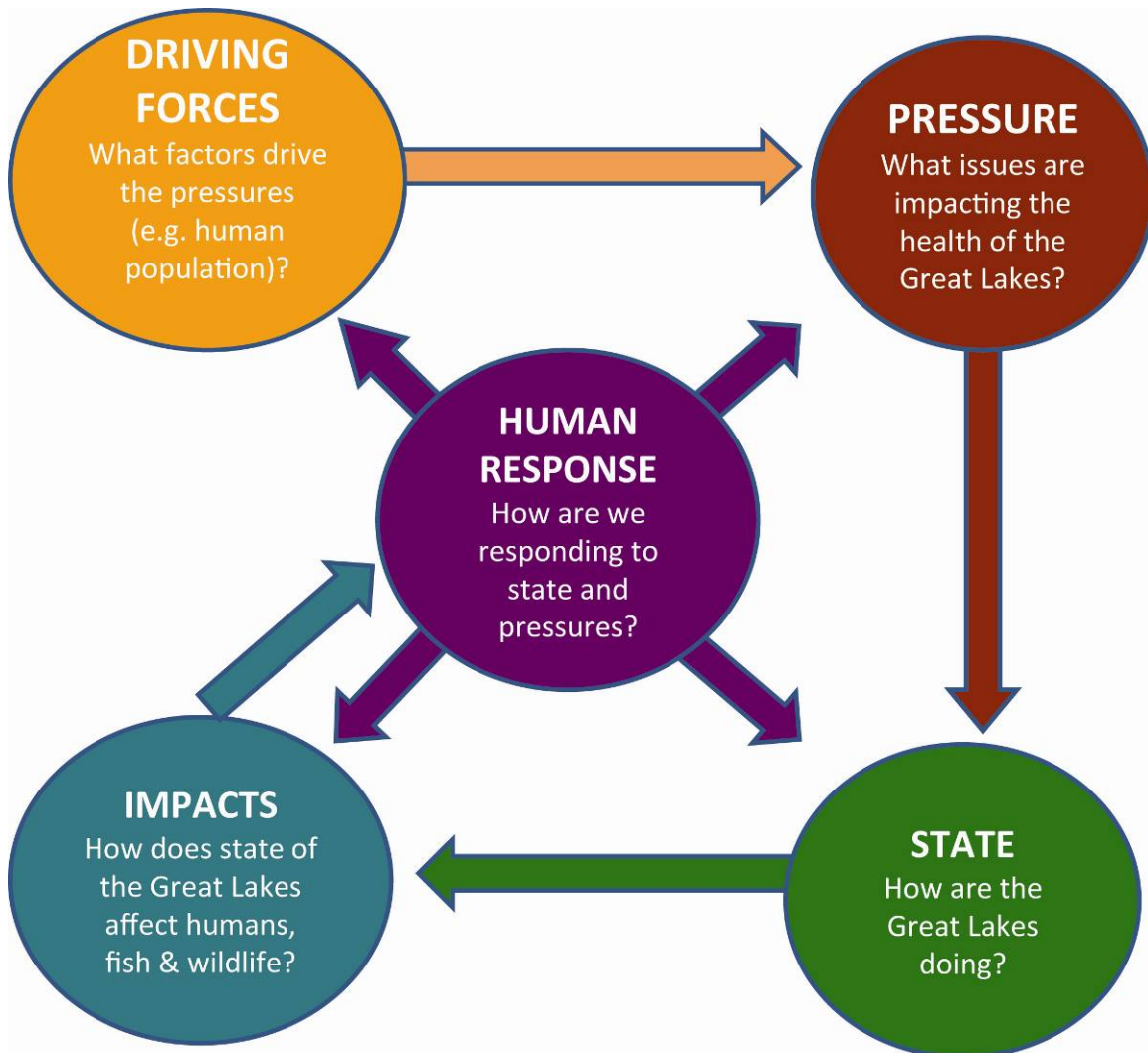
Name	Description	Rationale for Omission
<p>SOLEC 2008</p>	<p>The previous SOLEC framework was a bundling of relevant indicators into selected Great Lakes categories. The nine categories selected were Great Lakes management priority locations (e.g. coastal zone), issues (e.g. invasive species), and special focus areas (e.g. human health). The status and trend of each category was provided.</p>	<p>These categories do not truly represent the “state-of” the ecosystem. Rather, state-of information is imbedded within the categories. For example, the existing contamination category contains pollution loading indicators, human action indicators, and state-of water quality indicators.</p> <p>Under this framework, it is difficult to see causal relationships between the categories as well as how human activities are connected. Many of the same indicators are used to support multiple categories, creating repetition and confusion as to what a given indicator is supposed to represent.</p>
<p>Pressure-State-Response (PSR)</p>	<p>The PSR framework is a sub-set of the DPSIR framework. The Pressure-State-Response framework is based on the premise that human activities exert pressures (e.g. pollution emissions or land use changes) on the environment, which can induce changes in the state of the environment (e.g. water pollution levels). Society then responds to changes in pressures or state with environmental and economic actions intended to prevent, reduce or mitigate.</p>	<p>The PSR framework does not easily accommodate the delivery of some basic contextual information (e.g. human population), or why people should care (e.g., impacts). These are two important areas for decision making best served by the DPSIR framework.</p>
<p>SOLEC 2008 & PSR Framework</p>	<p>More strictly applying the PSR to the existing eight categories (SOLEC 2008) could assist in understanding relationships between human activity and state of the environment.</p>	<p>In this approach the SOLEC 2008 categories would be the primary context that the PRS Framework is applied - further away from using the GLWQA as the framework’s context. In the category “Human Health”, applying the PSR model could mean, for example, a need for indicators to represent the state of human health, pressures on human health, and responses to the state and/or pressures on human health.</p> <p>Also, the ecosystem would be defined as these categories with relationships occurring between indicators within a category, rather than across the entire suite of indicators.. The challenge of understanding cross category relationships as well as determining where each indicator best fits within the categories would remain.</p>

U.S.EPA Framework For Assessing and Reporting on Ecological Condition	<p>Systematic approach and framework for selecting state of environment indicators covering both ecosystem patterns and processes.</p>	<p>This framework is limited to “State of” information, whereas Great Lakes decision-makers are also interested in pressures (why).</p> <p>Strong emphasis on monitoring “processes”, such as how energy flows, or nutrients cycle, etc, This option is attractive academically but it is generally much more expensive to obtain and maintain – compared to monitoring “patterns” such as phosphorus concentrations.</p>
Goal-Indicator Matrix	<p>Links applicable indicators to established goals.</p>	<p>More applicable for reporting out on program goals.</p> <p>Carefulness is required to ensure the indicator(s) selected truly represent the goal’s intent.</p>
Various Sustainability Reporting Frameworks	<p>A number of sustainability-focused frameworks could be used to answer questions about what resources we have, the resource rate of use/renewal, and what will be left for the future.</p> <p>Frameworks include the Environmental Performance Index (a.k.a Environmental Sustainability Index) and Ecological Footprint.</p>	<p>Doesn’t serve the core purpose of SOLEC well because these framework focus on the amount of resources; compared to a broad understanding of environmental quality.</p> <p>SOLEC recognizes the importance of reporting out on sustainability. SOLEC has presented in this manner in the past (i.e. SOLEC 2004) as a complimentary piece of work to the core reporting.</p>

DPSIR Framework and Indicator Categories

DPSIR is a framework based on the premise that **Driving forces** (e.g. human population), produce **Pressures** (e.g. pollution), which then degrades the **State** of environment (e.g. water quality), which then **Impacts** humans (e.g. beach closures), causing society to **Respond** (e.g. wastewater treatment).

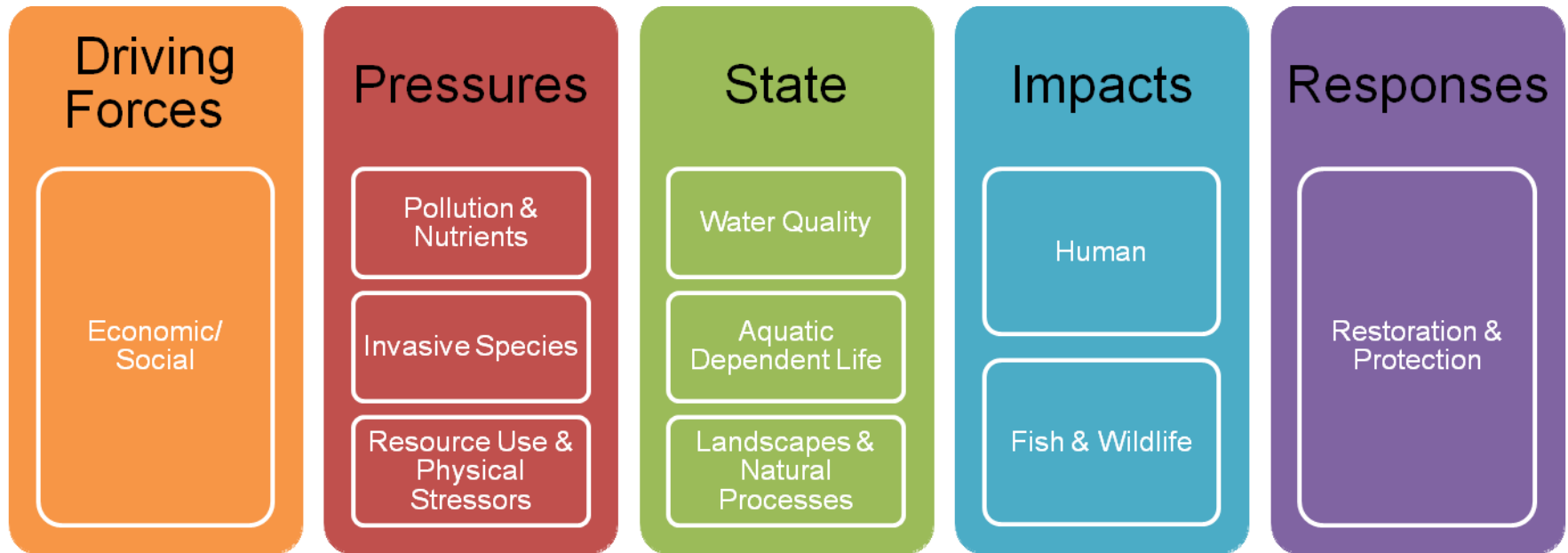
Figure 1: DPSIR framework concept



DPSIR framework allows decision-makers to understand the symptoms of stress as well as how human activities are related. It does not aim to make one-to-one linkages but does support relationships during reporting or issue analysis. The underlying DPSIR premise supports many successful environmental reporting initiatives, including the Chesapeake Bay Program and Ontario's 2010 State of Biodiversity report.

A weakness can be that without a strong context in which the framework is applied, it is difficult to determine if indicators are pressure or state indicators. This is not a weakness for SOLEC, because SOLEC operates under a strong context, the GLWQA

Figure 1: DPSIR Framework



Appendix Four - Indicator Decisions Summary

The 87 indicators (present in SOLEC 2008) were the product of an evolving eighteen year development period within the Great Lakes community. The present review was the latest opportunity to continue to improve, update and validate the indicator suite.

To undertake the current review, worksheets were prepared for each indicator that included all the prior review input received. New indicator suggestions were also gathered for consideration.

The indicators were reviewed using best professional judgment including factors such as:

- Contribution to the framework
- Redundancies and gaps
- Service to GLWQA decision-makers
- Applicable spatial scales
- Relevancy, usability, achievability, and reliability

Table 1: Indicator Decisions Summary

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
0006 Fish Habitat	This indicator will assess the quality, quantity and location of aquatic habitat in the Great Lakes ecosystem, including the percent of habitat that has been disturbed or destroyed, and will be used to infer progress in rehabilitating degraded habitat and associated aquatic communities.	X		X		Will have a baseline habitat data within a year or so, with EPA funding support. Suspend this indicator until the baseline data is available.
0009 Walleye	To show status and trends in walleye populations in various Great Lakes habitats. To infer changes in walleye health. To infer ecosystem health, particularly in moderately productive (mesotrophic) areas of the Great Lakes.	X				

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
0017 Preyfish Populations	To assess the abundance and diversity of preyfish populations. To infer the stability of predator species necessary to maintain the biological integrity of each lake.	X			X	Preyfish diversity abundance metric and a second stability metric may be useful within this indicator report.
0018 Sea Lamprey	To estimate adult sea lamprey abundance as an indicator of the status of invasive species. To infer the damage caused by sea lamprey to the aquatic ecosystems of the Great Lakes.	X				
0093 Lake Trout	To track the status and trends in lake trout populations. To infer the basic structure of the cold water predator community and the general health of the ecosystem.	X				
0104 Benthos Diversity and Abundance	Assess species diversity and abundance of aquatic oligochaete communities in order to determine the trophic status and relative health of benthic communities in the GLs.	X		X	X	Stream and nearshore data has been collected (for up to 20 years in some areas) but is not available due to lack of data analysis. Pursue sponsorship.
0109 Phytoplankton Populations	This indicator will assess the species and size composition of phytoplankton populations in the Great Lakes. It will be used to infer the impact of nutrient enrichment, contamination and invasive non-native predators on the microbial food-web of the Great Lakes ecosystem.	X			X	Revisit metrics and then decide on what should/should not be reported in this indicator. Explore a proxy for phytoplankton, such as Chlorophyll a, diatoms, or fluorometry.
0111 Phosphorus Conc. & Loadings	To assess total phosphorus levels in the Great Lakes. To support the evaluation of trophic status and food web dynamics in the Great Lakes.	X			X	Pursue separate loadings (pressure) and concentrations (state) indicator - report currently is mostly concentrations (nutrients in lakes), not loads. May need a separate group to deal with this nutrient issue. Explore N:P ratio.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
0115 Cont. in Col. Nesting Waterbirds	To assess the current chemical concentrations and trends in representative colonial waterbirds (gulls, terns, cormorants and/or herons) on the Great Lakes. To assess ecological and physiological endpoints in representative colonial waterbirds on the Great Lakes. To infer and measure the impact of contaminants on the health, i.e. the physiology and breeding characteristics of the waterbird population.	X			X	Revise to simplify indicator purpose for use as a measure of water quality. Explore in future the utility of additional program data for complementary separate indicator(s), such as wildlife impacts indicator and a biological integrity indicator.
0116 Zooplankton Populations	To directly measure changes in community composition, mean individual size and biomass of zooplankton populations in the Great Lakes basin To indirectly measure zooplankton production	X			X	Investigate how to adjust indicator to include nearshore data. Currently works as fish-food type indicator. Use zooplankton data also as an indicator of Great Lakes system's productivity.
0117 Atmospheric Deposition of Toxics	To estimate the annual average loadings of PBT chemicals from the atmosphere to the Great Lakes To determine trends over time in contaminant concentrations To infer potential impacts of toxic chemicals from atmospheric deposition on human health and the Great Lakes aquatic ecosystem To track the progress of various Great Lakes programs toward virtual elimination of toxic chemicals to the Great Lakes	X			X	Summary/highlights report from IADN. Keep but explore a way to simplify or change how we report. Explore natural levels, reference values, etc.
0118 Toxic Chemicals in Offshore Waters	To assess the concentration of priority toxic chemicals in offshore waters To infer the potential for impacts on the health of the Great Lakes aquatic ecosystem by comparison to criteria for the protection of aquatic life and human health To infer progress toward virtual elimination of toxic substances from the Great Lakes basin	X			X	A lot of chemicals included – useful with an online web site concept. For now, publish a list of the contaminants that are being monitored by this program – keep in technical report – don't have to include all of the information in the highlights report.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
0119 Cont. in Sediment Cores	To infer potential harm to aquatic ecosystems from contaminated sediments by comparing contaminant concentrations to available sediment quality guidelines To infer progress towards virtual elimination of toxic substances in the Great Lakes by assessing surficial sediment contamination and contaminant concentration profiles in sediment cores from open lake and, where appropriate, Areas of Concern index stations To determine the occurrence, distribution, and fate of new chemicals in Great Lakes sediments	X			X	Look at metric of sediment sites versus contaminants in cores (historic cores). Explore better spatial trends.
0121 Cont. in Whole Fish	To describe temporal and spatial trends of bio-available contaminants in representative open water fish species from throughout the Great Lakes To infer the effectiveness of remedial actions related to the management of critical pollutants To identify the nature and severity of emerging problems	X			X	Use to represent state of waterh quality. Linkages to fish consumption indicator (impact indicator) and fish health indicators.
0123 Benthic Amphipod (Diporeia)	To provide a measure of the biological integrity of the offshore regions of the Great Lakes by assessing the abundance of the benthic macro invertebrate Diporeia.	X				
0125 Status of Lake Sturgeon	To assess the presence and abundance of lake sturgeon in the Great Lakes and their connecting waterways and tributaries To infer the health and status of the nearshore benthivore fish community that does, could or should include lake sturgeon	X				
3514 Com. Industrial Ecoefficiency	Assess the institutionalized response of the commercial/industrial sector to pressures imposed on the ecosystem as a result of production processes and service delivery.	X			X	Change indicator name to industrial efficiencies with parameters yet to be determined. Use as response indicator.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
4175 Drinking Water Quality	To evaluate the chemical and microbial contaminant levels in source water and in treated water To assess the potential for human exposure to drinking water contaminants and the effectiveness of policies and technologies to ensure safe drinking water	X				
4200 Beach Advisories Postings Clos.	To assess the number of health-related swimming posting (advisories or closings) days for recreational areas (beaches) on the Great Lakes.	X				
4201 Cont. in Sport Fish	To assess potential human exposure to persistent bioaccumulative toxic (PBT) contaminants through consumption of popular sport fish species To assess the levels of PBT contaminants in Great Lakes sport fish To identify trends over time of PBT contaminants in Great Lakes sport fish or in fish consumption advisories	X			X	Develop some options on how to make this component even more effective for SOLEC as an impact (human) indicator. States now give fish consumption advisories, not EPA.
4501 CW Invertebrate Community Health	Directly measure specific components of invertebrate community composition. Infer the chemical, physical and biological integrity and range of degradation of GLs coastal wetlands.	X				
4502 CW Fish Community Health	Assess the fish community composition, and to infer suitability of habitat and water quality for the GLs coastal wetland fish communities.	X				
4504 CW Amphibian Div. And Abund.	Directly measure species composition and relative occurrence of frogs and toads. Infer condition of coastal wetland habitat as it relates to factors that influence the biological condition of this ecologically and culturally important component of wetland biotic communities.	X				
4507 CW Bird Communities	Assess wetland bird species composition and relative abundance. Infer condition of coastal wetland habitat as it relates to	X				

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
	factors that influence the biological condition of this ecologically and culturally important component of wetland biotic communities.					
4510 CW Area Extent by Type	Assess the periodic changes in area (particularly losses) of coastal wetland types, taking into account natural lake level variations.	X			X	Explore incorporation of Land-Use Adjacent to Coastal Wetlands (4863) indicator into 4510.
4858 Climate Change Ice Duration	Assess the ice duration and thereby, the temperature and accompanying physical changes to each lake over time, in order to infer the potential impact of climate change.	X			X	Need to revisit description to use as state of physical integrity; update as needed.
4861 Effect of Water Level Fluctuations	Identify data gaps with respect to assessing responses of vegetation to changes from natural lake level fluctuations over time. Address data gaps, formulate goals and measurable objectives for designing and implementing a baseline and monitoring program. Coordinate with other SOLEC indicators sharing common goals in protecting nearshore habitats (e.g. fauna) that are impacted by changes from natural variability on water levels.	X			X	Revise to water levels (drop effects component which was never obtained in report), and use as a indicator of physical integrity.
4862 CW Plant Com. Health	Assess the level of native vegetative diversity and cover for use as a surrogate measure of quality of coastal wetlands which are impacted by coastal manipulation or input of sediments.	X				
7002 Land Cover Land Conversion	Document the proportion of land in the GLs basin under major land use classes. Assess the changes in land use over time. Infer the potential impact of existing land cover and land conversion patterns on basin ecosystem health.	X			X	Indicator to serve many needs. Work with land-cover agencies and advise of SOLEC needs.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
7028 Sustainable Ag. Practices	Assess the number of environmental and conservation farm plans and environmentally friendly practices in place such as: integrated pest management to reduce the potential adverse impacts of pesticides; conservation tillage and other soil preservation practices to reduce energy consumption and sustain natural resources and to prevent ground and surface water contamination.	X			X	Develop an improved agriculture subset of indicators. Expect new and further developed agriculture indicators post-SOLEC 2011. Include 7061 Nutrient Management Plans and 7062 Integrated Pest Management indicators within this indicator report for SOLEC 2011.
7043 Economic Prosperity	Assess the unemployment rates within the GLs basin. Infer the capacity for society in the GLs region to make decisions that will benefit the GLs ecosystem (when used in association with other GLs indicators).	X			X	Keep some measure of economy in the indicators, as a driving force. Explore metric options.
7056 Water Withdrawal	Use the rate of water withdrawal to help evaluate the sustainability of human activity in the GLs basin.	X			X	Individual states and province are responsible for reporting on this data to a common database under the GL Compact. Data is almost developed – reporting process is just getting under way, existing water withdrawals at the end of 2009. Ramp up period now and probably not wise to develop an alternative means of gathering this information. View this indicator as a response – measuring how much is being withdrawn from the lakes.
7057 Energy Consumption	Assess the energy consumed in the GLs basin. Infer the demand for resource use, the creation of waste and pollution and stress on the ecosystem.	X			X	Use as a driving force indicator.
7065 Wastewater Treatment & Pollution	Measure the proportion of the population served by municipal sewage treatment facilities. Evaluate the level of municipal treatment provided. Measure the percent of collected wastewater that is treated. Assess the loadings of phosphorus, biological oxygen demand BOD, ammonia, and solids (and organic chemicals and metals, when possible) released by wastewater treatment plants into the water courses of the GLs basin.	X			X	Work with IJC working group. Split into two indicators treatment (response) and loadings (pressure).

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
7100 Natural GW Quality	Measure groundwater quality as determined by the natural chemistry of the bedrock and overburden deposits, as well as any changes in quality due to anthropogenic activities. Address groundwater quality impairments, whether they are natural or human induced in order to ensure a safe and clean supply of groundwater for human consumption and ecosystem functioning.	X			X	Report every 10 years. Update description. Explore a metric of per capita cost to treat source water as a proxy for the quality of source water.
7102 Base Flow Due to GW Discharge	Measure the contribution of base flow due to groundwater discharge to total stream flow. Detect the impacts of anthropogenic factors on the quantity of groundwater resource.	X			X	Measures changes in flow that are being influenced at the lake basin level. Baseflow is a good indicator of the groundwater system but not a good measure of amount of water in storage. Contact USGS to consult. Metric could be number of stream miles converted from cold to cool water; USFWS may have more information.
8131 Extent of Hardened Shoreline	Assess the amount of shoreline habitat altered in the GLs by the construction of shore protection including sheet piling, riprap, or other erosion control structures.	X				
8135 Cont. Affecting Prod. Of Bald Eagles	Assess the number of territorial pairs, success rate of nesting attempts and number of fledged young per territorial pair as well as the number of developmental deformities in young bald eagles. Measure concentrations of persistent organic pollutants and selected heavy metals in unhatched bald eagle eggs and in nestling blood and feathers. Infer the potential for harm to other wildlife caused by eating contaminant prey items	X			X	Make this primarily a bald eagle population indicator to reflect state of aquatic-dependent life. Can include contaminant information in the report, but not as a primary measure or purpose.
8142 Sediment Avail. For Coast. Nourish.	Assess the amount of water and suspended sediment entering the GLs through major tributaries and connecting channels, and to estimate the amount of sediment available for transport to nourish coastal ecosystems.	X		X		The process of nourishing coastal ecosystems is important, but but on hold until it is confirmed the measure of suspended sediment from tribs sufficiently represents what is available for coastal ecosystem nourishment.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
8146 Artificial Coastal Structures	Assess the number of artificial coastal structures on the GLs and to infer potential harm to coastal habitat by disruption of sand transport.	X				
8149 Protected Nearshore Areas	Asses the number and status of protected areas in the Great Lakes.	X			X	Also applicable to 8163; 8129 (alvars, sand dunes, islands and cobble beaches); 8164 – combine into one indicator including 8149 based on what is in the biodiversity strategies for each lake. Find similarities/ common indicators in the biodiversity strategies.
8161 Threatened Species	Assess the number, extent and viability of threatened species which are key components of biodiversity in the GLs basin, and to infer the integrity of ecological processes and systems (e.g. sand accretion, hydrologic regime) within the GLs habitats.	X			X	Define what species (metric definition) is needed to simplify indicator. Do not include plants.
8500 Forest Lands Cons. Of Biol. Diver.	Describe the extent, composition and structure of the GLs basin forests. Address the capacity of forests to perform the hydrologic functions and host the organisms and processes that are essential to protecting the biological diversity, physical integrity and water quality of the watershed.	X			X	Bring Forestry indicators to a targeted group, for simplification and service to the DPSIR framework. For example, forest disturbance as a pressure, forest cover as a state of the landscape, sustainable forestry as a response.
8501 Maint. Prod. Capacity Forest Ecosys.	Determine the capacity of GLs forests to produce wood products. Allow for future assessments of change in productivity over time, which can be representative of social and economic trends affecting management decisions and can also be related to ecosystem health.	X			X	Bring Forestry indicators to a targeted group, for simplification and service to the DPSIR framework. For example, forest disturbance as a pressure, forest cover as a state of the landscape, sustainable forestry as a response.
8503 Forest Lands Cons. Maint. Soil Water	Describe the extent to which GLs basin forests aid in the conservation of the basin's soil resources and protection of water quality. Describe the level of participation in the GLs states and Ontario in sustainable forestry certification programs.	X			X	Bring Forestry indicators to a targeted group, for simplification and service to the DPSIR framework. For example, forest disturbance as a pressure, forest cover as a state of the landscape, sustainable forestry as a response.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
9002 Aquatic Invasive Species	Assess the presence, number and distribution of nonindigenous species (NIS) in the Laurentian GLs. Aid in the assessment of the status of biotic communities, because NIS can alter both the structure and function of the ecosystems.	X			X	Add "watch list" to this indicator report. Explore invasive species by lake.
9002 Terrestrial Invasive Species	Evaluate the presence, number and impact of terrestrial NIS in the GLs basin. Assess the biological integrity of the GLs basin ecosystem.	X				
Air Temperature	To be developed. Air temperature trends, as a driving force or pressure indicator for the state of the lakes.	X				Part of improved climate / climate change theme, used as a physical stressor indicator.
Aquatic Habitat Connectivity	To be developed. To measure the connectivity of aquatic habitats surrounding the Great Lakes. State of physical integrity.	X				Includes dam information as the metric.
Bacterial loadings from Tributaries	To be developed. To measure loadings of bacterial to the Great Lakes from tributaries. Pressure (pollution) on the state of the lakes.	X				
Botulism Outbreaks	To be developed. To measure occurrences of botulism. Use as an impact (fish and wildlife) indicator.	X				
Cladophora	To be developed. To measure cladophora occurrences extent and trends. Use as an impact (human) indicator.	X				
Zooplankton health	To directly measure changes in community composition, mean individual size and biomass of zooplankton populations in the Great Lakes basin. To infer changes in food-web dynamics due to changes in vertebrate or invertebrate predation, system productivity, the type and intensity of predation, and the energy transfer within a system	X				Current zooplankton indicator works as fish-food type indicator. Use zooplankton data also as an indicator of Great Lakes system's productivity.
Dreissenid mussels	To be developed. To measure the extent and trends of dreissenid mussels population. Use an invasive species indicator in conjunction of the aquatic non-native species indicator.	X				

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
	Use as a pressure (invasive species) indicator.					
Endocrine Disruption	To be developed. To measure the occurrences, extent and trends of endocrine disruption. Use as an impact (fish) indicator.	X				
Extreme precipitation events	To be developed. To measure the trends in extreme precipitation events. Use as a pressure (resource use and other physical stressors) indicator.	X				
Fish Disease Occurrences	To be developed. To measure the occurrences, extent and trends of fish disease. Use as an impact (fish) indicator.	X				
Greenhouse Gas Emissions	To be developed. To measure the ghg emission trends from the Great Lakes community. Use as a driving force indicator.	X				
Harmful Algal Blooms	To be developed. To measure the occurrences, extent and trends of HABs. Use as an impact (human) indicator.	X				
Industrial Loadings	To be developed. To measure the status and trends of industrial releases of pollution in the Great Lakes basin. Use as a pressure (pollution & nutrients) indicator.	X				
Nutrients in Tributaries	To be developed. This indicator will assess the total phosphorus and nitrate/nitrite levels in the Great Lakes' tributaries and it will be used to support the evaluation of trophic status and aquatic ecosystem health in Great Lakes tributaries.	X			X	Include N:P ratio, and consider doing same for phosphorus indicator (#111). See indicator 4860.
Inland Water Quality Index	To be developed. This indicator will communicate water quality status relative to guidelines and support the evaluation of aquatic ecosystem health in Great Lakes tributaries.	X				
Stocking Native Fish	To be developed. To measure the trends in stocking native fish. Use as a response indicator. See indicators 008, 009 and 0093 for	X				

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
	more information.					
Pesticides in Tributaries	To be developed. To measure the status and trends of pesticides in tributaries. Use as a pressure (pollution and nutrients) indicator.	X				Review following completion of Inland WQI measure to ensure no redundancy.
Human Population	To be developed. To understand population trends in the Great Lakes and Lakes basins. Use as a driving force indicator.	X				
Tributary Flows	To be developed. This indicator quantifies the nebulous concept of flashiness, which is an important aspect of the hydrologic regime to which the aquatic ecosystem must be adapted. Changes in flashiness in either direction usually lead to ecosystem stress. Use as a state of the lakes (physical integrity, Landscapes and natural processes) indicator.	X				
Educating Great Lakes basin residents	To be developed. To gauge interest by academic institutions in Great Lakes and/or environmental issues as topics for study and research. Use as response indicator.	X				
Remediating sediment	To be developed. To measures trends in sediment management / remediation. Use as a response indicator.	X				
Surface Water Temperatures	To be developed. To measure trends in surface water temperatures. Part of set of new climate / climate change indicators. Use as a pressure (physical stressors) indicator.	X				
Piping Plover	To be developed. To measure population of piping plovers. Part of state of aquatic-dependent life.	X				

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
Value of Great Lakes	To be developed. To explore the connections, values, attitudes and general knowledge which residents of the Great Lakes basin hold about the Lakes. Use as a driving force indicator.	X			X	
Water Chemistry	To be developed. To measure water chemistry components that are telling of ecosystem health status and trends such as ph, dissolved oxygen, and secchi. Use as a state indicator (water quality).	X				As long-term water chemistry datasets becoming telling of ecosystem health and/or related to an established ecosystem objective it should be part of the story.
Water Clarity	To be developed. To measure status and trends of water clarity. Use as state indicator (water quality)	X				
Major Ions	To be developed. To measure major ions in the nearshore waters of the Great Lakes. Use as state indicator (water quality).	X				
Protecting and restoring habitats and species	To be developed. Use a response indicator.	X				
Watershed stressor index	To be developed. Cumulative stress on Great Lakes water quality/aquatic life from the watershed. Use as a pressure indicator.	X				
Municipal Wastewater loadings	To be developed. Use as a pressure indicator.	X				

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
0008 Salmon and Trout	To assess trends in population of introduced salmon and trout species. To infer trends in species diversity in the Great Lakes basin. To evaluate the resulting impact of introduced salmonines on native fish populations and the preyfish populations that support them.		X		X	Data may be incorporated into the new top predator fish and/or native fish stocking indicator.
0068 Mussels	Assess the location and status of freshwater native mussel populations and their habitats throughout the Great Lakes system, with emphasis on endangered and threatened species. Use this information to direct research aimed at identifying the factors responsible for mussel survival in refuge areas, which in turn will be used to predict the locations of other natural sanctuaries and guide their management for the protection and restoration of native GLs mussels.		X			Indicator served its purpose; data may be best utilized in the threatened species indicator. Ensure definition of threatened species can include native mussel species where applicable.
0114 Cont. in Spottail Shiners	Assess levels of PBTs in YOY spottail shiners. Inter local areas of elevated contaminants and harm to fish-eating wildlife. Monitor contaminant trends over time for the nearshore waters of the GLs.		X			Useful at local level, rather than spatial scope of SOLEC reporting.
0122 Hexagenia	Assess the recovery of Hexagenia in shallow mesotrophic waters of the GLs. Establish a quantitative goal for the restoration of Hexagenia nymphs in mesotrophic waters of the GLs.		X			More important for some lakes and locations, rather than the overall spatial scope of SOLEC reporting. Achievability basinwide is a challenge.
0124 EAPI for Nearshore Fish	Assess select external anomalies in nearshore fish. Identify nearshore areas that have populations of benthic fish exposed to contaminated sediment. Help assess the recovery of AOCs following remedial activities.		X			Achievability is a challenge, such as linking external anomalies to toxic issues. Important indicator at a local scale, rather than SOLEC's broader spatial scale.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
3516 Household Stormwater Recycling	Assess the level of public awareness and concern for the environmental consequences of stormwater runoff.		X			Sufficient grouping of response indicators available.
4177 Bio. Markers of Human Exposure	Assess levels of persistent toxic substances such as methyl mercury, PCBs and DDEs in human tissue in citizens of the GLs. Infer the efficacy of policies and technology to reduce these persistent bioaccumulating toxic chemicals in the GLs.		X			Reliability, achievability, usability are a problem. Connection to GL water challenging. Resources, agency and political commitment required to report on this issue binationally, within GL basin, and through SOLEC.
4179 Geographic Patterns in Diseases	Assess the geographic and temporal patterns in disease incidences in the GLs basin population, and to identify areas where further investigation of the exposure and effects of environmental pollutants on human health is needed.		X			Reliability, achievability, usability are a problem. Connection to GL water challenging. Resources, agency and political commitment required to report on this issue binationally, within GL basin, and through SOLEC.
4202 Air Quality	To monitor the air quality in the Great Lakes ecosystem To infer the potential impact of air quality on human health in the Great Lakes basin		X		X	Under the DPSIR framework there is a relevancy issue. Have air deposition indicator. Air quality and human health impact is well documented and reported in numerous other venues.
4506 Cont. in Snapping Turtle Eggs	Assess the accumulation of organochlorine chemicals and mercury in snapping turtle eggs. Assess contaminant trends and physiological and ecological endpoints in snapping turtles. Obtain a better understanding of the impact of contaminants on the physiological and ecological health of the individual turtles and wetland communities.		X			Spatial scope (locally valuable) and achievability are a challenge.
4511 CW Restored Area by Type	Assess the amount of restored wetland area, and to infer the success of conservation and rehabilitation efforts.		X			Sufficient grouping of response indicators available.
4516 Sediment Flowing into CW	Assess the severity of sediment yields flowing into coastal wetlands and potential impact on wetland health.		X			Achievability is a challenge. Have a strong set of coastal wetland indicators established, as well as enhanced tributary and land use indicators to

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
						represent wetland health.
4860 Phos. And Nit. Levels in CW	Assess the amount of nitrate and total phosphorus flowing into GLs coastal wetlands, and to infer the human influence on nutrient levels in the wetlands.		X		X	Nutrients indicators in Great Lakes open waters and nearshore waters, as well as tributaries, and new point source loadings. Combined with strong group of state of coastal wetland indicators will represent these issues.
4863 Land Use Adjacent to CW	Assess the basin-wide presence, location and/or spatial extent of land cover in close proximity to coastal wetlands. Infer the condition of coastal wetlands as a function of adjacent land cover.		X			Issue already represented through the land use and the land conversion indicators.
4864 Human Impact Measures	Assess the presence, location, and/or spatial extent of factors that are a direct of indirect result of human behaviours. Infer the condition of coastal wetlands as a function of these human impact measures.		X			Have separated a grouping of indicators (pressures) that represent how human activity is related to the state of the Great Lakes.
7000 Urban Density	Assess the urban human population density in the GLs basin. Infer the degree of land use efficiency for urban communities in the GLs ecosystem.		X		X	Issue articulated through land use, land cover, and hardened shoreline. Explore including as part of new driving force indicator, human population.
7006 Brownfield Redevelopment	Assess the area of redeveloped brownfields. Evaluate over time the area at which society remediates and reuses former developed sites that have been degraded or abandoned.		X			Relevancy is an issue. Undeveloped brownfields do not necessary impact the state of the Great Lakes. In use as a societal response, there is a dedicated and sufficient grouping of indicators to represent it.
7054 Ground Surface Hardening	Indicate the degree to which impervious surface affect natural water drainage and cause rapid runoff and erosion, which are the main sources of non-point pollution. Measure the impact of land development on aquatic systems.		X			Issue represented by land use, land conversion, hardened shoreline indicators.
7060 Solid Waste Generation	Assess the amount of solid waste disposed of in the GLs basin. Infer inefficiencies in human economic activity (i.e. wasted resources) and the potential adverse impacts to human		X			A group of driving force and pressure indicators sufficient represents impact of human activity on the state of the Great Lakes.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
	and ecosystem health.					
7061 Nutrient Management Plans	Determine the number of Nutrient Management Plans. Infer the environmentally friendly practices that help to prevent ground and surface water contamination.		X			A set of agriculture indicators are important for the DPSIR framework. The sustainable agricultural practices indicator remains to cover this human response issue. Other agriculture indicators are being developed.
7062 Integrated Pest Management	Assess the adoption of Integrated Pest Management (IPM) practices and the effects IPM has had toward preventing surface and groundwater contamination in the GLs basin by measuring the acres of agricultural pest management applies to agricultural crops to reduce adverse impacts on plant growth, crop production and environmental resource.		X			A set of agriculture indicators are important for the DPSIR framework. The sustainable agricultural practices indicator remains to cover this human response issue. Other agriculture indicators are being developed.
7064 Vehicle Use	Assess the trends and amount of vehicle use in the GLs basin. Infer the societal response to the ecosystem stresses caused by vehicle use.		X			Relevancy is an issue. A dedicated group of human response indicators aim to flow more directly from pressures on the Great Lakes and the state of the Great Lakes. Air quality indicator is shelved.
7101 GW and Land Use Intensity	Measure water use and intensity and land use and intensity. Infer the potential impact of land and water use on the quantity and quality of groundwater resources as well as evaluate groundwater supply and demand. Track the main influences on groundwater quality and quantity such as land and water use to ensure sustainable high quality groundwater supplies.		X			Achievability is issue. Ground water and land use issues are represented in other indicators; base-flow due to groundwater, groundwater quality, land use, land conversion, hardened shoreline, human population.
7103 GW Dep. Plant and Animal Comm.	Measure the abundance and diversity as well as presence or absence of native invertebrates, fish, plant and wildlife communities that are dependent on groundwater discharges to aquatic habitat. Identify and understand and deterioration of water quality for animals and humans, as well as changes in the productive capacity of flora and fauna dependent on		X			A sufficient group of biological integrity (aquatic-dependent life) indicators is established.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
	<p>groundwater resources. Use biological communities to assess locations of groundwater, intrusions. Infer certain chemical and physical properties of groundwater, including changes in patterns of seasonal flow.</p>					
8114 Habitat Fragmentation	<p>Assess the amount and distribution of natural habitat remaining within the GLs ecoregions, and 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.</p>		X			<p>A more focused indicator, aquatic habitat conductivity, has been adopted to represent this issue. Land use, land conversion, forestry, protected nearshore areas indicators also address aspects of this important issue.</p>
8129 Alvars	<p>Assess the status of GLs alvars, one of the 12 special lakeshore communities identified within the nearshore terrestrial area. Infer the success of management activities. Focus future conservation efforts toward the most ecologically significant alvar habitats in the GLs.</p>		X		X	<p>Incorporate information on special lakeshore communities, when available, into the protected nearshore areas indicator.</p>
8129 Cobble Beaches	<p>Assess the status of cobble beaches, one of the 12 special shoreline communities identified within the nearshore terrestrial area. Assess the changes in area and quality of the GLs cobble beaches. Infer the success of management activities. Focus future conservation efforts toward the most ecologically significant cobble beach habitats in the GLs.</p>		X		X	<p>Incorporate information on special lakeshore communities, when available, into the protected nearshore areas indicator.</p>
8129 Islands	<p>Assess the status of GLs islands, one of the 12 special lakeshore communities identified within the nearshore terrestrial area. Assess changes in area and quality of the GLs islands individually, within lake units and as an ecologically important system. Assess amount and suitability of island habitat for focal species and communities in the GLs ecosystem. Infer success of management activities. Focus future conservation efforts toward the most</p>		X		X	<p>Incorporate information on special lakeshore communities, when available, into the protected nearshore areas indicator.</p>

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
	ecologically significant island habitats in the GLs that face threats and are not adequately protected.					
8129 Sand Dunes	Assess the extent and quality of GLs sand dunes, one of the 12 special lakeshore communities identified within the nearshore terrestrial area.		X		X	Incorporate information on special lakeshore communities, when available, into the protected nearshore areas indicator.
8132 Nearshore Land Use	Assess the types and extent of major land uses within 1 km from shore and to identify real or potential impacts on land use on significant natural features or processes, particularly on the 12 special lakeshore communities.		X			Information to be presented in the land use and land conversion indicators.
8136 Ext. and Qual. Of Near. Landcover	Assess the amount of natural land cover that falls within 1 km of shoreline and 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 GLs.		X			Information to be presented in the land use and land conversion indicators.
8137 Near. Species Div. And Stability	Assess the composition and abundance of plant and wildlife species over time within the nearshore area, and to infer adverse effects on the nearshore terrestrial ecosystem due to stresses such as climate change and/or increasing land use intensity.		X			A group of biological integrity (aquatic-dependent life) indicators has been established to cover this issue.
8147 Pops and Cont. Affecting Am. Otter	Directly measure the contaminant concentrations found in American otter populations within the GLs basin. Indirectly measure the health of the Great Lakes habitat, progress in GLs ecosystem management, and/or concentrations of contaminants present in the GLs.		X			A group of contaminant indicators represents contamination well. A group of biological integrity (aquatic-dependent life) indicators represents species populations well.
8150 Breeding Bird Div. And Abund.	Assess the status of breeding bird populations and communities, and to infer the health of breeding bird habitat in the GLs basin.		X			Relevancy is an issue. Focus on aquatic-dependent life, with two bird related indicators existing; coastal wetland birds, and bald eagle.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
8162 Health of Terr. Plant Communities	Assess the presence, abundance, distribution and trends over time of non-native insects and diseases infesting plants and their impacts on plant mortality or damage (including deformities) as well as the impact of airborne and groundwater pollution on plant community health.		X			A number of indicators are established to represent the issue and impacts of non-native species.
8163 Stat. & Prot. of Special Places	Assess the status and degree of protection (at the landscape level) in area and quality of special place and special species of cultural and spiritual significance especially to First Nations/Tribes. Special places include: ecologically unique areas e.g. rocky outcrops, large dead trees, and cultural treasures, e.g. burial grounds and areas where medicinal herbs grow. Special or iconic species are ones such as pileated woodpeckers, turtle, wolf, martens, medicinal herbs, bald eagles, American Otter, or rare species. Infer the success of management activities associated with the protection of areas and species.		X		X	Alternatively will seek contributions from First Nations, Tribes and Metis in each Great Lakes indicator report, where applicable.
8164 Biodiversity Conservation Sites	Assess and monitor the biodiversity of the GLs watershed.		X			Usability is an issue. No metric, but good information. Incorporate information into protected nearshore areas indicator where applicable.
8502 Maint. Forest Ecosystem Health	Pulled from Criterion 3 - Developing SOLEC/Great Lakes Forest Indicators Area and percent of forest affected by processes or agents beyond the range of historic variation, e.g. by insects, disease, permanent flooding, Stalination, and domestic animals (16) Area and percent of forest land subjected to levels of specific air pollutants (e.g. sulfates, nitrate, ozone) or ultraviolet B that may cause negative impacts on the forest ecosystem (17) Area and percent of forest land with diminished biological components indicative of changes in the fundamental ecological processes (e.g. soil nutrient cycling, seed dispersion, pollination) and/or ecological continuity (monitoring of functionally important species		X			This indicator represents forest health, compared to the revised suite of three forest indicators that will aim to make stronger representation of the forest health as it relates to Great Lakes water quality.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
	such as fungi, arboreal epiphytes, nematodes, beetles, wasps, etc.)					
9000 Acid Rain	Assess the levels of sulphate and nitrate in precipitation in the GLs. Assess the area within the GLs basin in exceedance of critical loads of sulphate and nitrate to aquatic and terrestrial ecosystems measured as amount of total deposition (sulphate and nitrate) above the critical load. Infer the efficacy of policies to reduce sulphur and nitrogen acidic compounds released into the atmosphere.		X			Relevancy and usability to Great Lakes is an issue. Shelve for now, but an issue that may be brought forward in the future.
9003 Climate Change Crop Heat Units	Assess the trends in Crop Heat Units in the GLs basin as an indicator of climate change. A change in atmospheric temperature due to climate change has the potential to increase Crop Heat Units. This indicator may also aid to infer the potential impact climate change has on species diversity and crop productivity.			X		Shelve for now. A stronger grouping and incorporation of climate and climate change impacts information is being pursued.
Access to Information About the Great Lakes	To interpret the degree of public access to electronic information about the Great Lakes ecosystem.			X		As a social driving force, consider using this as a metric as part of a value of Great Lakes indicator that is under development.
Accessible Stream Length or Migratory Fish Passage	Access the artificial structures and how these impact the length that fish can swim. (How far can the fish swim before there is a barrier like a dam or another structure?)			X		New indicator, aquatic habitat connectivity to cover this issue.
Aquatic Species Shifts					X	Short-term achievability and usability for Great Lakes is an issue. Exploration of future utility.
Areas of Concern	To assess improvements in areas of concern. Measures could include contaminants in the American otter, snapping turtle eggs as well as brownfield redevelopment.			X		Possible response indicator if reporting on delisting or BUIs. Leave to local reporting.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
Bioindicator			X			More information required.
Capacity of Federal Programs for the Great Lakes Priorities	To assess the yearly overall funding for Great Lakes programs from the US and Canada federal agencies.		X			Achievability is one issue. SOLEC priority on pressure, state and impacts. Doesn't fit with SOLEC purpose.
Contaminants Affecting Human Health	Measure exposure of emerging chemicals (PCBs, Hg and pesticides) as well as exposure of newborns to chemicals.		X			Relevancy to Great Lakes is an issue.
Herptile Populations	Assess the status and trends of select species of amphibians and reptiles around the Great Lakes basin.		X			Have a group of biological integrity (aquatic dependent life) indicators, including coastal wetland amphibians.
High Impact Invasive Species	Not yet determined. This indicator would report on the status of all high risk potential invaders in the Great Lakes (Asian Carp).		X			A list of high-risk invaders to be newly included in non-native species indicators.
Industrial Response			X			Issue represented by industrial efficiencies indicator that is under development.
Inland Waters Nitrate Concentrations			X			Issue represented by indicator on nutrients in tributaries.
Medium-Large Carnivores	This indicator would focus primarily on populations of medium to large sized carnivores, and secondary on contaminants in these populations.		X			Usability is an issue. Many factors are impacting carnivore populations and contaminants in them. Focused on aquatic-dependent life.

Indicators Name and Number	Purpose	Keep	Shelve	On-hold	Revise	Decision Summary
National Park Visitations	To compare acreage of and visitation to Great Lakes National Parks and to other National Parks in the US and Canada in order to assess their values as recreational resources. To assess the human impacts of recreation on resources of the Great Lakes.		X			Possible metric for the Value of the Great Lakes indicator under development.
Nearshore Fish Community	Asses the fish populations in the nearshore zone. Two indicators could be used: MNR's nearshore community index trapnetting catch per unit effort and IBI scores from Hamilton, Toronto and Quinte AOCs.		X			Grouping of indicators established sufficiently represents the state of aquatic-dependent life.
Public Recreational Access to the Great Lakes	To assess public recreation access to the Great Lakes shoreline.		X			Possible metric for the Value of the Great Lakes indicator under development.
Sense of Place: Indian Tribes Around the Great Lakes Basin	To assess how and why Tribes and First Nations value natural resources, how natural resources are managed on native reserves and how Tribes and First Nations are affected by natural resources management decisions.		X			Alternatively will seek contributions from First Nations, Tribes and Metis in each Great Lakes indicator, where applicable.
Storm Water Ordinance	This indicator will assess the potential for watershed health to be maintained as development occurs based upon the local governmental stormwater ordinance requirements designed to minimize the affect development has upon the flow regime, habitat, water quality, and streambank integrity.		X			Potential response indicator requires more exploration.
Total Sulphur Levels	Assess the sulphur levels in the Great Lakes, as an indicator of acid rain.		X			Sufficient set of indicators exist to represent water quality. Acid Rain indicator is shelved.
Ungulate Populations and Locations	Assess the ungulate populations and their location around the Great Lakes basin.		X			Usability and relevancy may be an issue. May be most applicable to Lake Superior, rather than a basinwide indicator.

Appendix Five - SOLEC Great Lakes Indicators Model

Table 1: SOLEC Great Lakes Indicators Model

Reporting Areas	Driving Forces	Pressures			State			Impacts		Responses
Top Level Categories	Economic/Social	Pollution & Nutrients	Invasive Species	Resource Use/Physical Stressors	Water Quality	Aquatic-Dependent Life	Landscape & Natural processes	Human	Fish & Wildlife	Restoration & Protection
Reporting Indicators	<p><i>Human population</i></p> <p>Economic prosperity</p> <p>Energy consumption</p> <p><i>Value of Great Lakes</i></p> <p><i>Greenhouse gas emissions</i></p>	<p>Contamination in sediment</p> <p>Atmospheric deposition</p> <p><i>Inland water quality index</i></p> <p><i>Nutrients in tributaries</i></p> <p><i>Pesticides in tributaries</i></p> <p><i>Bacterial loadings from tributaries</i></p> <p><i>Municipal wastewater loadings</i></p> <p><i>Industrial loadings</i></p>	<p>Aquatic nonnative species including a watchlist of high risk</p> <p>Terrestrial nonnative species</p> <p>Sea lamprey</p> <p><i>Dreissenid mussels</i></p>	<p>Forest disturbance</p> <p>Artificial coastal structures</p> <p>Hardened shorelines</p> <p><i>Surface water temperature</i></p> <p><i>Air temperature</i></p> <p><i>Extreme precipitation events</i></p>	<p>Toxic chemicals in offshore waters</p> <p>Contaminants in whole fish</p> <p>Contaminants in waterbirds</p> <p>Groundwater quality</p> <p>Nutrients in lakes</p> <p><i>Water clarity</i></p> <p><i>Major ions</i></p> <p><i>Water chemistry</i></p>	<p>Wetland fish</p> <p>Wetland plants</p> <p>Wetland birds</p> <p>Wetland invertebrates</p> <p>Wetland amphibians</p> <p>Walleye</p> <p>Lake Trout</p> <p>Preyfish</p> <p>Benthos</p> <p>Diporeia</p> <p>Zooplankton biomass</p> <p><i>Zooplankton health</i></p> <p>Phytoplankton</p> <p>Threatened species</p> <p>Bald eagle</p> <p>Sturgeon</p> <p><i>Piping Plover</i></p>	<p>Land cover</p> <p><i>Aquatic habitat connectivity</i></p> <p>Fish habitat</p> <p>Base flow due to groundwater</p> <p>Water levels</p> <p>Ice duration</p> <p>Forest diversity</p> <p>Sediment coastal nourishment</p> <p><i>Tributary flashiness</i></p> <p>Wetland landscape extent and composition</p>	<p>Drinking water</p> <p>Beach advisories</p> <p>Fish consumption restrictions</p> <p><i>Harmful Algae Blooms</i></p> <p><i>Cladophora</i></p>	<p><i>Botulism outbreaks</i></p> <p><i>Fish disease occurrences</i></p> <p><i>Endocrine disruption</i></p>	<p>Withdrawing water sustainably</p> <p><i>Stocking native fish</i></p> <p>Treating wastewater</p> <p>Protecting and restoring of habitats and species</p> <p>Protecting special lakeshore areas</p> <p>Conserving forest lands</p> <p>Enhancing wildlife and conserving soil and water on agricultural lands</p> <p>Implementing industrial efficiencies</p> <p><i>Remediating contaminated sediment</i></p> <p><i>Educating GL basin residents</i></p>

Note: bold denotes existing indicator