A REPORT OF THE GREAT LAKES WATER QUALITY BOARD AND GREAT LAKES SCIENCE ADVISORY BOARD TO THE INTERNATIONAL JOINT COMMISSION

GREAT LAKES ECOSYSTEM INDICATORS –SUMMARY REPORT

THE FEW THAT TELL US THE MOST

June 2013

FINAL

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INTRODUCTION

How are the Great Lakes doing and what progress are we making in protecting and restoring them? These are two of the most frequently asked questions about the largest source of surface fresh water in the world. Unfortunately, we do not have clear answers for them. With the tremendous efforts and resources invested in restoration by governments, the private sector, and non-profit organizations in the United States and Canada over the past 40 years, we need to be able to respond much more clearly and definitively in the future.

Recognizing this, the International Joint Commission (IJC) through its Science Advisory Board and Water Quality Board initiated a project to put the Great Lakes community in a position to respond. The focus of the work is to identify a limited number of ecosystem indicators especially important to the health of the Great Lakes basin ecosystem and which tell us the most about it. Extensive work has been done over the years to measure the condition of the Lakes as part of the State of the Lakes Ecosystem Conference (SOLEC), and this work will form the basis for many of the indicators. What is being done now is selecting "the fewest that tell us the most."

The need for key indicators is even greater now with a new Great Lakes Water Quality Agreement (WQA) between the United States and Canada. The two countries have determined that we should be able to drink the water, eat the fish, and swim at the beaches. In order to evaluate the condition of the Lakes, the WQA includes a framework of chemical, physical, and biological integrity. The indicators presented in this report are organized within this framework. The focus here is on ecological indicators. Indicators for public health will be covered in a separate, but related, report.

1. BACKGROUND

Canada and the United States have been working together closely for over 40 years to protect and restore the Great Lakes. The two countries committed in the WQA to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem. Governments, the private sector, and the public have invested billions of dollars in pollution controls, restoration, and conservation work since 1972 and significant improvements have been accomplished. However, there are many continuing concerns and questions about how the lakes are doing, whether we really are making progress and, if so, how much.

To select the key indicators for the Great Lakes, IJC staff collected extensive information on indicators from other ecosystems and criteria for evaluating them. Using this information, the SAB and WQB Work Group agreed upon a set of criteria to be used for selecting a core set of indicators (Attachment A.) The Work Group then assembled a multidisciplinary group of over 50 scientific, technical, policy, and other experts to come up with a consensus on the key indicators for the Great Lakes. This was accomplished at a three day workshop in September 2012 (Attachment B) and a summary of the findings is included (Attachment C.)

Subsequent to the workshop, participants developed more comprehensive descriptions of the indicators and explanations of why they are important. These are summarized below and will be spelled out more comprehensively in the full technical report to be completed later. More details on how to monitor for the indicators will also be included in the full technical report and will be completed in the next phase of the project.

2. ECOSYSTEM INDICATORS

There are literally hundreds and perhaps thousands of ecosystem indicators for the Great Lakes. These have been developed and presented very thoroughly as part of the SOLEC process over the years. Under SOLEC, there have been efforts to focus on a smaller number of indicators and present them in a way that is suited for a broader audience, and good progress has been made. This report takes this effort a step further. In addition to grouping the indicators into chemical, physical, and biological categories, they can be arranged in other ways, as well. These include such things as driving forces, pressure, impacts, state, and response (see Attachment D.) It should be noted that this report recommends the indicators listed below not be fixed for the indefinite future. As time passes and knowledge expands, it may become evident that some previously unidentified indicators are more important, and current ones tracked are less important. Regular reviews and flexibility in the system to allow for such changes are recommended. At the same time, continuity of indicators over the years is important for tracking long term trends in the Great Lakes.

The primary objective of this report is identify indicators that can be used to characterize the condition of the resource and the progress in protecting, restoring, and conserving it, as opposed to identifying what is causing the problems or what the responses to them are accomplishing. The indicators discussed below focus on the state of the lakes and impacts from many sources. The following are considered the indicators that tell us the most about the most important ecological characteristics of the Great Lakes.

A. Chemical

Long-standing concerns over chemical loadings to the Great Lakes have been a major part of the WQA from the beginning. The list of chemicals of interest has grown, and they continue to be a major concern. The chemical indicators include nutrients, with a primary focus on phosphorus as a driver of eutrophication, PBTs in biota, chemicals of mutual concern in water, and the atmospheric loadings of chemicals of mutual concern (CMCs), including PBTs.

i. Phosphorus - This indicator includes phosphorus loadings and concentrations in each of the Great Lakes. Both total phosphorus (TP) and dissolved reactive phosphorus (DRP) are important. The primary concern is human-induced eutrophication, the difficult problem that still has not been brought under control especially in Lake Erie. Excess phosphorus causes excessive growth of algae, which die and are decomposed by bacteria which in turn consume dissolved oxygen at depth, killing fish and other organisms. Blooms of blue-green algae (cyanobacteria) can produce hazardous toxins which have been known to kill birds and dogs, and are toxic to people as well. Excess nutrients also disrupt the normal flow of energy in the ecosystem, favoring unwanted species.

ii. Persistent Bioaccumulative Toxic (PBTs) Chemicals in Biota - The PBTs in biota indicator is the concentration of persistent, bio-accumulating and toxic substances in whole fish and fish-eating birds. The PBT chemicals are called out as an indicator as they pose a danger to humans and wildlife that consume fish containing these chemicals.

iii. Chemicals of Mutual Concern (CMC) in Water – This indicator is the concentration in water of selected legacy toxic chemicals as well as chemicals of emerging concern. The indicator of chemicals of mutual concern in water captures a wider set of chemicals, including some that are more water soluble than PBTs. The major concerns regarding chemical pollution are the inputs, concentrations, and exposures. Regarding the latter, the concern focuses on the adverse effects, such as impaired reproduction in fish or in fish-eating wildlife.

iv. Atmospheric Deposition of Chemicals of Mutual Concern (CMCs), including PBTs - This indicator is the presence of toxic chemicals and other chemicals of concern in the atmosphere and precipitation of the Great Lakes region. These are important because of potential impacts of CMCs, including PBTs, via atmospheric deposition on the Great Lakes aquatic ecosystem.

B. Physical

Physical Integrity of the Great Lakes includes land cover, shoreline habitats, including wetlands, and tributaries that are most directly affected by human activity and are critical to wildlife and to humans. Physical integrity also encompasses such basic elements as the amount of water contained, as indicated by water level, and its temperature. Duration of ice-cover is related to temperature, and is an important factor in determining the effects of climate change on lake levels. Groundwater is also included as an important indicator.

i. Land Cover - This is an indicator of the rate and extent of change to, and the fragmentation of, natural land cover. The amount, rate, and pattern of change is important because as natural land cover is managed or changed to agriculture or urban use, the products and services provided by those cover types such as water storage and purification, wildlife habitat, carbon storage, recreation, and aesthetic beauty are diminished or lost.

ii. Tributary Physical Integrity - This is an indicator of the changes in stream flow as a result of changes in land use and climate, and of the connectivity of the tributaries to the lakes. It is important because the frequency, magnitude, and rapidity of short term changes in stream flow affect stream organisms and the transport of sediments. Connectivity is important to the organisms that use the streams as habitat for all or part of their life cycle.

iii. Coastal Wetlands - The coastal wetland indicator is a measure of the extent, composition and quality of wetlands greater than 4 hectares in size that have a direct surface water connection to the lakes. They are important because of the numerous important ecosystem functions they perform.

iv. Shoreline Integrity – Shoreline integrity is a measure of protected shoreline length that is physically and biologically unfavorable relative to the shoreline length that is favorable. Physical modifications to the shoreline have disrupted coastal and near shore processes, flow and littoral circulatory patterns, altered or eliminated connectivity to coastal wetlands/dunes, and have altered near shore and coastal habitat structure, all resulting in negative effects on the biological integrity of the lakes.

v. Water Levels - This indicator is the level for each of the five Great Lakes above sea level. Lake levels are important because they have a major influence on coastal wetlands, near shore land, and lake water quality, especially nutrient concentrations. They also affect commercial and recreational navigation, drinking water intakes, and shoreline erosion. Low levels can necessitate dredging, which may have adverse side effects.

vi. Surface Water Temperature and Ice Cover – The water temperature and the winter ice cover indicator include the surface temperature of the water and the extent, duration, and thickness of the ice on the lakes. The temperature and cover are important because they affect the wintertime evaporation from the lakes and can lead to more and earlier algae blooms, greater exposure of the shoreline to waves generated by winter storms that accelerate erosion, acceleration of the spread of some invasive species, and increased - turbidity that necessitates more water treatment for household use.

vii. Groundwater Quality and Quantity -This indicator includes the quality and quantity of the groundwater in the Great Lakes region, and its interaction with the surface water in the Great Lakes basin. Groundwater is an important component of the hydrologic cycle in the Great Lakes basin and, therefore, groundwater quality, quantity, and its interface with surface water is an important factor in determining the overall quality and quantity of water in the Lakes. It is important to the broader ecosystems in the Great Lakes region because it is, in effect, a large, subsurface reservoir from which water is released slowly to provide high quality, reliable flow of water to streams, lakes, and wetlands.

C. Biological

In considering the water quality of the Great Lakes, the biological conditions indicate the natural state of the lakes and their ability to provide important ecosystem services valued by the populations around the Lakes. Although some of the issues such as excessive algae and fish kills were thought to have been eliminated or reduced through earlier actions like reductions in phosphorus loading, their re-emergence indicates new ways in which various stressors impact these ecosystems. The biological indicators include the status of existing aquatic invasive species and the rate of additional species becoming established, the magnitude and frequency of harmful and nuisance algae blooms associated with levels of nutrients, fish and bird population abundance and distribution, habitat alterations on tributary connectivity and coastal wetlands, productivity of the lower food web and related fish species of interest and fish eating colonial birds, and the population stability of various biota as indicated by their underlying PBTs tissue loads.

i.Lower Food Web Productivity and Health – This indicator includes phytoplankton community structure and biomass, benthos abundance and diversity, and prey fish abundance and diversity. The significance of the indicator is how it shows the current state and efficiency of the food web at transferring material and energy to fish at the top of the food chain.

ii. Fish Species of Interest – The indicator is the populations of lake trout, walleye, whitefish, and sturgeon in the Great Lakes. This is important because of their value for commercial, recreational, and aboriginal fisheries and to infer health of the ecosystem from the health of species at the top of the aquatic food chain.

iii. Harmful and Nuisance Algae - This indicator includes those species of harmful algae with the potential to produce toxins that affect human health, as well as health of livestock, pets, and wildlife. Nuisance algae is a broader subset of algae that form- blooms which are not toxic to humans but which cause ecological and socioeconomic harm. Both forms of algae are important because of the damage they cause to the Great Lakes.

iv. Aquatic Invasive Species - This indicator is the status and impact of those aquatic invasive species present in the Great Lakes having detrimental effects to the ecosystem. It specifically excludes species that are benign or perceived to be desirable species. This indicator is important because it measures the extent to which Great Lakes are populated by detrimental invasive species and their negative impact. This indicator also includes the rate of new introductions because this assesses the efficacy of measures to curb the arrival of AIS.

v. Abundance and Distribution of Fish-Eating and Colonial Nesting Birds This indicator includes herring gulls and bald eagles because of their position at the top of the Great Lakes aquatic food web. The health of these birds and their ability to reproduce are important because they indicate the effects of chemical, physical, and ecological stressors within the Great Lakes ecosystem.

These 16 chemical, physical, and biological indicators represent a consensus among Great Lakes scientific, technical, policy, and other experts as to which ones tell us the most about the ecological condition of the resource and the progress being made in protection and restoration.

3. ALIGNMENT WITH THE GREAT LAKES WATER QUALITY AGREEMENT

For the indicators to have the most value, they must be ones that will help measure progress toward achieving the general and specific objectives of the WQA. In order to assess alignment, the environmental indicators were compared with both sets of objectives and the annexes. The findings are presented below.

GENERAL OBJECTIVES The Waters of the Great Lakes should:	**ALIGNMENT CHECK**
(i) be a source of safe, high-quality drinking water;	TBD in Project 2 (HPAB)

(ii) allow for swimming and other recreational use, unrestricted by environmental quality concerns;	TBD in Project 2 (HPAB)
(iii) allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants;	PBTs in Biota Also TBD in Project 2 (HPAB)
(iv) be free from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms, through direct exposure or indirect exposure through the food chain;	Chemicals of Mutual Concern • PBTs in Biota • CMCs in Water • Atmospheric Deposition Also TBD in Project 2 (HPAB)
v) support healthy and productive wetlands and other habitats to sustain resilient populations of native species;	Coastal Wetlands • Extent of coastal wetlands • Composition/quality of wetlands
(vi) be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem;	Algae • Nutrient concentrations and loadings • Harmful algae • Nuisance algae
(vii) be free from the introduction and spread of aquatic invasive species and free from the introduction and spread of terrestrial invasive species that adversely impact the quality of the Waters of the Great Lakes;	Aquatic Invasive Species • Status (presence, number, distribution) • New Species (number, rate) • GAP Terrestrial
(viii) be free from the harmful impact of contaminated groundwater; and	Groundwater
(ix) be free from other substances, materials or conditions that may negatively impact the chemical, physical or biological integrity of the Waters of the Great Lakes;	Chemical substances are addressed; Conditions addressed by water level and temperature
ANNEXES	
1. Areas of Concern	Indicators related to BUI's
2. Lakewide Management	Provides indicators relevant to defining status and tracking progress lake by lake
3. Chemicals of Mutual Concern	Chemicals of Mutual Concern • PBTs in Biota • CMCs in Water • Atmospheric Deposition
4. Nutrients	Algae • Nutrient concentrations and loadings • Harmful algae • Nuisance algae

5. Discharges from Vessels	PARTIAL GAP • Invasive Species and • Chemicals of Mutual Concern are addressed
6. Aquatic Invasive Species	Invasive Species • Status of Existing (presence, number, distribution) • New Species (number, rate)
7. Habitat and Species	Indicators address the following themes • Abundance/Distribution of Birds • Coastal Wetlands Extent/Quality/Composition • Coastal habitat • Fish Species of Interest • Land Cover and Habitat • Lower Food Web (offshore) Productivity/Health • Tributary Physical Integrity/Health
8. Groundwater	Groundwater
9. Climate Change Impacts	• Water Level and • Water Temperature
10. Science D. Ecosystem Indicators	Addressed as above

Clearly, the selected indicators closely align with the objectives of the WQA and will serve as excellent measures for progress in the future.

4. <u>CONCLUSION</u>

The Great Lakes community in the United States and Canada has invested billions of dollars over the past 40 years to protect and restore the resource and clearly there has been significant progress. Communicating that progress and the current condition of the lakes, however, is difficult because there has not been consensus on what constitute the most important indicators. With the 16 indicators listed above, the IJC is in a good position to work with the federal governments in both countries and other key stakeholders to characterize the resource and measure progress. With agreement in place, the Great Lakes community will be in a much better position to set priorities, develop management approaches, set goals, measure progress, and communicate with the public, elected officials, and other leaders in the region.

5. NEXT STEPS

Many additional steps are necessary before a set of indicators can be fully operational. The key actions that must be taken in the near term include:

-Complete selection of human health indicators (Project 2)

-Articulate each indicator in a form that can be measured (Detailed Report)

- Provide ecosystem and human health indicators to the Council of Great Lakes Research Managers to determine how monitoring of the indicators will be accomplished

- Provide ecosystem and human health indicators to Environment Canada and the U.S. Environmental Protection Agency so they can establish and maintain indicators, based on these, through SOLEC and with stakeholder involvement, as called for in Annex 10, Part D. of the WQA

- Encourage Environment Canada and the U.S. Environmental Protection Agency to work with the IJC to set goals and endpoints for the indicators in the Great Lakes where they do not exist already

- Begin the process of developing a report on the progress of the United States and Canada in implementing the WQA

ATTACHMENT A - CRITERIA

Ecological Indicators Workgroup - Selection of Criteria

Criteria	
Category	Indivdual Criteria
Usefulness	Compatable with Overall Framework - Either physical, biological or chemical integrity
	Understandable - Meaning and relevance is readily understood
	Diagnostic - Interpretation of the data is unambiguous
	Participatory - Developed with the participation of a broad range of stakeholders
	Redundancy - Not redundant with other metrics
	Relevance - Widely relevant in the Great Lakes
	Integration Can be integrated into SOLEC DPSIR framework and ecosystem models
Data Quality	High quality - Measurement error is low, measures are repeatable
	Low signal to noise - A modest number of samples could detect a trend
	Sensitive - Measurable across the range
	Robust - Not subject to interferences/false positives
	Objective - As opposed to subjective or dependent on the observer
	Standard - Analysis is performed in the same way in different laboratories
Availability	Historical - Records available
	Spatial Coverage - Adequate spatial coverage exists or could be if more work done
	Accessible - Data can be obtained and made available quickly. - Not requiring lengthy analysis and interpretation
Practicality	Low cost - Relatively inexpensive to collect and analyze
	Exisits - Is being collected or could be added to existing sampling programs
	Non-destructive - Does not threaten species at risk, damage the environment, etc…

ATTACHMENT B - WORKSHOP

An expert consultation workshop was held in Windsor, Ontario on September 5-7, 2012. The principle objective of the workshop was to develop a concise set of core environmental indicators. Participants at the workshop (Attachment E) included scientists with expertise in various disciplines and a diversity of affiliations. A summary of the diversity represented at the workshop is presented in the following tables:

Area of Expertise	Canadian	United States	Total
Biological	5	10	15
Biological – Human Health	1	1	2
Chemical	5	3	8
Physical	2	6	8
General	2	12	14

Affiliation	Canadian	United States	Total
Academia	4	8	12
Government	9	10	19
Industry/Consultant	1	5	6
NGO	1	6	7
First Nation/Tribal		3	3

Prior to the workshop the participants were requested to read a series of selected documents on environmental indicators .They were also asked to complete a pre-workshop assignment by developing a preliminary list of potential indicators. Over 75% of the participants completed the assignment; the findings were compiled and used as the basis for discussions at the workshop .

During the workshop, plenary sessions were held on the opening day. On subsequent days, a combination of plenary and breakout sessions were held to discuss physical, chemical, and biological indicators. Final consensus on the selection and initial prioritization of the environmental indicators was reached in plenary.

ATTACHMENT C – FINDINGS

The workshop participants reached consensus on 22 environmental indicators which addressed the physical (6), chemical (6), and biological (10) integrity of the Great Lakes ecosystem. Analysis of the selected indicators relative to the agreed criteria for indicator selection indicates that most of them met most of the criteria. Further, comparison of the selected indicators with the DPSIR framework suggested that the majority fall in the categories of State or Impact indicators. A more detailed analysis is presented in the more detailed technical report.

A voting process was used to further prioritize the indicators in an attempt to identify the "top" core indicators with each workshop participant allowed to submit 10 votes. The results, in order of priority with number of votes in parentheses, are presented below.

Top Priority Indicators

1. **Nutrient Concentrations and Loadings**: [31 votes]
   a) Phosphorus (Total and SRP) offshore and nearshore concentrations in lakes
   b) Phosphorus loads (Total and SRP) to the lakes
2. **Fish species of interest**: [28]
   Condition, population, and natural reproduction of fish species of interest (e.g., sturgeon, walleye, lake trout, potentially other top predators) [28]
3. **Harmful algae:** (extent, duration, frequency) [14] [both algae = 27]
4. **Nuisance algae:** (extent, duration, frequency, density) [13]
5. **Lower food web productivity/health:** [26]
   a) Phytoplankton community structure and biomass
   b) Benthos abundance and diversity
   c) Preyfish abundance and diversity
6. **Coastal wetlands**: Extent, composition/quality of coastal wetlands [25]
7. **PBTs in Biota:** [25]
   a) PBTs in whole fish (sport or forage fish?)
   b) PBTs in fish-eating birds (herring gull, bald eagle, cormorant, tern)
8. **Aquatic invasive species: [25]**
   Status of aquatic invasive species (presence, number, and distribution)
9. **Tributary physical integrity:** [21]
   a) Tributary connectivity
   b) Index of hydrologic alteration (including groundwater quantity)
   c) Sediment delivery
10. **Land cover and conversion index**: [18]

Medium Priority Indicators

11. **Abundance and distribution of fish-eating and colonial nesting birds**: [10 votes]
    a) Eagle, osprey, herons;
    b) Should enable assessment of chemical effects as well as ecological
12. **Chemicals of mutual concerns in water**: [10]
    Concentrations of water soluble chemicals of mutual concern (e.g., PPCP)
13. **Coastal habitat**: [8]
    Percentage and distribution of hardened shoreline and type of armoring
14. **Water level**: [9]
    Min/max, seasonable variability, change from historic record

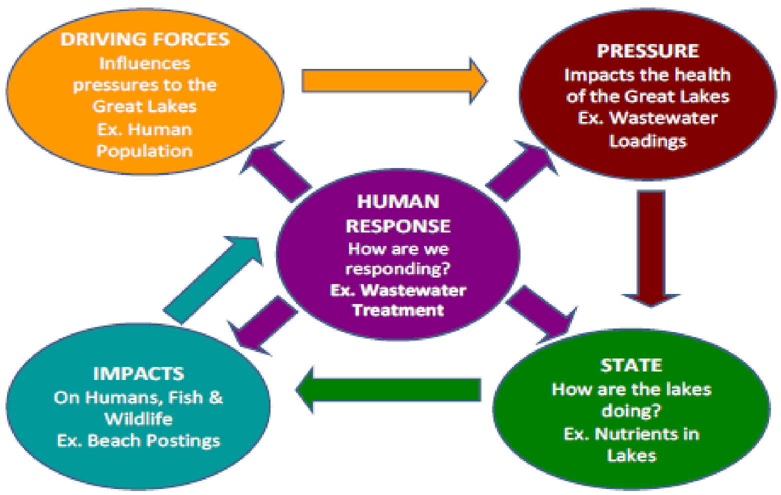
15. **Water temperature**: [7]
    Surface water temperature; min/max, seasonal variability; timing of onset of thermal stratification; ice extent and duration
16. **Air deposition**: [7]
    Net atmospheric deposition of toxics
17. **New invasive species**: (number, rate) [7]
    a) Invasive species introductions (number, rate)
    b) Existing high-risk invasive species status (presence, distribution)

__Lower Priority Indicators__

18. **Water Chemistry**: Lakewide average concentrations of chloride and other major ions [3]
19. **Wetland fish index** [1]
20. **Wetland bird index** [1]
    (NB, these two may be already covered with “Coastal Wetlands” indicator)
21. **Groundwater quality**: Groundwater quality measure [0]
22. **Biodiversity status report:** extracts information from other physical and biological indicators already established [0]

ATTACHMENT D - FRAMEWORK

Much work has been done by SOLEC in evaluating and refining the organizational and conceptual frameworks for indicator selection. The Work Group on Environmental Indicators reviewed this information and agreed to use the same DPSIR (Driving forces, Pressure, State, Impact, Response) Framework as a reference.



The DPSIR framework is an underlying tool to aid in the selection, organization, and reporting on indicators, which allows decision makers to understand the linkages between the conditions of the ecosystem, pressures on the ecosystem, and how human activities are related. The Work Group further decided that for the purposes of this project and expert consultation workshop, that priority be given to state and impact indicators which define the chemical, physical, and biological integrity of the Great Lakes ecosystem.

ATTACHMENT E – WORKSHOP PARTICIPANTS

Participants list for ecosystem indicator workshop held during September 5 - 7, 2012

Peter Annin Univerity of Notre Dame	**Gary Klecka** The Dow Chemical Company (Retired)
Bill Bowerman University of Maryland	Roger Knight Great Lakes Fishery Commissioin
Joel Brammeier Alliance for the Great Lakes	Gail Krantzberg Mcmaster University
Alan Burton Univeristy of Michigan	John Lawrence Environment Canada
Gavin Christie Fisheries and Oceans Canada	Scudder Mackey Scudder Mackey and Associates
Jan Ciborowski University of Windsor	Bill Mattes Great Lakes Indian Fish and Wildlife Commission
Steve Davis NRCS - USDA (Ohio)	Michael Murray National Wildlife Federation
Gary Dawson Consumers Energy	Victoria Pebbles Great Lakes Commission
Conrad Debarros Ontario Ministry of the Environment	Dale Phenicie Council of Great Lakes Industries
John Dellinger Concordia University Wisconsin	Jen Read Michigan Sea Grant - GLOS
Joe DePinto LimnoTech	Jeff Ridal St. Lawrence River Institute of Environmental Sciences
Scott Dyer The Procter & Gamble Company	Karen Rodriguez US EPA
Frank Ettawageshik United Tribes of Michigan	Don Scavia University of Michigan
Molly Flanagan Joyce Foundation	Kevin Shafer Milwaukee Metropolitan Sewerage District
Valery Forbes Univeristy of Nebraska	Mike Shantz Environment Canada
Norm Granneman USGS	Howard Shapiro Toronto Public Health
Drew Gronewold NOAA	Eric Smith Virginia Tech
Suzanne Hanson Minnesota Pollution Control Agency	Scott Sowa The Nature Conservancy
Paul Horvatin US EPA	**William D Taylor** University of Waterloo

Rob Hyde Environment Canada	Mary Thorburn Ontario Ministry of the Environment
Don Jackson University of Toronto	**David Ullrich** Great Lakes St. Lawrence Cities Initiative
Lucinda Johnson University of Minnesota - Duluth	Don Uzarski Central Michigan University
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Note: Names in bold are leading authors of the report.