-TECHNICAL APPENDIX-

~ FIRST TRIENNIAL ASSESSMENT OF PROGRESS OF PROGRESS REPORT ON~

GREAT LAKES WATER QUALITY

INTERNATIONAL JOINT COMMISSION

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Prepared by
The International Joint Commission Pursuant to Article 7 (1) (k) of the 2012 Great Lakes Water Quality Agreement

NOVEMBER 28, 2017

FIRST TRIENNIAL ASSESSMENT OF PROGRESS REPORT ON GREAT LAKES WATER QUALITY

TECHNICAL APPENDIX

International Joint Commission

Prepared by the International Joint Commission to provide additional details, background, references and technical analysis tosupport the International Joint Commission's (IJC) assessment of progress pursuant to Article 7(1)(k) of the 2012 Great Lakes Water Quality Agreement

November 28, 2017

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List of Acronyms

The following is a list of common acronyms used in the Technical Appendix:

AIS	Aquatic Invasive Species
ANS	Aquatic Nuisance Species
AOC	Area Of Concern
BSDG	Binational Strategy Development Group
BUI	Beneficial Use Impairment
BWM	Ballast Water Management
BWWG	Ballast Water Working Group
C3	Chemicals of Mutual Concern Sub-Committee
CAFO	Concentrated animal feeding operation
CEARA	Centre of Expertise for Aquatic Risk Assessment
CCME	Canadian Council of Ministers of the Environment
CMC	Chemicals of mutual concern
COA	Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health
CSMI	Cooperative Science and Monitoring Initiative
CSO	Combined Sewer Overflow
CWA	Clean Water Act
DDT	dichlorodiphenyltrichloroethane
DFO	Fisheries and Oceans Canada
DRP	Dissolved reactive phosphorus
DWQS	Drinking water quality standards
DWSP	Drinking Water Surveillance Program
EC3	Extended Sub-Committee
ECCC	Environment and Climate Change Canada
EDRR	Early Detection & Rapid Response Network Ontario
EPR	Extended Producer Responsibility
GLANSIS	Great Lakes Aquatic Nonindigenous Species Information System
GLC	Great Lakes Commission
GLEC	Great Lakes Executive Committee
GLEEM	Great Lakes Environmental Effectiveness Metric
GLERS	Great Lakes Ecological Reserve System
GLFC	Great Lakes Fisheries Commission
GLMRIS	Great Lakes Mississippi River Interbasin Study
GLNPO	Great Lakes National Program Office
GLPC	Great Lakes Phragmites Collaborative
GLPF	Great Lakes Public Forum
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Agreement
GIN	Groundwater Information Network
HABs	Harmful Algal Blooms
HBCD	Hexabromocyclododecane
HPAB	Health Professionals Advisory Board

IAGLR	International Association for Great Lakes Research
IAS	Invasive Alien Species
IJC	International Joint Commission
IMO	International Maritime Organization
INAC	Indigenous and Northern Affairs Canada
ITT	Identification Task Team
LAMP	Lakewide action management plan
LEEP	Lake Erie Ecosystem Priority
LSBP	Lake Superior Binational Program
MOECC	Ontario Ministry of Environment and Climate Change
NAS	Nonindigenous Aquatic Species
NOAA	National Oceanic and Atmospheric Administration
OMNRF	Ontario Ministry of Natural Resources and Forestry
PAC	Public Advisory Council
PBDEs	Polybrominated Diphenyl Ethers
PCBs	Polychlorinated Biphenyls
PROP	Progress Report of the Parties
RAP	Remedial Action Plan
RCC	Research Coordination Committee (SAB)
SAB	Great Lakes Science Advisory Board
SBCI	Saginaw Bay Coastal Initiative
SPC	Science Priority Committee (SAB)
SDWA	Safe Drinking Water Act
SOGL	State of the Great Lakes
SOGLHR	State of the Great Lakes Highlights Report
SOGLR	State of the Great Lakes Report
SOLEC	State of the Lakes Ecosystem Conferences
SSO	Sanitary Sewer Overflow
SWAP	Source Water Assessment Program
SWPP	Source Water Protection Plan
TAP	Triennial Assessment of Progress
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USEPA	Environmental Protection Agency
USGS	United States Geological Survey
WHO	World Health Organization
WQB	Great Lakes Water Quality Board
ZDDP	Zero Discharge Demonstration Project

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Chapter 1 Introduction

1.0 Purpose and intended audience

1. Purpose of the technical appendix

The International Joint Commission (IJC or Commission) is a binational organization created by Canada and the United States in the *Boundary Waters Treaty of 1909* (the Treaty). Under the Treaty, the two countries cooperate to prevent and resolve disputes relating to the use and quality of many lakes and rivers along their shared border. The Great Lakes Water Quality Agreement (GLWQA or Agreement) assigns the IJC an independent advisory role in assessing progress, engaging the public and providing scientific and policy advice to help the two countries restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes.

The2017 Triennial Assessment of Progress (TAP) report is the IJC's first triennial assessment of progress under the authority of the 2012 GLWQA.This **Technical Appendix to the TAP Report**provides technical analysis,additional detail and references to support the assessment. The technical appendix is the first of two appendices that accompany the TAP report. The second is the **Summary of Public Input on the Progress Report of the Parties**developed as a product of the public consultation process following the release of the Progress Report of the Parties (PROP) in September 2016 and the Draft TAP report in January 2017.

Article 7.1 (k) of the GLWQA charges the IJC with the responsibility of providing to the Parties, in consultation with the Boards established under Article 8, a triennial "Assessment of Progress Report" that includes:

> (i) a review of the Progress Report of the Parties;
>
> (ii) a summary of Public input on the Progress Report of the Parties;
>
> (iii) an assessment of the extent to which programs and other measures are achieving the General and Specific Objectives of this Agreement;
>
> (iv) consideration of the most recent State of the Lakes Report; and
>
> (v) other advice and recommendations, as appropriate

In addition to providing the technical information and scientific basis for the Triennial Assessment of Progress, this appendix includes background information on process and history for the first triennial assessment that can serve as context for subsequent triennial reports.

2. Audience

The technical appendix is written for a technical audience, that is scientists, engineers, and resource managers who may wish to get detailed information on one or more topics presented in the TAP report. The primary audience of the TAP Report and its appendices are the federal

governments of Canada and the United States as parties to the GLWQA. The report and appendices are also intended to be useful for the Great Lakes public including various other levels of government, nonprofit environmental organizations, academia, private industry, and all citizens who care about the well-being of the lakes.

The IJC has stated that its Assessment of Progress reports are intended to provide information and advice to help guide decisions. The information and advice in the TAP report can provide a basis for informed environmental management decisions affecting the Great Lakes basin, as well as informing and educating the public about this dynamic and fragile ecosystem.

Recognizing that the audience for the past 16 Biennial Reports included a wide range of readers from technical experts to those with general interests, the language and style of the TAP report is aimed towards an environmentally-informed public. The 16th Biennial Report (IJC, 2013) and several previous reports provided a summary report accompanied by a more technical report to support the findings. The technical reports provided additional detail for a scientific audience. For example, the 16th Biennial Report has one technical chapter for each indicator discussed and contains hundreds of references.

The same approach is used for this technical appendix, in that it contains much more detail and references to support the findings and recommendations that are presented in the more concise Triennial Assessment Report. Because public engagement is an important task assigned to the IJC under the GLWQA, the IJC determined that providing the summary of public comments on the PROP as a separate appendix would enable all aspects of the public hearings to be fully addressed and properly documented without any constraint on the length of the appendix. The final 2017 TAP report along with the Public Comment Appendix and this Technical Appendix collectively form one IJC product.

1.1 History of Great Lakes Water Quality Agreement

1. Background

The original GLWQA provided a strong framework for binational action towards restoring the physical, chemical and biological integrity of the Great Lakes when it was first signed in 1972. Significant changes to the agreement were instituted in 1978, 1983 and 1987. However, in 2006, the Parties launched the most recent review of the agreementbecause the agreement had not been updated for 19 years and was outdated.

The 2012 GLWQA was born from a long, rigorous and deliberate collaborative process that began with open public and expert consultations and agency reports that informed the formal US – Canadian negotiations that followed. A robust public consultation on the review of the 1987 GLWQA was orchestrated by the IJC at the direction of the Parties, resulting in over 4000 comments and input summarized in a synthesis report (IJC, 2006a) . During this period, the IJC published a special report transmitting its advice to the governments on their review of the GLWQA (IJC, 2006b).

Environmental non-governmental groups were also influential and were strong advocates for a new and effective, action-oriented GLWQA. The governments formed an Agreement Review

Committee consisting of nine binational, collaborative working groups (including the environmental groups) to review each section of the GLWQA. The committee also organized a Governance and Institutions workshop and synthesized the findings, results and recommendations in their September 2007 report to the Great Lakes Binational Executive Committee: *Review of the Canada – United States Great Lakes Water Quality Agreement* (Agreement Review Committee,2007).

Extensive bilateral negotiations were conducted between representatives of the two governments and the amended agreement was completed and signed on September 7, 2012, and entered into force on February 12, 2013 (https://binational.net/glwqa-aqegl).

The 2012 Agreement respondedtomuch of the advice given to the governments. New annexes covering aquatic invasive species and climate change impacts were welcome additions; elements carried over from the previous agreements were given a new focus for action by including time-bound commitments.

2. IJC reports on the GLWQA

Since the GLWQA was revised in 1978, the IJC has been assigned the responsibility of assessing and reporting on the progress made toward achieving the objectives of the Agreement and the effectiveness of programs and measures used under the agreement. The IJC issued 16 biennial reports between 1980 and 2013. This requirement to assess progress continues under the 2012 GLWQA, though the reporting period was extended to a triennial assessment.

Biennial Reports have addressed many important issues related to the physical, chemical and biological integrity of the Great Lakes, including persistent toxic substances, aquatic invasive species and many others. The last several Biennial Reports were devoted to: the challenge of accountability (13th report – IJC, 2006c); wastewater treatment and reduction of nutrient loadings from municipal sources (14th report – IJC, 2009); and the 15th(IJC, 2011) discussed issues related to water quality in the nearshore zone. In anticipation of a revised GLWQA, the 16th Biennial Report (IJC, 2013), assessed progress under the agreement from 1987 to 2012 and marked the return to undertaking a more comprehensive assessment. This last biennial report used seven indicators of chemical integrity, five indicators of biological integrity, two of physical integrity, and two performance indicators to assess progress over the past 25 years. The 16 indicators used in the report were selected by IJC staff based on relevance to GLWQA objectives and the availability of data.

The 16th Biennial Report had key recommendations, including that the governments select a set of core indicators related to the objectives of the GLWQA, monitor their status and report on trends over time. The Parties adopted this recommendation and restructured its State of the Lakes reporting into nine indicators, one for each of the General Objectives of the 2012 GLWQA (Great Lakes Public Forum, 2016).

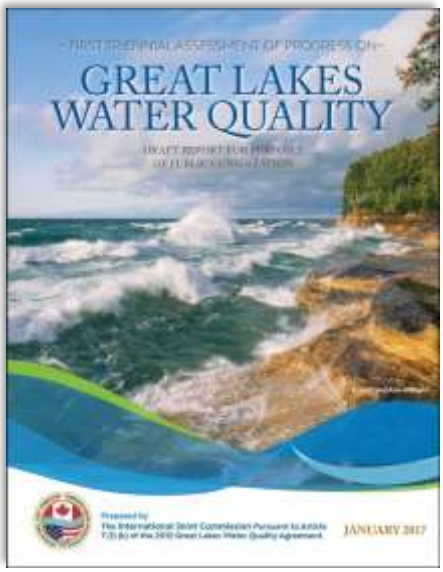
3. IJC advisory boards

The 2012 GLWQA prompted changes for both the governments and the IJC. To meet the challenges of the agreement, the IJC reconstituted its Great Lakes advisory boards – the Water Quality Board (WQB) and the Science Advisory Board (SAB) – to provide for a dynamic, inclusive and diverse membership. The IJC Health Professionals Advisory Board (HPAB) was also relied upon to provide additional support for human health related topics that are more prominently addressed in the new GLWQA. All of the advisory boards were consulted on the objectives and process associated with conducting the triennial assessment of progress. Advisory board advice, reports and projects helped to inform the IJC's advice and recommendations to the governments and were key elements in helping the IJC fulfill its responsibilities to assess the government's progress under the GLWQA.

1.2 Approach and methods

1. TAP report preparation

To develop the TAP, a planning workshop was held with IJC advisory board co-chairs and staff to develop a comprehensive report process. Participants focused on developing the overall approach, steps and roles that would guide the development process for the Triennial Report and its technical appendix.Periodic consultations with boards on this technical appendix were held, included a planning workshop, review of the scoping documents, discussions at board meetings, webinars, surveys, and commissioner - co-chairs meetings. In addition, a dialog was established between IJC staff authors and individual members of the IJC's WQB, SAB and HPAB to consult on sections of the technical appendix as they were being developed. All Great Lakes Advisory Boards then had an opportunity to review and comment on the draft Technical Appendix.Commissioners reported on the development of the report with the Great Lakes Executive Committee (GLEC) leadership at each IJC semi-annual meeting. The IJC released a draft TAP report and a draft Technical Appendix in January 2017 (IJC, 2017a, b). A public consultation plan was developed to ensure that public input on the PROP and the IJC's draft TAP report would be documented and considered in the development of the final TAP report and the final technical appendix.



Cover of the draft report of the first Triennial Assessment of Progress on Great Lakes Water Quality by the International Joint Commission, January 2017 (IJC, 2017a).

Input and feedback from everyone who commented on the draft TAP report and the draft Technical Appendix was considered in the development of the final report and appendices. The TAP report and appendices also provide information about the nature and extent of the public consultation process as a mechanism for improving the assessment process. Commissioners reviewed the draft technical appendix, considered IJC advisory board reports,other reports, public input and advisory board review of the draft report in the preparation of their final TAP report.

2. Emphasis on General Objectives

In contrast to the PROP, which is organized around the Annexes of the GLWQA, the IJC organized its assessment along the nine General Objectives of the agreement. This is in accordance with the direction to the Commission to assess the extent to which programs and measures are meeting agreement objectives.Progress on achieving the general objectives is affected by activities conducted by more than one annex. For example, the first three objectives to have drinkable, swimmable and fishable Great Lakes waters are directly or indirectly impacted by all of the work being done under the Annexes. By placing the focus on the General Objectives of the GLWQA like the State of the Great Lakes Report, and assessing progress based on indicators, this third-party review is able to take a more holistic approach to evaluating the progress of the Parties across all related Annexes.

3. Principles and approaches

One of the laudable features of the GLWQAis its inclusion of 16 guiding principles and approaches, ranging from accountability to zero discharge. The IJC has rendered its assessment

with these principles and approaches in mind. In particular, the Commission supports the approach of prevention, which the GLWQA defines as "anticipating and preventing pollution and other threats to the quality of the Waters of the Great Lakes to reduce overall risks to the environment and human health."An emphasis on prevention would have forestalled some of the most serious harms the Great Lakes ecosystem has suffered, such as the introduction of the zebra mussel, which was known to be a threat years before its arrival. The IJC is optimistic that adherence to the GLWQA's guiding principles and approaches will foster healthier and more resilient Great Lakes. The IJC hopes that this assessment stimulates a continued vigorous dialogue about progress and that it supports ideas and action to further strengthen Great Lakes protection and restoration.

4. Programs and measures

The IJC is tasked with assessing programs and measures to achieve the General Objectives of the GLWQA. These programs and measures are addressed in Article 4, as well as in each Annex. In fact, descriptions of programs and measures comprise approximately 25 percent of the text in the GLWQA. This presents a wide range of activity to assess. Table 1.1 provides a list of the key programs and measures.

Background for the List of Programs and Other Measures (Article 4 Implementation, GLWQA)
1. The Parties, in cooperation and consultation with State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, watershed management agencies, other local public agencies, and the Public, shall develop and implement programs and other measures:

(a) to fulfill the purpose of this Agreement, in accordance with the Principles and Approaches set forth in Article 2; and

(b) to achieve the General and Specific Objectives set forth in Article 3.

2. These programs and other measures shall include, but are not limited to:

(a) pollution abatement, control, and prevention programs for:

(i) municipal sources, including urban drainage;

(ii) industrial sources;

(iii) agriculture, forestry, and other land use;

(iv) contaminated sediments, and dredging activities;

(v) onshore and offshore facilities, including the prevention of discharge of harmful quantities of oil and hazardous polluting substances;

(vi) sources of radioactive materials; and

(vii) other environmental priorities that may be identified by the Parties;

(b) aquatic invasive species programs and other measures to:

(i) prevent the introduction of aquatic invasive species;

(ii) control or reduce the spread of existing aquatic invasive species; and

(iii) eradicate, when feasible, existing aquatic invasive species;

(c) conservation programs to:

(i) restore and protect habitat; and

(ii) recover and protect species;

(d) enforcement actions and other measures to ensure the effectiveness of the programs described in (a), (b) and (c); and

(e) research and monitoring programs to support the commitments made in this Agreement.

Table 1.1 Key programs and measures listed in each of the ten annexes of the GLWQA.

Key Programs and Measures Described in Annexes to the Agreement
#1- Areas of Concern
Restore Beneficial Uses
Remove BUI Designation When Criteria Met
Develop, Implement, & Communicate Remedial Action Plans
Delist Areas Of Concern (AOCs)/Designate as AOC in Recovery
#2- Lakewide Management
Establish Ecosystem Objectives
Assess Existing Scientific Info for Current and Future Potential Threats
Identify Need for Government and Public Action to Address Threats
Develop Lake Binational Strategies for Substance Objectives
Develop Integrated Nearshore Framework
#3- Chemicals of Mutual Concern
Identify Chemicals of Mutual Concern
Prepare Binational Strategies for Chemicals of Mutual Concern
Develop and Apply Domestic Water Quality Standards in Law
Reduce Anthropogenic Releases of Designated Chemicals
Evaluate Effectiveness of Pollution Prevention Measures
#4- Nutrients
Develop & Implement Regulations to Reduce Phosphorus Loading (Urban, Industrial, Agriculture, Residential)
Evaluate Practices to Manage Phosphorus Input
Develop Lake Erie Action Plan to Meet Substance Objectives
Identify Priority Watersheds for Nutrient Control
#5- Discharges from Vessels
Implement Laws & Regulations for Vessel Discharges
Adopt Programs for Prevention of Oil and Hazardous Substance Discharges
Provide Reception Facilities for Disposal of Vessel Wastes
#6- Aquatic Invasive Species
Undertake Measures to Prevent Ballast Water Release of Aquatic Invasive Species
Conduct Risk Assessments for Pathways for Introduction & Spread of AIS
Develop Regulations & Management Strategies Based on Risk Assessments
Undertake Education & Outreach Efforts
Implement Early Detection & Rapid Response Initiative
#7- Habitat and Species
Conduct Baseline Survey of Existing Habitats
Implement Conservation Strategies/Lakewide Action & Management Plans
Increase Public Awareness of Habitats & Conservation Efforts
#8- Groundwater
Publish Reports on Groundwater Science
Identify Science Priorities & Actions for Groundwater Protection
Coordinate Binational Activities to Assess & Protect Groundwater Quality
#9- Climate Change Impacts
Binational Communication of Science & Actions to Address Climate Change Impacts
#10- Science
Use Adaptive Management Framework for Science-Based Management
Undertake Monitoring to Address Environmental Concerns
Facilitate Information Sharing

For the purpose of this technical appendix, some of the programs and measures shown in Table 1.1 were assessed in a narrative form considering the degree of program implementation as observed by IJC staff and as reported by the governments in the Progress Report of the Parties. IJC staff also reviewed government programs and actions that are carried out in support of each General Objective.

1.3 Organization

The technical appendix of the IJC's Triennial Assessment of Progress report consists of six Chapters, based on the requirements of Article 7 (k) and the nine General Objectives of the GLWQA:

- *Chapter 1* provides background on the GLWQA and the approach to preparing the Triennial Assessment of Progress and this technical appendix.
- *Chapter 2* reviews the Progress Report of the Parties.
- *Chapter 3* discusses the process of public engagement and coordination.
- *Chapter 4* discusses the challenge of assessing and reporting on the condition of the Great Lakes using indicators and communicating the findings to the public. The chapters also reviews the State of the Great Lakes Report and provides suggested improvements for future reporting.
- *Chapter 5*of this reportpresents a comprehensive review and assessment of programs and measures undertaken in support of the nine General Objectives of the GLWQA, including work on indicators, national and binational programs. There are nine sections in Chapter 5, with one section corresponding to each of the nine general objectives of the Agreement.
- *Chapter 6* assesses key challenges that are critically important for making progress toward achieving the objectives of the GLWQA but that are not directly addressed in Chapter 4, including issues related to data availability and accessibility and future improvements to Great Lakes indicators.

The Triennial Assessment of Progress Report itself is structured in a similar manner, so that supporting details in this staff developed technical appendix may be easily referenced from the IJC's TAP.

1.4 References

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Chapter 2 Review of the Progress Report of the Parties

2.0 Introduction

1. Purpose

The GLWQA Article 7.1(k) assigns the IJC responsibility to provide to the Parties a triennial "Assessment of Progress Report" and specifies that the report should include a review of the Progress Report of the Parties (PROP). The production of a triennial PROP is a new commitment by the Parties under the 2012 Agreement. Article 5.2(e) specifies that the PROP shall document actions taken domestically and binationally in support of the Agreement and that the report shall be prepared in consultation with the Great Lakes Executive Committee. The government production of the PROP and the IJC's Triennial Assessment of Progress (TAP) report are key government accountability features under the 2012 Agreement. The production of the PROP report, in itself, is a major advancement in accountability under the 2012 Agreement.

Cover of Progress Report of the Parties released September 28, 2016
by the governments of Canada and the United States.

The purpose of this chapter is to reviewthe PROP. The chapter will present review criteria and then apply that criteria to the report. The review aims to assess how the well the PROP report meets the reporting requirements set out in the Agreement and how well applicable Agreement principles and approaches, accountability, adaptive management, coordination, and public engagement, are implemented. The chapter concludes with a summary of key findings from the review. The assessment of the extent to which programs and other measures presented in the PROP are achieving the objectives of the Agreement is presented in Chapter 5.

2. Accountability under the Great Lakes Water Quality Agreement (GLWQA)

Article 2.4 of the GLWQA sets out the principles and approaches that are to guide the Parties in their implementation of the Agreement. The first principle listed is accountability. Accountability is defined in the Agreement as establishing clear objectives; regular reporting made available to the Public on progress, and transparently evaluating the effectiveness of work undertaken to achieve the objectives of the Agreement.

In its 13th Biennial Report on Great Lakes Water Quality (IJC, 2006) , the IJC looked in depth at accountability under the Great Lakes Water Quality Agreement. Although that report looked specifically at accountability under the 1987 GLWQA, its approach and many of its findings and recommendations are applicable to the renewed 2012 Agreement. The 13th Biennial Report states that accountability is generally understood as an obligation to render an account for expected or agreed-upon performance. The Auditor General of Canada defines accountability as a relationship based on obligations to demonstrate, review and take responsibility for performance, both in terms of the results achieved, based on agreed expectations, and of the means used.

The Biennial Report goes on to state that "successfully implemented, accountability focuses action on end goals and ensures that promises are kept and commitments are honored. The best accountability frameworks specify measurable results, the actions to be taken, by whom and by when, how reporting back will occur and the consequences of inaction. Accountability encourages improved performance by learning from what works and what does not. Accountability so conceptualized is pivotal to achieving anything that is as complex and important as the goals of the Great Lakes Water Quality Agreement."

The PROP, the IJC review of the PROP in the TAP report and public input on the PROP, are not the only mechanisms for government accountability under the 2012 Agreement. Article 3.4 directs the Parties to publicly report on progress in achieving the General Objectives, Lake Ecosystem Objectives and Substance Objectives in the State of the Great Lakes Report and Lakewide Action and Management Plans (LAMPs), as well as the PROP. The IJC is directed to consider the most recent State of the Great Lakes (SOGL) report in this assessment of progress. Under Annex 1: Lakewide Management, the IJC has the opportunity to provide advice and recommendations when a LAMP report is issued. The IJC also has a role under Annex 1 of reviewing proposals to delist Areas of Concern (AOC) or redesignate them as Areas in Recovery. IJC review of LAMPs and AOC delisting reports are discussed in section 5.9.

3. Criteria for review of the Progress Report of the Parties

This review of the PROP aims to assess how well Agreement reporting requirements are satisfied by the PROP and how well applicable Agreement principles and approaches are implemented. Criteria for review of the PROP were designed to meet these aims. Relevant sections of the Agreement, followed by the associated review criteria, are presented in Table 2.1. . Reporting requirements for the PROP include specific details of what should be in the report, general reporting requirements and points of process. Accountability has been mentioned as the key principle to be implemented through PROP reporting. Other applicable principles and approaches that are applicable to the task of reporting include: adaptive management, coordination and public engagement. The assessmentsof the extent to which programs and measures described in the PROP are achieving the objectives of the Agreement are presented in Chapter 5.

Table 2.1: Criteria for Review of the Progress Report of the Parties

Great Lakes Water Quality Agreement			PROP Review Criteria
Article/Annex	**Sub Section**	**Text**	
Article 2: Purpose, Principles and Approaches	4(a)	The Parties shall be guided by the following principles and approaches in order to achieve the purpose of this Agreement: (a) accountability – establishing clear objectives, regular reporting made available to the Public on progress, and transparently evaluating the effectiveness of work undertaken to achieve the objectives of this Agreement;	Does the report show progress relative to stated objectives? Does the report show the evaluation of effectiveness of work undertaken or provide sufficient information for others to do so?
Article 2: Purpose, Principles and Approaches	4(b)	(b) adaptive management - implementing a systematic process by which the Parties assess effectiveness of actions and adjust future actions to achieve the objectives of this Agreement, as outcomes and ecosystem processes become better understood;	Does the report provide a basis for adaptive management (perhaps by showing what has worked and what has not and demonstrating responsiveness in implementation)? If not, does it provide a basis for the others to assess the need for corrective action?
Article 2: Purpose, Principles and Approaches	4(e)	(e) coordination - developing and implementing coordinated planning processes and best management practices by the Parties, as well as among State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, watershed management agencies, and local public agencies	Does the report show howthe Parties, have worked with State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, watershed management agencies, and local public agencies to develop and implement coordinated planning processes and best management practices?
Article 2: Purpose, Principles and Approaches	4(k)	(k) Public engagement - incorporating Public opinion and advice, as appropriate, and providing information and opportunities for the Public to participate in activities that contribute to the achievement of the objectives of this Agreement;	Does the report present information in a publicly accessible manner?
Article 3: General and Specific Objectives	4. Reporting	The Parties shall publicly report, in the Progress Report of the Parties, State of the Great Lakes Report and Lakewide Action and Management Plans, on the progress in achieving the General Objectives, Lake Ecosystem Objectives and Substance Objectives.	Does the report discuss progress in achieving the general objectives, lake ecosystem objectives and substance objectives?
Article 5: Consultation, Management and Review	2(e)	The Parties hereby establish a Great Lakes Executive Committee to help coordinate, implement, review and report on programs, practices and measures undertaken to achieve the purpose of this Agreement: (e) the Parties shall prepare, in consultation with the Great Lakes Executive Committee, a binational Progress Report of the Parties to document actions relating to this Agreement, taken domestically and binationally. The first such report shall be	Was the report prepared in consultation with the Great Lakes Executive Committee? Does the report document actions taken domestically and binationally? Was the report provided to the public before the Great Lakes Public Forum?

		provided to the Public and the Commission before the second Great Lakes Public Forum, and subsequent reports shall be provided before each subsequent Great Lakes Public Forum.	
Annex 1: Areas of Concern	C. Reporting	The Parties shall report on progress toward implementation of this Annex every three years through the Progress Report of the Parties, including: 1. a listing of current AOCs; 2. the status of BUIs in each AOC; 3. the actions completed or initiated in each AOC during the reporting period; and 4. the remaining actions required in each AOC for the removal of the designation as an AOC.	Does the report include these details related to AOCs?
Annex 3: Chemicals of Mutual Concern	D. Reporting	The Parties shall report on progress toward implementation of this Annex every three years through the Progress Report of the Parties. The report shall include: 1. an identification of chemicals of mutual concern; and 2. the status of initiatives to develop binational strategies to address issues involving chemicals of mutual concern and the status of implementing binational strategies for chemicals of mutual concern.	Does the report include these details related to chemicals of mutual concern?
Annex 4: Nutrients	F. Reporting	The Parties shall report on progress toward implementation of this Annex every three years through the Progress Report of the Parties. This report shall document: 1. Lake Ecosystem Objectives and Substance Objectives; 2. implementation of the binational strategies and domestic action plans; 3. changes in phosphorus loading and concentrations; and 4. progress toward achievement of the Substance Objectives for phosphorus concentrations, loading targets and loading allocations apportioned by country, established under to this Annex.	Does the report include these details related to nutrients?
Annexes 1-10	Reporting	The Parties shall report on progress toward implementation of each Annex every three years through the Progress Report of the Parties.	Does the report set out progress in the implementation of each Annex?

2.1 Review

The PROP reporting requirements include details of what should be in the report, general reporting requirements and points of process. Most notably, the report is required to document actions relating to the Agreement that have been taken domestically and binationally.

Does the report document actions taken domestically and binationally?

Yes, the PROP reports on actions taken domestically and binationally. This is, indeed, the key accomplishment of the PROP. The report presents a clear and readable catalogue of actions related to the articles and annexes of the Agreement.

Does the report discuss progress in achieving the general objectives, lake ecosystem objectives and substance objectives?

In the Agreement, the Parties committed to reporting on progress in achieving the general and specific objectives of the Agreement, however, this commitment is spread across three documents, the PROP, the State of the Great Lakes Report (SOGLR) and Lakewide Action and Management Plans (LAMP) reporting. Relative to this commitment, the Parties describe the PROP as "an overview of binational and domestic activities that have contributed to the achievement of GLWQA objectives" (Governments of Canada and the United States, 2016). Progress in achieving the general objectives is primarily discussed in the SOGL report as opposed to the PROP. Lake ecosystem objectives and substances objectives have yet to be developed except for some objectives related to nutrients in Lake Erie, so progress in lake ecosystem and substance objective achievement is not yet reported. This emphasizes the importance of establishing them early in the next triennial cycle so the progress can be assessed in 2020.

Reporting on progress relative to the General Objectives of the Agreement is presented in the 2017 SOGLR using indicators related to each of the objectives (Governments of Canada and the United States, 2017). The SOGLR is discussed further in Chapters 4 and 5. This reporting of progress by the Parties is essential information for the IJC's assessment of progress. However, despite publication of the PROP in September 2016, the SOGL Highlights report was not published until June 2017 and the accompanying Technical Report was not published until August 2017. The PROP on its own provides only a partial basis for the assessment of progress and it needs the SOGLR as a companion document. The time lag between the PROP and the SOGLR makes it difficult for readers of the PROP to grasp the progress towards each general objective and created a substantial impediment to the IJC in conducting a thorough assessment of progress following the issuance of the PROP. Coordinated release of the PROP and SOGLRs and cross-references or links between the PROP and SOGLR would yield a clearer and timelier overall product. The coordinated release would also enable the public and the IJC to perform a more comprehensive and timely review.

Comparing the PROP to the SOGLR, the connection between binational and domestic activities and achievement of GLWQA objectives is clearest where there is a direct link between the annexes (reported in PROP) and the GLWQA general objectives (reported in the SOGLR). As there are no GLWQA annexes related to the drinking water, recreational waters or fish consumption objectives, actions related to the achievement of these objectives is less clear.

Does the report show progress relative to (other) stated objectives?

The general objectives, lake ecosystem objectives and substance objectives of the GLWQA are important objectives for continuing work on the Great Lakes. However, they give limited insight into other objectives, stated as implementation goals and management actions for a triennial cycle. Possible objectives against which the progress of the governments could be measured include commitments made in the 2012 GLWQA and the priorities for science and action that the governments are required to develop under Article 5.2.

The PROP clearly reports against commitments made in the 2012 Agreement. This is effective in some cases, particularly where progress is reported relative to specific, time-bound commitments. For example, the commitment in annex 4 that the Parties shall by 2016, "develop Substance Objectives for phosphorus concentrations for nearshore waters, including embayments and tributary dischargefor each Great Lake" presents a clearer, time-bound objective than the commitment in annex 9 the Agreement that the Parties will "coordinate binational climate change science activities (including monitoring, modeling and analysis) to quantify, understand and share information that Great Lakes managers need to address climate change impacts…" In these cases, where Agreement commitments are more general, assessment of the appropriateness of the extent, depth and timing of the task(s) undertaken is more difficult and there is less accountability for the degree of progress made.

Moving forward, with each three-year work cycle of Agreement implementation, there will be fewer specific time-bound commitments in the Agreement to report against. For example, apart from cyclical commitments (such as the requirement for the Parties to issue a LAMP for each Great Lake every five years) there is only one specific time-bound commitment written into the Agreement for years after 2016 (the commitment to develop binational phosphorus reduction strategies and domestic action plans for Lake Erie by 2018). As the existing milestones are met, specific deadlines dwindle and only general Agreement commitments will remain. Therefore, other mechanisms for short-term objective setting will be required, if the governments are serious about maintaining accountability for their progress under the Agreement.

Priorities for Science and Action set at the beginning of each three-year work cycle offer additional objectives against which to measure progress in implementation and action. The PROP would benefit from addressing priorities for the 2014-2016 work cycle as directly and clearly as the time-bound commitments in the Agreement. However, the 2014-2016 priorities for science and action were not mentioned in the PROP at all, except for the fact that the commitment to set the priorities was met.

Reporting in the PROP against these priorities would help the IJC and the public to evaluate government actions relative to expectations. For example, the PROP's report on the Chemicals of Mutual Concern (CMC) Annex fails to mention that progress falls well short of the Annex's 2014-2016 priorities for action that included the development of binational strategies for the first set of CMCs by summer 2015 (only two draft strategies had been developed by October 2017). However, these priorities will only be helpful for evaluating progress if, as per this example, the priorities are specific and time bound. Unfortunately, the Parties' proposed 2017-2019 priorities for science and action lack specific milestones for proposed CMC activities, and a number of other annexes.

Priorities for science and action can also be used by the governments to show how they will prioritize activities that are most critical, both between and within the GLWQA Annexes and objectives. This would be a further step in achieving, clear, transparent, effective and accountable stewardship.

Another type of objective against which progress could be measured relates to the status and trends of the SOGL indicators. These would be longer term and perhaps more aspirational than priorities for action in a triennial cycle. However, they could be clearly defined and more immediately achievable than the GLWQA's general objectives, for example to achieve an improving trend in a particular indicator by a set date.

Does the report show the evaluation of effectiveness of work undertaken? Does the report the report provide a basis for adaptive management (perhaps by showing what has worked and what has not and demonstrating responsiveness in implementation)? If not, does it provide a basis for the others to make these assessments?

The PROP does not show any evaluation of effectiveness of work undertaken or provide a basis for adaptive management. The PROP paints a very positive picture of Agreement implementation. Although that picture is oft times justified, transparency would be improved if the report included discussion of where past or current programs have fallen short of bureaucratic or outcome expectations. In addition to making the PROP a more honest and transparent report of progress, this discussion would give the governments the opportunity to show how they are implementing an adaptive management approach by assessing the effectiveness of actions and adjusting those actions to achieve the objectives of the Agreement as outcomes and processes become better understood (if they are indeed implementing such an approach). The evaluation of program effectiveness relative to outcomes (by the Parties or by others) would be facilitated by coordinated release with the SOGLR. This would provide the capability to make comparisons with SOGLR's indicator data.

Does the report show how the Parties, have worked with State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments, watershed management agencies, and local public agencies to develop and implement coordinated planning processes and best management practices?

The lists of organizations and government agencies involved in Agreement Annex Committees in the PROP, shows significant coordination among federal, state and provincial bodies in the implementation of the Agreement. However, coordination beyond these bodies is less clear. Whereas some Annex committees (notably Annexes 2 and 6) have broad and varied composition, others (for example Annexes 3, 8 and 10) have predominantly, if not exclusively, government membership. The Annex 6 subcommittee is most notable with respect to coordination in that it not only has a reasonably broad membership, but also works in close cooperation with the Great Lakes Panel on Aquatic Nuisance Species that predates the 2012 Agreement and has its own broad membership. The Parties would demonstrate wider coordination and engagement if, as per Annex 3, details of the extended subcommittee were provided, either in the report or on binational.net.

Review of participants in Annex Committees shows who is best positioned to coordinate with governments on Annex implementation but it does not show the quantity or quality of that coordination. Greater evidence of coordination could be shown in the PROP document through greater inclusion of binational and domestic actions conducted by a larger range of organizations, including academia, environmental non-government organizations, and private industry. Actions listed for the Aquatic Invasive Species Annex (Annex 6) provides some good examples of coordination in action.

Looking specifically at coordination with indigenous governments, the PROP does not paint a strong picture. Only five different indigenous governments are listed as being on Annex Committees (though the Annex 3 subcommittee does not specify which tribal governments are represented) and only four Annex subcommittees have representation from these groups. The lists of binational and domestic actions only include three projects that mention indigenous involvement.

Was the report prepared in consultation with the Great Lakes Executive Committee (GLEC)?

A draft of the PROP report was shared with the GLEC membership, commissions and observers in late May 2016 for discussion at the June 2016 GLEC meeting. The Parties took comments until mid-June. Therefore, the report was prepared in consultation with GLEC but the timeline for the submission of comments was limited – just over two weeks. However, many Annexes prepared their sections of the PROP report in consultation with their Annex Committee members, therefore select GLEC members would have been consulted on PROP reporting for areas of agreement implementations where they are directly engaged. It is notable that the majority of the discussion about the PROP report at the June GLEC meeting related to the need for the report to be more engaging for the public, including that the PROP should have more storytelling. The final PROP report did not significantly include storytelling. Issues of public engagement are discussed below.

Does the report present information in a publicly accessible manner?

The PROP is a clear, readable catalogue of actions. However, the report does not include stories or anecdotes, many of the graphics were not particularly clear or compelling and there were few photographs or pictures to engage the reader. One of the more engaging sections was Annex 7, Habitats and Species, where text boxes and photos were used to show examples of how biodiversity strategies are being used in each lake.

In future rounds of reporting, the Parties should improve the report in content by providing relatable case studies, pictures, legible graphics, and perhaps links to video orlinks to more detailed and technical information such as the SOGL technical reports. This would make the report more appealing to the public, and would likely engage a wider variety of readers.

Was the report provided to the public before the Great Lakes Public Forum?

The PROP was released to the public on September 28, 2016, six days before the Great Lakes Public Forum, October 4-6, 2016. Therefore, the Parties met their commitment to release the PROP before the Forum. However, the PROP was not released sufficiently in advance of the Forum such that people would have ample time to review it prior to the event, and this reduced the usefulness of the document. It is also notable that the PROP was released with little publicity. It was made available on the binational.net website and announced on the Great Lakes Information Network but there was no press release or other publicity surrounding the report release. At the Great Lakes Public Forum, the report was rarely mentioned and the report was not referred to in the presentations that discussed progress under the Annexes.

The IJC's public engagement activities aimed at getting input on the PROP showed that the PROP was not effectively communicated to the public. This was demonstrated by the lack of awareness of the PROP at the IJC public engagement sessions (see Public Consultation appendix). Only 34% of the people who completed the survey at the public engagement sessions were aware of the PROP. More importantly, only 5 of the 307 comments submitted, either verbally or by writing in response to the IJC's call for public input explicitly mentioned the PROP.

Although survey statistics for public awareness of the IJC's draft TAP report were similar to those for the PROP, the IJC received a good number of public and stakeholder comments directly related to the draft report, showing that the IJC's promotion of the report on line, in the press and on social media combined with IJC presence in the basin for public meetings resulted in a greater public profile for the TAP report.

The IJC recognizes the challenge of delivering the report on time but, to be an effective vehicle for public engagement at the Forum, the PROP (along with the SOGL) should be released at

least amonth before the event using a variety of traditional and social media outlets. Public engagement around the report would have been improved if, as had been expected, the Parties had used it at the Forum as a context for the various presentations.

SPECIFIC ANNEX REPORTING REQUIREMENTS

The PROP also addresses each of the specific reporting requirements mentioned in the annexes, though some are addressed to only to a limited extent.

Does the report set out progress in the implementation of each Annex?

The PROP sets out programs and actions implemented for Agreement Articles and Annexes. Specific reporting requirements for the Annexes are discussed below.

Does the report include the required details related to AOCs?

The PROP report contains lists of all Canadian and US AOCs (current and delisted), showing the BUIs have been removed (along with the year of removal) and the BUIs still impaired. Lists were also included to show the status of key actions at each AOC and the expected date for the completion of all actions. The report does not specify all actions completed or initiated in each AOC during the reporting period, however, key actions are highlighted. In future reporting periods, the key actions accomplished in the reporting period could be presented.

Does the report include the required details related to chemicals of mutual concern (CMC)?

The PROP report meets the requirement of listing the chemicals that have been designated as CMCs. The PROP also states that draft binational strategies are being developed for all of the CMCs designated, with polychlorinated biphenyls (PCBs) and hexabromocyclododecane (HBCD) to be the first chemicals addressed. However, this is a minimal response to the requirement for the PROP to report on the status of initiatives to develop binational strategies to address issues involving chemicals of mutual concern. More detail could be provided on the status of strategy development and key issues being addressed. The PROP does not report on the status of implementing binational strategies for chemicals of mutual concern as no strategies have been developed to date.

Does the report include the required details related to nutrients?

The Agreement states that PROP reporting on nutrients shall document:

1. Lake Ecosystem Objectives and Substance Objectives;

2. Implementation of binational strategies and domestic action plans;
3. Changes in phosphorus loading and concentrations; and
4. Progress toward achievement of Substance Objectives for phosphorus concentrations, loading targets and load allocations apportioned by country, established under this Annex.

The PROP report discusses the development of binational substance objectives for phosphorus concentrations, loading targets, and loading allocations for Lake Erie by 2016 and how these objectives will help to address some of the Lake Ecosystem Objectives mentioned in the Agreement. However, there is no reporting of the status of the nearshore or open waters of the various Great Lakes relative to the Lake Ecosystems Objectives and the only reporting relative to substance objectives (either the interim objectives listed in the Agreement or the newly agreed targets) is a graph of total phosphorus loads to Lake Erie by source type for 1967-2013. More cross referencing with the SOGL indicator about the nutrients objective could include more relevant discussion.

The PROP states that binational phosphorus reduction strategies and domestic action plans are being developed. Minimal detail is provided regarding strategy and plan development, however, the PROP does include significant information on nutrient reduction activities and nutrient management strategies, policies and legislative actions in each country.

Improved reporting on progress relative to Lake Ecosystem Objectives and Substance Objectives as well as phosphorus reduction strategy and domestic action plan implementation will be expected in the next round of progress reporting in 2019. The requirements listed in the Agreement should be seen as a minimum level of analysis and reporting.

2.2 Chapter Summary

- The production of the PROP report is a major advancement in accountability under the 2012 Agreement.

- The PROP report presents a clear and readable catalogue of actions taken domestically and binationally related to the articles and annexes of the Agreement.

- The time lag between the release of the PROP and the release of the SOGLRs presented a significant impediment to the IJC conducting a timely and comprehensive assessment of progress following issue of the PROP. Coordinated release of the two reports at least one month in advance of the GLPF is essential in future triennial cycles.

- The report does show progress relative to commitments in the Agreement but analysis of the effectiveness of that progress, and the need for any corrective action, is limited, in part, by the lack of timely SOGL information.

- As time bound commitments in the Agreement are overtaken, binational priorities for science and action could work as a new target setting process under the Agreement. Specific, time-bound priorities are the most useful for accountability.

- The PROP report shows evidence of good coordination between various government agencies. Coordination with non-government agencies and indigenous governments could be better demonstrated and consultation with the GLEC better executed.

- The PROP is not an effective tool for public engagement and the timing and mode of its release did not promote engagement.

- The PROP (along with the SOGLR) should be released at least a month before the Great Lakes Public Forum using a variety of traditional and social media outlets and be used at the Forum as a context for the various presentations to increase awareness of the report and public engagement with its contents.

- Priorities for science and action can also be used by the governments to show how they will prioritize activities that are most critical, both between and within the GLWQA Annexes and objectives. This would be a further step in achieving, clear, transparent, effective and accountable stewardship

2.3 References

Governments of Canada and the United States, 2016. Progress report of the Parties: pursuant to the Canada-United States Great Lakes Water Quality Agreement, page 5. Retrieved from https://binational.net/2016/09/28/prp-rep/

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Chapter 3 Engagement and Coordination

3.0 Introduction

Chapter 3 discusses the importance of coordination and public engagement principles in GLWQA implementation and the reporting of their implementation.

Engagement and coordination in the 2012 GLWQA

In the preamble to the 2012 Great Lakes Water Quality Agreement (GLWQA), the Parties recognize that the involvement and participation of state and provincial governments, Tribal governments, First Nations, Métis, municipal governments, watershed management agencies, local public agencies, and the public are essential to achieve the Agreement's objectives. The public is defined in the GLWQA as "individuals and organizations such as public interest groups, researchers and research institutions, and businesses and other non-governmental entities."

The Parties also acknowledge the importance of the Great Lakes public by identifying public engagement as an approach to guide them as they implement the GLWQA. In Article 2.4(k), public engagement means "incorporating Public opinion and advice, as appropriate, and providing information and opportunities for the Public to participate in activities that contribute to the achievement of the objectives of this Agreement." Under Article 4.3(e), the Parties also commit to seeking public input and advice on all pertinent matters, as appropriate, in their implementation of the GLWQA.

The Parties define coordination in Article 2.4 (e) as developing and implementing coordinated planning processes and best management practices by the Parties, as well as among state and provincial governments, Tribal governments, First Nations, Métis, municipal governments, watershed management agencies, and local public agencies. In Article 4.1, the Parties incorporate the approach of coordination into Agreement implementation by committing to develop and implement programs and other measures in cooperation and consultation with the same governments and groups, as well as the public.

Thus, the GLWQA commits the Parties to the first four of the five levels of involvement in the public participation spectrum, as outlined by the International Association for Public Participation (Figure 3.1; Sheedy, 2008).

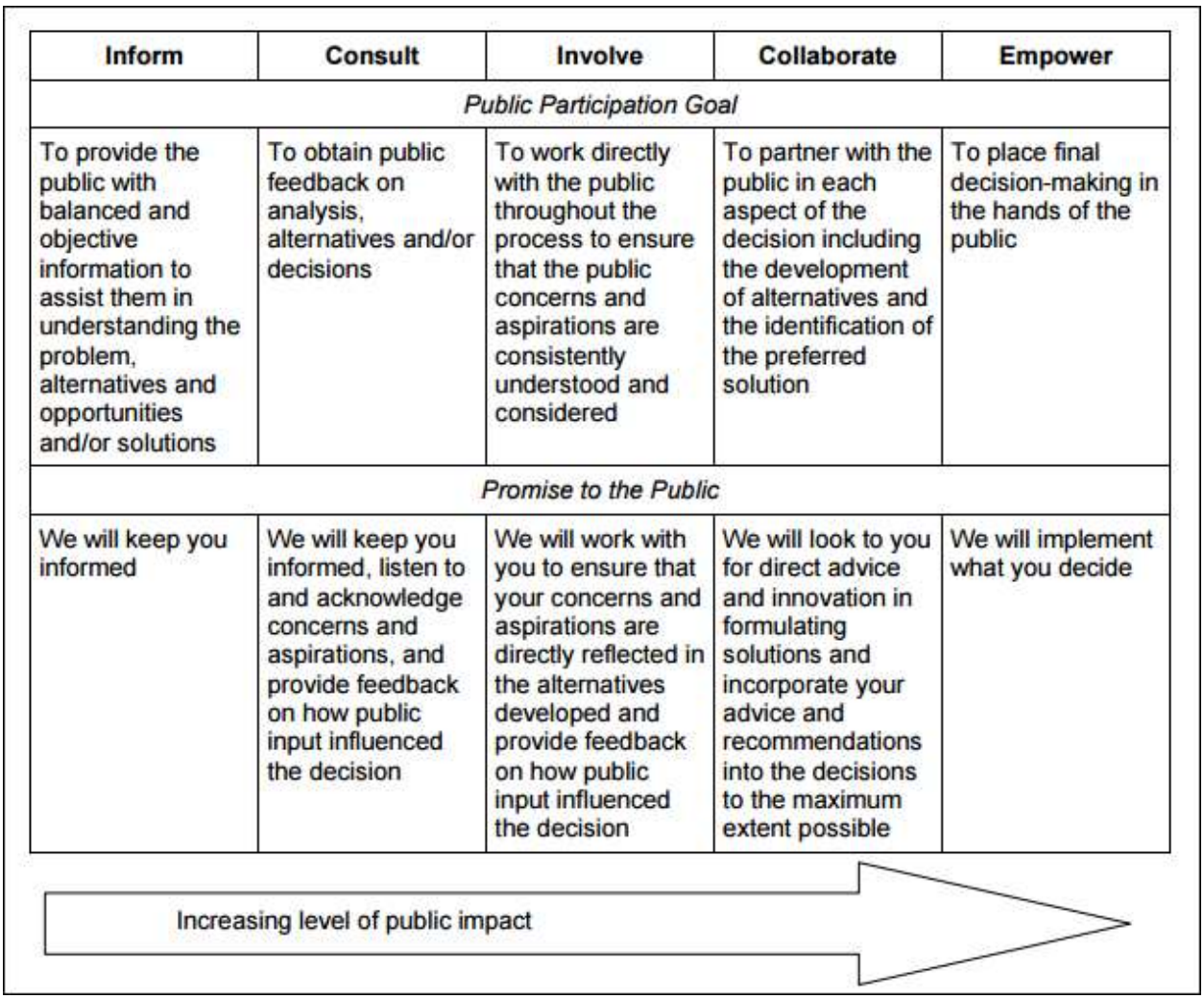

Figure 3.1

+1 Public Engagement, Source: International Association for Public Participation (Sheedy 2008)

It also reflects the widespread acceptance of public information, consultation and participation as beneficial for policy decision making, including decisions related to water quality management (EEA, 2014). Meaningful public involvement yields a range of benefits, including:

• Builds relationships based on trust, transparency, accountability, openness and honesty

• Integrates a wider range of public needs, interests and concerns into decision making

• Resolves problems more effectively, through collaborative means

• Ensures that decisions and solutions incorporate perspectives, knowledge and technical expertise that would not otherwise be considered

• Places issues and projects within a broader technical, social, cultural or ethical context

• Increases the level of public acceptance and ownership of decisions and policies. (PHAC 2013).

The complexity of Great Lakes governance and management systems makes the inclusion of and coordination among the many different governments and organizations involved with Great Lakes waters a necessity for successful management. McLaughlin and Krantzberg (2011) set out the challenges for policy implementation in the Great Lakes, noting the number of governments, non-governmental organizations and individual citizens involved. They conclude that a lack of adequate coordination between these various groups and authorities is the root of the problem in successful and thorough policy implementation.

3.1 Review

Assessing engagement and coordination

Summary of public engagement and coordination in the implementation of the GLWQA was reported in the PROP chapter 2 (Governments of the United States and Canada, 2016). This chapter outlined the extended coordination between federal, state and provincial bodies, and stakeholder communities through the work of the Lake Partnerships, Annex Subcommittees, and webinars. The report provided less evidence of coordination beyond these bodies, especially the involvement of indigenous people. Chapter 2 of this report suggested that broader coordination could be demonstrated through reporting on the composition of extended subcommittee membership for each Annex and the larger range of organizations working on binational and domestic actions.

The PROP does not show significant amounts of public engagement across GLWQA implementation. Despite repeated mention of the principle of public engagement at the beginning of the PROP, discussion of actual engagement conducted as a part of policy development and implementation is limited.

The Parties should be commended for making the biannual meetings for the Great Lakes Executive Committee (GLEC) open to the public. However, public attendance is generally limited to the informed public and no outreach or promotional attempts designed to attract a larger public are conducted in conjunction with or during the meetings.

The PROP repeatedly mentions the Great Lakes Public Forum (GLPF) as a mechanism for public engagement. The October 2016, GLPF was an informative, well organized event with attendance and reach well beyond the GLEC meetings and the potential for involving a broader array of stakeholders. The inclusion of students and First Nations and Tribes is to be commended. However, opportunities for public engagement were primarily question and answer periods at the end of presentations which significantly limited public input – let alone engagement – on key items such as the proposed priorities for binational science and action. The PROP was not released until shortly before the Forum and little mention was made of the report during the conference. Thus, citizens who attended the Forum were not fully aware of the PROP or did not have sufficient time to adequately reflect on the governments' reported progress before the event. It is notable that the reach of the GLPF as a public information mechanism was greatly

increased by the streaming of the event's first two days online and the resulting press and television coverage.

As a part of the IJC's public comment session at the GLPF as well as at the two public meetings held in Toronto and Milwaukee in October 2016, citizens expressed the need for enhanced public engagement by governments, which was identified as low, process-oriented, underfunded, and often missing the voices of those communities where the least Agreement progress has occurred, including indigenous communities.

With respect to Annex implementation, Lakewide Action and Management Plans (LAMPs),developed under Annex 2 of the GLWQA, are discussed in section 5.9. The eight webinars involving 800 participants regarding progress under Annex 1 provided good opportunities to inform and consult the public, or stages one and two of the public participation spectrum, and in some cases invited involvement in plan development as well. However, it is notable that almost four years after the 2012 Agreement came into effect, the LAMP partnerships have only recently begun to establish their work group outreach and engagement subcommittees. The first LAMP issued, the Lake Superior LAMP, would have benefited from a more detailed discussion of how relevant constituencies and communities were engaged and involved in the plan's development.

The PROP mentions the opportunities for public input in the Chemicals of Mutual Concern (CMC) process, however as reported in section 5.4 of this report, lack of transparency and engagement have been issues of concern in the implementation of Annex 3 to date.

A more successful example of public consultation was in the establishment by the Parties of phosphorus reduction targets for Lake Erie. As noted in section 5.6 of this report, as part of the process the Parties undertook a robust public engagement process to explain and justify the proposed targets.

As well as setting out binational activities undertaken by GLWQA Annex committees, the PROP also lists domestic actions undertaken in support on the Agreement. Looking at public engagement in the listed domestic activities, Canadian action in support of the aquatic invasive species annex was most notable in its mention of public engagement. The mention of public engagement in US actions under the Agreement was most notable with respect to nutrients.

The commitments the Parties agreed to in the GLWQA to inform, engage and cooperate with the public as they strive to accomplish the Agreement's goals are laudable, and reflect the value and proven benefits of incorporating the public into public policy development and implementation. However, based on a review of the PROP, it is difficult to conclude that significant public engagement has been incorporated into either country's policy development or implementation for the GLWQA. Additional information on such engagement was requested from the Parties but IJC staff was referred to the information available in the PROP. Additional information on engagement in the following areas would assist in this evaluation:

- Direct public involvement in the work of the Annex committees, and/or
- Ongoing advisory relationships with the Annex committees, and/or
- Other opportunities for the expression of views on the subjects and work of the Annex committees, including webinars, consultations on documents, meetings, or requests for

public comments on particular topics, proposed projects or other elements of Agreement implementation, and/or

- Other planned public engagement activities that are not captured in bullets 1-3 above, and
- Any further information regarding over-arching engagement activities across the breadth of the Agreement or in relation to its articles.

3.2 Chapter Summary

- The commitments the Parties agreed to in the GLWQA to inform, engage and cooperate with the public as they strive to accomplish the Agreement's goals are laudable, and reflect the value and proven benefits of incorporating the public into public policy development and implementation. However, based on a review of the PROP, it is difficult to conclude that significant public engagement has been incorporated into either country's policy development or implementation for the GLWQA.

3.3 References

EEA (European Environment Agency), 2014. Public participation: contributing to better water management. Experiences from eight case studies across Europe.European Environment Agency, Copenhagen.

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Chapter 4 Considering the State of the Great Lakes Report: Informing the Public about Great Lakes Status and Trends

4.0 Introduction

1. Purpose

The Agreement requires the IJC's triennial assessment to include "consideration of the most recent State of the Lakes Report." This chapter discusses the challenges of assessing the condition of the Great Lakes and communicating status and trends with the public. The Parties developed a State of the Great Lakes Highlights Report to overcome this challenge. The chapter also reviews why indicators are used, presents the work of IJC advisory Boards on indicators, reviews the Parties State of the Great Lakes Report (SOGLR), and provides suggested improvements for future reporting.

2. Background

The Great Lakes Water Quality Agreement (GLWQA) requires the Parties to establish and maintain comprehensive, science-based ecosystem indicators to assess the state of the Great Lakes, to anticipate emerging threats and to measure progress in relation to achievement of the Agreement's general and specific objectives. These indicators shall be periodically reviewed and updated as necessary. The GLWQA also dictates that the Parties shall issue a SOGLRt to the IJC and the public every three years, which describes basinwide environmental trends and lake-specific conditions using these ecosystem indicators. The Parties presented their plans for the first SOGLR to be developed under the 2012 GLWQA at the October 2016 Great Lakes Public Forum (GLPF). The SOGL Highlights report (SOGLHR) was released in June 2017. The first full technical report was released in September 2017. As the technical report was releasedshortly before the finalization of this report, the IJC had limited time to extensively consider its contents in this assessment.

The Agreement requires the IJC's triennial assessment to include "consideration of the most recent State of the Lakes Report." One of IJC's responsibilities under the GLWQA is to assess the progress made by the Parties towards achieving the objectives of the agreement. Another responsibility is engaging with the public to increase awareness of the inherent value of the waters of the Great Lakes to inspire actions to restore and protect these waters. Assessing and reporting on the condition of a large scale regional ecosystem such as the Great Lakes Basin is challenging and communicating the findings to the public can be equally demanding. Yet it is essential for the Parties and the IJC to present scientific information in terms that can easily be understood by non-scientists. This will enable the public to further their understanding of the condition of the Great Lakes and foster informed public participation in Great Lakes policy development.

In addition, IJC's assessment should be able to answer the key question: *are the Great Lakes getting better or worse?* However, for IJC to issue its own bi-national, independent, and third party-assessment and communicate effectively with the public, it needs to work in collaboration with the Parties, because IJC does not collect monitoring data.

Consequently, in the IJC's 16th (and final) Biennial Report on Great Lakes Water Quality, the IJC issued advice to the Parties to help improve state of the lakes reporting and facilitate the IJC's first triennial assessment. The IJC remarked that SOGL reporting is broad in scope and very useful and would be even more helpful if organized in a manner that clearly linked to the Agreement's objectives (IJC, 2013). In the 16th Biennial Report, the IJC also requested that the governments identify a core set of indicators and use a "report card" format to provide the public plain language descriptions of core indicators and discussion of trends.

One more point is needed before jumping into more specific discussion about using indicators to communicate Great Lakes science with the public and considering the Parties most recent State of the Great Lakes Report. While a small set of indicators is needed for effectively communicating with the public by contrast, policy makers need additional scientifically-sound information to make informed monitoring, restoration, and prevention decisions (IJC, 2013). Therefore, it is critically important for the US and Canadian governments to also fund and maintain a comprehensive binational water quality monitoring program within the Basin that includes more indicators (or sub-indicators) than the report designed to convey status and trends to the public. The topic of monitoring, collecting data, and indicators for decision making is discussed more fully in Chapter 6 – Other Advice.

4.1 Using indicators to describe status and trends

Indicators are commonly used to describe the condition of the environment in the same manner as indicators are used to describe human health (*e.g.*, blood pressure) and economic status (*e.g.*, Dow Jones Index). The Heinz (2008) report on the state of the US ecosystems notes that the United States has an official suite of indicators for the economy and concludes that the environment needs one too. Clearly, that message could apply to any country, and most certainly Canada, or to any large regional system such as the Great Lakes.

This challenge to communicate technical information is not unique to ecological assessment but to other branches of science as well. Two examples are discussed by Tufte (1997). For instance, the 1854 Cholera epidemic in London was solved by creating a map of deaths and community pump wells to determine which well was causing the mortalities. The Challenger disaster of 1986 could have been averted by not launching on an abnormally cold day in January because O-ring failure (the cause of the disaster) is far more likely to occur in cold weather. Showing decision makers a simple line graph with temperature on one axis and O-ring failure on another, would have clearly conveyed the risk of launching on a cold day. The briefing given to decision makers included more complex charts making it harder to visualize the association between cold temperatures and O-ring failure.

While all branches of science have challenges communicating technical information, ecology reflects the interaction of a multitude of organisms with each other and their environment.

Studying any one organism (such as humans), or any one ecosystem (such as the nearshore), or any one process (such as meteorology), is complex enough, and additional effort is needed to communicate environmental indicators that consider biotic and abiotic factors and their interrelationships.

For non-specialists to grasp the complexity, information needs to be presented in a less complex manner. Ecologists may be best-suited to make this complex information understandable (Norton, 1991). Ecologists can communicate complex information most effectively when using graphics (such as line and bar graphs, maps, drawings and models) and combining them with text features such as headings, bullets points, topic points, transitions, and figurative language (*e.g.*, "Wetlands are nature's kidneys, they filter pollutants" [Rowan, 1999]). It is also important to describe in the text what each indicator conveys about the environment. For example, the indicator "lichen communities" shows the effects of air pollution on the forest including changes in the numbers and types of plants that are found in the forest (Schiller et al., 2001).

Maps, line graphs, and the other techniques identified in the preceding paragraph have been used by both countries even at the national scale. However, narrowing down the set of indicators used for getting a quick status and trends assessment for the two large North American nations is a challenge. The United States Environmental Protection Agency, Report on the Environment (USEPA, 2016) is a web-based report that uses 85 indicators to report on five areas: air; water; land; human health and exposure; and ecological condition. The web-based report uses a hierarchical structure to obtain more specific information under any of these themes. Similarly, Environment and Climate Change Canada (ECCC, 2016) groups dozens of indicators on their web site into three categories: air and climate; water; and nature. Within each of these categories there are more indicators and the ability to get details such as maps and data sets. For instance, the water quality of rivers section categorizes the proportion of all Canadian rivers as excellent or good, fair, marginal or poor and has deeper levels of detail.

Other regions besides the Great Lakes also produce status and trends reports and even at a regional scale, a sizeable number of indicators are needed to track progress. The Chesapeake Bay Program (2016) tracks more than 30 environmental indicators to gauge the success of efforts to protect and restore the Bay, its tributaries and the lands that surround them. Some indicators, such as blue crab abundance, water quality and forest cover, track aspects of watershed health. Others including public access, protected land and open fish passage, track restoration and protection work. Each indicator includes text, bar graphs and some include videos. For instance, the American Shad indicator has a video showing how population has changed over time and what scientists are doing to restore the anadromous fish to the Bay.

Even at the individual lake scale, many indicators are still needed to communicate status and trends to the public. The Lake Champlain Basin Program is another binational program based on collaboration between the United States and Canada. The program periodically publishes the State of the Lake report to update the public and policy makers on the condition of Lake Champlain, its sub-basins, and its watershed. The 2015 State of the Lake Ecosystem Indicator Report (Lake Champlain Basin Program, 2015a) uses line graphs, bar graphs, maps and a combination of other pictures and pulled out facts. In the report, a vast array of information is presented in an eye-catching manner and clear format to enable understanding by non-experts. This "one lake report" uses a couple dozen indicators but it also selects nine of the most pertinent indicators to present in a briefer handout (Lake Champlain Basin Program, 2015b).

4.2 Consideration of the State of the Great Lakes Highlights Report

The SOGLHR(Governments of Canada and the United States, 2017) is a clear and concise report that sets out indicator status and trend information for each GLWQA general objective in an engaging way. The SOGL Technical report provided detailed information on each sub-indicator. The Parties improved the SOGL 2017 reporting from past State of the Lakesreporting by adopting IJC's (2013) recommendation to reorganize the report into nine indicators (with various metrics or sub-indicators) that are linked to the GLWQA's general objectives (Table 4.1).

Table 4.1.Indicators correspond to each General Objective of the Agreement

Source: Great Lakes Public Forum (2016).

General Objectives and Indicators

GLWQA General Objectives	Great Lakes Indicators
Be free from other substances, materials or conditions that may negatively impact the chemical, physical or biological integrity …	**Watershed Impacts and Climate Trends**
Support healthy and productive wetlands and other habitats to sustain resilient populations of native species.	**Habitats and Species**
Be free from the introduction and spread of aquatic … and terrestrial invasive species …	**Invasive Species**
Be free from nutrients … in amounts that promote growth of algae …	**Nutrients and Algae**
Be free from the harmful impact of contaminated groundwater.	**Groundwater**
Be free from pollutants … that could be harmful to human health …	**Toxic Chemicals**
Allow for human consumption of fish and wildlife.	**Fish Consumption**
Be a source of safe, high-quality drinking water.	**Drinking Water**
Allow for swimming and other recreational use.	**Beaches**

Another IJC recommendation that was adopted by the Parties was to use a report card format to describe progress made towards each objective and providing the public with plain language descriptions of the core indicators and discussion of trends.

The Highlights report along with the Technical report (Environment and Climate Change Canada and the US Environmental Protection Agency, 2017) are both outstanding and looking ahead to future reporting cycles, the IJC wishes to offer suggestions for further improvements for SOGL reporting. Coordinated release of the SOGLR with the Progress Report of the Parties (PROP), as discussed in Chapter 2 of this report, would yield a more comprehensive product and facilitate a better understanding of the Parties actions and progress, and enable the IJC to provide a more insightful assessment. The next SOGLR could include links to or from the PROP report and use some of the techniques employed by the other assessments presented. For instance, maps and videos with information about methods, results, and management actions being undertaken could

be included. Using AIS as an example, there could be maps with zoom in features to show sea lamprey abundance and videos showing efforts to control sea lamprey or keep Asian Carp out of the Great Lakes. Other videos could discuss impacts of AIS and would help the public understand the need for preventative actions. Other potential improvements include developing a video that would summarize the Highlights Report, periodic reporting (or video) updates, and a Q&A function.

It would also be useful to create an interactive map that would allow readers to explore in more detail specific areas, in particular those that are troublesome or those reflect a success story. For example, beaches of the United States were open and safe 96 percent of the season, but for more detail, the interactive map would show which beaches closed, for how long and how often, and the cause of the closure. One of the best examples comes from the United States Environmental Protection Agency - *The Environmental Justice Screening and Mapping Tool* (https://ejscreen.epa.gov/mapper/). The map allows the viewer to select a geographic region and create a report within the selected area. The report contains environmental and demographic indicators, as well as environmental justice indexes, and compares the selected region with the state and the entire country. This particular map was user-friendly, aesthetically pleasing, and conveyed the wanted data in a comprehensive manner. Another excellent example is the National Oceanic and Atmospheric Administration's *Interactive Radar Map Tool* (https://www.ncdc.noaa.gov/data-access/radar-data/radar-map-tool) which allows the user to search the entire country for temperature and climate data from 1995 to the present.

2. Sub-indicators and measures for trend analysis

It is a challenge to summarize the status and trends of several sub-indicators in a succinct manner, especially when dealing with a large spatial scale such as the Great Lakes. One approach that has been used involves devising a technique to quantitatively or qualitatively express the sub-indicators into a score or categorical ranking. For instance, the Fish Index of Biotic Integrity (Fish IBI) quantitatively combines various sub-indicators into one indicator (Karr 1981). The Fish IBI combines several metrics about fish to quantitatively describe the condition of the fish community and it can be applied to making resource management decisions (Karr, 1991). Other indices have been developed for particular communities even within the Great Lakes region. For example, the Index of Community Integrity for the benthic community is used to categorize the quality of various benthic communities of the Northern Lakes and Forests Ecoregion, which is characterized by mixed conifer and deciduous forests and wetlands (Butcher et al., 2003).

The Parties used a quicker, and effectiveapproach for their first Triennial SOGLR. The Parties graded the status of indicators and sub-indicators (*e.g.*, good, fair, or poor). The public prefers common language indicators and concise statements to convey about the condition of the environment (Schiller et al.,2001) and the Parties have achieved that with their indicator reports as shown in Table 4.2. This is an excellent approach to convey all the key information succinctly when no index or quantitative approach exists and is very understandable to a public audience. The IJC believes that the Parties have done an outstanding job in their highlights Report by having various tiers of summary data. The Highlights Report includes a concise table that presents the ranking and trend for each indicator, another summary consisting of one-two pages for each indicator that presents the ranking and trend for each sub-indicator, and a third summary

that presents a lake by lake snapshot. This approach provides three different sets of public information with varying levels and types of details in about 25 pages.

Looking ahead to future reports, now that the time period for reporting has been changed from two to three years, it is more likely a trend can be detected between reporting cycles. Future reports could describe changes over various points in time and depict key changes (e.g., a 3 year trend, a nine year trend, and a 30 year trend). There would be value in using arrows up (improving conditions) or down (declining or deteriorating condition), which would be consistent with the State of the Lakes Ecosystem Conference (SOLEC) Highlights Report (US Environmental Protection Agency and Government of Canada, 2013) and the Lake Champlain report. Finally, the distinction between non-native species and invasive species could be better communicated since they are presented similarly in the SOGL graphic presented in the Highlights Report.

Table 4.2: Status and Trends of each Food Web Sub-Indicator. Source: Great Lakes Public Forum (2016).

Habitat and Species #2 (Food Web)

Status: GOOD | FAIR | POOR

SUB-INDICATORS	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ERIE	LAKE ONTARIO
Zooplankton	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Benthos	Unchanging	Unchanging	Unchanging	Deteriorating	Unchanging
Diporeia	Unchanging	Deteriorating	Deteriorating	Deteriorating	Deteriorating
Lake Trout	Unchanging	Improving	Improving	Improving	Improving
Phytoplankton	Unchanging	Deteriorating	Deteriorating	Deteriorating	Unchanging
Preyfish	Unchanging	Deteriorating	Undetermined	Improving	Deteriorating
Walleye	Unchanging	Unchanging	Unchanging	Improving	Unchanging
Lake Sturgeon	Improving	Improving	Improving	Improving	Improving
Fish Eating and Colonial Nesting Birds	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging

3. Storytelling

Indicators trends are one key part of communicating with the public, but the indicator trends do not tell the whole story (US Environmental Protection Agency and Government of Canada, 2014). Narrative non-technical explanations help the public understand cause and effect or relationships between multiple sub-indicators. The story behind the indicators is needed to

increase public awareness of the inherent value of the lakes. The stories also help the public and resource managers to better understand the stressors affecting the lakes and to have more information to take action to mitigate those stressors. Interpreting the key scientific findings via storytelling would help people understand that behind every vital sign or indicator that is a lot of other factors to consider. Storytelling, as was done in the SOGL 2011Technical Report,helps the public understand causes and effects. Telling stories about how forest and land cover, rainfall, temperature, Dreissenid mussels, nutrients in lakes, and harmful algal blooms are all inter-related enables the public to understand the importance of all these sub-indicators.

The IJC commends the governments for their use of storytelling in the SOGL 2011 Technical Report (US Environmental Protection Agency and Government of Canada, 2014). The stories told on pages 9-26 of the 2014 Technical Report include stories such as why harmful algal blooms are recurring despite lower total phosphorus levels, why native fish species are struggling to survive, and how land use many kilometers away from the lakes may influence the water quality of the Great Lakes. The report also includes stories about clear water, chemical levels in water, biota and sediment, invasive species, coastal wetland communities, dam removals, and land use. These are excellent stories and the kinds of stories that need to be told to help the public understand the many complexities of factors that influence the condition of the Great Lakes.

The IJC, supported by the work of the SAB Science Priority Committee (2016), recognizes that a concise set of status and trends of indicators and storytelling are needed to communicate with the public. However, these indicators cannot provide all the information needed to adaptively manage the Great Lakes or describe to the public how well government programs are accomplishing all of their Specific Objectives described in the GLWQA. Another way to even further improve the next SOGL highlights report and public communication is to include storytelling, or provide links to stories. The stories effectively told in the SOGL 2011 Technical Report could get more visibility in future SOGL reporting if included in the Highlights Report which is read by more citizens and managers, than the more technical report.

4. IJC Proposed Vital Signs

Before the Parties presented their plan to have one indicator for each objective, the IJC asked its Science Advisory Board, Science Priority Committee (SAB-SPC) to identify asmall set of indicators that would be most useful for communicating with the public. Reporting could be further enhanced with binational coordination and focus on some key vital signs and delivery of information to Great Lakes leaders and the public via meaningful graphics (e.g., Figure 4.1) and brief narrative explanations.

The SAB sought to develop a process that would be objective, repeatable, defensible and transferable to other types of indicators (*e.g.,* human health) and developed a report on what it called “communication indicators” (SAB-SPC, 2016). Communication indicators and sub-indicators were selected based on whether they told a compelling story (relationship to public interest), visible (ability to see or sense changes), easy to understand, and are a direct measure of lake health.

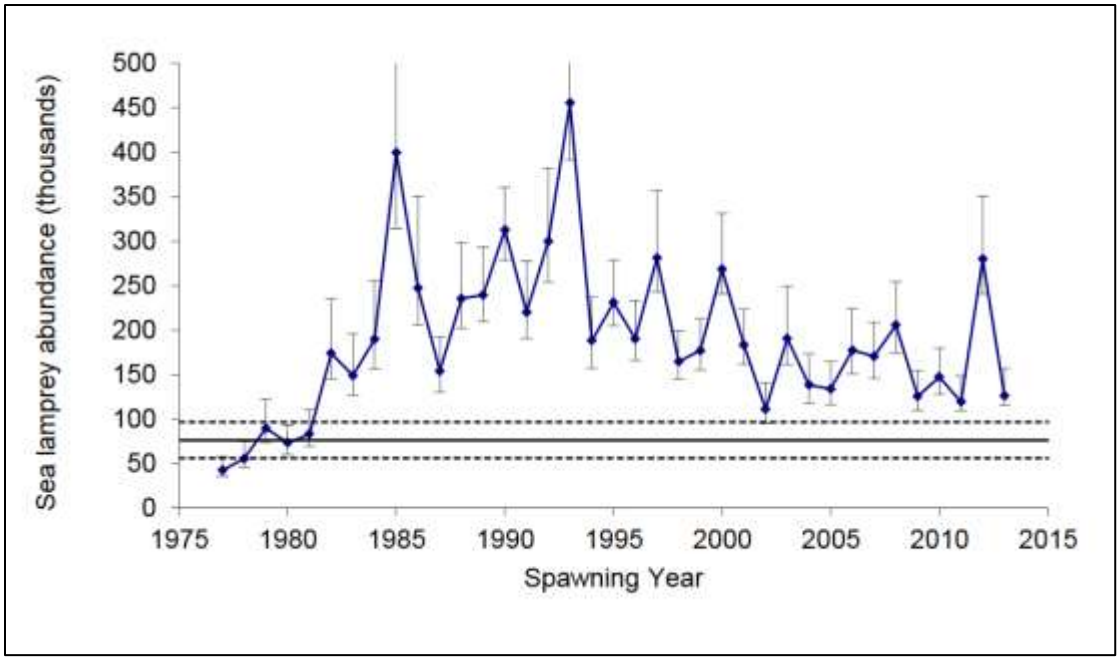

Figure 4.1.Annual lake-wide population estimates of adult sea lampreys in Lake Huron, 1980-2013 with 95% confidence intervals (vertical error bars). Target level is indicated by the solid horizontal line with 95% confidence intervals (dashed horizontal lines). Source: Great Lakes Fishery Commission (2013)

The SAB-SPC found data availability and quality issues and determined there were insufficient data to assess and report on individual lakes or their subunits, making it a challenge to identify trends. To meet the time constraints for the 2017 draft IJC Triennial Report, the SAB-SPC selected the best eight indictors and metrics for communicating the status and trends of the Great Lakes ecosystem with the public.

SAB-SPC members have more expertise in ecosystems than human health and did not pick measures for the three General Objectives related to human health. The SAB did not select an indicator or metric for groundwater because its members believed that it was more important to select indicators that better resonated with the public around chemical, physical, and biological integrity. The SAB recommended that this process be repeated on a regular basis, perhaps every six to nine years, and that for the next triennial the process be applied to human health indicators.

The SOGL Technical Report is developed for scientists, engineers, resource managers and others practitioners wanting detailed technical information. Consequently, the venues for the Parties to shareinformation on the vital signs would be the Great Lakes Public Forum (GLPF) and the SOGL Highlights Report, since the SOGLHR is the version intended for the public. The IJC reviewed the SAB-SPCrecommended vital signs, compared them to the SOGLHR and GLPF (2016) presentation, and then reached its own conclusions on the supplemental information the IJC would like to provide to the public (Table 4.3).

Table 4.3 Set of sub-indicators thatare most informative for the public.

Agreement Objective	SAB Selected Indicator and Metric	Relationship to SOGLHR and GLPF	IJC Position
4. Keep Great Lakes free from pollutants that could be harmful to human health or aquatic organisms.	Persistent bioaccumulating toxics (PBT) in biota – PBTs in whole fish	SOGLHR presents PCB levels in whole fish in Lake Ontario.	Trends of PBTs in whole fish is most useful data and graphic to present to public about progress towards general objective #4.
	Chemical levels in Water – Mercury and Atrazine *	Mercury was presented at the GLPF. SOGLHR showed PCB levels in air.	Trends of mercury and atrazine levels in water should be shown in the highlights report.
5. Trends in populations of native species	Fish species of interest – Lake trout / lake whitefish abundance (walleye for Lake Erie)	These were two of the species presented at GLPF. SOGLHR presents Diporeia.	Lake trout and lake whitefish best reflect objective #5. The IJC supports using figures showing their abundance trends in each lake in a highlights report. Other communities (e.g., benthos) and species (e.g., Diporeia) are important but not as useful for communicating with the public.
6. Controlling impacts from nutrients.	Harmful and nuisance algae – nuisance algal blooms.	Lake Erie severity index presented at GLPF.	The IJC recommends using harmful algal bloom data for western Lake Erie, Saginaw Bay, and Green Bay. The Lake Erie Severity Index and the pictures showing the extent of the bloom presented at GLPF (2016) are suggested for the highlights report along with similar severity indexes for Green Bay and Saginaw Bay.
	Total phosphorus in lakes	Spatial distribution of Total P in lakes was presented at GLPF and included in SOGLHR.	Based on other SAB work (SAB-RCC 2016) the IJC recommends showing trends of concentrations of total phosphorus and concentrations of dissolved reactive phosphorus in the tributary loadings and offshore concentrationsin thenearshore and offshore as the second set of important measures for Objective 5.
7. Control impacts from Aquatic Invasive Species (AIS)	Aquatic Invasive Species – Sea lamprey abundance*	GLPF showed Sea Lamprey abundance. SOGLHR shows number of non-natives but calls them invasives.	The IJC agrees with the SAB that these are the key data to present related to communicating trends about this objective and recommends that the Parties present the figure showing Sea Lamprey abundance in each lake in their Highlights report similar to Figure 4.1.

8. Keep the lake free from other conditions that may impact the Great Lakes, including climate change.	Maximum ice cover; and Water level – Long term water level variability	Maximum ice cover presented at GLPF. SOGLHR shows water level variability in Lakes Huron and Michigan.	These two sets of data effectively communicate trends about climate change. The GLPF figure (See Figure in Section 359) showing annual maximum ice coverage effectively portrays this by showing trends over different time periods.

* An abbreviated process that considered the filters but relied on best professional judgement was used to select the metrics for Chemical Levels in Water and Aquatic Invasive Species.

In many instances, the IJC, SAB, and the Highlights Report all propose similar metrics be used for a particular indicator or sub-indicator that corresponds to a general objective (Table 4.3). For instance, all three organizations have used or support using PBTs in whole fish as the set of data to communicate with the public the concerns about chemical levels in fish. For chemical levels in water, all three organizations support showing the public mercury levels, but the SAB and IJC also support including atrazine. Atrazine is commonly used to control weeds, is commonly measured, and is increasing in concentrations (US Environmental Protection Agency and Government of Canada 2014) and can help reflect the general trend in herbicide use and levels.

The IJC generally concurs with six of the eight metrics recommended by SAB-SPC but has different views on nuisance algae blooms and total phosphorus. IJC believes harmful algal blooms (HABs) are more of an issue and has discussed the importance of reducing HABs in two other reports (IJC, 2013 and 2014a). IJC believes that harmful algal blooms (HABs) were a better measure than nuisance algal blooms, because of the health impacts, because no nuisance algae target exists, and because the Parties effectively reported on HABs at the GLPF (2016) by presenting a western Lake Eric eutrophic severity index. IJC is hopeful the Parties can expand the use of eutrophic severity indexes to Green Bay and Saginaw Bay. IJC (2013 and 2014b) also support the importance of measuring dissolved reactive phosphorus (DRP) along with total phosphorus (TP) because DRP is more readily available for uptake by algae and because HABS have been occurring with declining TP levels and increasing DRP levels.

These IJC vital signs are well suited for public communication and represent sub-indicators.

1- persistent bioaccumulative toxics in whole fish;

2- mercury and atrazine concentrations in water;

3- lake trout / lake whitefish abundance (walleye for Lake Erie);

4- HABs in western Lake Erie, Saginaw Bay, and Green Bay using remote sensing pictures and the Lake Erie Severity Index (presented at the Great Lakes Public Forum);

5- total phosphorus and dissolved reactive phosphorus tributary loadings for the three sub-basins mentioned above and concentrations in the offshore in all the lakes

6- sea lamprey abundance;

7- maximum ice cover; and

8- long-term water level variability.

Reporting to the public on whether the lakes are getting better or worse and progress being made towards objectives would be enhanced by including these eight vital signs in the next TAP Report. In order to do that, the IJC requests that the Parties collect data and somewhere in SOGLRprovidetstatus and trends data for these eight "vital signs" that were developed by the IJC as way to disseminate information to the general public on the health of the Great Lakes.

4.3 Section Summary

This chapter reviewed some of the history of IJC's and the Parties work towards improving the use of usingindicators for communicating the status and trends of the Great Lakes ecosystem with the public. The chapter also reviewed relevant literature on approaches for communicating environmental information with the public and a few other assessment efforts outside the Great Lakes.

The IJC proposed recommendations to the Parties in its 16th Biennial Report (IJC 2013) about having a small set of indicators and linking them to the Objectives of the Agreement. The Parties have now adopted this approach which improves communication with the public about status and trends.

The Parties SOGL Highlights Report also reflects other great improvements and does an outstanding job communicating with the public about a multitude of complex ecological information and concepts in varying levels of detail. These include a one page summary that describes the status and trends of progress towards achieving the objectives of the Agreement, another longer summary that describes the progress made towards sub-indicators associated with each of the nine indicators, and a one page summary for each of the Great Lakes that briefly describes the status and trends of key indicators in each lake. All of this is now effectively accomplished in a 24 page report.

Even further improvements can be made to the next Triennial SOGLR. Links to and from the PROP and to other web sites, interactive maps, and videos would help the public understand connections better. Potential improvements include links to maps (e.g., NOAA's Radar Map) and videos (e.g., Chesapeake Bay's Tracking Progress).

Another potential future improvement would be to expand the SOGL Highlights Report by several pages to include storytelling such as how rainfall, impervious surfaces, invasive mussels, tributary phosphorus loading, and surface water temperatures all contribute to harmful algal blooms. Including stories in the SOGL Highlights report, similar to the style presented in the SOGL 2011 Technical Report will reach more readers.

Reporting to the public on whether the lakes are getting better or worse and progress being made towards objectives would be enhanced by including the eight vital signs proposed by IJC in the

next TAP Report. In order to do that, the IJC requests that the Parties collect data and somewhere in the SOGLR(and preferably the Highlights Report) provide dataabout these eight "vital signs" that were developed by the IJC as a way to disseminate information to the general public on the health of the Great Lakes.

Finally, the Parties would be able to able to consider more of the IJC suggested improvements in this report in a more timely manner if a draft of the second SOGL Highlights Report was shared with the IJC in advance. This would enable the IJC tooffer comments for the Parties to consider before the final report is issued allowing the Parties to improve the report before public release.

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Chapter 5 Review and Assessment of General Objectives

5.0 Introduction

Purpose

Chapter 5 presents a comprehensive review and assessment of programs and measures undertaken in support of the nine General Objectives of the *Great Lakes Water Quality Agreement* (GLWQA). The assessment is based largely on a review of:

- Data and information from the **2017 State of the Great Lakes Report** and presentations by the Parties at the 2016 Great Lakes Public Forum;
- The **Progress Report of the Parties** (Governments of the United States and Canada, 2016);
- Observations of GLWQA Annex implementation, where applicable; and
- Review of other programs, as necessary.

General Objectives of the GLWQA

Under Article 3 of the GLWQA, the Parties agreed that the waters of the Great Lakes should:

> *(i) be a source of safe, high-quality drinking water;*
> *(ii) allow for swimming and other recreational use, unrestricted by environmental quality concerns;*
> *(iii) allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants;*
> *(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;*
> *(v) support healthy and productive wetlandsand other habitats to sustain resilient populations of native species;*
> *(vi) be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth ofalgae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem;*
> *(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;*
> *(viii) be free from the harmful impact of contaminated groundwater; and*
> *(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.* (GLWQA, 2012)

GLWQA Annexes

The GLWQA also includes a set of 10 annexes that set out programs and measures that the Parties have agreed to undertake in support of one or more of the General Objectives (Table 5.0).

Table 5.0 List of Annexes under the Great Lakes Water Quality Agreement (2012)

Annex 1	Areas of Concern
Annex 2	Lakewide Management
Annex 3	Chemicals of Mutual Concern
Annex 4	Nutrients
Annex 5	Discharges from Vessels
Annex 6	Aquatic Invasive Species
Annex 7	Habitat and Species
Annex 8	Groundwater
Annex 9	Climate Change Impacts
Annex 10	Science

Organization

Each of the following nine sections of Chapter 5 addresses a General Objective. Each section:

- reviews publicly available information on relevant SOGL indicators and, where appropriate, provides a critique of the indicators used;
- reviews information provided in the PROP;
- reviews, where applicable, the implementation of programs and measures undertaken through one or more of the GLWQA Annexes that may be relevant to the achievement of that particular General Objective;
- reviews, where appropriate, supplemental information from other management programs and activities carried out by federal, state and provincial governments, local governmental agencies and non-governmental organizations in Canada and the United States in support of the General Objective;
- provides a summary of key observations with respect to progress toward achieving the General Objective and the need for future improvements towards meeting the objective.

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5.1 Drinking Water

This section reviews and assesses progress toward achieving General Objective 1 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 1 states that the waters of the Great Lakes should "be a source of safe, high-quality drinking water."

While there is no single Annex in the GLWQA dedicated to the achievement of Objective 1, it directly relates to several annexes that drive action to restore and protect the Great Lakes drinking water by removing beneficial use impairments (Annex 1), improving lakewide action and management (Annex 2), chemicals of mutual concern (Annex 3), and managing nutrient loadings (Annex 4). The assessment also reviews source-water protection programs in Canada and the United States. Protection of source water is related to implementation of the prevention principle set out in Article 3 of the GLWQA.

5.1.1 Background

The Great Lakes are a source of drinking water to over 40 million Canadians and Americans living in the basin. However, they are susceptible to contamination from a variety of point and non-point sources, including combined sewer overflows and runoff from agricultural, urban and industrial lands. As a result, the protection of these source waters is important for the provision of safe drinking water, particularly for those few populations who may not have access to treated drinking water. For most people, protecting drinking water requires a comprehensive, multi-barrier approach, including source water protection, appropriate treatment, distribution system maintenance and monitoring throughout the distribution and delivery system. A public survey of Great Lakes basin residents conducted in 2015 found that the majority of those surveyed felt the Great Lakes are a valuable resource and should be protected for the health of its residents, particularly as it relates to safe drinking water" (WQB, 2016).

However, residents of the Great Lakes basin have experienced a number of tragic drinking water contamination incidents, including: the *E. coli*O157:H7 contamination of a source water supply in Walkerton, ON in 2000; the 2014 "do not drink" advisories by Toledo, OH and Pelee Island, ON in response to unsafe levels of microcystin in the treated water; and the 2015 crisis in Flint, MI, in which elevated levels of lead leached from distribution pipes as a result of failure to apply adequate anti-corrosion control.

Though only the Toledo and Pelee Island incidentswere from the waters of the Great Lakes, all these incidents serve as a reminder of the importance of safe drinking water. In addition, they may offer lessons that can lead to improvements in the protection and delivery of safe drinking water. For example, the Walkerton incident resulted in the establishment of the *Ontario Safe Drinking Water Act* and the *Ontario Clean Water Act*, which together form a regulatory

framework for a comprehensive management approach. The Flint crisis has put increased pressure on the US Environmental Protection Agency (USEPA) to strengthen its Lead and Copper Rule to prevent any future incidents. Since the Toledo incident, the Ohio EPA has updated its "State of Ohio Harmful Algal Bloom (HAB) Response Strategy" and adopted new HAB rules that establish: microcystin action levels for drinking water; monitoring requirements for drinking water plants; treatment technique requirements; and requirements for public notification of violations (OH EPA, 2016). Additionally, in 2016 the EPA developed three tools to help communities prepare for and reduce risks from cyanotoxins in drinking water. These tools include a template and example plans for cyanotoxin management in drinking water, a cyanotoxin drinking water treatment optimization document, and a cyanotoxin risk communication toolbox.

While it is a positive step that lessons have been learned through these tragic events, a proactive, approach that embodies the prevention principle called for by the GLWQA is required. The GLWQA defines prevention as anticipating and preventing pollution and other threats to the quality of the waters of the Great Lakes to reduce overall risks to the environment and human health.

5.1.2 Assessment of indicators

1. Overall assessment

The Parties' 2017 State of the Great Lakes Highlights report uses a"Drinking Water" indicator to assess the overall quality of treated drinking water in the Great Lakes. This assessment illustrates that the Great Lakes provide high-quality treated drinking water for Canada and the United States. In both Canada (Ontario) and the United States, the Great Lakes have an overall status of "good" with an "unchanging" trend for treated drinking water since the last SOGL report in 2011. The lakes are not individually assessed(Governments of Canada and the United States, 2017).

In Ontario, 60% of the population gets their drinking water from the Great Lakes and treated drinking water samples met the Ontario Drinking Water Quality Standards (DWQS) 99.8 to 99.9 percent of the time for the years 2007-2014(Governments of Canada and the United States, 2017). The samples included microbial, chemical and radiological parameters. Treated drinking water samples met radiological standards 100 percent of the time, chemical standards at least 99.67 percent of the time and microbial standards at least 99.85 percent of the time. (GLPF, 2016)

In the United States, from 2012-2014, 95-97 percent of the population living in the Great Lakes basin (approximately 27 million people) were served by water treatment systems meeting health-based water quality standards(Governments of Canada and the United States, 2017). During this same time period, 6 percent of the water treatment systems incurred health-based system violations (GLPF, 2016). Overall, people living in the Great Lakes basin can safely drink municipally treated drinking water, unless an advisory is in place (e.g. do-not-drink or boil water advisories). Drinking water advisories can result from contaminants in the source water and

subsequently treated water (such as high levels of microcystin at the Toledo, OH intakes in 2014) or from a failure in the equipment and/or processes used to treat, store or distribute drinking water.

Overall, people living in the Great Lakes basin can safely drink municipally treated drinking water, unless an advisory is in place. However, not all populations in the basin have municipally treated drinking water and even for the samples reported there is not 100 percent compliance with drinking water standards. Drinking water advisories and access to safe drinking water is an issue of particular concern in First Nations and Tribal communities. When it comes to drinking water, anything less than 100 percent is not acceptable.

2. Indicator measures: source water and treated water

In 2014, the IJC's Health Professionals Advisory Board (HPAB) released its recommended human health indicators to assess progress under the GLWQA (HPAB, 2014). These human health indicators were transmitted to the Canadian and US governments by the IJC, with the recommendation that they be evaluated for use as potential indicators in the SOGL reporting process, as they can contribute to the governments' efforts to provide the public with a meaningful assessment of the state of the lakes. The 2014 HPAB report included recommendations specific to General Objective 1, focusing broader attention on the Great Lakes as a source, in addition to treated drinking water. The recommendations included two proposed source water indicators: Chemical Integrity and Biological Hazards. With the 2017 SOGL framework these could be sub-indicators within the drinking water indicator.

As noted in the HPAB (2014) report, a focus on source water allows for a more direct connection with the first objective of the Agreement that the lakes are a source of safe high-quality drinking water and addresses risks to human health. The report also notes that focusing exclusively on source water is not adequate to protect human health and suggests that source water monitoring be augmented by monitoring of treated drinking water.

As described below, the HPAB recommends several source water parameters, as components of the proposed chemical integrity and biological hazards sub-indicators, to use in future SOGL drinking water indicator reporting. Costs for such sampling may not justify the benefits at this time. However, as technology advances, costs of sampling and analysis may decrease, or the risks from exposure to these toxins may rise, which may make increased sampling more practical and of increased benefit in the future.

Chemical integrity

The HPAB (2014) recommends that the drinking water indicator include several measures of chemical integrity including endocrine disrupting compounds (estrogenicity assay), atrazine and cyanotoxins (microcystin-LR, anatoxin-aandcylindrospermopsin. These measures provide a cross-section of compounds that are widely dispersed and potentially hazardous to human health, and those where emerging science indicate a cause for concern. The HPAB further recommended that these compounds should be monitored at the intakes of drinking water facilities with standardized methodologies on a weekly basis.

Atrazine is listed as a drinking water contaminant and regulated in treated drinking water in both the US and Ontario. In the US atrazine is regulated under the EPA's Safe Drinking Water Act and in Ontario under the Ontario Drinking Water Quality Standards.

Ontario has a Maximum Acceptable Concentration for microcystin-LR in treated drinking water, but no current US regulations exist for cyanotoxin levels. However, the US EPA includes the cyanotoxins, microcystin-LR, anatoxin-a, and cylindrospermopsin on its 2009 Candidate Contaminant List 3 as well as its draft 2015 Candidate Contaminant List 4. The Contaminant Candidate List is a list of drinking water contaminants that are known to occur or anticipated to occur in water supply systems, but are not currently regulated. The contaminants listed may require future regulation under the US *Safe Drinking Water Act*.

Biological hazards

HPAB (2014) also recommended biological hazard measures that include expanding the monitoring of *E. coli* to include *Cryptosporidium parvum* and *Giardia lamblia*, nitrate and turbidity at the intakes of drinking water treatment plants, on a daily basis. *E. coli* is commonly found in the digestive tracts of humans and animals and is used as a proxy for the presence of other pathogenic bacteria in surface waters. Increased turbidity (*i.e.*, suspended particles) in source waters is associated with waterborne pathogen contamination (Aramini, et al.,2000; Atherholt, et al.,1998; Jagai, et al., 2012). Microbiological contamination and increased turbidity can result from processes such as erosion, surface runoff, sewage effluent, combined sewer overflows, and other discharges. The HPAB further recommends that these parameters be measured with a daily frequency.

Turbidity

Turbidity levels can also be lowered by filter feeders such as the invasive zebra mussel (Holland,1993). The HPAB (2014) report acknowledges that zebra and quagga mussels improve water clarity, but still recommends turbidity be measured at the drinking water intakes. In the nearshore (again where intakes are located), turbidity can quickly change as a result of storm events and precipitation (storm water discharges, overland runoff, CSOs) and strong winds (sediment resuspension). Turbidity can also indicate the presence of other contaminants such as bacteria, nutrients (e.g. nitrates), pesticides, and metals. Higher levels of turbidity make it more difficult and expensive to treat the water. Per the HPAB report, increased turbidity in source waters is associated with increased risk of acute gastrointestinal illnesses. Turbidity can be used as an easy, inexpensive surrogate measure to indicate the presence of pathogens. The HPAB further notes that turbidity measures would complement the other recommended biological parameters of E. coli and nitrate.

Current Practice of Measure

Turbidity is monitored and reported at drinking water intakes in the United States (Interim Enhanced Surface Water Treatment Rule, 1998; Long Term 1 Enhanced Surface Water Treatment Rule, 2002) and Ontario (Drinking Water Systems: Ontario Regulation 170/03, 2006)

based on drinking water treatment regulations. Various methods for measuring and reporting *E. coli, Cryptosporidium parvum* and *Giardia lamblia* in source and drinking waters in the United States and Canada have been developed. All three microorganisms are monitored and reported for treated drinking water, per requirements outlined in standards in the United States (National Primary Drinking Water Regulations) and Ontario (Ontario Drinking Water Quality Standards). Ontario's Provincial Water Quality Monitoring Network monitors *E. coli* in source waters at select sites, with *C. parvum*and *G. lamblia* included during project-specific studies. There is no continuous national program for monitoring these three microorganisms in source waters in the United States. Baseline monitoring for *C. parvum* was established as part of the US EPA's Long Term 2 Enhanced Surface Water Treatment Rule, 2006, but this monitoring was not established as a continuous long-term program. In further developing the biological hazard indicator, the next phase should be the examination of the status of current data sets and identifying methods for standardization of measurement and reporting.

Nitrates

For source water used for drinking water, the IJC is concerned about water quality in the nearshore zone, where drinking water intakes are located (IJC, 2011). Sources of nitrate typically include runoff from agricultural/livestock operations, septic tanks, sewage sludge application, and natural occurrence in soils. These all have direct interactions/influence on the nearshore. Several studies found increasing levels of nitrates throughout the Great Lakes: Findlay et al., (2000); Sterner (2011); Eimers and Watmough (2016); and Michigan State University, http://bogls.science.wayne.edu/talks/Monday/Ostrom-NE-PH-Ostrom-KR-Salk.pdf

a. An additional concern is higher concentrations of nitrates in the nearshore than the offshore. Nearshore Waters of the Great Lakes (USEPA, 1997) – provides a figure (Figure 9) that illustrates higher concentrations of nitrate in the nearshore areas of the lakes vs. offshore.
b. Land-Lake Interaction at the Margins of the Great Lakes (presentation by MOECC, 2009) – illustrates nitrate concentration gradient from a river discharging to Lake Huron and along the nearshore.
c. Water Quality of Nearshore Lake Ontario (presentation by MOEEC, 2012) – illustrates rising nitrate concentrations in the nearshore (as well as in-lake) of Lake Ontario.

3. Improvements in indicator reporting

The "Drinking Water" indicator presented in the Parties' 2017 SOGL Highlights report, uses treated drinking water quality only. While it is useful for the public to know it is safe to drink treated water, it does not properly assess progress towards Objective 1 that the waters of the Great Lakes "should be a *source* of safe, high-quality drinking water" (emphasis added). In Ontario, through the voluntary Ontario DWSP, both untreated (*i.e.*, source water) and treated drinking water samples are collected from drinking water facilities and analyzed for a suite of organic and inorganic contaminants, both regulated and non-regulated.

There is currently no national US database for source water data (*i.e.*, source water used as a public drinking water supply). The lack of US source water data creates a gap in comprehensively assessing progress toward meeting Objective 1 under the GLWQA. A federal repository for source water data could be established (or current repositories augmented, such as the electronic Storage and Retrieval/Water Quality Exchange data systems), to enhance indicator reporting under the SOGL reporting. Additionally, collecting such data over long time periods would allow for assessment of trends and changes in source water quality and informing source water assessments and protection planning.

5.1.3 Assessment of the Progress Report of the Parties

The PROP (Government of Canada and the United States, 2016) focuses on reporting progress on the actions taken by Canada and the United States in meeting the commitments under the Articles and Annexes of the GLWQA during the 2013-2016 timeframe. The actions undertaken in each of the Annexes are intended to lead to the protection, restoration, and enhancement of the Great Lakes waters and will therefore subsequently result in the protection, restoration, and enhancement of sources used as a public drinking water supply. However, there is no Annex that specifically supports the achievement of Objective 1 and therefore no reporting directly related to the achievement of this objective. The 2012 GLWQA highlights the importance of the connection of the quality of the waters of the Great Lakes to health, particularly the need to restore nearshore waters given that they are a major source of drinking water. The IJC recommended developing goals, targets, and monitoring of the nearshore in its 15th Biennial Report on Great Lakes Water Quality (IJC, 2011) and the Science Priority Committee of the Science Advisory Board identified the nearshore as one of five priority recommendations on which the Parties should focus(SAB-SPC, 2016).Reporting on the progress towards the protection and restoration of the nearshore is particularly relevant to the achievement of Objective 1.

Although several Annexes have relevance to drinking water (i.e. Annex 3 – Chemicals of Mutual Concern, Annex 9 – Climate Change), linkages between the protection and restoration of the nearshore drinking water sources are recognized in the work undertaken in Annex 1-Areas of Concern (AOCs), Annex 2 – Lakewide Action and Management Plans (LAMPs) and Annex 4 – Nutrients.

1. Annex 1 – Drinking water activities in Areas of Concern

The annex on Areas of Concern (AOCs) commits the Parties to restoring beneficial use impairments (BUIs) in AOCs through the development of Remedial Action Plans (RAPs). There are 14 BUIs representing specific environmental impacts, one of which includes “restrictions on drinking water consumption, or taste and odour problems.” Of the 43 AOCs designated by the Parties, ten of those have (or had) a BUI associated with restrictions on drinking water consumption (Table 5.1.1). Of the ten BUIs, seven have been removed, with two of them removed since the GLWQA came into effect in 2013.

Table 5.1.1Status of BUI "*Restrictions on drinking water consumption, or taste and odour*" in Great Lakes AOCs (Source: Progress Report of the Parties, Government of Canada and the United States, 2016)

	Restrictions on drinking water consumption or taste and odour	
AOC	BUI Removed	BUI Impaired
St. Clair River (MI/ON)		X
Detroit River (MI/ON)	2011	
Bay of Quinte (ON)		X
St. Lawrence River (ON)	1997	
Grand Calumet (IN)	2012	
Muskegon Lake (MI)	2013	
Saginaw River and Bay (MI)	2008	
White Lake (MI)	2014	
Fox River/South Green Bay (WI)		X
Rochester Embayment (NY)	2011	
TOTAL	7	3

The Parties expect to continue to make progress in the three remaining AOCs with the drinking water restriction impairment:

Bay of Quinte (ON)

All priority actions are expected to be completed by 2019 (Government of Canada and the United States, 2016). The BUI specific to drinking water restrictions is currently undergoing re-designation as *not impaired*. In 2014, a municipal drinking water taste and odor survey was completed and the majority of residents were satisfied with their drinking water. Additionally, less than 20 percent of source water samples for the past three years have exceeded the odor threshold concentration for taste and odor compounds. There has been no increase in taste and odor complaints since 2004, and for the past five years all health related water quality parameters in drinking water, including *E. coli* and microcystin-LR, have been at concentrations equal to or below the regulated Maximum Acceptable Concentration (http://www.bqrap.ca/bui/9/, accessed July 2016).

St. Clair River (ON/MI):

Ontario: All RAP actions are expected to be completed by 2020 (Government of Canada and the United States, 2016). The Canadian Remedial Action Plan Implementation Committee recently commissioned a discussion paper (Avanti Insight Consulting, 2016) to help assess the next steps in re-designating the BUI for drinking water restriction to *not impaired* status. The paper cites significant improvements to drinking water risk reductions since the 1987 Stage 1 RAP due to: the implementation of source water protection plans; improvements in spills modeling; institution of regulatory requirements for spill prevention and contingency plans; improved government oversight for spills prevention; a 100-fold reduction in the number of spills; and fewer water intake closures. This paper will form the basis of a public consultation process, the results of which will be considered in the final review of the BUI for re-designation.

Michigan: All RAP clean-up actions were completed in 2015 (Government of Canada and the United States, 2016). The PROP indicates that the St. Clair River AOC is undertaking actions to evaluate and assess its BUIs. The drinking water restriction BUI will be removed when monitoring data for two years show that public water supplies meet the current health standards, objectives or guidelines for treated drinking water, and that treatment needed to make source water potable and palatable does not exceed standard methods (MDEQ, 2008).

Fox River/South Green Bay (WI):

RAP actions are not expected to be completed before 2026 (Government of Canada and the United States, 2016). The drinking water restriction BUI was originally listed based upon "unknown risks of toxic substances to human health" and the health risks of exposure to the multitude of chemicals suspected to exist in the AOC (WDNR, 2015). However, the BUI's current status is unknown and requires further assessment of several factors, including: densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances (including cyanobacteria and cyanotoxins) in treated drinking water; the presence of taste and odor in treated drinking water; and treatment costs to make source water suitable for drinking (WDNR, 2016). The Wisconsin Department of Natural Resources initiated an effort in 2016 to design the assessment process, the results of which are anticipated in 2019. The assessment is expected to be challenging as the surface waters of the AOC are not currently used as a drinking water supply, with Lake Michigan used as the preferred alternative.

To summarize the progress on the AOC BUI for drinking water, the removal of the drinking water restrictions on BUIs from AOCs has improved, with several removed in the last five years. In addition, the remaining BUIs in the Bay of Quinte and St. Clair River are expected to be removed within the next two to three years.

2. Annex 2 – LAMPs

The 2012 GLWQA requires the development of an integrated nearshore framework. When implemented, the framework will allow for an overall assessment of the state of the nearshore waters of the Great Lakes. It will identify waters that are or may become stressed, and establish priorities for action. The draft nearshore framework was released in May of 2016 (Lakewide Management Annex Nearshore Framework Task Team, 2016). The framework highlights the importance of restoring and protecting nearshore areas, not only for recreational uses and the ecological link to the open waters, but also as a source of drinking water for communities. As a result, one of the five key guiding principles under the framework is "healthy Great Lakes support healthy people" – recognition that the lakes provide a source of drinking water to more than 40 million people. The framework's assessment of nearshore waters will take into account the impact of nearshore conditions on human uses, such as drinking water.

Building on the information provided by the assessment, management actions will be identified to protect nearshore areas of high ecological value, protect water quality and restore degraded areas. The extent to which drinking water sources will be taken into account in both the assessment and management actions is yet to be determined. The Parties' 2017-2019 draft

Binational Priorities for Science and Action includes the piloting of the nearshore framework assessment component in select areas to refine the approach for basin-wide implementation.

3. Annex 4 – Nutrients

In June 2015, the governors of Ohio and Michigan and the premier of Ontario signed the Western Basin of Lake Erie Collaborative Agreement to reduce phosphorus inputs to the western waters of Lake Erie by 40 percent over the next ten years. In February 2016, the governments of Canada and the United States announced the adoption of a binational target to reduce total phosphorus entering Lake Erie by 40 percent. To meet this target, the Parties are committed to developing domestic action plans by February 2018, as outlined in their draft 2017-19 Binational Priorities for Science and Action. The governments further identified eight priority watersheds for phosphorus control to address algal blooms in the nearshore waters. The domestic action plans will identify and prioritize watershed efforts and actions to meet the phosphorus reduction goals. The success of the domestic action plans is critical to restoring Lake Erie's water quality and to protecting the waters for the millions of people that rely on the lake for their drinking water. The Parties' phosphorus reduction strategies and domestic action plans are discussed in more detail in section 5.6.

4. Gaps in Annex Implementation

The 2012 GLWQA highlights the importance of the connection of the quality of the waters of the Great Lakes with human health, particularly the need to restore nearshore waters given that they are a major source of drinking water. The connection between human health and the quality of the waters of the Great Lakes under the GLWQArequires greater prominence in Agreement implementation. This could be achieved through reporting of human health activities under the GLWQA, enhancing the public's understanding of the Parties' efforts to address human health as affected by the waters of the Great Lakes, and examining emerging issues that could impact the quality of water used for drinking.

more consideration also needs to be given to the links among the various Annexes that impact the source waters used for drinking (e.g. climate change, chemicals of mutual concern), increasing the importance of, and giving greater consideration to, drinking water impacts. Additionally, greater engagement of First Nations, Tribal and Métis communities, populations which may not have access to safe drinking water, and have traditional knowledge to offer, could be better incorporated into discussions about source water quality. These tasks could potentially be addressed through the development of a committee, similar to an annex sub-committee or task team (e.g. the Annex 10 Traditional Ecological Knowledge task team), focused on achieving the drinking water objective. The committee could also enhance the public's understanding of the Parties efforts to address human health as affected by the waters of the Great Lakes.

5.1.4 Assessment of key government programs

In Canada, drinking water guidelines are developed through the Federal-Provincial-Territorial Committee on Drinking Water and are administered by Health Canada. These are non-enforceable guidelines and the provision of safe drinking water is left to each province and territory. In Ontario, the Ministry of Environment and Climate Change is responsible for regulating drinking water quality. It is the agency responsible for overseeing the implementation of the *Ontario Safe Drinking Water Act* (ON SDWA) (treatment, distribution, and monitoring requirements) and the *Ontario Clean Water Act* (ON CWA) (source protection requirements). Together they form a regulatory framework for a *source-to-tap* (or "multi-barrier") approach for the provision of safe drinking water. The combination of these two Acts has resulted in Ontario being recognized as having one of the "most ambitious source water protection programs in Canada" with some of the country's "strongest treatment, testing, operator training and public reporting standards" (Ecojustice, 2011).

In the United States, two significant federal statutes contribute to the provision of safe drinking water, the 1974 *US Safe Drinking Water Act* (US SDWA) and the *US Clean Water Act* (US CWA). The protection of public health is the focus of the national drinking water program. Since the institution of the US SDWA, increases in the percentage of population served by water systems meeting all health-based standards has been attributed to the implementation of a multi-barrier approach (USEPA, 1999). Under the US SDWA, the US EPA establishes national enforceable standards for drinking water quality and ensures monitoring for compliance with these national standards. The US SDWA also delegates primary responsibility to the states for program implementation. The US CWA includes a combination of water quality-based and technology-based approaches to regulate the discharges of pollutants into the waters of the United States and to regulate quality standards for contaminants in surface waters. The EPA has implemented pollution control programs under the US CWA that address water quality standards (*e.g.*, total maximum daily loads), point discharges (*e.g.*, National Pollutant Discharge Elimination System) and nonpoint sources.

1. Source water protection in Ontario

Ontario enacted the *Ontario Clean Water Act* as a first step of the multi-barrier approach. The ON CWA supports the implementation of many recommendations resulting from the Walkerton Inquiry (Part II) Report (2002), which investigated the cause of *E. coli* O157:H7 contaminated drinking water that resulted in several deaths and a multitude of illnesses. The stated purpose of the act is to "protect existing and future sources of drinking water" by requiring the development of watershed-based source water protection plans (SWPP). These plans are required to include:

- the identification of local activities that could potentially pose a risk to drinking water supplies (wells and surface waters);
- an assessment of the level of risk posed; and
- actions to reduce, eliminate and/or manage the identified risks.

A total of 22 SWPPs have been submitted and approved by the Ontario Minister of Environment and Climate Change, which fulfilled Ontario's commitment to have all the plans approved by the end of 2015. The effective dates of these plans range from October 2014 to July 2016 (http://conservationontario.ca/what-we-do/source-water-protection, accessed August 2016). The approved plans include legally binding policies to mitigate source water threats, to be implemented by various bodies, including ministries/government agencies, municipalities, and conservation authorities (local provincial watershed management agencies).These mitigation policies can include land-use planning, regulations, and stewardship, such as education and best management practices. Once a SWPP is in place, municipalities or planning authorities cannot undertake any activity that conflicts with that plan.

Together, the 22 plans protect the source waters of more than 450 municipal drinking water systems, with 154 of these systems having intakes in the Great Lakes (Office of the Auditor General of Ontario, 2014). If a source protection area contains water that flows into the Great Lakes, then the SWPP is required to consider the GLWQA, the Great Lakes Charter, Canada-Ontario Agreement and any other agreements related to the Great Lakes basin, to which the governments of Ontario or Canada are party.

In addition, SWPPs are one of many tools used by Ontario in its plan to combat algal blooms and cyanotoxins in the Great Lakes (https://www.ontario.ca/page/blue-green-algae, accessed July 2016). For example, SWPPs may manage local activities such as storage and handling of manure and maintenance of septic systems, which can contribute nutrients and promote algal blooms, as well as educate residents on actions they can take to reduce nutrient runoff.

Ontario's action on source water protection received an "A" ranking — the highest in Canada — in Ecojustice's Canada's Drinking Water Report Card(Ecojustice, 2011).

2. Source water protection in the United States

Through amendments to the US SDWA, the United States included requirements to first protect groundwater, in 1986, through the development of wellhead protection programs and then ten years later for surface waters. The 1996 amendments included provisions intended to protect the nation's drinking water at all sources in order to reduce water treatment costs and risks to public health. The US SDWA required, by 2003, that each state develop a Source Water Assessment Program (SWAP), for approval by the USEPA, to assess the susceptibility of public drinking water supplies to contamination. An Assessment Agreement for Great Lakes Sources was developed for Great Lakes states, to help ensure a more coordinated approach in assessing intakes using Great Lakes source water. The Agreement identified two factors that could affect the sensitivity of the intakes: length of intake pipe and depth of intake. The key steps in the source water assessment process are:

- Identify the sources of all public drinking water supplies (groundwater and surface water).
- Map the land area that could contribute water and pollutants to the water supply.
- Identify existing and potential sources of contaminants within the delineated area.
- Determine the susceptibility of water supplies to contamination.

The resulting assessments are intended to provide information to local stakeholders to help prioritize actions in protecting the drinking water supply. The EPA's Source Water Protection Program is intended to support and encourage partnerships among local, state and regional agencies to better manage and prevent contamination by using a combination of regulatory tools (*e.g.*, land use restrictions) and non-regulatory tools (*e.g.*, public education/awareness). The Source Water Collaborative, which consists of 26 national organizations including the US EPA, works to support coordinated actions between agencies and organizations to promote the implementation of source water protection and increase its chances of success (http://sourcewatercollaborative.org/about, accessed August 2016). However, there is no specific federal mandate for the development or implementation of a source water protection program/plan. Rather, the source water protection program relies on voluntary state and local efforts. Without an overarching federal mandate, this leads to a lack of consistency in the development and implementation of source water protection programs among the states. Additionally, the absence of an EPA mandate has been found to be one of the challenges in implementing effective source protection planning (USEPA, 2005; Canadian Environmental Law Association, 2008; Water Research Foundation, 2012). A key challenge is that voluntary programs tend to receive a lower priority for implementation, given limited government resources and the variety of mandates that states must comply with to ensure not only drinking water quality, but other environmental and non-environmental standards.

In August 2015, the USEPA amended the US SDWA with the *Drinking Water Protection Act,* requiring the USEPA to develop a strategic plan for assessing and managing risks associated with algal toxins in drinking water provided by public water systems. The strategic plan was developed in November 2015 and provides steps and timelines for USEPA activities to address issues such as, source water protection practices to mitigate adverse public health effects human health effects from exposure to algal toxins; factors likely to cause HABs, and drinking water treatment options for removal of algal toxins (USEPA, 2015).

3. Tribes and First Nations

Water is sacred to Tribes and First Nations and plays an important role in cultural practices and teachings. In Ontario, First Nations recognize their special relationship and responsibility to protect the waters and lands upon which they depend for life, cultural ceremonies, and teachings (Chiefs of Ontario, 2008). Similarly in the US, many tribal nations recognize water as sacred and vital to their subsistence, cultural practices, health and welfare (http://www.ncai.org/policy-issues/land-natural-resources/water, accessed June 2017). Drinking water advisories on Tribal lands and First Nations reserves are disproportionately high compared to non-tribal and non-First Nation communities (Human Rights Watch, 2016; Natural Resources Committee Democrats, 2016)

Tribes

Tribal public water systems in the United States have more health-based violations of the US Safe Drinking Water Act (SDWA) than the US national average. They also have more SDWA violations overall, including those related to monitoring and reporting. (Natural Resources Committee Democrats, 2016).In 2010 in the United States, over 5 percent of tribal homes did not have access to safe drinking water (Infrastructure Task Force, 2010). Tribes can face significant

challenges in implementing the complex programs that ensure safe drinking water as a result of low levels of financial and human resources (Teodoro et al., 2016). Additionally, many tribes are decades behind non-tribal communities in developing systems for compliance with environmental programs as a result of their exclusion from major environmental statutes established in the 1970's, such as the US SDWA (Teodoroet al., 2016). The US SDWA along with other major environmental laws originally established in the early 1970's, did not include provisions for implementation on tribal lands until the mid-80s or early-90s.

USEPA works with Tribal governments and utilities to assist them in complying with the standards and requirements of the US SDWA, including the limitation of contaminant levels in drinking water. The Tribal Public Water System Supervision Program, established under the US SDWA, ensures that water systems comply with the requirements and standards of the US SDWA. Funding support for this program is provided through state and tribal allotments. For Region 5, the tribal allotment was $648,000 for FY2017, 3.5 percent of the total funding for the region (https://www.epa.gov/sites/production/files/2017-06/documents/wsg_202_pwss_fy17_allotments.pdf, accessed July 2017). The allocation of these funds is based on tribal population, tribal land area and number of water systems located within the tribal boundaries.

Funding for the provision of safe drinking water is also made available to tribes through the Drinking Water State Revolving Fund to finance new drinking water infrastructure and improvements to existing infrastructure. The2016 *Water Infrastructure Improvements for the Nation Act* expanded the activities that can qualify for funds under the tribal set-aside Drinking Water State Revolving Fundto include training and certification of operators of drinking water systems serving tribal communities. The USEPA is authorized to set-aside up to 2 percent of the revolving fund for systems that serve Tribes. Funding is allocated to USEPA Regional Offices based on a formula that includes a base funding amount and the Region's percentage of tribal drinking water system "needs". These "needs" are based on the USEPA's *Drinking Water Infrastructure Needs Survey* and the Indian Health Services report *Sanitation Deficiency System*, which are updated every four years and annually, respectively. The *Drinking Water Infrastructure Needs Survey* is a requirement under the US SDWA to assess the nation's public drinking water infrastructure investment needs, over a twenty year period. The needs of water systems serving American Indians and Alaska Native Villages totaled $2.9 billion (of $334.8 billion nationally) in 2007 and $3.3 billion (of $384.2 billion nationally) in 2011 (USEPA, 2009; USEPA, 2013). The National Congress of American Indians (2017)report highlights the inequality of drinking water quality between tribal systems and non-tribal systems and calls for a funding increase of the tribal set-aside of the revolving fund , from 2 percent to 5 percent. In FY 2012, Tribes received $0.75 per every $100 of need identified in the 2007 Drinking Water Needs Survey (National Congress of American Indians, 2017).

The development of a Source Water Assessment Program (SWAP) under the US SDWA is a requirement of the states, but not for Tribes, although it is strongly encouraged. Within the Great Lakes basin several Tribes have developed SWAPs, including the Bay Mills Indian Community and Hannahville Indian Community. These source water assessments are used to implement source protection activities. Many of the Tribes in the basin have water protection programs in place. Under the US Clean Water Act, tribes are eligible for funding to implement water

protection activities such as, water quality monitoring, development of a source protection plan, and implementing pollution control measures (e.g. ordinances). Funding is allocated to each state and interstate agencies based on a formula that accounts for the extent of pollution in the state. A portion of the funds are set-aside to USEPA Regional Offices for allotments to tribes. In FY 2016 funding allocated to Region 5 was $38,491,000, with $4,068,000 of that set-aside for tribes (https://www.epa.gov/sites/production/files/2017-04/documents/final_fy_16_section_106_with_rescission_standard.pdf, accessed July 2017).

To further improve access to safe drinking water the US government established a multi-agency tribal Infrastructure Task Force in 2007. The goal of the task force is to develop and coordinate federal activities to deliver water infrastructure, wastewater infrastructure and solid waste management services to tribal communities. One of the goals of the task force was to achieve a 50 percent reduction from 2003 to 2015 in the number of tribal homes that lack access to safe drinking water and wastewater disposal. As of 2010 the number of homes that lacked access to safe drinking water and wastewater disposal had been reduced by 13 percent (Infrastructure Task Force, 2010). Since the establishment of this task force the group has identified best practices to improve the sustainability of tribal water and wastewater infrastructure; created an online directory of contacts for technical assistance to tribal water and wastewater operators; and streamlined the application processes to access multiple federal funding sources (Infrastructure Task Force, 2013)

First Nations

Drinking water advisories are used to alert communities when drinking water is not safe for consumptive use. In Canada, these advisories occur disproportionately more frequently in First Nations communities. As of July 2017, Ontario had 92 drinking water advisories on First Nations reserves, which includes one of the longest standing boil water advisories, over 22 years, on the Neskantaga First Nation (https://www.canada.ca/en/health-canada/topics/health-environment/water-quality-health/drinking-water/advisories-first-nations-south-60.html#ont, accessed July 2017). Several of these drinking water advisories are on reserves located in the Great Lakes basin, with some in place since 2003. A Human Rights Watch (2016) report highlights several items contributing to the water crisis experienced by First Nations including, lack of binding regulations on water quality for First Nations reserves; continuous under-funding for water system costs (capital, operations and maintenance); worsening conditions of source water; and lack of capacity and support for water operators.

In Canada, provincial and territorial regulations for safe drinking water do not extend to First Nations reserves. Only the federal government has the authority to pass binding regulations applicable to First Nations reserves. There are currently no drinking water regulations on reserves, though the federal government does provide protocols and standards for design, construction, operation, maintenance and monitoring of drinking water systems in First Nations communities. The responsibility for the provision of drinking water is a shared responsibility among:

- First Nations band councils
    - Own, manage and operate facilities
    - Design and construct facilities in accordance with standards
    - Monitoring

    - Issue drinking water advisories, usually upon the recommendation of Health Canada
- Indigenous and Northern Affairs Canada (INAC)
    - Provides funding and advice on design, construction, operation and maintenance of facilities
    - Funds training of First Nations operators
    - Sets standards through Agreements (not enforceable)
- Health Canada
    - Ensures monitoring programs are in place
    - Helps First Nation communities identify potential drinking water quality issues
    - Verifies monitoring of drinking water quality at the tap
    - Reviews First Nation infrastructure projects from human health perspective
- Environment Canada
    - Provides guidance on source water protection and sustainable water use

The federal government has taken steps to remedy the lack of legally-enforceable protections for safe drinking on reserves.In June 2013 the *Safe Drinking Water for First Nations Act* was passed and came into force in November 2013. The Act allows the Government of Canada, in collaboration with First Nations, to develop regulations that would ensure access to safe drinking water; effective treatment of wastewater and protection of source waters on First Nation lands. INAC, with support from Health Canada, is currently engaging with First Nations to establish long-term actions to ensure safe drinking water and to address the concerns of First Nation communities regarding the *Safe Drinking Water for First Nations Act*(https://www.aadnc-aandc.gc.ca/eng/1496056786210/1496056888386, accessed June 2017). However, First Nations have objected to the Act, with the passing of a resolution by the Assembly of First Nations in December of 2015. The resolution calls for the repeal of the Act as the government did not appropriately consult with First Nations nor does the Act guarantee federal government investments needed to support capital and human resource costs (Assembly of First Nations, 2015). Some First Nation leaders are also concerned that the Act, in deeming the First Nations as owners of the water systems, allows the government to pass the problems of inadequate infrastructure to First Nation communities to deal with, but not provide the funding to meet the requirements of the Act (Human Rights Watch, 2016).

Deficiencies exist in First Nations water and wastewater infrastructure systems in Ontario (Indian Affairs and Northern Development, 2011). The Indian Affairs study found that out of 158 systems assessed, 45% are at high risk (i.e. major deficiencies that may lead to potential health and safety or environmental concerns; require immediate action), 39% are at medium risk (i.e. deficiencies that pose medium risk to water quality and human health; does not require immediate action, but should be addressed to avoid future problems), and 16% are at low risk (i.e. minor deficiencies; usually meets water quality parameters specified by the appropriate guidelines). The report further estimated the costs of construction, non-construction (e.g. training, source water protection plans), operation and maintenance to upgrade these systems to meet INAC Agreement standards for design, construction, operation, maintenance, and monitoring of these systems. For Ontario, these costs totaled over $241.7 million for construction and non-construction costs and $4.03 million for additional annual operation and maintenance.

The funding of water and wastewater services on First Nations reserves is through the federal government and INAC specifically, whereas off-reserve municipalities fund these services through taxes, user fees, and subsidies from the provincial and federal governments. INAC, funds all capital costs for water systems and 80% of operation and maintenance costs, with the remaining 20% to be covered by First Nations. In some cases First Nations generate revenue in a variety of ways such as levying property tax and operating First Nation-owned casinos (www.cbc.ca/news/canada/how-does-native-funding-work-1.1301120, accessed June 2017). The government of Canada, as part of its 2016 budget, committed to ending long-term boil water advisories and ensuring proper operation and maintenance of water and wastewater facilities on reserves through an investment of $1.8 billion over 5 years, starting in 2016-17 (Government of Canada, 2016a). This will also be complemented by an investment of $141.7 million, over 5 years, to improve the monitoring and testing of on-reserve community drinking water.

Ontario is working with First Nation communities and the federal government to help achieve the federal commitment to eliminate long-term drinking water advisories on reserves. The Ontario government is doing this in several ways. They are offering in-kind support to First Nation communities for on-site assessment of water systems; technical reviews of design and construction projects; operator training; and source water protection planning. The Walkerton Clean Water Center, an agency of the provincial government, provides hands-on training and education for drinking water operators, with a particular focus on small remote systems, including First Nations. The MOECC also established the Indigenous Drinking Water Projects Office to provide engineering and technical advice and support for First Nation drinking water and wastewater systems.

With regard to the role of First Nations in source water protection planning, INAC through its Agreement for Safe Drinking Water in First Nations communities has required First Nations to develop source water protection plans. However, as of 2011only 11% of First Nation communities had a plan, with the reasons cited as lack of funding and challenges in engaging relevant stakeholders (Human Rights Watch, 2016). Ontario also established regulations requiring the development of source water protection plans under its Ontario Clean Water Act, within 19 source protection regions (15 of these rely on the Great Lakes and their connecting channels for source water). Of the 19 Source Protection Committees created under the CWA, 12 have seats dedicated to First Nations representatives, with six First Nations communities having appointed members to sit on the committees as an observer (https://www.ontario.ca/page/ontarios-great-lakes-strategy-2016-progress-report#section-4, accessed July 2017). A drinking water system that serves or plans to serve a First Nation reserve can be included in the source protection planning process if the Ontario Minister of Environment receives a Band Council resolution requesting the system be included and that the province then passes a regulation under the Ontario CWA to include that system. There are currently three First Nations systems included in the source protection planning process – Chippewas of the Rama First Nation, Six Nations of the Grand River and Chippewas of Kettle and Stony Point First Nation – all located within the Great Lakes basin. Their inclusion in source protection plans will help to ensure that off-reserve actions will protect the First Nations' drinking water sources.

4 Infrastructure

The IJC's 14th Biennial Report (2009) focused on examining surface-water pollution from municipal wastewater systems (treatment plants and sewer collection systems). The report noted the consequences of polluted wastewater discharges including, increased costs of drinking water treatment, beach closures and loss of recreation and tourism, and human illness. The report further called for governments to ensure that economic measures address wastewater system needs in the Great Lakes basin. Ensuring adequate funding for water and wastewater infrastructure costs is particularly important for economically stressed and/or minority/disadvantaged communities, who face funding limitations for infrastructure investments or may have a large number of low-income households unable to afford water and wastewater utility rates. Additionally, in March of 2017 the Great Lakes Commission (GLC) released a statement calling on the United States and Canada to implement large-scale initiatives with increased federal investment to upgrade and improve the Great Lakes region's drinking water, wastewater, and stormwater infrastructure (GLC, 2017). The GLC statement recommended the continued support of infrastructure programs with adequate funding as well as seeking new approaches for financing water infrastructure. Additionally, such programs should prioritize those projects that will assist disadvantaged communities.

Agreement Objectives commit the Parties to assuring the waters of the Great Lakes are a source of safe, high-quality drinking water, allowing for swimming and consumption of fish and wildlife unrestricted by concerns due to harmful pollutants. The quality of the waters of the Great Lakes is threatened if infrastructure is inadequate or failing. Combined sewer overflows (CSOs) and overtaxed wastewater systems can result in source water impacts. Inadequate treatment plans or problems in water distribution, including the potential for lead to leach from pipes, can result in impacts to the drinking water delivered to the public. Therefore, providing and maintaining infrastructure adequate to meet these objectives isone of the governments' most basic – and expensive responsibilities. Infrastructure ages and meeting the costs to maintain and update these systems is a challenge. Additional stressors such as climate change (more frequent, intense storm events) and cyanotoxins in source water further compound this challenge. The Commission's HPAB (2017) discusses the challenges in maintaining safe aquatic environments for recreation and drinking water uses in response to cyanotoxins. One of the recommendations stemming from that report included making improvements to drinking water treatment systems to ensure the effective removal of cyanotoxins to protect public health.

Infrastructure Funding Needs and Investments

Both Parties have partnered with provincial, state –municipal, First Nations and Tribal governments in supporting essential infrastructure for drinking water, wastewater, and stormwater management systems. Infrastructure investments will continue to place considerable demands on public budgets, and planning for future needs is essential. Ensuring the adequacy of existing infrastructure to meet the objectives of the Agreement for future generations, and assessing anticipated costs required to provide this infrastructure, requires continual attention from governments.

Land-use planning creates goals for how the community desires to develop into the future, based on analyses of a community's present and future needs. Well-developed land-use plans can protect a community's environmental and human health, implement robust infrastructure plans, and promote economic development. Land-use plans guide the development of zoning

ordinances, which provide the legal framework to regulate land use. Zoning ordinances establish permitted land uses; differentiate between different land use types; and ensures that incompatible land uses are not located next to one another. For example, zoning ordinances can set restrictions on building on flood plains or wetlands, which can support a community's land use planning goal of improving resiliency to severe storm events and protecting residents' safety. When used together, land use plans and zoning ordinances can protect the health of the communities' environment and its residents.

A significant challenge to adaptation planning and implementation is limited funding. Investments in infrastructure are also needed to support communities in improving their capacity to respond to extreme storm events, as related to not only CSOs, but also planning, zoning and adaptation activities. The need to reduce the impacts of urban areas on the Great Lakes was highlighted in a 2009 report to the IJC by its advisory boards, finding that local communities need to be supported by senior levels of government in terms of improving wastewater and storm water infrastructure; restricting land development beyond current urban zones; and adopting land use planning measures that deters urban sprawl (SAB et. al., 2009). A WQB (2016) report further echoed this notion, through the lens of climate change adaptation, calling on the need for an assessment of storm water infrastructure in the region to prioritize investment in improvements and to illustrate to governments at all levels, the need to invest in climate-resilient infrastructure to address issues from severe precipitation events. Many of the infrastructure solutions and actions for climate change resilience must be at the local level.

The Federation of Canadian Municipalities (2017) issued a policy statement that highlighted Canadian communities' increasing vulnerability to the effects of climate change and the potential impacts on infrastructure that the municipal governments must deal with, including water and wastewater systems. They acknowledge that action is necessary but that they lack the resources to plan for and respond to the impacts, calling on support from the federal government through dedicated investment in extreme weather adaptation projects, such as sewer retrofits, green infrastructure and wetland acquisition/protection. Both federal governments need to develop new strategies and mechanisms to fund local resilience and adaptation projects for urban infrastructure, allowing them to use local knowledge to assess and determine needed projects (Center for Clean Air Policy, 2009; Global Leadership for Climate Action, 2009; Government of Canada, 2016b).

United States

A recent report on US infrastructure has given the nation an overall grade of "D+", with a grade of "D" for both drinking water and wastewater infrastructure (ASCE, www.infrastructurereportcard.org/, Accessed August 2017). Drinking water pipes were laid in the mid-20th century with a lifespan of 75-100 years and are being replaced at a rate where it would take approximately 200 years to replace the system. Similarly, as new users are connected to older waste water collection and treatment systems, it is estimated that 532 new systems will need to be constructed by 2032 to meet these future needs. Municipalities generate revenue for water and wastewater infrastructure operation, maintenance and improvements through public rate payers. Water and wastewater rates vary greatly across the nation and rising bills to meet infrastructure needs can present affordability issues to users, particularly those in low-income communities and communities with shrinking populations (ASCE, www.infrastructurereportcard.org/, Accessed August 2017). Increased water and wastewater

rates are likely to continue, but will not finance the funding gap and municipalities and utilities will need to increase reliance on other funding sources to meet their system needs (Fails Management Institute, https://www.fminet.com/fmi-quarterly/article/2015/06/u-s-water-infrastructure-funding-needs-who-picks-up-the-tab/, accessed August 2017). The federal government offers financial assistance through subsidized loans to support state and local drinking water and wastewater infrastructure projects through the Drinking Water State Revolving Fund and the Clean Water State Revolving Fund, respectively.

The US EPA conducts both a Drinking Water Infrastructure Needs Survey and a Clean Watersheds Needs Survey every four years to assess the nation's capital infrastructure needs for drinking water, wastewater and stormwater (including combined sewers)and allocate funding for the Clean Water and Drinking Water State Revolving Funds. The most recent Clean Watersheds Needs Survey concluded that over the next 20 years, six of the eight Great Lakes states (Minnesota, Wisconsin, Illinois, Indiana, Michigan and Ohio) need an estimated $77.5 billion in capital investment for wastewater, stormwater and combined sewer overflow infrastructure (USEPA, 2016a). To continue the provision of safe drinking water in the Great Lakes states, a 2013 EPA report indicates that over the next 20 years an investment of $102 billion is needed for drinking water infrastructure (USEPA, 2013). The USACE (2011) estimated that the annual funding gap to maintain and upgrade drinking water and wastewater treatment systems across the US in 2010, 2020 and 2040 is $54.8 billion, $84.4 billion and $143.7 billion, respectively.

Spending on water and wastewater infrastructure by federal, state and local governments grew on average 3%-4% per year through the 1980s, then approximately 1%-2% since the 1990s, likely influenced by the growing number of utilities, rising costs of labour and materials and increasing regulations (Environmental Finance Center, http://efc.web.unc.edu/2015/09/09/four-trends-government-spending-water/, Accessed August 2017). This spending peaked in 2010 and decreased by 8% to 2014, due to a decline in capital expenditures. In the 1970s and 1980s the federal government provided substantial amounts of funding (in the form of grants) for water and wastewater projects. Since the mid-80s (around the time the State Revolving Funds came into effect) the federal government switched from providing mostly grants to providing mostly subsidized loans, which has diminished the real purchase power of these programs. Since the inception of the revolving funds in 1987, appropriations to the drinking water and wastewater funds have remained relatively steady over the years and have resulted in over a total of $69 billion in appropriations (Congressional Research Service, 2012). State and local spending has increased every year since 1956 until 2009; thought to be a result of decreased federal funding or because more utilities were in operation from previous federal funding, or both (Environmental Finance Center, http://efc.web.unc.edu/2015/09/09/four-trends-government-spending-water/, Accessed August 2017). Further, the gap between state and local funding and federal funding widened over those years until 2014, where state and local spending accounted for 96% of all spending on water and wastewater systems, with the majority likely spent by local governments.

For the 2016 fiscal year, Congress appropriated $863 million for the EPA's State Revolving Fund programs for drinking water infrastructure and $1.39 billion for wastewater infrastructure (Congressional Research Service, 2016). More recently, the drinking water and wastewater infrastructure appropriations have decreased by $43.6 million and $55 million, respectively, from the 2014 and 2015 fiscal year (http://www.nemw.org/reports-output/tracking-of-federal-funds/, accessed January 2017).

In 2014 a federal credit program under the Water Infrastructure Finance and Innovation Act (WIFIA) was established, which works in coordination with the State Revolving Fund programs to subsidize high-cost water and wastewater infrastructure projects. The WIFIA program provides long-term, low-rate loans and is available to local, state, Tribal, and federal governments. For the 2017 fiscal year, $25 million has been appropriated to this program, translating to almost $1.5 billion in loan capacity (https://www.epa.gov/newsreleases/bill-signed-president-trump-gives-epas-wifia-program-additional-help-meet-communities, accessed July 2017). The 2016 Water Infrastructure Improvements for the Nation Act (WIIN) was signed into to law and also provides for improvements to critical water infrastructure, including flood protections, dams, and drinking water. Within the WIIN Act (Title II Water and Waste Act) are provisions to assist small and disadvantaged communities, including Tribes, to improve their drinking water services; reduce lead concentrations in water (including replacement of lead service pipes) and conduct drinking water testing. It also authorizes financial relief to communities facing drinking water disasters (such as the disaster experienced by Flint, MI) and needs for infrastructure investments. This law includes the authorization of $100 million in State Revolving Fund grants, along with the $25 million under the WIFIA program (www.natlawreview.com/article/water-infrastructure-improvements-nation-act-wiin-water-infrastructure, accessed June 2017). The provisions within WIIN and WIFIA will assist in fulfilling the EPA's Drinking Water Action Plan (2016b), of which one of the priorities is to build capacity for drinking water infrastructure financing in low-income, small and environmental justice communities. The overall goal of this plan is to engage and urge all levels of government, Tribes, utilities and others to work together to strengthen the nation's system for drinking water safety by addressing priorities ranging from source water protection to unregulated contaminants.

Canada and Ontario

One-third of Canada's entire municipal infrastructure is rated as being in fair, poor or very poor condition (CCA et. al., 2016). For drinking water, wastewater and stormwater infrastructure the percentage of infrastructure that is in fair, poor or very poor condition is 29, 35 and 23, respectively. The average age of core public infrastructure in 2013 (includes roads, bridges, transit, water, wastewater, culture and recreation, and sports infrastructure) was 14.7 years, the youngest since 1961 (Fraser Institute, 2017). Table 5.1.2 below illustrates the average infrastructure age and estimated useful life of water supply systems, wastewater treatment systems and sanitary and storm sewers in Canada and Ontario.

Table 5.1.2Average Age and Useful Life of Infrastructure assets in Canada and Ontario in 2007 (Source: *Statistics Canada, 2008a*)

Infrastructure Asset	Average Age (years)		Useful Life (%)*	
	Canada	Ontario	Canada	Ontario
Water Supply Systems	14.8	13.1	40	36
Wastewater Treatment	17.8	16.9	63	60
Sanitary and Storm Sewers	17.9	18.3	53	54

*ratio of the average age to years of useful life (i.e. its estimated productive life at time of acquisition)

In Ontario the age of water supply systems peaked at 21.2 years (in 1987) and then reduced to 13.1 years (in 2007), as a result of increased investments over those years (Statistics Canada, 2008a). Wastewater systems in Ontario were at a low age of 13.4 years in the mid-70's, with relatively low investments the age rose to 16.9 years in 2007 (Statistics Canada, 2008a). Similarly, the age of storm and sanitary sewers had their lowest age during the 70's (14.2 years), slowly rising to 18.3 years in 2007, as a result of moderate investments (Statistics Canada, 2008a).

Canada's investment in all infrastructure was in a steady decline from the mid-50's, with the late 70's as the point where the infrastructure gap began to emerge (MacKenzie, 2013). Further, over the years from 1955 to 2011, ownership of public infrastructure has shifted financial burdens from the federal government to municipal governments, with the federal government's share at 13% (from 44%), provincial at 35% (from 34%) and municipalities at 52% (from 22%) (Mackenzie, 2013). In Ontario, in 2005 the share for all infrastructure was: federal 10% (from 31% in 1961); provincial 22% (from 31% in 1961); and municipal 67% (from 38% in 1961) (Statistics Canada, 2008b). Municipalities bear a significant portion of the lifecycle costs of an infrastructure asset, but recover little of that investment through tax revenues.

Major capital needs for drinking water and sewage treatment exist in Ontario. The Government of Canada's 2016 budget included a commitment of investing $5.0 billion over 5 years for investments in water, wastewater and green infrastructure projects to support Canada's transition to a clean economy and adapt to impacts of climate change (Government of Canada, 2016a). The 2016 budget also includes a $1.8 billion investment over 5 years, through INAC, for on-reserve water and wastewater infrastructure to address health and safety needs. To help carry out this commitment, the government created the Clean Water and Wastewater Fund. In September 2016 the Canadian federal government and Ontario provincial government announced a bilateral agreement that will make more than $1.1 billion in combined funding available under the Clean Water and Wastewater Fund (https://news.ontario.ca/moi/en/2016/09/canada-and-ontario-reach-agreement-under-the-new-clean-water-and-wastewater-fund.html, accessed April 2017). The federal government is providing almost $570 millionfor projects, while the provincial government will invest almost $270 million. Municipalities, First Nations and local service boards will cover the remaining costs. The Clean Water and Wastewater Fund program is aimed at funding projects that will upgrade and improve drinking water treatment and distribution infrastructure and wastewater and stormwater treatment, collection and conveyance infrastructure. A multitude of Ontario projects have been approved, including many within the basin (http://www.infrastructure.gc.ca/pt-sp/projects-list-liste-projets-on-eng.html, accessed June 2017). For example, the Ontario cities of Windsor, Petrolia and Sarnia are all undertaking projects to separate portions of their existing combined sewers.

Combined Sewer Systems

Combined sewer systems are wastewater collection systems that convey storm waters, untreated sewage and industrial wastewater through a single pipe. These systems transport all the water to a wastewater facility for treatment before discharge to a water body. However, during periods of intense rainfall or snowmelt, the volume of water collected by a combined sewer can exceed its capacity or that of the treatment plant. As a result the systems will overflow to a nearby water

body from a combined sewer outfall. The discharges from these outfalls are called combined sewer overflows (CSOs) and can contain contaminants such as pathogens, sediment, toxics and nutrients. Discharges from combined sewers can impact not just drinking water supplies, requiring greater and more costly treatment, but also the recreational use of the waters. It can be difficult to identify the human health impacts caused by CSOs directly, as these events tend to occur with other wet weather events than can contribute pollutants to water. Some research has shown a relationship between increased risk of gastrointestinal illness when in recreational contact with water that has been impacted by CSOs (Donovan, et. al., 2008) and drinking water sources impacted by CSOs (Jagai et. al., 2015). The USEPA has estimated that the annual number of illnesses attributable to exposure of CSO and sanitary sewer overflows (SSO)contaminated waters at beaches is between 3,448 and 5,576 (USEPA, 2004). With regard to drinking water, between1985 and 2000 there were 251 reported outbreaks of illness related to contaminated drinking water, with 55 outbreaks linked to contamination from human sewage and only one of those linked specifically to a CSO/SSO event (USEPA, 2004).

There are many cities in the Great Lakes basin that have combined sewer systems that are over 100 years old. Ecojustice (2008) estimated that in 2006, just 20 of these cities, in the United States and Canada, released 92 billion gallons of untreated sewage and stormwater in one year to the Great Lakes via CSOs. In the United States in 2014, there were 1,482 CSO events that resulted in 22 billion gallons of untreated combined sewage being released into the Great Lakes (USEPA, 2016c). Under climate change scenarios, projected changes in precipitation for the Great Lakes basin includes more frequent and intense rain events (WQB, 2017). This will put an even greater strain on the already antiquated storm and waste water collection systems in the region.

United States

In the US Great Lakes states there are 184 communities with combined sewer systems and permits to discharge their overflow to surface waters, with eight of these communities discharging directly to the Great Lakes and the remainder to a tributary of the lakes (USEPA, 2016c). The greatest numbers of CSO communities are found in the Lake Erie and Lake Michigan basins, with 92 and 72 communities respectively. In the US, CSOs are subject to permit requirements under the US CWA as part of the National Pollutant Discharge Elimination System (NPDES) program. In October 2015, a proposal under the US 2016 fiscal year spending package proposed to amend the US CWA by prohibiting direct and indirect CSO discharges to the Great Lakes. However,according to the National Law Review (2017) opponents to the proposal noted that the cost of compliance with this rule would be an extreme financial burden, exceeding $70 billion (http://www.natlawreview.com/article/proposal-to-eliminate-cso-discharges-great-lakes-region-excluded-final-2016-spending, accessed June 2017). The proposal was ultimately excluded from the spending package and instead mandated the USEPA to develop requirements for the public notification of CSOs to the Great Lakes, with implementation by December 2017. The proposed rule would require CSO permittees in the Great Lakes basin to implement public notification using (regulations.gov, accessed June 2017):

- signs identifying CSO outfalls and publicly accessible areas potentially impacted by CSOs

- notice to local public health departments and potentially impacted entities (e.g. drinking water plans, beaches and recreation agencies), within four hours of CSO discharge
- notice to the public within four hours of CSO discharge, via various media, such as e-mails, texts, social media alerts, radio and/or TV
- annual CSO notice to the public that includes a summary of the prior year's discharges and future CSO control activities

The USEPA has estimated that the average incremental cost for utilities to implement this rule is approximately $2,000 per year; however the National Association of Clean Water Agencies has indicated that costs are higher and can range from $8,000-$100,000 per year depending on the number of CSO outfalls a utility has (http://www.nacwa.org/docs/default-source/resources---public/2017-03-14glcso.pdf?sfvrsn=4, accessed June 2017).

Canada (Ontario)

Ontario has 107 combined sewer systems (Ecojustice, 2008). No new combined sewer systems have been allowed to be constructed in Ontario since 1985. The MOECC through the Ontario Water Resources Act regulates sewage disposal and sewage works by prohibiting the discharge of contaminants that may adversely impact water quality. The MOECC also provides procedures for managing combined sewer systems, *Procedure F-5-5 Determination of treatment requirements for municipal and private combined* and *Procedure F-5-1 Determination of Treatment Requirements for Municipal and Private Sewage Treatment Works*. These are not enforceable, but permit applications are assessed according to the requirements in these procedures. Procedure F-5-5 in particular includes a requirement for the development of Pollution Prevention and Control Plans, to address water quality problems, particularly those caused by CSOs. To address the impacts of CSOs the plan is to include a characterization of the combined sewer system (e.g. location, receiving water body, capacity); maintenance and inspection of the systems; CSO control alternatives (e.g. inflow reduction, treatment technologies, sewer separation); and an implementation plan with a schedule and cost estimates.

Nationally, the Canadian Council of Ministers of the Environment (CCME), in 2009, developed the *Canada-wide Strategy for the Management of Municipal Wastewater Effluent*; a harmonized framework to ensure that wastewater facility owners (including First Nations) have clarity in managing wastewater effluents for the protection of human health and the environment. In addition to providing performance standards to address common pollutants in wastewater discharges, the strategy outlines management activities to reduce the risks associated with combined and sanitary sewer overflows. For example, the strategy requires that the frequency of CSOs should not increase as a result of development and discharges should not occur during dry weather, except during emergencies and spring thaw. It further requires these standards to be met within seven years, with long-term plans in place to reduce CSO events. In 2014, the CCME released its first, five-year progress report on the implementation of the strategy, with Ontario meeting both of the standards outlined for CSO management (i.e. prohibit construction of new combined sewers and prohibit dry weather overflows).

The Ontario Great Lakes Strategy, a roadmap to help protect, restore and conserve the Great Lakes, commits the province to continue working with municipalities and others to minimize untreated sewage discharges, such as CSOs, by improving tracking and reporting of overflows; encouraging the completion of Pollution Prevention and Control Plans; and promoting green

water infrastructure. Public notification of when a CSO occurs is not required in Ontario. The Lake Ontario Waterkeeper, in 2014 filed an application for review under Ontario's *Environmental Bill of Rights*, requesting that the City of Toronto be required to report to the public when sewage by-passes, including CSOs, occur (http://www.waterkeeper.ca/blog/2015/8/5/toronto-to-start-issuing-updates-when-wet-weather-affects-lake-ontario-government-releases-response-to-waterkeepers-legal-application-press-release, accessed June 2017). After a year of investigation, the MOECC decided that the City of Toronto will start issuing notification to the public about by-pass events in real-time. Similarly in 2014, the Ontario Rivers Alliance submitted an application for review, also under the *OntarioEnvironmental Bill of Rights*, to request the development of a standardized policy across Ontario that articulates when and how the public is to be altered during a sewage bypass event (Ontario Rivers Alliance, 2014). Some municipalities in Ontario provide public notification alerts including Ottawa, Sudbury, and Kingston. Kingston in particular has been recently touted as leader and model for other cities in providing real-time alerts to the public when the water may not be safe to enjoy as a result of sewage bypasses and CSOs (http://watercanada.net/2017/utilities-kingston-unveils-real-time-sewage-overflow-monitoring-and-notification-system/, accessed July 2017).

5.1.5 Section Summary

- Treated drinking water quality in the Great Lakes is generally of a high quality on both the US and Canadian sides of the Great Lakes basin. The United States federal and state governments and the province of Ontario, along with local governments, have done an excellent job of providing safe drinking water in municipal systems almost all of the time throughout the basin. However, unsafe drinking water incidents have occurred in major cities and some FNs and tribes have had long standing boil water advisories.

- The assessment of this objective, that is, the Great Lakes are a *source* of high quality drinking water is not confirmed because of a lack of source water reporting by both countries. The assessment would be improved by reporting on comparable source water quality metrics for both nations.

- Another potential improvement in the future for enhancing the reporting of progress under this objective is to include monitoring and SOGL reporting on source water parameters that include, atrazine, cyanotoxins (microcystin-LR, anatoxin-a and cylindrospermopsin, and expanding *E. coli* to include *Cryptosporidium parvum* and *Giardia lamblia.* Ideally, HPAB (2014) suggests these measures would be taken from source water sites in both countries on a weekly or daily basis. Costs for such sampling may not justify the benefits at this time. However, as technology advances, costs of sampling and analysis may decrease, or the risks from exposure to these toxins may rise, which may make increased sampling more practical and of increased benefit in the future.

- The removal of the drinking water restrictions on BUIs from AOCs has improved, with several removed in the last five years. In addition, the remaining BUIs in the Bay of Quinte and St. Clair River are expected to be removed within the next two to three years.

- Continued work on preventing contamination of source water is needed to help ensure that incidents of drinking water contamination do not occur. Prevention is the basic principle behind the implementation of source water protection in a multi-barrier (or *source-to-tap*) approach for the provision of safe drinking water.

- Actions taken through Annexes such as those for Areas of Concern (Annex 1), Lakewide Action and Management Plans (Annex 2) and Nutrients (Annex 4) can ultimately result in the protection, restoration, and enhancement of sources used as a public drinking water supply. For example, progress has been made in restoring the BUI "restrictions on drinking water consumption, or taste and odor problems" in various AOCs. Under Annex 2, the Parties have developed a draft nearshore framework to support the overall assessment of the state of the nearshore waters of the Great Lakes, which recognizes the importance of drinking water sources in the nearshore.

- Under the GLWQA, there is no Annex that specifically supports the achievement of Objective 1. Progress toward achieving this objective could benefit from improved organization around the *human use* of Great Lakes waters used for drinking, through the development of a committee for the human health-related objectives.

- A key component in the delivery of safe drinking water is the development and implementation of source water protection plans. The requirement for the development and implementation of source water protection plans varies between Ontario, where it is regulated, and the US states, where it is voluntary. Having a US federally-regulated requirement to develop and implement source water protection planning would create greater consistency across states and provide a higher level of priority for implementation.

- All longstanding boil water advisories and persistent drinking water violations need to be removed.

- Infrastructure investments will continue to place considerable demands on public budgets, and planning for future needs is essential. Ensuring the adequacy of existing infrastructure to meet the objectives of the Agreement for future generations , and assessing anticipated costs required to provide this infrastructure, requires continual attention from governments.

5.1.6 References

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5.2 Swimming and Recreational Use

This section reviews and assesses progress toward achieving General Objective 2 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 2 states that the waters of the Great Lakes should "allow for swimming and other recreational use, unrestricted by environmental quality concerns."

While there is no single Annex in the GLWQA dedicated to the achievement of General Objective 2, work toward this objective is supported by work on Areas of Concern (Annex 1), and improving lakewide action and management (Annex 2) and science (Annex 10). The discussion of recreational waters is also related to implementation of the adaptive management principle set out in Article 3 of the GLWQA.

The section presents an assessment of programs and other measures in support of this objective. This assessment is based largely on the review of publicly available information from:

- data and information from the *2016 State of the Lakes* presentation by the Parties (GLPF 2016)
- the 2017 State of the Great Lakes Technical Report (ECCC and USEPA, 2017a), and Highlights Report (ECCC and USEPA, 2017b)
- theProgress Report of the Parties (PROP, 2016).

5.2.1 Background

The public beaches of the Great Lakes and their tributariesprovide a source of recreation to the 40 million United States and Canadian citizens that reside in the basin, and to tourists from outside the basin. Millions of people each year use beaches on the Great Lakes (Great Lakes Information Network, 2012). A recent survey by the IJC's Water Quality Board Public Engagement Work Group asked residents of Ontario and the eight Great Lakes states their views on the importance of watershed and Great Lakes protection. (WQB, 2016). Survey results for residents who recently visited a Great Lakes beach indicated the majority felt it was very important (78%),or important (8%) to them to have the lakes available for leisure or recreational purposes. This compares with those claiming recreation not at all important (three percent), not important (four percent), or "neither important nor unimportant" (seven percent).

Coastal and in-lake recreation in the Great Lakes has many positive recreational and economic benefits. Activities such as swimming, boating, and beach use may also adversely affect human health through exposure to biological hazards (for example, bacteria or viruses) which may be

present in the waters. Targeted epidemiological studies have shown a number of adverse health effects (including gastrointestinal and respiratory infections) to be associated with fecally-polluted recreational water in marine and freshwater systems(Marion et al., 2010; USEPA, 2015), including those of the Great Lakes (Wadeet al., 2008). These effects can result in a significant burden of disease and economic loss (World Health Organization, 2003).

Humans living in close proximity to or in frequent contact with the Great Lakes live in complex and extremely varied environments. Their health patterns are strongly affected by their own behaviors and influences unrelated to biological hazards in the Great Lakes. The health effect of any particular recreational water hazard depends on how much, over what period of time and by what pathway (via ingestion, dermal exposure, or inhalation) individuals come into contact with that hazard. Routes of exposure to biological hazards in recreational fresh water include "body contacts, immersion and ingestion" during their recreational activities namely, "swimming, bathing, surfing, water skiing, tubing, water play by children, and similar water contact activities"(Gorham and Lee, 2015; USEPA, 2012). In general terms, this combination of proximity to biological hazards and human behavior, moderated by government advisories, serves as a starting point for examining the question of human illness risk from waters.

Human illness risk may vary depending on the types and extent of activities of beach goers. The relative risk of a health effect, such as developing gastrointestinal illness, is higher among beach visitors who bury their body in the sand as compared to those who are simply digging in the sand (Heaney et al., 2009). The survival and potential regrowth of organisms such as *Escherichia coli* (*E. coli*) and enterococci in sand and surficial sediments serves as an important source of microbial pollution (Desmaraiset al., 2002; Solo-Gabriele et al., 2000; Solo-Gabriele, et al.,2015). Another study of human health risk looked at exposure to recreational water contaminated with urban sewage effluents in the Chicago Area Waterways System. Even though there were advisories against human activities (including rowing, canoeing, fishing, boating, and kayaking) in these waters due to sewage contamination, people still used the waters and gastrointestinal illnesses and eye infection risk was found to be elevated following the exposure in comparison to fresh water with less sewage contamination (Dorevitchet al., 2012).

In additional to human behaviors, environmental factors such as precipitation impact the risk of gastrointestinal illnesses in combinations of hydrodynamic contexts such as lake temperature, wave height and lake stage. According to Patz *et al*. (2008), the projected probability of extreme weather events will rise by 50 to 120 percent in 100 years. They also projected that the incident rate of gastrointestinal diseases will rise in association with the estimated increase of sewage contamination. Improper management and disposal of sewage and other wastes in freshwater systems can also contribute to organisms and contaminants in recreational and drinking water source waters. Such sources of sewage and wastes include combined sewer overflows (CSOs), sanitary sewer overflows (SSO), urban runoff, and urban and agricultural storm water runoff (Rose et al., 2001; Marsalek and Rochfort, 2004;Dorfman and Haren, 2014). McLellan and Hollis (2007) conducted a three-year survey on the source apportionment of bacterial invasion following sewage overflow and used *E. coli* as an indicator organism. They found that sewer overflows due to severe rainstorms caused a significantly higher increase in *E. coli* concentrations in the receiving water (Lake Michigan) as compared to rain precipitation less than

five cm (2 inches). According to their analysis, the proportion of human fecal pollution and non-point sources of *E. coli* was equal during CSO and SSO events.

Finally, different benchmark approaches for government advisories can be found in the Great Lakes region. TheUS Environmental Protection Agency (USEPA) implementedthe health-protective Beach Action Value, which serves as a precautionary benchmark for making swimming safety decisions. A high percent exceedance rate of Beach Action Values indicates contaminated coastal recreational waters (Dorfman and Haren, 2014; Allan et al., 2015).Under this benchmark, the Great Lakes have consistently been reported to have the highest percentage of beach water samples in the United States exceeding this recreational water quality criteria (Dorfman and Haren, 2014).The percentage of exceedance for the Great Lakes narrowly surpasses other US regions, such as the Gulf Coast and New England, due in part to the high rate of criteria exceedance at Ohio beaches. According to the NRDC (Dorfman and Haren, 2014), chronically high bacteria counts indicate that beach water is probably contaminated with human or animal waste.

Canadian Great Lakes beaches that demonstrate they have met strict international criteria for water quality monitoring,public communication, and reporting based on applicable water quality standards and other education and management criteria can hold the Blue Flag certification (Environmental Defence, 2016), and the number of beaches achieving this increases each year.

Blue Flag status has been awarded to many beach sites around the world, and status is maintained by both local monitoring and inspections from the international Blue Flag network based on specific water quality standards (Blue Flag, 2017). In particular, the program emphasis on public outreach and education is instructive, and useful to consider given the challenges of effectively communicating beach status to visitors and residents of the Great Lakes basin in both countries. Blue Flag offers an attractive model that promotes beach safety, environmental monitoring, and public communication of water quality to protect public health, using standardized activities and practices.

5.2.2 Assessment of indicators

The reporting by the Parties on recreational waters includes an indicator addressing the number of beach closures in both countries. Around the Great Lakes, the criteria for beach closures are determined by First Nation/ Tribes, states, provinces and local governments, based on the regulations and programs supporting quantitative monitoring that have been implemented in both countries. However, monitoring and criteria that support beach closing decisions vary across jurisdictions (Nevers and Whitman, 2010), adding to the complexity of interpreting trends in beach closures.

1. Sub-indicators status and trends

The Parties assessed trends in recreational water quality and its relationship to human health using one sub-indicator, Beach Advisories, which assesses the reported health-related swimming advisories or closings days for recreational areas, to determine the number of days that

monitored Great Lakes beaches are open and safe for swimming during the summer season. For the current assessment cycle, the Parties reported that the overall status of the Beach Advisories sub-indicator is Fair to Good and the trend is Unchanging since 2011 (Great Lakes Public Forum, 2016).Public beaches of the Great Lakes and their tributariesare open and safe for swimming during 96 percent of the season in The United States and 78 percent of the season in Ontario. Part of this difference can be attributed to differences in criteria for determining beach safety for recreational use, as Ontario uses more stringent standards that result in additional beach closings. This difference can lead to inconsistent evaluation of indicator trends between the two countries.

Individual lake assessments show that Lake Erie's condition remains Poor. Among the remaining lakes, Lakes Superior, Michigan, and Huron maintain their status of Good," and Lake Ontario's status remains Fair to Good (Table 5.2.1).Spatial distribution of these closings is limited to the broad lake-by-lake assessment, which averages indicator levels across lakes. This approach obscures the positive impacts of local improvements, or the negative impacts of compromised local water quality.

Swimming and Recreational Use

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Beach Advisories	Unchanging	Unchanging	Unchanging	Deteriorating	Unchanging

Status:	GOOD	FAIR	POOR	UNDETERMINED

Table 5.2.1 (Source: ECCC and USEPA, 2017a, 2017b)

2. Recommended Additional sub-Indicators for Human Health

Any attempt to assign indicators of Great Lakes human health must attempt to account for beachgoer activities, environmental factors and other causal factors that might result in an individual's health outcome. Considering these varied causes, only the strongest correlations will be evident for a health outcomes analysis in the Great Lakes. The IJC's Health Professionals Advisory Board (HPAB) identified improvements for human health indicators to assess progress in implementing the GLWQA (HPAB, 2014). The HPAB's work resulted in two recommended indicators for Recreational Water Contact, the first *Risk of illness from Great Lakes beaches*focuses on known health hazards (e.g., microbiological hazards) and the second *Identified risks at Great Lakes beaches* looks at the sources of those hazards and uses a survey of best practices.

Recommended Additional Sub-Indicator #1.Risk of illness from Great Lakes beaches

The IJC, based on HPAB (2014), recommends continuing to measure *E. coli* levels in Great Lakes water, relying on the concept of "indicator organisms" as time- and resource-efficient for estimating the existence of other microbiological hazards in source and recreational waters (HPAB, 2014). This measurement is well understood, has abundant historical reference information and is clearly linked to human health. *E.coli* is the dominant bacterium in the gastrointestinal tract of all warm-blooded animals and humans, anda widely used indicator organism for recreational water. There are 11 recognized pathogenic types of *E.coli* (Hamelin et

al., 2006) that can result in illness, though most strains of *E.coli* are not hazardous. Nevertheless, monitoring this organism for general fecal contamination of recreational water has proven historically useful, based on the assumption that it has sensitivity and specificity that is appropriate as an indicator for the presence of bacteria, viruses, and parasitic cysts in water.

The weaknesses and strengths associated with using both *E. coli* and enterococci in current regulations of both countries are openly acknowledged in the 2012 Recreational Water Quality Criteria (USEPA, 2012) and Guidelines for Canadian Recreational Water Quality. However, Health Canada has concluded that *E. coli* and enterococci are still the best available indicators due to the considerable knowledge and scientific evidence available regarding both the merits and limitations inherent in indicators of microorganisms in source and recreational water (Health Canada, 2012). In addition to culture-based assessment of E. coli and enterococci the 2012 criteria allow for the use of Enterococcus quantitative polymerase chain reaction (qPCR) which is a more rapid molecular measurement that has stronger health relationships to GI-illness than Enterococcus culture. E. coli qPCR methods are also available and can be used for on a site specific basis.

Recommended Additional Sub-Indicator #2.Identified risks at Great Lakes beaches

The second suggested addition to SOGL reporting would include two measures identified by and described in HPAB, 2014. The first would provide a periodic and uniform assessment of the sources of contamination for Great Lakes beaches using the Beach Sanitary Survey or Environmental Health and Safety Survey as described by the US EPA (US EPA, 2008) and Health Canada (Health Canada, 2012). A measure to determine microbial source has been identified as key to improving the current binational monitoring regime. The second measure would calculate the percentage of beaches that employ a Beach Sanitary Survey or Environmental Health and Safety Survey in a given year. Sanitary surveys are recommended best practices for beaches by both the US EPA and Health Canada, and this measure provides context as to how many beaches comply with this best practice and provide data for this indicator.

The IJC recommended the results of the HPAB-led indicator development exercise in a letter to governments in 2014. More recently, the Research Coordination Committee (RCC) of the IJC's Science Advisory Board concluded there is an opportunity for the Parties to strengthen their reporting on activities towards and indicators related to recreational water objective of the GLWQA (SAB-RCC, 2016). It is recognized that completely integrating datasets across national boundaries and formats for recreational water indicators will require considerable – though not insurmountable – effort.

5.2.3 Assessment of key monitoring programs

Both the US 2012 Recreational Water Quality Criteria and the Criteria Guidelines for Canadian Recreational Water Quality have provisions to use *E. coli* and enterococci in bacterial quality monitoring of fresh and marine waters (Health Canada, 2012; USEPA, 2012). In the US, current recreational water quality monitoring (USEPA, 2012) includes provisions to protect human

health from illnesses through possible primary and secondary exposure to various causes of human illnesses (USEPA, 2012). The *Canadian Guidelines for Canadian Recreational Water Quality Act* was passed in 2012 and in the same year, Health Canada set different, individual criteria for both primary and secondary contact with recreational water.

The *US Beaches Environmental Assessment and Coastal Health Act*(Beach Act) was passed in 2000 with a strong emphasis on the bacterial monitoring of recreational waters. It requires all coastal states, including Great Lakes states, to develop programs for effective water quality monitoring and public notification at coastal recreational beaches. All eight states in Great Lakes basin have signed onto the Act, including Wisconsin for Lake Superior, where previously there was no bacterial monitoring (Sampson et al., 2005). The US EPA also developed a Great Lakes Beach Sanitary Survey to identify sources of contamination at Great Lakes beaches, first in 2004 under the Great Lakes Regional Collaboration, and then updated in 2008 (USEPA, 2008). These programs generally are implemented through state health or natural resources departments. Local and state health departments in the United States have experienced major budget and staff reductions since 2008, which presents challenges to meeting their public health responsibilities. Moreover, sustained funding for the Beach Act historically has required extensive Congressional lobbying to preserve the program and its continued support is by no means certain.

In Ontario, the Safe Water Program requires Boards of Health to conduct surveillance of public beaches and assess factors and emerging trends related to illnesses and injuries (Ontario Ministry of Health and Long-Term Care, 2014a). Ontario Public Health Standards (Ontario Ministry of Health and Long-Term Care, 2008) establish recreational water monitoring Agreements based on authority from the Ontario's *Health Protection and Promotion Act* (Government of Ontario, 1990). Environmental surveys are also a key element of beach management, and are required as part of public beach management (Ontario Ministry of Health and Long-Term Care, 2014b). This approach presents challenges for the health units, in that beach monitoring represents one portion of a wide-ranging mandate for public health in a funding-restricted environment.

Consistent and proper management of sewage and other wastes in freshwater systems is critical to protecting public health by reducing both the inflow of organisms and contaminants into both recreational and drinking water sourcewaters, and incidents of CSO and SSO in Great Lakes communities. Microbial presence in recreational water originates from a range of anthropogenic and non-anthropogenic sources, including wildlife, CSOs and SSOs, sediments, algae, inputs from tributary streams and surface and agricultural runoff (Anastasi *,et al.,* 2010; Ishii et al.,2007; Nevers*et al.,* 2013; Roll and Fujioka, 1997). CSOs and SSOs are the major source of viruses and pathogenic bacteria likely to have originated from humans (Aslan et al.,2011). Other major anthropogenic sources of *E.coli* in the Great Lakes basin are the effluent of municipal sewage, unlawful ship discharge of untreated waste and factory effluents (Liu et al.,2006; Rose and Dreelin, 2008). Impacts of CSO and SSO on drinking water and recreation sources, are further detailed in Technical Appendix Chapter 5, Drinking Water Section 5.1.4.4.This section also outlines historical water infrastructure investment by both governments, and the Parties currentsupport to provincial, state and municipal, First Nations and Tribal governments for essential infrastructure for drinking water, and waste water, and stormwater treatment management systems.

Significant risks from these multiple sources of untreated and diluted sewage discharge include forced beach closures, health advisories, harm to wildlife and damage to tourism (Healing our Waters Great Lakes Coalition, 2010).For instance, USEPA recently attributed between 3,448 and 5,576 human illnesses annually to exposure to beach waters contaminated by CSOs and SSOs (USEPA, 2004).The Great Lakes basin is projected to encounter more frequent and intense rain events under future climate change scenarios (WQB, 2017), and with it potential increased incidents of gastrointestinal diseases (Patz, et al.,2008). Managing both our current realities and potential risks will put pressure on the Parties' ability to restore and maintain the biological, chemical and physical integrity of the Great Lakes. Given the source of risks to recreational water in the Great Lakes basin, infrastructure investment should be viewed as a restoration strategy for the region (Healing our Waters Great Lakes Coalition, 2010).

In this 21st century, after over 100 years of water treatment, except under extremely rare conditions, the public can no longer tolerate the dumping of raw sewage into the Great Lakes.The Parties should determine an accelerated and fixed period of time by which zero discharge of inadequately and untreated sewage into the Great Lakes will be achieved and dedicate sufficient resources to accomplish the task. Progress toward the goal should be reported in each triennial Progress Report of the Parties.

In addition to current monitoring and infrastructure programs, another important key priority among recommendations in the IJC's last two binennial reports to governments is for rapid communication to alert the public when beaches need to be closed.(SAB-SPC, 2015).Significant advances in recreational water surveillance include models supporting recreational water quality forecasting. Ongoing work by the USEPA (2016) and the United States Geological Survey (USGS, 2016a) holds significant promise for predicting real-time water quality conditions and increasing the accuracy of beach closure notifications. These programs are particularly valuable given the current lag time in availability of *E. coli* data can be up to 24 hours (Francyet al.,2013) and the recognition that beach water quality can change quickly (USEPA, 2010).

Advances are being made on the development of molecular tools for fecal source tracking markers that, if implemented widely and binationally, could provide supplemental information to support IJC's recommended indicator *Risk of illness from Great Lakes beaches.*Human fecal markers and other fecal source identification marks are new tools that can be used to better understand the risks and sources of fecal contamination (Boehm et al., 2013; Stewart et al.,2013). Efforts are also underway by the USEPA and stakeholders to collect information on model performance across the Great Lakes and to have the information publically available. Microbial source tracking using qPCR and other advanced methods to identify bacterial sources has been studied by both countries. EPA has published methods to apply microbial source tracking for developing bacterial Total Maximum Daily Loads (TMDL) (USEPA, 2011). Environment and Climate Change Canada has developed laboratory methods for microbial source tracking which can identify between bovine and human bacteria (Al-Zabat, *2016 personal communication*).

There are challenges inherent in any effort to expand monitoring efforts in support of Objective 2. Current approaches for beach monitoring and advisories were developed based on the need to inform decision-making at the level of individual jurisdictions. However,the Parties should enhance reporting on progress toward achievement of the Agreement's human health objectives

by collecting and reporting health data specific to the waters of the Great Lakes. The Parties should disregard political boundaries when displaying binational health and environmental data, to facilitate public understanding and analyze the distribution of affected populations and impacts, such as beach closings.Leveraging existing monitoring activities to provide additional support for Objective 2 of the GLWQA would require significant investment by the Parties. Costs due to human illness from recreational water exposuremay be significant (IJC, 2009), and could also be coupled with the economic benefits of open beaches when weighing projected monitoring costs.

5.2.4 Assessment of Annex activities

The Parties support achievement of the recreational use objective of the GLWQA proceeds under a mix of activities within the Agreement's Annexes, and SOGL reporting on progress through the Swimming and Recreational Use Indicator. Annexes that support work related to the recreational use objective of the GLWQA include Annex 1 (Areas of Concern), Annex 2 (Lakewide Management) and Annex 10 (Science). As a result, there are numerous activities that: indirectly monitor and protect recreational water quality; rely on assessment of recreational water quality during decision-making (for example, AOC beneficial use impairments before delisting); and consider recreational water quality when developing management action plans (LAMPs).The monitoring to support SOGLR is supported under Annex 10, which includes human health indicators.

A beneficial use impairment (BUI) is "a reduction in the chemical, physical or biological integrity of the waters of the Great Lakes" as defined in the PROP report (Governments of Canada and the United States, 2016). For Annex 1 within this reporting cycle, three AOCs have been delisted for the BUI Beach Closings (Table 5.2.2), River Raisin (US), Muskegon Lake (US) and Detroit River (Canada). Twenty four remaining AOCs have BUIs for Beach Closing in place.

For Annex 2, The Lake Superior LAMP reported that beaches were open Lake Superior's beaches were open over 95% of thetime in the US and over 88% of the time in Canada (Binational.net,2016). In May 2016, the Lakewide Management Annex Nearshore Framework Task Team, released a draft report (2016) describing the importance of nearshore areas both for recreational use and maintenance of a healthy lake ecosystem. An integrated nearshore framework is required under the 2012 GLWQA to inform management action to protect the nearshore and its water quality and restore ecologically impaired areas. Target regions for testing this framework assessment are discussed in the Parties' 2017-2019 draft Binational Priorities for Science and Action with an aim of eventual application across the basin.

The SOGLR provides appreciable insight into the status of the Great Lakes basin ecosystem. However,there is currently no human health-oriented summary of the quality of the waters of the Great Lakes or the Annex activities of the Parties to address these human health issues in the Progress Report of the Parties. PROP reporting could be improved to address specific initiatives related to beach improvement/maintenance, and the numerous activities under the different Annexes.Finally, there is no provision for routinely identifying and reporting emerging issues

related to human health general objectives, and for coordinating Annex activities related to recreational water and human health.

The GLWQA currently lacks a provision for coordinating human health related Annex activities, reporting and identification of emerging issues Progress towards achieving the recreational use objective would benefit from improved government coordination by the Parties around beach and recreational water issues. The Parties should fix their fragmented approach to achieving the GLWQA health objectives by developing mechanisms to enhance accountability, including more specific goals and timelines and a formalized approach to eliminate the silo effect across the Agreement Annex Committees. One way to improve coordination would be to task a binational committee, either existing or new, to report on progress and examine emerging issues related to the GLWA health objectives, including recreational water. A binational committee could also provide a forum for identifying synergies of various Annex activities and improvements for recreational water reporting under the GLWQA to enhance public understanding of the Parties' actions to address human health as affected by the waters of the overall in the Great Lakes basin.

Table 5.2.2 Status of BUI Restrictions for Beach Closures in Great Lakes AOCs(Source: Progress Report of the Parties, Government of Canada and the United States, 2016)

	Restrictions for Beach Closings	
AOC – Canada	BUI Removed	BUI Impaired
• Thunder Bay		X
• St. Mary's River		X
• Spanish Harbor	1999	
• Collingwood Harbor	1994	
• St. Clair River		X
• Detroit River	2016	
• Niagara River		X
• Hamilton Harbor		X
• Toronto and Region		X
• Bay of Quinte		X
• St. Lawrence River		X
AOC – US		
• Waukegan Harbor	2011	
• Grand Calumet River		X
• Clinton River		X
• Detroit River		X
• Kalamazoo River	2011	
• Manistique River	2010	
• Muskegon Lake	2015	
• River Raisin	2013	
• Rouge River		X
• Saginaw River and Bay		X
• St. Clair River		X
• St. Marys River		X
• Menominee River	2011	
• Rochester Embayment		X
• Black River		X
• Cuyahoga River		X

• Maumee River		X
• Presque Isle Bay		X
• Lower Green Bay & Fox River		X
• Milwaukee Estuary		X
• Sheboygan River		X
• St. Louis River		X
TOTAL	9	24

For example, the re-emergence of harmful algal blooms (HABs) in the Great Lakes, addressedthrough Annex 4, could impact human health for beachgoers, anglers and coastal boaters.Recent work specific to the Great Lakes includes NOAA's experimental products in HABs tracking and forecasting (Wynne *et al.*, 2015). The work of the USGS on western Lake Erie (USGS, 2016b*)* also supports HABs modeling capabilities for both monitoring recreational water trends and informing beach closure decision making. Yet the path for recognizing HABs as a recreational water issue and incorporating new HABs monitoring technologies into present recreational water reporting under the GLWQA is unclear.Finally, a primary goal of this committee could be to achieve Blue Flag certification throughout the basin.

5.2.5 Assessment of principles and approaches

The GLWQA's principle of Adaptive Management addresses how to evaluate current actions and adjust future actions once outcomes and ecosystem processes in the Great Lakes become better understood. The principle provides a rationale for expanding indicators for assessing progress towards the recreational water objective. Advances in science and local monitoring programs now provide quantitative information for levels of bacteria such as *E. coli*, along with qualitative information on their likely potential source from survey information. This additional information would improve reporting on human health risks.

Applying an adaptive management approach for this objective would be supported by the use of *technology forcing* to motivate development of new sub-indicators, and the data sharing practices and standardized measurement techniques to support reporting and analysis. Technology forcing is a strategy that mandates that currently unachievable and uneconomic performance standards be met at some future date as part of a regulatory or monitoring framework.

For the sub-indicators recommended by the HPAB (2014), that don't have data, technology forcing for monitoring could be implemented for inclusion of Human Health Indicators as part of Great Lakes monitoring within a five-to-ten- year time frame, or within two or three reporting cycles of the Triennial Assessment of Progress.

Current technologies used for beach closure decisions are related to microbial risks are notoriously unreliable, often reflecting past risk better than current and short-term future risk. Meanwhile, most predictions about climate change impacts (increased precipitation and temperature, etc.) favor worsening of bacterial contamination in the Great Lakes basin, so risks cannot be assumed to be stable. Public safety demands better, more accurate near-real-time risk assessment. The same technology advances supporting near real-time analysis also contribute to

better characterization of human health risk trends over time, which is the intent of indicators. Thus both consumer protection and lake health monitoring demand a similar technology surge.

While new indicators reporting will incur additional costs by the Parties, there are also significant costs associated with illness attributable to swimming and other activities at Great Lakes (and other) beaches (IJC, 2009; DeFlorio-Barkeret al., 2016). The costs of improving monitoring, notification, and reporting, may lead to actions which would improve water quality and offset costs of illness. Indicator refinement for this objective would not involve new monitoring, though a significant effort would be needed to standardize and integrate existing *E. coli* and Beach Sanitary Survey or Environmental Health and Safety Survey data streams from states, provinces and Tribes/First Nations into the SOGL process. General recommendations from the HPAB regarding differences between indicators are relevant to GLWQA Objectives 1, 2 and 3.In particular, HPAB recommended additional dialogue between the HPAB and the SOGL reporting regarding indicator approaches.Standard monitoring approaches in both countries and adoption of indicators recommended by the IJC are steps that could help improve reporting and help protect beaches.

5.2.6 Section Summary

- The Parties continue their reporting on recreational water quality and human health using the SOGL Beach Closures indicator. This indicator reports on closure decisionsfor recreational waters.

- Great Lakes public beaches are open and safe for recreational use the majority of the time in both countries. However, Great Lakes governments at all levels must strive to further improve safety and beach health. Given the importance of lake recreation to the Great Lakes public, the Parties should increase their attention to recreational waters in the implementation of the GLWQA.

- The Parties should enhance reporting on progress toward achievement of the Agreement's human health objectives by collecting and reporting health data specific to the waters of the Great Lakes. The Parties should disregard political boundaries when displaying binational health and environmental data, to facilitate public understanding and analyze the distribution of affected populations and impacts, such as beach closings.

- Improper management and disposal of sewage and other wastes can contribute to organisms and contaminants in recreational waters. Microbial presence in recreational water originates from a range of sources, including wildlife, CSOs and SSOs, sediments, algae, inputs from tributary streams and surface and agricultural runoff. CSOs and SSOs are the major source of viruses and pathogenic bacteria likely to have originated from humans.

- Within this reporting cycle, two AOCs have been delisted for the BUI Beach Closings, Muskegon Lake (US) and Detroit River (Canada). Twenty four remaining AOCs have BUIs for Beach Closing in place.In May 2016, the Lakewide Management Annex Nearshore Framework Task Team, released draft report (2016) outlining an integrated nearshore framework. The Lake Superior LAMP reported that beaches were open Lake Superior's beaches were open over 95% of thetime in the US and over 88% of the time in Canada.

- Standard monitoring approaches in both countries and adoption of indicators recommended by the IJC are steps that could improve reporting, protect beaches, and increase public safety when using Great Lakes beaches. A quantitative indicator (Risk of Illness from Great Lakes beaches) would support a streamlined process for establishing common methodsof measurement, monitoring, and trends reporting. It also would help the general public use Great Lakes waters for recreation in a safer manner.

- Another sub-indicator using qualitative data from existing survey and indicator organism programs (Identified risks at Great Lakes beaches) would provide a wider range of information to assess conditions for recreational water use.

- The Parties should fix their fragmented approach to achieving the GLWQA health objectives by developing mechanisms to enhance accountability, including more specific goals and timelines and a formalized approach to eliminate the silo effect across the Agreement Annex Committees. Abinational committeefocused on the human health objectives of the GLWQAcould report on progress and examine emerging issues specific to human health, and enhance the public's understanding of the Parties' efforts to address human health as affected by the waters of the Great Lakes basin. Pursuant to the recreational water objective, a primary goal of this committee could be to achieve Blue Flag certification throughout the basin.

- Given the source of risks to recreational water in the Great Lakes basin, infrastructure investment should be viewed as a restoration strategy for the region.The Parties should determine an accelerated and fixed period of time by which zero discharge of inadequately and untreated sewage into the Great Lakes will be achieved and dedicate sufficient resources to accomplish the task. Progress toward the goal should be reported in each triennial Progress Report of the Parties.

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5.3 Consumption of Fish and Wildlife

This section reviews and assesses progress toward achieving General Objective 3 of the *Great Lakes Water Quality Agreement* (GLWQA).Objective 3 states that the waters of the Great Lakes should "allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants."

While no single Annex in the GLWQA is dedicated to the achievement of Objective 3, work toward this objective is supported by work on Areas of Concern (Annex 1), improving lakewide action and management (Annex 2) and advances in science (Annex 10). The assessment also discusses the findings of other IJC reports related to fish consumption. The discussion of fish and wildlife consumption is related to implementation of the adaptive management principle set out in Article 3 of the GLWQA.

The section presents an assessment of programs and other measures in support of this objective. This assessment is based largely on the review of publicly available information from:

- data and information from the *2016 State of the Lakes* presentation by the Parties (GLPF 2016)
- the 2017 State of the Great Lakes Technical Report (ECCC and USEPA, 2017a), and Highlights Report (ECCC and USEPA, 2017b)
- The Progress Report of the Parties (Governments of the United States and Canada 2016).

5.3.1. Background

Fish and wildlife harvesting in the Great Lakes provide a range of commercial and recreational opportunities and sustenance for the region's population. In addition to substantial economic benefits of commercial fisheries in the Canada and the United States, Great Lakes recreational fishing results in over $4 billion for US local communities along with 55 million angler days of recreation (Minnesota Sea Grant, 2016), and $2.2 billon to the economy of Ontario. (Government of Ontario, 2016). Bird and turtle populations, especially snapping turtles, also support isolated local recreational and subsistence activities though they do not sustain commercial harvesting.

Many Great Lakes residents support their diets with local fish, gaining an important source of omega fatty acids and protein. Although the nutritional value and health benefits from consuming Great Lakes fish are significant, fish can also accumulate toxic chemicals from their environment that may interfere with any conferred benefit. Potential health impacts are not restricted to anglers, as many species of Great Lakes fish are available for sale in commercial markets, such as lake trout, walleye, and perch. Duck and snapping turtle populations are prone to similar exposure to contaminants.

Research has shown that a primary pathway for exposure to PCBs and mercury is through consuming sport and commercial fish from the lakes (Turyk et al., 2012), especially a concern for children and women of childbearing age. Native Americans, First Nations and Métis may also experience distinct cultural, economic, and spiritual impacts resulting from their commercial

and subsistence fish production, particularly in Lake Superior (Dellinger et al., 2012). Legacy toxic substances and emerging contaminants have triggered health advisories recommending limited human consumption of some species in some locations. Fish consumption advisories exist for some fish in each of the Great Lakes. Advisories are meant to communicate information on safely consuming fish to a broad audience, and influence behavior to protect human health. These advisories vary across the region and are most notable for long-lived top predators and fish that have more fat, such as walleye, lake trout and salmon. Polychlorinated biphenyls (PCBs) are responsible for the majority of advisories, followed by mercury and dioxins.

Widely different ethnic, cultural, and socio-economicfactors influence fishing practices, consumption patterns, and importantly, compliance with fishadvisories (Health Professionals Task Force, 2004; Beeler et al., 2001). Health advisories related to Great Lakes fish consumption are of greatest concern for those who consume large amounts of Great Lakes fish. These groups include indigenous communities, urban anglers and their families, and some Asian and African-American communities. Health advisories are also of great concern to those who are most vulnerable to the impact of toxic substances, such as women of child bearing age and children.

Contaminants in fish have been previously reported by the Partiesusing the indicators Contaminants in Whole Fish and Fish Consumption Restrictions (SOLEC, 2014).Contaminants in Whole Fish assessed two species, lake trout and walleye, for several chemical contaminants. The Fish Consumption Restrictions indicatorsynthesizes state and provincial information on the frequency and severity of restrictive fish consumptionadvisories. A novel Fish Consumption Advisory Rating indicator was also included to score advisories based on the severity of the restriction, using a scale of 1 to 5. The Parties did not previously report on contaminants in other Great Lakes wildlife species consumed by humans.

5.3.2 Assessment of Indicators

1. Indicators status and trends

For the 2017 reporting, the Parties shifted their approach, and assess trends in fish and wildlife consumption and its relationship to human health using one indicator, Fish Consumption, that relied on one sub-indicator, Contaminants in Edible Fish (ECCC and USEPA, 2017a, 2017b).

A shift in approach to a fish contaminant indicator focused on the edible fish portions better represents the human diet, is more suited to capturing human health risk, and responds to the HPAB (2014) recommendation forwarded by the IJC to the Parties.

The Parties reported PCB levels for edible portions of five fish species (lake trout,lake whitefish, walleye, Chinook salmon, and Coho salmon) as decreasing over time, though still above the levels of consumption benchmarks. The Parties noted that while PCBs drive most of the fish consumption advisories, high levels of mercury, dioxins, mirex and toxaphenedetected by state

run monitoring programs have also caused advisories. Figures of contaminant levels and trends over time were presented for PCB and mercury, though not other chemicals noted.

For the current assessment cycle, the Parties reported that overall and lake by lake, the status of this indicator was Fair. Individual lake trends show mixed results, with the trend Improvingfor Lakes Michigan and Ontario or Unchanging for Lakes Superior and Huron. Lake Erie's condition is reported as Deteriorating (Table 5.3.1).

Fish Consumption

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Contaminants in Edible Fish	Unchanging	Improving	Unchanging	Deteriorating	Improving

Status:	GOOD	FAIR	POOR	UNDETERMINED

Table 5.3.1.(Source: ECCC and USEPA, 2017a, 2017b)

Contaminant levels for whole fish species monitored by the Parties have decreased since monitoring commenced in the 1970s (ECCC and USEPA, 2017a, 2017b). This report indicates a similar trend for edible fish, where mercury contamination is currently lower than most health advisories levels, though mercury and PCBs have remained stable or slightly increasing for Lakes Erie and Huron. Levels of PCBs, responsible for most fish advisories, plateaued in the 1990s and have remained stable in recent years at levels higher than advisory guidelines.(ECCC and USEPA, 2017ab). As a result, consumption limits likely will need to remain in place over the long term. The observations of lake-specific contaminant trends reflect dependence of trends on a variety of competing factors, such as composition of the fish community and associated foodwebs, physio-chemical characteristics of the contaminants, and in-lake hydrology (SOLEC, 2014) In addition, acceptable consumption levels have declined for some contaminants.

The Parties discuss the risks and benefits when advising on fish consumption and discuss the nutritional benefits of Great Lakes fish as a source of Omega-3 fatty acids, and note that further research to understand the levels of Omega-3 fatty acids in Great Lakes fish is needed. Neither a basin-wide status, nor lake specific levels and trends, of omega-3 fatty acids in the five fish species were presented.

2. IJC Proposed Sub-Indicators for human health

In 2012, the IJC tasked the Health Professionals Advisory Board (HPAB) with providing a small set of indicators tying the assessment objectives of the GLWQA to the health of residents and resource users of the Great Lakes basin. The HPAB considered the close link between ecological and human health, and identified an indicator associated with human health hazards arising from consuming Great Lakes fish, Contaminant Levels in Great Lakes Edible Fish Species. The IJC included this indicator, in its recommendations on human health to the governments of Canada and the United States based on the HPAB (2014) report. The indicator is designed to provide a foundation for tracking threats to human health. Using the recommended indicator would describe temporal and spatial trends of bioavailable chemicals of concern in the edible portions of five Great Lakes fish: Lake Trout (*Salvelinusnamayacush*), Walleye (*Sander vitreus*), Yellow

Perch (*Percaflavescens*), Whitefish (*Coregonusclupeaformus*), and Smallmouth Bass (*Micropterusdolomieu*).

Contaminants measured as part of the recommended indicator would include legacy persistent bioaccumulative toxicants, such as PCBs (with limited congeners), total dichloro-diphenyl-trichloroethane (DDT), 1,1-Dichloro-2,2-bis(p-chlorophenyl)ethylene (DDE), mercury, total chlordanes, toxaphene and mirex. Fish consumption advisories and trend data have been used to select chemicals for monitoring. Not all chemicals would be measured in all five lakes and the chemicals may change over time (for example, mirex levels have decreased and at some future point may be removed from the list). Consistent standards should be developed for issuing fish consumption advisories (IJC, 2011). HPAB (2014) recommends additional dialogue between the HPAB and SOGLR authors regarding standardizing indicator approaches that pertain to human consumption of Great Lakes fish.

A comparison of previous reporting and indicators discussed above can be found in Table 5.3.2. The Parties shifting indicator reporting from whole fish to fish portions is a positive development but the indicator is only reported for three the five proposed fish species and two of the six proposed chemicals. The number of contaminants for which lake-by-lake specific levels and trends were reported under the Fish Consumption indicator also decreased relative to previous reporting by the Partieson the whole fish indicator (SOLEC, 2014). Previous reporting on whole fish included broader basin-wide status reporting for a larger suite of contaminants. PCBs and mercury drive most health advisories in the region, though states recognize that DDT and other contaminants remain a concern. While recognizing that the source data for this indicator was drawn from different programs, inclusion of detailed levels and trends analysis of a broader suite of contaminants is recommended.

The Parties' use of five fish species of interest for human consumption in the SOGL 2017 report is commendable, though the species list emphasizes top predator and sports fish. Top predator fatty fish, such as lake trout and salmon species, represents a reasonable "worst case scenario" for fish consumption advisories. Top predators accumulate larger amounts of chemicals during their life span, and advisories are typically driven by organic chemicals that accumulate preferentially in fatty tissue (such as PCBs). The use of the most commonly consumed fish species in the Great Lakes region as recommended by HPAB (2014) would broaden the emphasis of reporting beyond sports fish to include fish at different trophic levels in the ecosystem caught by a broader population of fishers.

A common set of fish species and chemicals is needed for future data collection and assessment. Such differences in collection, analysis, and reporting of data remain challenges in developing a Great Lakes basin-wide indicator for fish consumption.

Table 5.3.2. Basin-wide and lake-by-lake levels and trends for contaminants and species for reported and recommended fish consumption indicators from IJC and the Parties. * SOLEC, 2014; ** HPAB, 2014; ***ECCC and USEPA, 2017a.

	SOLEC 2014*	IJC 2014**	ECCC & USEPA, 2017
Indicator	Contaminants in Whole Fish	Contaminant Levels in Great Lakes Edible Fish Species	Contaminants in Edible Fish

Fish Species	Lake Trout , Walleye	Lake Trout, Walleye, Yellow Perch, Whitefish, Smallmouth Bass	Lake Trout , Lake whitefish, Walleye, Chinook Salmon, and Coho Salmon
Legacy Contaminants	polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), mercury, chlordane, Mirex, dieldrin, toxaphene, polybrominated diphenyl ethers (PBDEs)	PCBs (with limited congeners), total DDT/DDE, mercury, total chlordanes, toxaphene and mirex.	PCBs and Hg
Emerging Contaminants	perfluorinated acids, synthetic musks	NA	Perfluoroalkyl acids

Tribes and First Nations, many states and Ontario already collect contaminant data on the concentrations in the edible portions of these fish species. However, considerable work remains to establish environment-human health relationships and monitor potential indicators in similar ways over time. For instance, data gathered by the Ontario Ministry of the Environment and Climate Change's long-term monitoring program are appropriate to use for long-term trend analysis but do not address Lake Michigan. The Chippewa-Ottawa Resource Authority collects contaminant data in the edible portions of fish from Lakes Superior, Michigan, and Huron (Dellinger et al.,, 2014).

5.3.3 Assessment of Annex activities

As noted previously, the GLWQA does not include a specific Annex that contributes to the achievement of the objective for fish consumption. However, beneficial use impairments for Restrictions on Fish and Wildlife Consumption and Tainting of Fish and Wildlife Flavor are addressed as part of the AOC delisting process (Annex 1) and criteria for Lakewide Management (Annex 2).For example, declines in concentrations for PCBs (Ridal et al., 2012) and mercury (Neff, *et al*, 2013) in fish have been noted for the AOCs at Bay of Quinte and Cornwall, respectively. However, the rates of decline are slow; the delisting criteria have not been met for either AOC. The AOC process has resulted in more focused research and monitoring at these Great Lakes locales relative to other sites, and this information could be leveraged for context in future reporting by the Parties.During this reporting cycle, the Deer Lake, Ashtabula River Areas of Concern was delisted in 2014, allowing for the lifting of restrictions on fish and wildlife consumption. Previous delistings include Collingwood Harbor (1994), Severn Sound (2002) Oswego River (2006), Wheatley Harbor (2010), Muskegon Lake, (2013), and White Lake (2013). Fish and wildlife consumption BUIs remain in place for all other US AOCs and Canada AOCs, save Nipigon Bay (CAN) and Port Hope Harbor (CAN) (Governments of the United States and Canada, 2016).

Whereas the other General Objectives of the GLWQA have associated annexes and annex committees to manage initiatives related to those objectives, there are no GLWQA annexes or implementation committees devoted exclusively to the three human health objectives.This absence may hinder the mobilization of resources needed to support progress toward attainment of the objectives. It is appropriate, therefore, to develop processes that will efficiently harness

energies of governments and non-governmental entities alike to pursue attainment of the human health objectives. Progress towards achieving this objective could benefit from improved government coordination around fish consumption issues. A human healthcommittee devoted to the three human health general objectives of the GLWQA could examineemerging issues related to fish consumption in the Great Lakes, and linkages between the SOGL reporting and Annex activities related to fish consumption and fish consumption advisories..

While Annex 10 provides a nexus for coordination of scientific efforts by the Parties, it is of concern that human health indicators and emerging issues are not recognized separately under the Key Commitments listed by the Parties on the Annex's web page (https://binational.net/annexes/a10/).

5.3.4 Assessment of key programs

Both countries maintain long-running programs to examine levels of chemicals in Great Lakes fish commonly consumed by humans, and there are multiple drivers for monitoring contaminants in fish and wildlife in both countries. Environment and Climate Change Canada (ECCC) implements Canada's Chemical Management Plan which in part provides for monitoring and surveillance activities to inform risk management under the *Canadian Environmental Protection Act* (Government of Canada, 1999). In the United States, the *Toxic Substances Control Act* gives the Environmental Protection Agency (USEPA) authorities to evaluate potential human health risks posed by legacy, current, and new chemical contaminants.

For the 2017 SOGL report, the Parties altered reporting on contaminants from whole fish to edible fish portions, based on data from of Ontario's FishContaminant Monitoring Program, the 8 GreatLakes State monitoring programs, and US EPA's 2010 Great Lakes Human Health Fish Fillet Tissue Study (SOGL Technical Report 2017).Whole fish monitoring continues, based on programs establishedin the Great Lakes by the United States and Canada since the early 1970's (Gewurtzet al., 2011; McGoldrick and Murphy, 2015) in response to the 1972 GLWQA and is maintained today under the current agreement and its Annex 3 Chemicals of Mutual Concern.

Robust monitoring programs also support public notification of human health risks related to fish consumption. Ontario has developed a comprehensive fish consumption advisory, including in recent years consumption advice for subsistence or frequent consumers (of up to 32 meals/month) (Province of Ontario, 2017).Tribal and First Nations organizations have also worked to develop fish advisories (Assembly of First Nations, Chiefs of Ontario, Health Canada, 2001; Great Lakes Indian Fish and Wildlife Commission, 2017), which are structured to communicate the benefits of consuming fish in addition to the contaminant risks.

In the United States, all of the eight Great Lake states collect and analyze tissue and issue fish consumption advice (Illinois Department of Public Health, 2016; Indiana Department of Health, 2017; Michigan Department of Health and Human Services, 2017; Minnesota Department of Health, 2017; New York State Department of Health, 2017; Ohio Department of Health, 2017; Pennsylvania Fish and Boat Commission, 2017; Wisconsin Department of Natural Resources, 2017), and the USEPA has published general guidance for fish consumption based on contaminant concentrations. Some states, including Minnesota and Wisconsin, issue joint advice

for shared water bodies. Additionally, the Great Lakes Consortium for Fish Consumption Advisories has developed Agreements for issuing consistent advice for select contaminants (Andersen, et al., 1993; Hornshaw, 2006; McCann et al., 2007). This consortium originally formed as a task force undera charge from the Council of Great Lakes Governors to develop and distribute consistent, science-based fish advisories.

Despite the collaboration of the eight Great Lakes States, uniform fish consumption advice for the shared waters of the Great Lakes has not yet been achieved. For example, fish advisories for both Ontario and New York apply to lake trout caught in Lake Ontario, though the advice will differ depend on where the fish was swimming when it was caught. For Ontario, the advisories are generated for detailed fish size and location caught. At one example location (Table 5.3.3), the Ontario advisory stated that the general population was limited have 0-1 meals per month for fish greater than 60 cm / 24 in, and 0 meals per month for sensitive populations (defined as women of child-bearing age and children under 15); For shorter fish, the general population limits included 4-12 meals per month for fishes sized 20-45 cm/ 8- 18 inches, and 2 meals per month for 45-60 cm/ 18-24 inches. Limits were stricter for sensitive populations, recommending 4-12 meals per month for fish lengths of 20-45 cm/ 8- 18 inches, and 0 meals per month for any larger fish.

Table 5.3.3 Lake Troutadvisories for one location in Lake Ontario (https://www.ontario.ca/environment-and-energy/sport-fish-consumption-advisory?id=43567717). *Sensitive Population: Women of child-bearing age and children under 15.

Length (cm) →	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	>75
Length (in) →	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	>30
General population		12	12	8	4	4	2	2	2	1	1	0	0
Sensitive population*		12	12	8	4	4	0	0	0	0	0	0	0

New York's advisory was stricter for age and used fewer distinctions for fish size. Men and women over 50 could consume up to up to 1 meal/month for fish greater than 25 in. (63cm), and up to four meals/month for fish less than 25 in(63 cm) long. For women under 50 and children under 15 the advisory stated "Do Not Eat" for any size fish. These discrepancies can cause confusion for visitors and the populationsliving around Lake Ontario, especially regarding the differences for at risk groups.

In addition to the structural and monitoring difference noted by the HPAB (2014), ensuring the proper communication of fish consumption advisories can be challenging. IJC's Health Professionals Task Force (which became the HPAB) noted that 38% of fish eaters surveyed used only conventional sources of information, most often the media, when deciding whether to eat their catch (HPTF, 2004). It's important that jurisdictional fish advisories consider the perception

of those being advised and site-specific data and cultural and socio-economic factors(HPTF, 2004). For example, advisories aimed at restricting meals of local fish may lead to unintended social, cultural and health consequences for First Nations/ Tribes and Métis communities (HPTF, 2004; Assembly of First Nations, 2007; Hoover, 2013). An understanding of knowledge gaps in current advisories (Christensen et al., 2016), along with message refinement and alternative outreach efforts may be needed to increase compliance with fish consumption guidelines, particularly among subpopulations that exceed the guidelines more frequently (Tildenet al.,1997; Imm, *et al*., 2005; Connelyet al.,2014; Connelyet al., 2017). A study of women of childbearing age who purchased fishing licences in Great Lakes states found that one quarter exceeded fish consumption guidelines, with rates as high as 41% exceeding the guidelines in Michigan and Minnesota (Connelyet al.,2017). Certain subpopulations of urban anglers, especiallynon-white, African-American and immigrant communities, may be at increased risk for exposure to potentially contaminated fish (Lauberet al.,2017a; Shakoor and Kashian, 2017). Fish advisory exceedances have been reported to be higher for women, non-whites and older anglers. (Lauberet al.,2017a). Advisories to these communities may be best targeted by using community-based programs to communicate fish consumption advice (Lauberet al.,2017b).

There is a need for greater collaboration among national, state/provincial and Tribes/First Nations and Métis for fish consumption guidance, and a standardized sampling approach and analytical methods. Standardised data interpretation and the issuing of advice for fish consumption indicators would strengthen health assessments and resource management in the Great Lakes. (HPTF, 2004; HPAB, 2014).Such standardization would allow for the development of a basin-wide human health indicator to characterize risks and benefits from fish consumption. Achieving such standardization is a tremendous challenge, though such an effort would provide tremendous support for binational human health protection. The Parties should also set goals toward reaching all populations of frequent and/or vulnerable Great Lakes fish consumers, including subsistence anglers, indigenous communities, and women of child bearing age, with accessible and protective fish consumption advisories, and draw up a plan to do so.

Wildlife consumption is listed as a separate entity within this objective. However, the 2016 SOGL does not connect human health with wildlife consumed in the Great Lakes other than fish species. While fish and fishing includes a large portion of provisioning services for food within the waters of the Great Lakes, human health risks from consuming wildlife from the waters of the Great Lakes such as duck, are not reported under the SOGL. At present, neither country maintains a program comparable to fish monitoring as previously described to report on chemical contaminants in other forms of Great Lakes wildlife consumed by the human population. Some US states have active health advisories for certain game species of waterfowl (New York State Department of Health, 2016; Pennsylvania Game Commission, 2016; Wisconsin Department of Natural Resources, 2016) and snapping turtles (New York State Department of Health, 2016) due to concerns over levels of contamination by mercury and organic chemicals such as PCBs as determined through state monitoring programs.

Although this objective notes that the waters of the Great Lakes should allow for human consumption of wildlife unrestricted by concerns due to harmful pollutants, the PROP does not mention programs related to wildlife consumption. As well, SOGL reporting does not connect human health with wildlife consumed from the Great Lakes basin ecosystem. Information regarding the widespread consumption of Great Lakes wildlife is limited and potentially informative; however the level and spatial distribution of consumption patterns may not justify binational activities.

Communicating Advisories
Ensuring the proper communication of fish consumption advisories can be challenging. In 2004, the IJC's Health Professionals Task Force (now the Health Professionals Advisory Board) noted that 38 percent of fish eaters surveyed used only conventional sources of information, most often the media, when deciding whether to eat their catch. Jurisdictional fish advisories should consider the perception of those being advised and site-specific data, as well as cultural and socio-economic factors. Agencies developing advisories aimed at restricting meals of local fish should keep in mind the social, cultural and health consequences of these advisories for First Nations, Tribes and Métis communities.

An understanding of knowledge gaps in advisories along with message refinement and alternative outreach efforts are needed to increase compliance with fish consumption guidelines, particularly among subpopulations that exceed the guidelines frequently.. Advisories to these communities may be best targeted by using locally based programs to communicate fish consumption advice.

Risks and benefits should be considered in decisions whether to consume Great Lakes fish. Fish supply healthy unsaturated fats and high-quality protein, but may contain contaminants at high enough levels to impact human health. Common alternative foods to fish may provide health promoting nutritional value, but also saturated fats or sugars and contaminants of their own.

5.3.5 Assessment of principles and approaches

The GLWQA puts forth principles and approaches to define basic concepts to guide the Parties work towards achieving the GLWQA's Objectives. The principles and approaches also provide a framework for assessing the success of current programs and measures that support the GLWQA.

As a concept in the GLWQA, adaptive management addresses how to evaluate current actions and adjust future actions once outcomes and ecosystem processes in the Great Lakes become better understood. In recommending that the Parties shift to indicators that support human consumption of fish (Objective 3), the IJC relied on the HPAB assessment that advances in science provide for better monitoring and reporting on human health than are currently implemented (HPAB, 2014). The GLWQA's principle of adaptive management provides rationale for such a shift.

5.3.6 Assessment of other reports

A recent report by the IJC evaluated the implications of atmospheric mercury deposition as an external source of mercury to fish in the Great Lakes (IJC, 2015). The USEPA notes studies showing that "generally, the declines in mercury concentrations observed up until approximately 1990 have ceased and that mercury concentrations in fish have started to increase. This suggests that concentrations of mercury in top predator fish are atmospherically driven and the recent increases may be a reflection, in part, of increased global mercury emissions US EPA (2014)." EPA's research also indicated that global anthropogenic sources of atmospheric mercury could account for 14 to 18 percent of mercury in the Great Lakes. It is valuable for the Parties to continue international efforts to address atmospheric deposition coming from North America.

Long range transport mercury is of major concern internationally to both human and ecosystem health, and 140 countries including Canada and the United States reached agreement on a treaty in January 2013, the Minimata Convention, intended to reduce anthropogenic emissions and releases of mercury and mercury compounds. While the Minimata Convention has not yet gone into force pending full ratification by 50 countries, the Parties are implementing many measures of the Convention in the interim.

The Minimata Convention is important step towards reducing risks by mercury to human health and the environment. Other contaminants such as pesticides, flame retardants and other chemicals present a continued risk to the Great Lakes and also have significant atmospheric sources.

5.3.7 Section Summary

- The Parties have shifted reporting for fish contaminants and human health. The Fish Consumption indicator provides trends in PCBs for edible fish portions of five fish species in the Great Lakes.

- Contaminant levels for whole fish monitored by the Parties decreased since monitoring commenced in the 1970s. Reporting indicates mercury contamination in edible fish portions is currently lower than most health advisories levels. For edible fish portions, levels of PCBs, responsible for most fish advisories, plateaued in the 1990s and have remained stable in recent years at levels higher than advisory guidelines. As a result, consumption limits likely will need to remain in place over the long term.

- The Contaminants in Edible Fish sub-indicator focused on mainly predator and sports fish species, and reduced the number of contaminants reported compared to previous reporting on whole fish. The use of multiple top predator and sports fish species is commendable,though broadening the emphasis of reporting beyond sports fish would enable the inclusion of fish at different trophic levels in the ecosystem caught by a broader population of fishers. While PCBs drive many health advisories in the region, mercury, DDT, and other contaminants remain a concern and reporting for additional chemicals (DDT/DDE, mercury, total chlordanes, toxaphene and mirex) is warranted. The previous indicator Fish Consumption Restrictions was not included in present reporting on fish contaminants.

- The governments have not demonstrated sufficient progress toward the achievement of the human health objectives in their implementation of the GLWQA. Health considerations factor into the implementation of various Annexes, but there are no annexes or implementation committees to consolidate reporting on the human health aspects of these programs or to identify emerging human health issues in the basin. This absence may hinder the mobilization of resources needed to support progress toward attainment of the objectives. A Human Health Committee devoted to the three human health general objectives of the GLWQA could examine emerging issues related to fish consumption in the Great Lakes, as well as linkages between the SOGL reporting and Annex activities related to fish consumption and fish consumption advisories

- The Parties need to set a goal of reaching all populations of frequent and/or vulnerable Great Lakes fish consumerswith accessible and protective fish consumption advisories, and draw up a plan to do so. Populations include frequent consumers of Great Lakes fish such as subsistence anglers, many African Americans, indigenous communities, and some immigrant and other minority communities. It also includes those vulnerable to contaminants such as women of childbearing age and young children. In developing a plan to reach this goal, the Parties should collaborate more closely with representatives of these communities.

- The IJC has recognized that a standardized sampling approach, analytical methods, data interpretation and the issuing of advice for fish consumption indicators would strengthen health assessments and resource management in the Great Lakes. This standardization would

allow for the development of a basin-wide human health indicator to characterize risks and benefits from fish consumption.

- Long range transport mercury is of major concern internationally to both human and ecosystem health. In January 2013, 140 countries including Canada and the United States reached agreement on a treaty the Minimata Convention, intended to reduce anthropogenic emissions and releases of mercury and mercury compounds.It is valuable for the Parties to continue international efforts to address atmospheric deposition coming from North America.

- The wildlife consumption provisions of the GLWQA are not included as part of the 2016 PROP of SOGL 2017 reporting. It is useful that some Great Lakes states have issued health advisories based on their own monitoring programs. It is recognized that the level and spatial distribution of consumption patterns may not justify binational activities or SOGL reporting

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5.4 Pollutants

5.4.1 Introduction

1. Purpose

This section reviews and assesses progress toward achieving General Objective 4 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 4 states that the waters of the Great Lakes should "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."

The section presents an assessment of programs and other measures in support of this objective. This assessment is based largely on the review of publicly available information from:

- data and information from the *2016 State of the Lakes* presentation by the Parties (GLPF 2016)
- the 2017 State of the Great Lakes Technical Report (ECCC and USEPA, 2017a), and Highlights Report (ECCC and USEPA, 2017b)
- the Progress Report of the Parties (Governments of the United States and Canada, 2016); and
- implementation measures undertaken in support of the GLWQA Annex 3: Chemicals of Mutual Concern.

2. Background

The Great Lakes are uniquely vulnerable to chemical contamination because they have a large surface area and flush slowly, which means many chemicals can enter the lakes via multiple pathways and collect in fish, wildlife and sediment. This is especially true for chemicals such as PCBs and DDT that build up (bioaccumulate) in the food web and break down slowly in the environment. Thus, chemical concentrations decline only gradually once controls are put in place (Fuller et al., 1995).

Historically, intense industrial activity in the Great Lakes region and long-range atmospheric transport and deposition of chemicals from out-of-basin sources have contributed to chemical pollution of the Great Lakes (Fields, 2005;IJC, 2015a). In addition to harming aquatic life, certain chemicals pose human health risks, largely through consumption of contaminated fish (Fuller et al.,1995).

5.4.2 Assessment of indicators

1. Sub-indicators status and trends

The 2017 State of the Great Lakes (SOGL) Report includes a Toxic Chemicals indicator that corresponds to General Objective 4 of the GLWQA. The indicator includes the following sub-indicators: toxic chemicals in Great Lakes Herring Gull eggs; toxic chemical concentrations (open water); atmospheric deposition of toxic chemicals; toxic chemicals in sediment; and toxic

chemicals in Great Lakes whole fish. A summary of the status and trends for all of the Toxic Chemicals sub-indicators is presented in Table 5.4.1.

The overall assessment of the toxic chemicals in Great Lakes herring gulls sub-indicator is that the status is good and the trend is improving. The long-term trends of virtually all legacy contaminants such as polychlorinated biphenyls (PCBs), dioxins and furans, and organochlorine pesticides are declining levels. However, it was also found that "non-legacy" compounds (for example, dechlorane plus and hexabromocyclodoecane (HBCD), which are used in place ofPolybrominated diphenyl ether (PBDE) as flame retardants) have increased. The lake-by-lake assessment for these sub-indicators found that the status levels for Lakes Superior, Michigan and Huron are good and that their trends are improving. For Lakes Erie and Ontario, the status levels are fair and the trends unchanging.

The status for the *toxic chemical concentrations sub-indicator* is good with an unchanging trend overall in the Great Lakes basin. On a lake-by-lake basis the status levels for Lakes Superior, Huron, and Michigan are excellent to good with improving to unchanging trends. Lakes Erie and Ontario were found to each have a fair status for this sub-indicator with the trend unchanged. Key findings identified that while long-term trends for many legacy toxic chemicals such as mercury are declining, there has been little to no changes recently.

Table 5.4.1.Summary of the status and trends of the State of the Great Lakes Toxic Chemicals sub-indicators for the overall Great Lakes basin and each Great Lake

Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Toxic Chemical Concentrations	Improving	Unchanging	Unchanging	Unchanging	Unchanging
Toxic Chemicals in Sediments	Unchanging	Unchanging	Unchanging	Improving	Improving
Toxic Chemicals in Great Lakes Whole Fish	Unchanging	Improving	Unchanging	Unchanging	Improving
Toxic Chemicals in Great Lakes Herring Gull Eggs	Improving	Improving	Improving	Unchanging	Unchanging
Atmospheric Deposition of Toxic Chemicals	No lake was assessed separately Great Lakes Basin assessment is **Fair** and **Improving**				

Status:	GOOD	FAIR	POOR	UNDETERMINED

(Source: ECCC and USEPA, 2017a, 2017b)

The *atmospheric deposition of toxic chemicals sub-indicator* status is fair for the overall assessment of the basin with an improving trend. A lake-by-lake assessment was not completed for this sub-indicator. The assessment found that although levels of toxic chemicals in the air are generally low, the large surface area of the Great Lakes results in significant atmospheric deposition. Monitoring for some chemicals of emerging concern, including PBDEs, is increasing and efforts are being made to identify other chemicals that should be included in Great Lakes monitoring programs.

The basin-wide assessment for the *toxic chemicals in sediment sub-indicator* showed that the status for the Lakes is fair and the trend is improving. Lake Superior and Huron were classified as good in terms of their status with unchanging trends. The trend for Lake Michigan was unchanging and its status is fair. Toxic chemical concentrations in sediments in Lakes Erie and

Ontario statuses are fair with improving trends. Some of the key findings are that legacy toxic chemical concentrations continue to decrease and are generally below sediment quality guidelines. Many emerging and new toxic chemicals are showing increased concentrations in sediment and may be potential sources of stressors to the ecosystem now and in the future.

The *toxic chemicals in Great Lakes whole fish sub-indicator* status is fair with an improving trend. The status levels for Lakes Superior, Huron and Erie were fair with unchanging trends. Lakes Michigan and Ontario were found to each have fair status and improving trends. While there continue to be guidance exceedances for some substances, contaminant levels in Great Lakes whole fish have decreased. Legacy chemicals will continue to be monitored but efforts are being made to incorporate emerging chemicals into both US and Canadian monitoring and surveillance programs. These emerging chemicals are identified through scientific studies, general screening, risk assessments and the identification of chemicals of mutual concern as part of the Parties Annex 3 process under the GLWQA.

Chemicals of Emerging Concern

A common element of the majority of the sub-indicator results presented at GLPF (2016) and SOGLR is that while legacy chemical levels are generally decreasing or remaining unchanged, emerging chemicals levels are increasing. Most of the sub-indicator presentations indicate that monitoring and surveillance programs are taking this change into consideration and are attempting to incorporate new and emerging chemicals into their routine work. However, there does not appear to be a consistent approach to addressing new and emerging chemicals as the level of effort to identify and incorporate new and emerging toxic chemicals varies across programs.
The Parties have made good efforts to report on the increased levels of new and emerging toxic chemicals as part of their monitoring and surveillance programs. However, there is a need to develop a more consistent strategy for this process.

Chemicals of Mutual Concern (CMCs)– Annex 3

The toxic chemicals in Great Lakes whole fish report states that monitoring and surveillance programs in the United States and Canada are identifying chemicals of interest through a variety of methods, including the Annex 3 process for identifying chemicals of mutual concern (CMCs). The CMC process is discussed further in section 5.4.4 of this report. This is the only toxic chemicals sub-indicator report that mentions the inclusion of CMCs in monitoring and surveillance programs specifically. It is unclear as to whether the programs associated with the other toxic chemicals sub-indicators are making similar efforts sub-indicators are making similar efforts or are considering CMCs in a similar manner.

5.4.3 Assessment of Progress Report of the Parties

The (CMC) chapter in the PROP serves to highlight the binational actions taken by the Parties in relation to key commitments under Annex 3 since the GLWQA came into force in 2013. The chapter is a high-level summary of successes achieved to date related to select commitments for Annex 3 and emphasizes related domestic actions taken in both Canada and the United States.

GLWQA commitments for the identification of CMCs have been met. While progress has been made in addressing commitments related to targeting CMCs for action and the coordination of science priorities, it is clear that more work is needed in terms of implementing related programs and measures (as discussed below).

5.4.4 Assessment of Annex implementation

1. Overview

Annex 3 commits the Parties to contributing to the General and Specific Objectives of the GLWQA by protecting human health and the environment though cooperative and coordinated measures to reduce the anthropogenic release of chemicals of mutual concern into the waters of the Great Lakes.

Under the *Programs and Other Measures* section of Annex 3, the Parties have committed to two areas of focus: the identification of chemicals of mutual concern; and targeting those chemicals for action.

To ensure that the Parties are able to realize those commitments, a CMCs Sub-Committee has been established. The mandate, principles, roles and responsibilities, organizational structure and membership of the Sub-Committee have been established in a terms of referencedated March 7, 2014 (United States and Canada, 2014a).

According to the terms of reference, the mandate of the Chemicals of Mutual Concern Sub-Committee (referred to as the "C3") focuses primarily on the two areas identified in Annex 3 -- the identification of chemicals of mutual concern and targeting those chemicals for action, as well as supporting the Great Lakes Executive Committee (GLEC) as required. The terms of reference also identifies the *Principles* that the C3 shall adhere to, including: no impairment to the waters of the Great Lakes; accountable, adaptive and science-based management actions; virtual elimination and zero discharge of CMCs to be implemented as appropriate, life-cycle management as well as others.

The responsibility of the C3, according to the terms of reference, is to develop, maintain and deliver three-year work plans designed to ensure that the Parties meet the commitments of the GLWQA. Membership of the C3 consists of government representatives from relevant federal, state, provincial, First Nation, Métis and Tribal agencies in Canada and the United States that are responsible for protection of the ecosystem health within the Great Lakes basin. The C3 is co-chaired by individuals designated by the GLEC Co-Chairs. Decisions of the C3 are made by consensus based on a quorum of nine members including the co-chairs and with a minimum of four participants from each country.

As shown in Figure 5.4.1, the C3 reports directly to the GLEC and has established an Extended Sub-Committee (EC3) as well as Task Teams to address the tasks set forth in the current work plan on an as-needed basis.

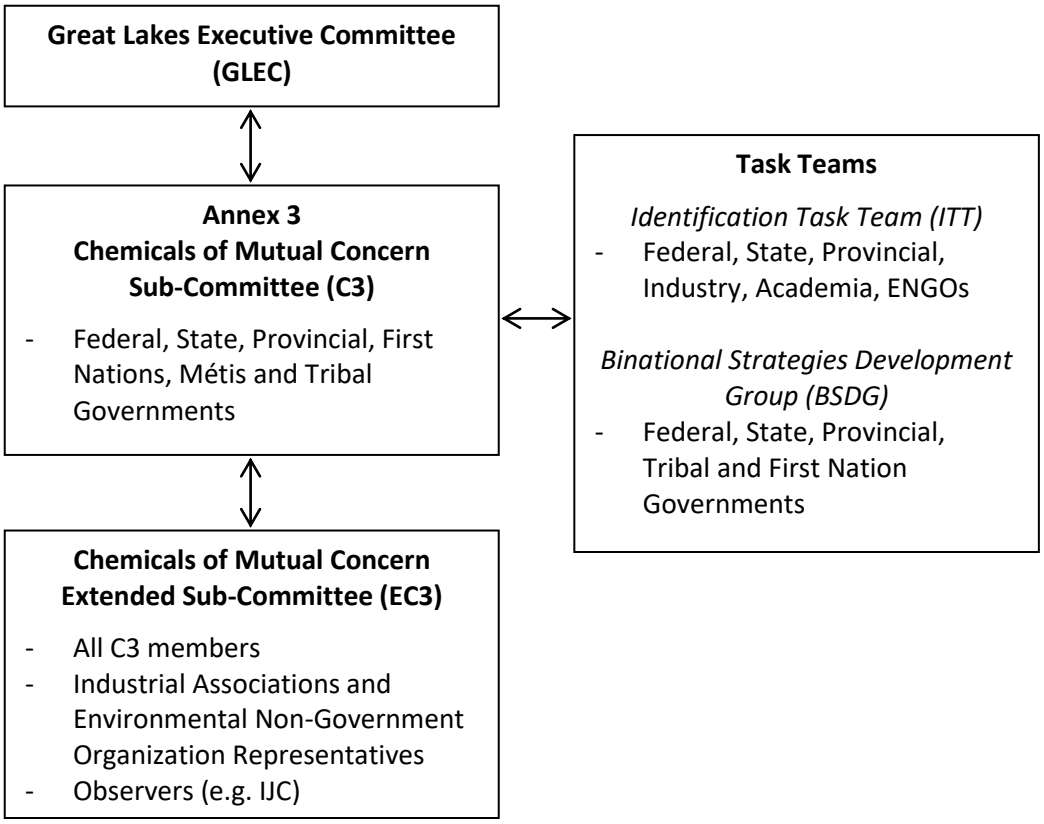

Figure 5.4.1 Annex 3 – Chemicals of Mutual Concern Implementation Organizational Model

The role of the EC3 is to provide input and feedback to the C3 on the development and implementation of the Annex 3 – CMCs work plan. Its membership includes all C3 members as well as selected representatives from industrial associations and environmental non-government organizations. Observers may also be appointed to the EC3 following a "formal request" with C3 co-chairs reserving the right to deny any application to observe due to venue capacity, meeting balance or other relevant considerations. The IJC has requested and been granted Observer status to the EC3.

The C3 may also form Task Teams on an as-required basis to assist in the delivery of the Annex 3 work plan for a fixed duration of time. Members of the Task Teams are selected by the C3 with input from the EC3 and are required to possess relevant expertise.

To meet its responsibilities, the C3 developed a work plan that focuses on the development and implementation of approaches and processes associated with the identification of CMCs, the development of binational strategies for those CMCs and the development of new or revised domestic water quality standards, and objectives, criteria and guidelines for CMCs during the 2013-2016 timeframe. Specifically, the 2013-2016 t work plan committed the C3 to identifying and designating two separate sets of CMCs, developing binational strategies for the CMCs identified, and beginning work on the implementation of those strategies where applicable (United States and Canada, 2013a).

The C3 also stated that Year 1 of the work plan "is a pilot year to establish, test and refine our process and associated governance" (United States and Canada, 2013b).

Further to the C3's work plan, the Parties agreed to the following Priorities for Action for 2014 through 2016 (United States and Canada, 2014b) to guide their work under Annex 3:

- develop a binational process and considerations to identify and designate Chemicals of Mutual Concern on an ongoing basis;
- identify the first set of candidate Chemicals of Mutual Concern in spring 2014;
- apply the binational process and considerations to the first set of candidate chemicals and recommend resulting Chemicals of Mutual Concern for consideration by the GLEC in fall 2014;
- designate the first set of Chemicals of Mutual Concern by the Parties in fall 2014;
- identify and evaluate existing water quality standards, objectives, criteria and guidelines, or, when warranted, develop new water quality standards, objectives, criteria and guidelines for the first set of Chemicals of Mutual Concern in Spring 2015 (to be available on-line);
- complete the development of binational strategies for the first set of Chemicals of Mutual Concern by summer 2015; and
- identify the second set of candidate Chemicals of Mutual Concern in spring 2015.

2. Process Used for Identifying CMCs

The GLWQA requires the Parties to identify and designate, on an ongoing basis, CMCs that originate from anthropogenic sources and that are agreed to by both Parties as being potentially harmful to the Great Lakes environment and human health.

To accomplish this task, the C3 established an Identification Task Team (ITT). Membership of the ITT included eight representatives from federal, state and provincial governments, four from industry, three from academia and two from environmental non-government organizations. For the first set of candidate CMCs, the governments of Canada and the United States proposed a list of seven chemicals or classes of chemicals and charged the C3 with identifying those that should be recommended as CMCs. Those chemicals included: PCBs; nonylphenol and its ethoxylates; mercury; chlorinated paraffins (short, medium and long chain); perfluorinated chemicals (perfluorooctane sulfonate [PFOS]), perfluorooctanoic acid [PFOA] and long-chain perfluorocarboxylic acids [PFCAs]); bisphenol A (BPA); and brominated flame retardants (polybrominated biphenyl ethers [PBDEs] and HBCD). The ITT was tasked with reviewing and critically evaluating relevant existing data and information for the seven proposed CMC in accordance with the Binational Considerations for Identifying Candidate Chemicals of Mutual Concern in the Great Lakes Basin that was developed by the C3 (see Figure 5.4.2).

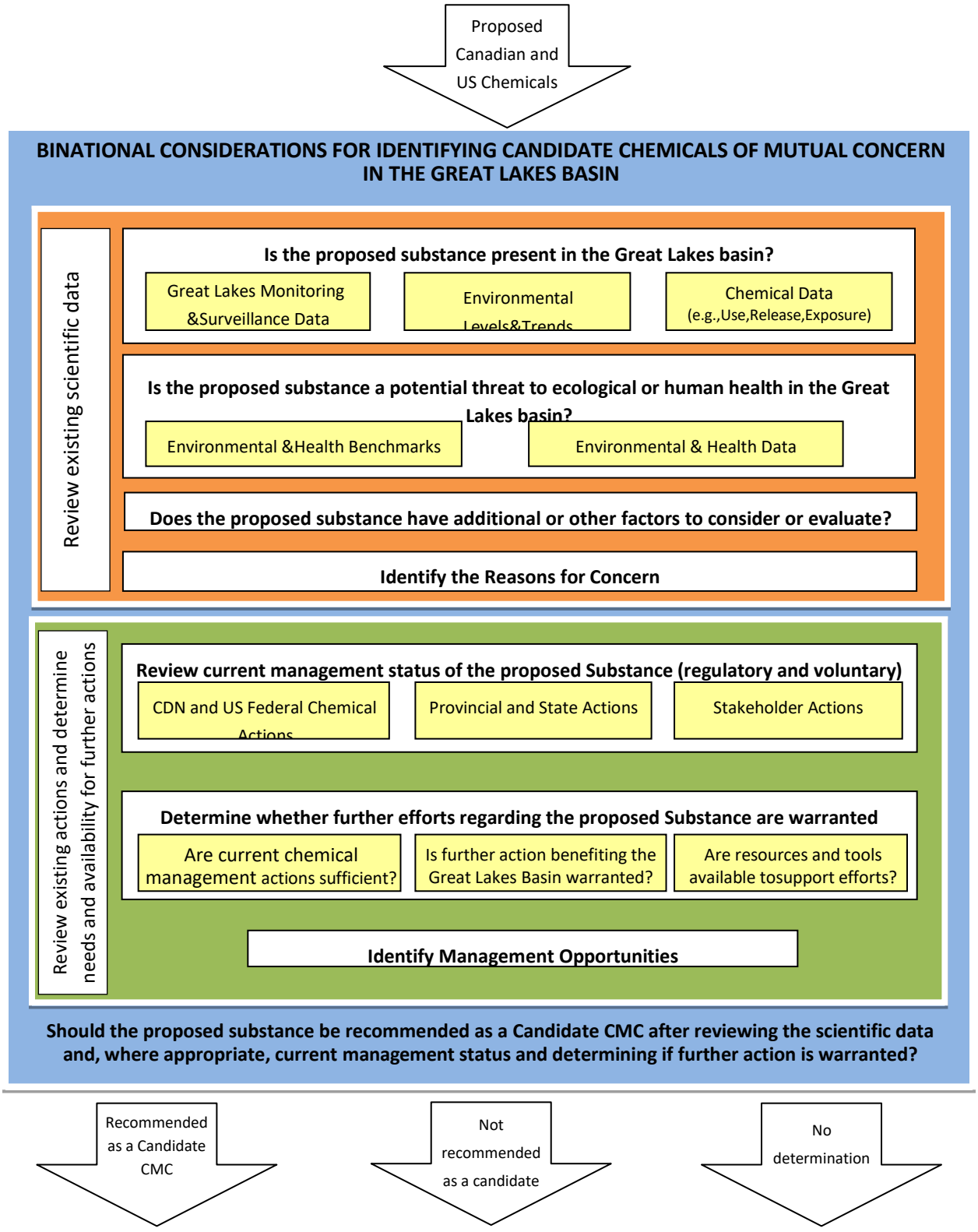

Figure 5.4.2.Binational considerations for identifying Chemicals of Mutual Concern (CMCs) in the Great Lakes Basin(Source: developed by the GLWQA Annex 3 Sub-Committee)

The ITT produced a Binational Summary Report for each candidate CMC, based on the evaluations they performed. Each report provided the findings and justification for whether the particular chemical or class of chemicals should be:

- recommended as a chemical of mutual concern;
- not recommended as a chemical of mutual concern;
- no determination - no recommendation made due to insufficient data

The ITT recommended to the C3 that the four following chemical groups be designated as CMCs: PCBs; mercury; perfluorinated chemicals; and PBDEs (brominated flame retardant class). Nonylphenol and its ethoxylates, chlorinated paraffins, bisphenol A and HBCD (brominated flame retardant class) received a "No determination" classification.

The ITT recommendations were submitted to the C3 and released for public comment in May 2015. Members of the EC3, and the GLEC were also invited to comment on the Binational Summary Reports. All stakeholder comments were summarized and provided to the C3 for consideration while they decided which chemicals should be recommended for designation to the GLEC (United States and Canada, 2015b). While considering its recommendations the C3 reviewed the principles under the Agreement, it's Terms of Reference (2014) and further considered the meaning of designation under the Agreement (United States and Canada, 2015c). As a result, the C3 agreed to emphasize certain areas for each chemical to guide its deliberations including:

- evidence the chemical is persistent, bioaccumulative and inherently toxic;
- evidence of long range transport;
- inclusion of the chemical under international and/or multilateral environmental agreements; and
- knowledge that additional data from the Great Lakes will be available in the near future to complement current data sets.

Following its deliberations the C3 recommended that PCBs, mercury, PFOS, PFOA, long-chain perfluorocarboxylic acids (PFCAs), PBDEs and HBCD (brominated flame retardant class), and short-chain chlorinated paraffins (SCCPs) be designated as CMCs. The C3 decided that there was insufficient information available for medium and long chain chlorinated paraffins (MCCPs and LCCPs), nonylenol and its ethoxylates (NP/NPE), and bisphenol A (BPA) on which to base a determination at that time and did not recommend them for designation.

The C3 presented the first set of recommended CMCs, as mentioned above, to the GLEC at its June 2015 meeting. The GLEC was then responsible for forwarding the recommendations to the Parties for a decision on official designation as CMCs. A summary of this process is represented in Figure 5.4.3.

When presenting its findings and recommendations to the GLEC in June 2015, the C3 also discussed next steps which included an evaluation of ways in which to improve the ITT process. It also considered establishing a mechanism to collect, review and summarize new data that

becomes available for chemicals and that received an "insufficient information" classification and how those chemicals could be re-considered for designation as a CMC by the Parties.

On May 31, 2016 Canada and the United States announced that the following chemicals or classes of chemicals would be the first set of CMCs under the GLWQA:

- Hexabromocyclododecane (HBCD);
- Long-Chain Perfluorinated carboxylic acids (LC-PFCAs);
- Mercury(Hg);
- Perfluorooctanoic acid (PFOA);
- Perfluorooctane sulfonate (PFOS);
- Polybrominated Diphenyl Ethers (PBDEs);
- Polychlorinated Biphenyls (PCBs); and
- Short-Chain Chlorinated Paraffins (SCCPs).

3. Potential Improvements to Process for Identifying CMCs

The efforts of the Parties to enhance stakeholder engagement activities are encouraging. As noted, the C3 and GLEC Co-Chairs have indicated that this first work plan should be considered as a "pilot" and is an opportunity to develop and refine the processes and governance associated with their Annex 3 commitments. An example of the C3 working to refine the processes associated with Annex 3 is the creation of a process through which stakeholders can propose specific chemicals for consideration as candidate CMCs. . During the, the Parties from various stakeholders who expressed an interest in becoming more involved in Annex 3 activities. In response, the GLEC and C3 have developed a process that enables stakeholders from Canada and the United States to formally propose specific substances for consideration as candidate CMCs. The process applies to states and provinces, environmental and human health non-governmental organizations, industry, academia and members of the general public. The governments informed EC3 members and observers that the following substances were put forward as candidate CMCs under the new public nominations process.

- Radionuclides
- Sulfates
- Lead
- Polycyclic aromatic hydrocarbons (PAHs)

The Parties could continue to identify areas and opportunities for the public in the Great Lakes region to become more involved in Annex 3 activities.. As part of the ITT Statement of Work developed by the C3, there was a commitment to conduct an evaluation of the process to attempt to identify what went well and challenges that were encountered. This evaluation provided

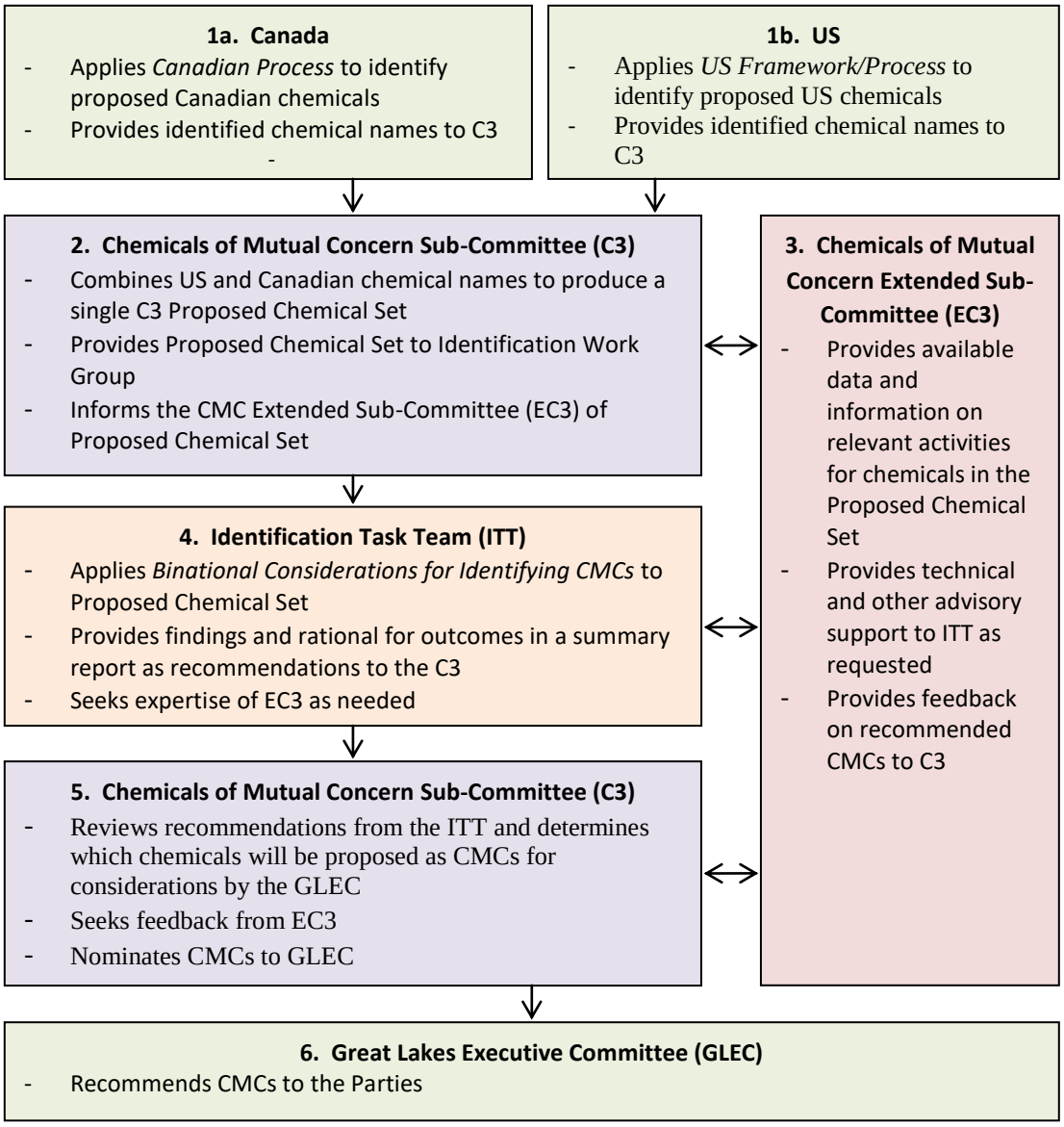

Figure 5.4.3.Summary of Annex 3's Process for Recommending Chemicals of Mutual Concern to the Parties

members of the ITT with an opportunity to identify issues and provide feedback and suggestions regarding the process for consideration by the C3.

As noted, a work plan for Annex 3 was developed that specifically committed the C3 to identify and designate two separate sets of CMCs and to develop binational strategies for the CMCs identified along with starting work on the implementation of those strategies where applicable (United States and Canada, 2013b). These commitments are also reflected and reinforced in the *2014-2016 Priorities for Science and Action* for Annex 3 that the Parties officially agreed to and released to the public in 2014. It was only in May 2016 that the Parties designated the first set of CMCs under the Agreement.Draftbinationalstrategies for two of the identified CMCs as a pilot to be applied to the remaining substances were released for public review in June 2017.

. The work plan was viewed as a "pilot" since it was the first developed for Annex 3 under the revised GLWQA and governments may have overestimated what could reasonably have been accomplished in the 2013-2016 timeframe. There may have been an underestimation of the resources needed to accomplish the identified tasks in a timely manner. This is reflected not only in the slow implementation of the work plan but also in documented comments from various members of the EC3 and ITT and others to both the C3 and GLEC Co-Chairs (CGLI, 2014a; CGLI, 2014b; CGLI, 2015; ENGO, 2015a; ENGO, 2015b; United States and Canada, 2015a). An expedited process is necessary to fulfil all GLWQA Objective 4 commitments in a timely manner.The current process is resource-intensive and requires considerable effort and time on the part of the members of the ITT. This is not the most efficient use of their experience and expertise, which should be focused instead on reviewing materials and providing input and feedback to the various parts of the review process.

Inadequate resources may have also resulted in a lack of clarity related to many of the guidance documents developed for the ITT process. Members of the EC3 and ITT have noted that documents such as the ITT's *Statement of Work* and the *Binational Considerations When Evaluating Candidate Chemicals of Mutual Concern* lack sufficient detail in certain areas, which resulted in confusion regarding the role and expectations of members as well as a certain level of ambiguity related to the interpretation of the CMC designations described earlier. Additional work by support staff at the beginning of the process to develop clear and consistent guidance documents as well as during the development of the Binational Summary reports could have prevented some of the issues that developed and may have allowed members to spend less time on more routine resource-intensive tasks such as compiling data and information. As well, utilizing experts from the Parties' national programs and processes with the appropriate experience and backgrounds to assist the ITT would enable the completion of assigned tasks in a more efficient and timely manner.

The ITT also identified a need to conduct more meetings in-person. If resources had been available for face-to-face meetings, members believed that they would have provided a valuable opportunity for deliberation and would have assisted the ITT in completing the Binational Summary Reports in a more efficient manner.

As part of the draft Lake Superior Lakewide Action and Management Plan (LAMP), nine toxic substances (mercury, PCBs, dioxin, hexachlorobenzene, octachlorostyrene and four pesticides [dieldrin, chlordane, DDT, and toxaphene]) have been identified as part of a Lakewide Objective to achieve zero release as part of the Lake Superior Zero Discharge Demonstration Program (Binational.net, 2016) . Of the nine substances, only two have been recommended for designation as CMCs. The Lake Superior LAMP also addresses "substances of concern" or chemicals of emerging concern such as personal care products and pharmaceuticals. At this point, it is not clear the extent to which these substances and the lessons learned from this and similar programs will be considered in relation to the Annex 3 CMC identification process.

Finally, it should be noted that the 2017-2019 priorities for science and action are less specific than the 2014-2016 priorities, which could make it harder to assess the Parties progress in next work cycle.

3. Targeting CMCs for action

Under the GLWQA, the Parties in cooperation with their government partners and the public commit to targeting CMCs for action under a number of provisions. These include:

- preparing binational strategies for chemicals of mutual concern;
- coordinating the development and application of water quality standards, objectives, criteria, and guidelines;
- reducing the anthropogenic release of CMCs and products containing CMCs throughout their entire lifecycles;
- promoting the use of safer chemical substances and the use of technologies that reduce or eliminate the use and release of CMCs;
- continuing progress toward the sound management of CMCs using approaches that are accountable, adaptive, and science-based;
- monitoring and evaluating the progress and effectiveness of pollution prevention and control measures for CMCs, and adapting management approaches as necessary; and
- exchanging information on monitoring, surveillance, research, technology and measures for managing CMCs.

One of the key commitments listed above is the preparation of binational strategies for substances that have been designated as CMCs by the Parties. In June 2017, the C3 released draft strategies for public comment for two of the designated CMCs: PCBs and HHBCD. These two draft strategies are to serve as examples for the development of the binational strategies for the remaining CMCs, taking into account lessons-learned from the initial processes.

As specified in Annex 3, strategies may include research, monitoring, surveillance and pollution prevention, and control provisions to be used to address gaps in data and information as well as reducing the anthropogenic release of CMCs into the waters of the Great Lakes (United States and Canada, 2016). According to the draft *Roles and Responsibilities for Developing Binational Strategies* guidance document (United States and Canada, 2015d) developed by the C3, the strategies may also include actions associated with the development and application of new and modified domestic water quality standards, objectives, criteria and guidelines by the Parties and other government entities. The continuation of current actions that will result in human health and environmental benefits or enhanced understanding of the sources, fate or effects of CMCs may also be included. Actions specified may be voluntary or mandatory in nature and may be implemented by different levels of government or non-government stakeholders.

To assist in the preparation of the strategies the C3 has established a Binational Strategy Development Group (BSDG). The BSDG is comprised of 19 members including representatives from Canadian and US federal agencies, the province of Ontario, the states of Illinois, Michigan, Minnesota, Ohio, and Wisconsin, and Tribal/First Nations governments.

A statement of work for the BSDG has been completed and the C3 development of draft binational strategies for PCBs and HBCD has progressed to a round of public comment set to expire in July 2017. It is expected that the draft Strategies will be completed for review during winter 2017. As part of that process, the BSDG will be seeking input from external stakeholders. The first such request solicited information for draft strategies on mercury, PBDEs,

perfluorinated compounds (PFOA, PFOS), along with short and long chain chlorinated paraffins , and concluded in July 2017.

As outlined in Annex 3, the Parties recognize "the need to manage chemicals of mutual concern including, as appropriate, by implementing measures to achieve virtual elimination and zero discharge of these chemicals (US and Canada, 2012)." Virtual elimination and zero discharge are identified as part of the guiding principles and approaches to the2012GLWQA. These longstanding concepts have been addressed under earlier versions of the GLWQA. In particular, the general principles for Annex 12 on Persistent Toxic Substances in the 1987 GLWQA included: "the intent of programs specified in this Annex is to virtually eliminate the input of persistent toxic substances …" and "the philosophy adopted for the control of inputs of persistent toxic substances shall be zero discharge (US and Canada, 1987)."

Some programs, such as the Lake Superior Zero Discharge Demonstration Program, have been successful and "lessons learned" from them, such as the use of Critical Milestones to track desired chemical reduction goals (Lake Superior Work Group and Task Force, 2012),should be incorporated into the binational strategies and used as the basis for discussion on the path toward achieving the purpose of the Annex at a basin wide level (IJC, 1990).The concept of virtual elimination and its implementation under existing regulations is described in the draft strategies for PCBs and HBCD. The concept of zero discharge is only described in the draft strategy for PCB. The strategies identify five categories for action in each draft: regulations and otherrisk mitigation and management actions; compliance promotion and enforcement; pollution prevention monitoring; surveillance, andother research efforts; and domestic waterquality (ECCC and USEPA, 2017c, and 2017d).Clear timelines for milestones toward zero discharge are not included under actions in the draft binational strategies for PCB or HBCD. As the Lake Superior Zero Discharge Demonstration Program produced such a series of milestones for PCBs (though not HBCD), a discussion of those milestones within the final PCB strategy document would be appropriate.

One of the Principles identified in the GLWQA under Article 2, section 4(a) is accountability, defined as " establishing clear objectives, regular reporting made availbale to the Public on progress and transparently evaluating the effectiveness of work undertaken to achieve the objectives of [the GLWQA]". Transparency – is an important part of that approach. Concerns have been raised regarding the transparency of the identification and ITT process under Annex 3.

Members of the EC3 and ITT have expressed concern at various times that not enough information is being provided regarding the decision making procedures for various parts of the CMC identification process. For instance, concerns have been raised regarding the fact that interested stakeholders such as members of the EC3, ITT or even the public are not permitted to attend or even observe the meetings of the C3. Materials and summaries of those meetings, including records of decisions and their rationale, are also not generally made available publically. These factors make it difficult for the public to stay informed regarding the work being done and decisions being made by the C3.

The 2016 PROP outlines numerous domestic actions being undertaken by both Canada and the United States with regard to various chemicals and substances. However, it is not clear how that work will feed into the Annex 3 process. It is also unclear how the newly adopted "Public Nomination Process" previously mentioned will be included. The *Annual Process for*

Recommending Chemicals of Mutual Concern in the Great Lakes Basin developed by the C3 (outlined in Figure 4.4.3) only refers to the Parties applying their own "process" or "framework/process" to identify proposed chemicals and does not specify what that process entails.

It is also uncertain how previous work of the Parties will be used as part of that process. Implementation activities from past versions of the GLWQA, such as the *Binational Toxics Strategy*, produced excellent products and information. It is not clear whether or how those previous efforts are being considered as part of the identification process.

Finally, while the Parties did designate the first set of CMCs under the GLWQA it is not clear how the decision was made to include eight candidate chemicals. As mentioned previously, the ITT recommended that four of the seven candidate chemicals or chemical classes be designated as CMCs under the GLWQA. However, after further deliberations and consideration of public and other input on the Binational Summary Reports the C3 recommended that eight chemicals be designated as CMC without a public explanation of how or why the decision was made. The C3 did present its findings and recommendations to the GLEC in June of 2015 with a general overview of the process but without additional details, it appears the work of ITT as a part of the designation process is not an efficient use of limited resources, including the time of the volunteer ITT members.

In June 2015, the C3 committed to improving the ITT process including the establishment of a mechanism to re-consider candidate CMCs for which it was decided that insufficient information was available to make a decision on whether or not they should be recommended for designation (United States and Canada, 2015d). However, no additional information regarding these improvements has been made available publicly since that time. It is unclear what, if anything, the Parties are planning on doing to meet this commitment.

The development of the draft binational strategies for PCBs and HBCD also raises some concerns related to the Principle of transparency under the GLWQA.The BSDG, which is responsible for the development of the draft binational strategies, is composed of representatives from government agencies only. No representatives from other Great Lakes groups, organizations or stakeholder are included, and while the C3 has indicated that external stakeholders will be consulted as part of the binational strategy process they have not provided any information on how those consultations will be carried out.

To avoid some of the issues that developed as part of the ITT process, the Parties could make further efforts to ensure that the Binational Strategies development process is transparent to the public and engages interested external stakeholders on a consistent and timely basis.

4. Public engagement

Public Engagement is also one of the principles and approaches identified under Article 2 of the GLWQA. The Parties have taken some steps, such as the creation of a public nomination process for candidate CMCs, to implement this principle as they work to achieve the objectives of Annex 3; though some organizations have suggested that more could be done (ENGO 2015a, US and Canada 2015a). The Parties have also called for public comment on draft binational strategies for

PCBs and HBCD, and solicited input as they draft binational strategies for mercury, PBDEs, perfluorinated compounds, (PFOA, PFOS) and short and long chain chlorinated paraffins.

Members of the EC3 and ITT have expressed concern about the lack of information that is publicly available regarding the work being undertaken for this Annex. The Parties' website (binational.net) provides a good general overview of key commitments under Annex 3 and how implementation will be carried out, but not much else. Specific information regarding the C3, EC3, task teams and the work that is being done is not readily available. Making available all Annex documents, such as the ITT Statement of Work, and posting regular updates of progress on binational.net would help in keeping the public better informed.

In addition, it is unclear whether Annex 3 has a public outreach strategy. The creation of a public nomination process for CMCs was done in response to interest expressed by stakeholders to be engaged in Annex 3 activities and does not appear to be a part of a strategic approach. Some of the Annex issues may have been avoided if a clear and consistent strategy had been developed and made available publicly thus managing the public's expectations on what to expect during all stages of the implementation process. Engaging the public often and early would enable the C3 to address any issues or potential issues in a timely manner. As well, the C3 also could consider additional methods for engaging the public through social media.

During IJC public input sessions, concerns about radionuclides and nuclear activity and the desire to have radionuclides designated as a CMC were heard repeatedly across the basin. The IJC also heard from the nuclear industry that radionuclides should not be designated as a CMC given the rigorous federal regulations, standards and licensing requirements for nuclear facilities that are already in place to protect human health and the environment. Independent of what the governments decide, the evaluation criteria and supporting information considered, the reasoning behind decision making, and any alternative or additional actions to be taken must be very clear to all concerned to maintain the integrity of the designation process and uphold the principles of the GLWQA.

Now that the public has been engaged in the implementation of Annex 3 through the public nomination of CMCs, the governments will need to think constructively and strategically about how this public interest is maintained and what it can bring to the CMC process.

5.4.5 Assessment of principles and approaches

The GLWQA's principle of Adaptive Management addresses how to evaluate current actions and adjust future actions once outcomes in the Great Lakes become better understood (US and Canada, 2012). The principle provides a rationale for expanding on IJC's recent recommendation that Extended Producer Responsibility (EPR) should be implemented by responsible governments throughout the basin for PBDE's (IJC, 2016). While there are many definitions of EPR, it is generally described as a pollution prevention policy that focuses on product systems rather than just the production of the product (Haskel, 2009).

As a policy approach, Extended Producer Responsibility (EPR) holds producers financially responsible for collection, recycling and disposal activities of products that consumers no longer want (Lifset, 1993), shifting end of life costs from governments to producers and consumers.

Correct implementation of EPR theoretically provides stable financing for collection and recycling programs (Mayers, 2013; Bury, 2014), incentivizing producers to reduce various waste streams at their source and develop environmentally friendly, non-toxic product and packaging design that truly reflect product development costs (Nash and Bosso, 2013; OECD, 2016). EPR regulations extend throughout the product chain and lifecycle, and can apply to specific products or more broadly to product categories (Hickle, 2017). Common product/category examples include waste electrical and electronic equipment, packaging, and products considered household hazardous waste. Implementing EPR programs often involves significant contributions not just from producers, but local and provincial/state governments, waste management firms, environmental advocates and other entities (Kalimoet al., 2015).

EPR is a key component of EU legislation intended to reduce waste and improve recycling of manufactured and consumer goods, based on four broad policy categories, or instruments: product take-back requirements (assigns responsibility to producers), economic and market based instruments (fees and taxes), regulations and performance standards (example: minimum recycled content), and information-based instruments (supporting public awareness) (OECD, 2016). EU Directives provide a framework of requirements for reporting and treatment of waste, but European Union member states have flexibility in building strategies to finance activities and achieve targets for waste collection and treatment (Haughland, 2013; OECD, 2016). Case study reviews of existing programs over time indicate the importance of program flexibility, data availability and good reporting to support oversight of producer responsibility actions in member states (OECD, 2016).

Canada's first Extended Producer Responsibility Program was established in British Columbia in 1994, mandating the take-back of waste paint and paint containers. EPR has matured into a pollution prevention and environmental life cycle reduction program across the country (Bury, 2013). The Canadian Council of Ministers of the Environment (CCME) established the Extended Producer Responsibility Task Group to provide guidance on the development and implementation of a harmonized approach to EPR that could be applied across Canada. This effort resulted in the CCME Canada-wide Action Plan for Extended Producer Responsibility, approved by CCME in 2009, with common coordinated policies and commitments for government action and common key elements for building producer responsibility for priority products (CCME, 2009). Provincial governments are responsible for developing regulatory approaches and setting performance measures/targets, under the framework based on local needs and priorities. Each regulation impacts a broad scope of products with incentives for producers to work collectively to address their obligations (Heckle, 2013). EPR implementation for different waste streams varies across the country (McKerlieet al., 2006). For instance, Great Lakes provinces Ontario and Quebec both have legislated EPR programs in place for electronics (CCME, 2014), though no such a program had been enacted for corrosives and irritants by either province. At the time of the CCME report, Quebec was considering action on these products though Ontario had yet to move in that direction (CCME, 2014).

At the federal level, Canada's national government participates in CCME. Environment Canada has also identified EPR as a risk management option for products containing substances that are considered toxic under the Canadian Environmental Protection Act, 1999). EPR can reduce the risks associated with the disposal of products containing toxic substances by promoting environmentally sound end-of-life management (Environment Canada, 2017).

Canada's history of applying EPR principles has resulted diversion of materials and products from disposal, and in a reduction of taxpayer burden for these costs now assumed by consumers and producers (Environment Canada, 2014). In Canada, incentives and fees under current provincial regulations may have limited influence on national or international companies' decisions on product or packaging design or (Bury, 2014; Lakhan, 2016). Nevertheless, the effectiveness of Canada's outcome-based framework approach has been recognized by state governments in the United States (Hickle, 2013).

In the United States, state governments bear similar responsibilities to Canadian provinces to innovate on legislation and implementation of EPR programs, while US federal government action has largely focused on removing barriers to state initiatives (Nash and Bosso, 2013). Early EPR legislation focused on a product-by-product approach; however such detailed legislation limits the number of products managed under EPR and decreases EPR program flexibility (Hickle, 2013). More recently, EPR stakeholders have begun pursuing state legislation based on a framework approach (Nash and Bosso, 2013; Hickle, 2013). To date Maine has enacted a framework based law in 2010 (2010 Me. Laws 516)and other framework bills have been introduced in various states since 2010.

Opportunities exist for collaboration between Canada and the United States for joint identification and designation for products and materials for EPR action (Hickle, 2013). Most EPR programs implemented globally, and in Canada and the United States, have yet to demonstrate significant improvements in environmental product design and reductions of waste at the source (Gui, et al., 2013; Kalimoet al.,, 2015; OECD, 2016), and a binational forum on EPR in the Great Lakes could enable focus on these issues (Hickle, 2013).

5.4.6 Assessment of other reports

1. Polybrominated Diphenyl Ethers (PBDEs) and Extended Producer Responsibility

PBDEs have been widely used as flame retardants since the 1970s and have been deliberately added to a wide range of commercial and consumer products, such as electronic devices, plastics, mattresses and carpets. Numerous studies have demonstrated adverse impacts on the environment and wildlife from exposure to PBDEs, which have been identified as persistent, toxic, and bioaccumulative (IJC, 2015a). PBDEs were designated as a CMC under the GLWQA by the Parties, who are now committed to developing a binational strategy for the substance. . In 2016, the IJC released a report on PBDEs (IJC, 2016), based on a report by its Great Lakes Water Quality Board (WQB, 2016). The reportprovides suggestions for consideration by the Parties in developing a strategy to address PBDEs in the Great Lakes.

Recommendations in the report specifically address the following, as specified in Annex 3:

- reducing the anthropogenic release of CMCs and products containing CMCs throughout their entire lifecycles;
- continuing progress toward the sound management of CMCs using approaches that are accountable, adaptive, and science-based;
- promoting the use of safer chemical substances and the use of technologies that reduce or eliminate the use and release of CMCs;

- monitoring and evaluating the progress and effectiveness of pollution prevention and control measures for CMCs, and adapting management approaches as necessary; and
- exchanging information on monitoring, surveillance, research, technology and measures for managing CMCs.

The key theme of the IJC's PBDE report is that governments should no longer consider only control of pollutants after they are generated but rather the full product life cycle, from initial design to final disposal. PBDEs illustrate the problems that are created when the environmental fate of a chemical product is either not anticipated or externalized to society at large. In the future, manufacturers should be encouraged or mandated to consider the full life cycle in the design of new products, using environmentally benign materials instead of hazardous chemicals, or to reduce the need for chemical additives. For example, product design changes to help address flammability issues would help to reduce or eliminate the dependence on chemicals to address flammability. The producers of PBDE-containing products need to have a more substantial role in ensuring that recycling and disposal problems are avoided. The Organization of Economic Cooperation and Development (OECD) defines Extended Producer Responsibility (EPR) as *"*… an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle." (OECD, 2001).

In the report, the IJC advised that the EPR approach should be implemented by responsible governments (federal, provincial and state) throughout the basin, and require industries to be responsible for their products containing PBDEs after use. This could include embeddingin the binational strategies the control or elimination of CMCs by the US and Canadian governments. The IJC urges the Parties to consider the substitution of nonhazardous substances in the implementation of strategies for other flame retardants.

PBDEs are just one example of a wide array of toxic substances in products broadly available around the basin. The Parties should use what is learned through the PBDE experience to deal with other substances in products and how to avoid the creation of these problems in the first place. The IJC concluded that the recommended strategy components presented in its 2016 report, while specific to PBDEs, can be adapted for other substances.

2. Atmospheric deposition of mercury to the Great Lakes basin

Mercury is also one of the substances included in the first set of CMCs designated under the GLWQA. One of the major pathways for mercury entry in the Great Lakes basin that should be accounted for during the development of a binational strategy is atmospheric deposition.

In November 2015, the IJC published a report, *Atmospheric Deposition of Mercury in the Great Lakes Basin*(IJC, 2015b) The report notes that after several decades of effective action by Canada and the United States to address sources of mercury within the Great Lakes basin, the need to address atmospheric deposition of this toxic substance from out-of-basin regional and global sources is increasingly evident.

The USEPA has noted studies showing that decreases in mercury concentrations have ceased and that mercury concentrations in some fish species have started to increase. EPA data analysis suggests that concentrations of mercury in top predator fish are atmospherically-driven and

recent increases in mercury in some Great Lakes fish may be in part a result of increased global mercury emissions (USEPA, 2016).

Continued strong efforts by Canada and the United States are needed to coordinate action at the international level, supported by sustained monitoring efforts within the Great Lakes basin to determine the effectiveness of such action. Monitoring mercury pollution is a critical need in light of persistent mercury contamination of Great Lakes fish.

Finally, in the report, the IJC recommended that the Canadian and US governments increase and provide sustainable funding for an optimized binational monitoring network to track atmospheric deposition of mercury in the Great Lakes Basin as well as funding for modeling to allow for source attribution. The IJC also commended the governments for their positive action with respect to pursuing global mercury reduction policies, including support for the mercury-focused Minamata Convention.

5.4.7 Section Summary

- The Parties' SOGL Toxic Chemicals Indicator indicates that the status of the Great Lake basin overall ranges from *Good* to *Fair* with *Improving* to *Unchanging* trends.

- While levels of legacy toxic chemicals such as PCBs and dioxins are generally declining or remaining unchanged across the Great Lakes, levels of several new and emerging toxic chemicals, such as dechlorane plus and hexabromocyclodoecane (BBCD), appear to be increasing. These pollutants could represent future stressors to the Great Lakes ecosystem.

- By developing a binational process and designating the first set of CMCs under the GLWQA, the Parties have met their commitments under Annex 3 for identifying CMCs. They have also have made some progress on meeting commitments related to targeting CMCs for action and coordination on science priorities.

There are concerns over slow implementation of Annex 3, especially the significant delays to designatingthe first CMCs in 2016

- There are also concerns with some of the procedures and processes used to identify CMCs and with some of the initial efforts related to targeting those CMCs for action through the binational strategy development process. Concerns include the need for greater transparency in decision making and more effective engagement of stakeholders and the public in the BSDG. To avoid some of the issues that developed as part of the ITT process, the Parties could make further efforts to ensure that the Binational Strategies development process is transparent to the public and engages interested external stakeholders on a consistent and timely basis.
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- Lessons learned from previous efforts and initiatives to achieve zero dischargecould be incorporated into current and future efforts to reduce and eliminate pollutants from the Great Lakes.

- Binational strategies would benefit from incorporation of the principle of extended producer responsibility. Implementation of extended producer responsibility could be achieved through federal and provincial lawmaking.

5.4.8 References

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5.5
Wetlands and Other Habitats

This section reviews and assesses progress toward achieving General Objective 5 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 5 states that the waters of the Great Lakes should "support healthy and productive wetlands and other habitats to sustain resilient populations of native species."

The assessment also reviews supplemental information from the other management programs and activities carried out by governments, local governmental agencies and non-governmental organizations in Canada and the United States.

5.5.1 Background

The GLWQA charges the governments of Canada and the United States with achieving progress toward supporting healthy and productive wetlands and other habitats to sustain resilient populations of native species in the Great Lakes. Since 2013, the Canadian and US governments have been implementing measures that are specifically stated in the GLWQA Habitat and Species Annex (Annex 7) through "conserving, protecting, maintaining and enhancing the resilience of native species and their habitat, as well as by supporting essential ecosystem services" (GLWQA 2012).

The Great Lakes consist of more than 121,406 hectares (300,000 acres) of coastal wetlands, 16,431 km (10,210 mile) of shoreline, 246,049 km^2 (95,000 $mile^2$) water surface area, and 22,925 km^3 (5,500 $mile^3$) water volumeThese features provide critically important habitats for native insects, reptiles, amphibians, fish, waterfowl, water birds, mammals and plants. Coastal wetlands play an essential role in maintaining the health of the Great Lakes aquatic ecosystem in improving water quality by filtering pollutants and sediment, and storing and cycling nutrients and organic material from land into the aquatic food web. Wetlands also help to minimize the impacts of flooding on shoreline properties. Although healthy wetlands have always provided essential functions to support thriving plant, animal, and human communities, their value has not always been appreciated. Other habitats (e.g., non-wetland shoreline ecosystems, and coastal tributaries) and habitat features (e.g., connectivity to Great Lakes tributaries, coastal shoreline characteristics, lake substrates composition, water current movement and energy, and water quality and quantity) are also critically important to aquatic lives, ecosystem function and human uses of the Great Lakes.

In addition, the Great Lakes are home to numerous native fish species. Some of these species, such as lake trout, white fish, walleye, yellow perch, largemouth bass, muskellunge, northern pike and sturgeon, are socially and/or economically important. Other smaller native fish species (e.g. minnows, darters) contribute to the biodiversity of the system and some of these serve as prey for their predators, and hence are important in maintaining ecosystem function and process. In turn, those small fish are supported by invertebrates such as benthos, zooplankton and ultimately by phytoplankton. Thus, the flow of energy from sunlight and minerals to primary producers (phytoplankton and other algae), to herbivores, and then to secondary consumers (invertebrates and fish) ultimately supports the predatory species that are often valued for fishing.

The biological food web formed by the interactions among plankton and benthos, preyfish, and top predators and supported by a variety of habitats have been dramatically altered by natural and man-made processes, such as food web alteration by invasive species and fish migration barriers from dams. Other human activities in the watersheds and the lakes have led to chemical pollution and excessive nutrient input, which have also impacted native species. Recognizing the

importance of native species and human disturbance to the system, it is necessary not only to know whether the wetlands and other habitats are improving but also to know whether the populations of native species supported by them are improving.

Land use planning and zoning are ways to safeguard coastal and shorelines regions and provide protection of fish and wildlife habitat. Protecting wetlands also helps mitigate the impacts of flooding. Environmentally responsible, ecologically based municipal land use planning can be accommodated within the existing land use planning tools and practices already in place, and a book has been written on that precise topic (Honachefsky, 2000).

Land use planning tools include a master plan and zoning ordinances. A master plan is a document and policy guide designed to help guide communities in their decisions on land use development and preservation. According to the Michigan Association of Planning (2017), in order to implement the master plan upon its creation, planning commissions develop and administer the Zoning Ordinance. The Zoning Ordinance is the specific law related to land use in a community. The Ordinance, along with a Zoning Map, describes the specific types of uses allowed on any given property and are adopted as law by the legislative body.

The Michigan Association of Planning (2017) describes requirements that are set up by the Michigan Department of Environmental Quality to ensure wetlands remain healthy and how to move to net gain. A permit or other permission is needed before building on or disturbing any of the following wetlands:

- Connected to one of the Great Lakes or Lake St. Clair.
- Located within 1,000 feet of one of the Great Lakes or Lake St. Clair.
- Connected to an inland lake, pond, river, or stream.
- Located within 500 feet of an inland lake, pond, river or stream.
- More than 5 acres in size.

5.5.2
Assessment of indicators

Progress toward achieving Objective 5 and the implementation of the Habitat and Species Annex of the GLWQAis measured by the Parties in SOGL 2017 using two indicators, one on coastal wetlands and another on the food web. Seven sub-indicators were used to measure coastal wetlands (Table 5.5.1) and nine sub-indicators were used to measure food web status and trends (Table 5.5.2).. Each sub-indicator was assessed and reported collaboratively by multiple authors using data from multiple sources. The SOGL assessment of this objective took over one-year and involved more than 30 Great Lakes regional experts from government agencies and non-government organizations.

1. Assessment of coastal wetland indicators

The trends in health of coastal wetlands and other habitats can be assessed using two indicators, one on coastal wetlands and another on the food web. For the current assessment triennial cycle, the governments of Canada and the US (the Parties) used seven sub-indicators to assess status and trends for coastal wetlands by using sub-indicators for amphibians, birds, fish, invertebrates, plants, extent and composition of wetlands and aquatic habitat connectivity within coastal wetlands (ECCC and USEPA, 2017a).

The Parties concluded that the overall health of coastal wetlands is unchanging, though no individual lake assessments have been conducted for coastal wetland fish and coastal wetland invertebrate sub-indicators. The extent and composition of coastal wetland sub-indicator is not assessed for individual lakes, and Great Lakes Basin assessment is undetermined, although it was estimated that 50 percent of Great Lakes wetlands have been lost basinwide, with losses of up to 90 percent occurring in some areas (USEPA, 2005). Aquatic habitat connectivity is the only sub-indicator showing improvement for all five lakes
(Table 5.5.1).

2. Assessment of food web indicators

The status and trends of the food web were measured using nine sub-indicators to assess the biological composition, function and process of the ecosystem. Those nine sub-indicators are phytoplankton, zooplankton, benthos, *Diporeia*, preyfish, lake trout, walleye, lake sturgeon and fish-eating and colonial-nesting waterbirds (Table 3.5.2; ECCC and USEPA,2017a and 2017b).

The Parties concluded that the overall trend of aquatic native species is unchanging although the lower food-web component sub-indicators (phytoplankton and *Diporeia*) show a deteriorating trend. Lake sturgeon populations are improving in all five lakes (Tables 5.5.1 and 5.5.2).

Table 5.5.1 Summary of trends for the seven coastal wetlands and connectivity indicators by the Parties

Sub-Indicators Supporting the Indicator Assessment					
Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Coastal Wetland Amphibians	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Coastal Wetland Birds	Unchanging	Unchanging	Unchanging	Deteriorating	Improving
Coastal Wetland Fish	No lake was assessed separately Great Lakes Basin assessment is **Fair** and **Improving**				
Coastal Wetland Invertebrates	No lake was assessed separately Great Lakes Basin assessment is **Fair** and **Deteriorating**				
Coastal Wetland Plants	Undetermined	Undetermined	Deteriorating	Deteriorating	Unchanging
Coastal Wetlands: Extent and Composition	No lake was assessed separately Great Lakes Basin assessment is **Undetermined**				
Aquatic Habitat Connectivity	Improving	Improving	Improving	Improving	Improving

Status: GOOD | FAIR | POOR | UNDETERMINED

(Source: ECCC and USEPA, 2017b)

Table 5.5.2
Summary of trends for the nine food web sub-indicators

Sub-Indicators Supporting the Indicator Assessment					
Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Phytoplankton	Unchanging	Deteriorating	Deteriorating	Deteriorating	Unchanging
Zooplankton	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging
Benthos	Unchanging	Unchanging	Unchanging	Deteriorating	Unchanging
Diporeia	Unchanging	Deteriorating	Deteriorating	Deteriorating	Deteriorating
Prey fish	Unchanging	Deteriorating	Undetermined	Improving	Deteriorating
Lake Sturgeon	Improving	Improving	Improving	Improving	Improving
Walleye	Unchanging	Unchanging	Unchanging	Improving	Unchanging
Lake Trout	Unchanging	Improving	Improving	Improving	Improving
Fish Eating and Colonial Nesting Waterbirds	Unchanging	Unchanging	Unchanging	Unchanging	Unchanging

Status: GOOD | FAIR | POOR | UNDETERMINED

(Source: ECCC and USEPA, 2017b)

3. Strengthening future assessments

The Parties' PROP report is comprehensive and reflective of available data. The IJC, with the support of its Science Advisory Board, recognizes the efforts put into the work and the progress in reporting since SOGL 2011. Further possible improvements in the assessment of wetlands and other habitats and populations of native species are set out in the sections below.

Data collection strategy

For coastal wetland sub-indicators, data for assessing wetland amphibians, birds, fish, invertebrates, and wetland plants are mainly from one basin wide sampling program that has been funded by the USGreat Lakes Restoration Initiative (GLRI). The first five-year data collection effort (2011-2015) sampled almost all coastal wetlands that are ≥4 hectares (9.88 acres) with a surface water connection to the Great Lakes (Uzarski et al., 2016) and cost $10 million. The second five-year data collection effort (2016-2020) costing another $10 million is underway. It will enable the majority of the wetlands to be resampled. The SOGL 2017 also used data that are not collected by established monitoring programs, such as data collected by University of Minnesota Duluth's Great Lakes Environmental Indicator project funded by GLRI and wetland bird data from Canadian's Great Lakes Marsh Monitoring Program.

Because most of the wetlands were sampled systematically only once and the data from other sources include only some of the wetland sub-indicators or only limited temporal scales, there is no individual lake status assessment for three of the sub-indicators and no trend assessment for one sub-indicator. For the coastal wetland extent and composition sub-indicator the data were generated in 2004 by the Great Lakes Coastal Wetlands Consortium. Since then the data have not been updated completely. Thus, the "current areal extent and composition of coastal wetlands across the entire Great Lakes basin cannot be reported" (ECCC and USEPA,2017a, 2017b). Therefore, an improved wetland data collection strategy is needed to ensure the detection of trends of this sub-indicator.

For the benthic and planktonic food web sub-indicators, data for phytoplankton, zooplankton, benthos, and *Diporeia*are mainly from the Great Lakes Open Water Monitoring Program and the Cooperative Science and Monitoring Initiative. Since those are long-term programs, the present monitoring programs for off shore are adequate to detect trends of those sub-indicators. However, it would be helpful if assessment of those sub-indicators could be extended into nearshore areas. This effort would require a systematic data collection by EPA's Office of Waters National Coastal Condition Assessment and the Cooperative Science and Monitoring Initiative programs in those areas. The IJC has discussed the importance of protecting the nearshore in its 15th Biennial Report of Great Lakes Water Quality (IJC, 2011) and the Science Advisory Board, Research Coordination Committee (RCC) recently identified this earlier recommendation to focus more on the nearshore, as one of five priority areas (RCC, 2016).

For the fish food web sub-indicators, data for the assessment of preyfish, walleye, lake trout, and sturgeon sub-indicators are derived from the federal, state, and provincial fish stock assessment programs and records of recreational and commercial harvests. These data are from long-term sampling for the Great Lakes fisheries management, which are adequate for detecting trends of those indicators. However, the assessment of those indicators is largely qualitative due to the limited spatial coverage of data. For example, the trend of walleye sub-indicator for Lake Michigan is assessed only using angler harvest data from Green Bay, which largely reflects anglers' use of the fishery and is influenced by various factors that may not be necessarily related to fish population abundance and recruitment status. Hence, it would be helpful to use standardized lake-wide models to calculate adult population abundance and abundance at age and derive estimates of recruitment from the fish stock assessment program data for walleye and lake trout sub-indicators as recommended in the IJC's Great Lakes Ecosystem Indicator Report (IJC, 2014a).

Data management and sharing

In previous State of the Great Lakes reports (e.g., SOLEC, 2014), each sub-indicator has been assessed and reported by one or several co-authors using data from multiple sources. Although this is the best (and possibly the only) practical way to handle the assessment with such a large magnitude of spatial coverage and time constraints, a couple aspects of data collection, management and sharing could be improved (SAB-RCC, 2016).

First, there is a need to standardize how each sub-indicator is assessed and what data are used. Currently, the author(s) of each sub-indicator makes this decision with the approval of the Parties' task team for each assessment cycle. In the past, some of the sub-indicator authors have changed among assessment years due to retirement or job changes, resulting in a change in assessment standard and data used. These changes can create inconsistency in assessing long-term trends, which may obscure the accuracy of lake health status assessment.

Second, there is a need to synthesize the data that have been used for the past assessments and to maintain the summarized data for each sub-indicator in a centralized, publicly accessible location. Presently, only the sub-indicator authors know where the data come from and how they are synthesized, and have access to such summarized data. Due to the change of some of the sub-indicator authors, the continuity of detecting consistent trends may be jeopardized. Additionally, maintaining the summarized data for each sub-indicator in a centralized publicly accessible location will increase the assessment creditability and transparency, as many of sub-indicator assessments in the SOGL do not have details on the data sources and how the data have been synthesized and used.

Indicator reporting

The 16 sub-indicators used for the assessment of this General Objective and the Habitat and Species Annex are outstanding. For the six wetland sub-indicators, a single wetland indicator may be more informative and more easily communicated than six individual sub-indicators. It is also critically important to update the data needed for assessing the extent and composition of coastal wetlands. With the development of satellite and LiDAR technology and data availability, it is feasible to develop an improved baseline of wetland extent and composition that can be repeated consistently through time. Additionally, since *Diporeia* a rice-size amphipod and keystone species that forms the base of the food web have almost vanished, another key food web measure could be added as an additional sub-indicator. *Mysis* could be added using data that have been collected and summarized by the Great Lakes Open Water Monitoring Program since 2002. The current SOGL report does not include nutrient and food web sub-indicators in the nearshore. It would be a great improvement if those sub-indicators are monitored and reported since the conditions of those sub-indicators are very different between nearshore and offshore for much of the lakes (RCC 2016).

5.5.3 Assessment of Annex implementation

The GLWQA Habitat and Species Annex mandates the Parties to undertake the following initiatives:

- conduct a baseline survey of the existing habitat against which to establish a Great Lakes Basin Ecosystem target of net habitat gain and measure future progress;
- complete the development and begin implementation of lake-wide habitat and species protection and restoration conservation strategies that use adaptive management approaches, identify conservation mechanisms, and address the most significant stressors to native species and habitat;
- assess gaps in current binational and domestic programs and initiatives to conserve, protect, maintain, restore and enhance native species and habitat as a first step toward the development of a binational framework for prioritizing activities;
- facilitate binational collaborative actions to reduce the loss of native species and habitat, recover populations of native species at risk, and restore degraded habitat;
- renew and strengthen binational collaborative actions to conserve, protect, maintain, restore and enhance native species and habitat by identifying protected areas, conservation easements and other conservation mechanisms to recover populations of species at risk and to achieve the target of net habitat gain; and
- increase awareness of native species and habitat and the methods to protect, conserve, maintain, restore and enhance their resilience.

Since 2013, the Parties have established the Habitat and Species Annex Subcommittee and Task Teams to address the above tasks. The most significant achievements during the past three years are the development and implementation of lake-wide habitat and species protection and restoration conservation strategies s in each lake and establishment of a consistent basin-wide approach to survey Great Lakes habitat and measure net habitat gain a (Governments of the United States and Canada,2016).

The strategies, which have been developed for all five lakes as of 2015, assess the status and threats to lake-wide biodiversity and recommend conservation priorities for native species and their habitat. Each strategy serves as a tool to foster and guide a shared implementation of priority conservation actions among federal, state, provincial, tribal, academic, municipal and watershed management agencies (Governments of the United States and Canada,2016), . Numerous government and non-government efforts are in the process of planning, applying and implementing the strategies at local or sub-basin scales, and therefore have met the mandate of the GLWQA during this period.

The basinwide asssessmentwas developed by the Annex Task Team with support from experts and partners through a series of workshops, meetings and webinars (BATT, 2016). The Assessment proposed to quantify the quantity and condition of existing Great Lakes habitat to allow for future determination of habitat change. The assessment clearly defines that habitat gain can be measured by: a spatial increase in “priority habitats”for communities of native fish and wildlife species; improvement in habitat condition and functionality of habitat types from severely degraded and not functional to degraded but functional and then to high quality and highly functional; and maintaining the condition of high quality habitat.

Three assessment consists of three phases. Phase 1, to delineate the Great Lakes and connecting rivers into units defined by ecosystem type, based on physical factors that form the basis of habitat structure and change at a relatively slow rate (e.g., depth, fetch, currents). Phase 2, to assess the condition of each unit using habitat factors that are influenced by disturbance, and thus change more rapidly (e.g., substrate, water quality). Finally, phase 3, will use biological information to confirm the condition status of the units. This can only be accomplished in areas where biological data are available.

The Assessment provides a scientifically sound and operational definition to measure habitat gain and identifies the specific processes for its implementation. However, the Assessment is relatively weak on three key elements that are critical for the successful implementation. The Assessment needs standardized and consistent methods and criteria for spatial unit delineation and classification. Although the rationale for using physical factors to delineate and classify spatial units is clear, the methods for delineating the hierarchical spatial units and developing the classification have not yet been identified.

In addition, the assessment needs to emphasize the importance of standardized and consistent data collection through time in order to ensure that future measurements can be compared to the baseline data. Data consistency used for establishing the baseline and for measuring the future changes will ensure the accuracy of habitat gain reporting. The programs proposed to supply the needed data include the USEPA-led National Coastal Condition Assessment of US coastal areas of the Great Lakes (water quality data), long-term monitoring of water quality on Canadian Great Lakes coastal water by the Ontario Ministry of the Environment and Climate Change, the binational Cooperative Science and Monitoring Initiative and the Great Lakes Fisheries Commission lower trophic lake monitoring programs in open water areas. To meet the need of implementing the approach, coordination and sampling method harmonization between the coastal condition assessment and long term monitoring are needed because they are clearly domestic focused programs.

The assessment needs an effective data management system and coordination mechanism. The assessment recognizes that the baseline survey will use information from many sources and will require a mechanism for data coordination; data sharing amongst partners will be facilitated by the “open data” initiatives by Great Lakes partner agencies, organizations and communities. However, no effective data management system and coordination mechanism are proposed to specifically meet the needs of the approach. There is a clear need to store the data and information used to develop baseline conditions, along with all subsequent data, in a strategic, consistent, and accessible manner and system that accommodates future assessment cycles through time. This system should be managed by a reliable and unbiased entity supported by stable funding.

5.5.4 Assessment of binational programs

Achieving the GLWQA objectives requires binational collaborative partnerships and programs among federal, state and provincial, tribal, First Nation, Métis, municipal, watershed management agencies and non-government organizations. Given the large geographic scale of

the Great Lakes and their social and ecological importance, numerous collaborative partnerships and program are ongoing, many of which directly support Objective 5. Table 5.5.3 provides examples of some bi-national and domestic basin-wide partnerships that have played key roles in providing resources, coordinating management actions and developing cohesive strategies and policies for addressing this objective.

Those basin-wide binational collaborative partnerships and programs have provided essential resources, technical support, and synergy to the implementation actions of local partnerships. Sections below,use examples to illustrate the contributions of such programs to Objective 5.

Table 5.5.3
Examples of basin-wide government and non-government programs and partnerships that have contributed to the protection, enhancement and restoration of Great Lakes habitats

Partnerships	Year Established	Countries
Action Plan for Clean Water (http://www.tbs-sct.gc.ca/hidb-bdih/initiative-eng.aspx?Org=0&Hi=30)	2007	Canada
Council of Great Lakes Governors (http://www.cglslgp.org/)	1997	Canada and US
Great Lake Action Plan (http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=DF30B51A-1)	1989	Canada
Great Lakes Basin Fish Habitat Partnership (http://greatlakes.fishhabitat.org/about)	2001	US
Great Lakes Marsh Monitoring Program http://www.birdscanada.org/volunteer/glmmp/	1995	Canada
Great Lakes Nutrient Initiative (http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=4FF37866-1)	2012	Canada
Great Lakes Restoration Initiative (https://www.glri.us/)	2010	US
Great Lakes State Wildlife Action Plans (http://teaming.com/state-wildlife-action-plans-swaps)	2005	US
National Wetland Conservation Fund (https://www.ec.gc.ca/financement-funding/default.asp?lang=En&n=923047A0-1#_09)	2014	Canada
North American Waterbird Conservation Plan (http://www.waterbirdconservation.org/nawcp.html)	2002	US
North American Waterfowl Management Plan (https://www.fws.gov/birds/management/bird-management-plans/north-american-waterfowl-management-plan.php)	1986	Canada and US
Ontario's Great Lakes Strategy 2016 (**https://www.ontario.ca/page/ontarios-great-lakes-strategy-2016-progress-report#section-5**)	2016	Canada
Partners in Flight North American Landbird Conservation Plan (**http://www.partnersinflight.org/cont_plan/default.htm**)	2004	Canada and US
Sustain Our Great Lakes (http://www.sustainourgreatlakes.org/)	2004	Canada and US
US Shorebird Conservation Plan (http://www.shorebirdplan.org/)	2000	US

1. US Great Lakes Restoration Initiative

A large domestic program for the Great Lakes in United States is the GLRI (USEPA, 2015). Since 2010, this program has provided near $300 million annually to focus on the areas of toxic

substances and Areas of Concern, invasive species, nearshore health and nonpoint source pollution, habitat and wildlife protection and restoration, accountability, education, monitoring, evaluation, communication and partnerships each year from 2010-2014 (Table 5.5.4). This program has funded 191 projects in the US watersheds and the five lakes themselves, conducted by 46 different agencies and organizations throughout the Great Lakes (Figure 5.5.1). This program has contributed significantly to the progress made toward achieving Objective 5.

Table 5.5.4
Great Lakes Restoration Initiative Fiscal Year 2010-2014 focus area allocations (as of October 2014)
(Source: Great Lakes Restoration Initiative Report to Congress and the President Fiscal Years 2015)

Focus Area	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
Toxic Substances and Areas of Concern	$146,946,000	$100,400,000	$107,500,000	$111,000,000	$106,000,000
Invasive Species	$60,265,000	$57,500,000	$56,900,000	$45,000,000	$57,000,000
Nearshore Health and Nonpoint Source Pollution	$97,331,000	$49,250,000	$54,300,000	$45,000,000	$56,000,000
Habitat and Wildlife Protection and Restoration	$105,262,000	$63,000,000	$57,200,000	$65,500,00	$60,500,000
Accountability, Education, Monitoring, Evaluation, Communication and Partnerships	$65,196,000	$29,250,000	$23,600,000	$17,000,000	$20,500,000
TOTAL	$475,000,000	$299,400,000	$299,500,000[1]	$283,500,000[2]	$300,000,000

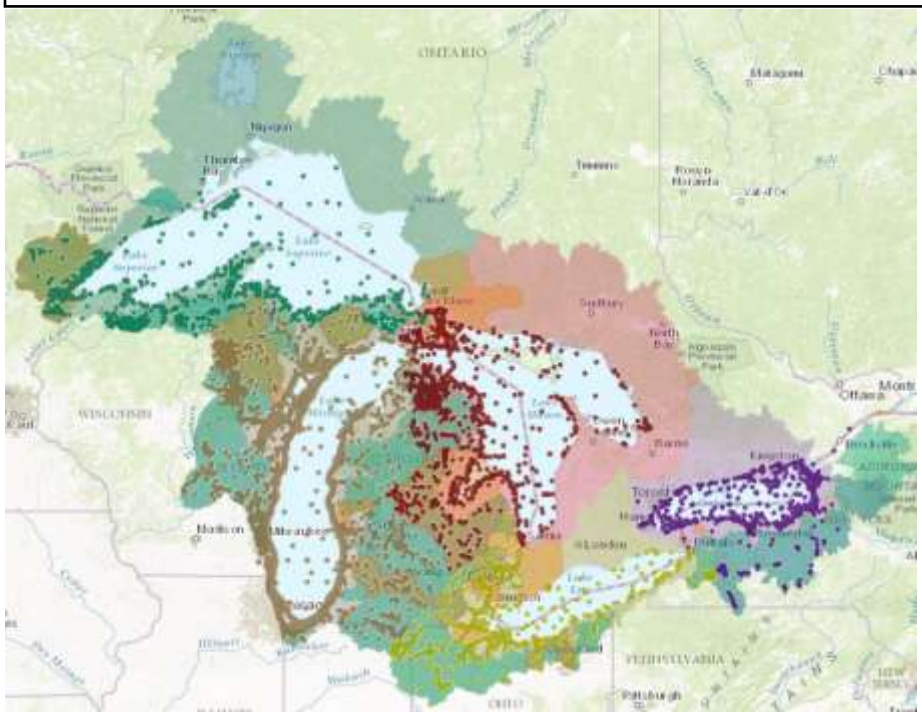

Figure 5.5.1
The 191 Great Lakes Restoration Initiative funded projects that represent 46 different agencies and organizations throughout the Great Lakes

(Source: http://www.glri.us/)

2. Local partnerships

In addition to basin-wide or lake-wide programs, localized partnership programs are effectively making progress to achieve the objective. These programs have received funding from federal, state, provincial and non-government sources, and have proven effective at leveraging existing resources. There are many such location-based partnership programs that provide long-term targeted regional protection and restoration plans and actions. Examples include the Saginaw Bay Coastal Initiative (SBCI), the St. Clair-Detroit River System Initiative, and the effort of the native American Tribes and First Nations.

The SBCI, established in 2006, brought together groups of interested people, businesses and local governments collaborating with state and federal agencies to improve Saginaw Bay. Collaborating with the federal and state governments' Areas of Concern programs, Saginaw Bay Watershed Initiative Network, Adaptive Integrated Framework and other partnerships, SBCI and its partners have protected 60 percent of the targeted coastal wetlands through public ownership and permanent conservation easements and removed the "loss of fish and wildlife habitat beneficial use impairment" for the Saginaw River/Bay Areas of Concern (Ducks Unlimited, 2013, MOGL, 2014) (Figure 3.5.2). As a result, the fish population in Saginaw Bay has improved significantly.

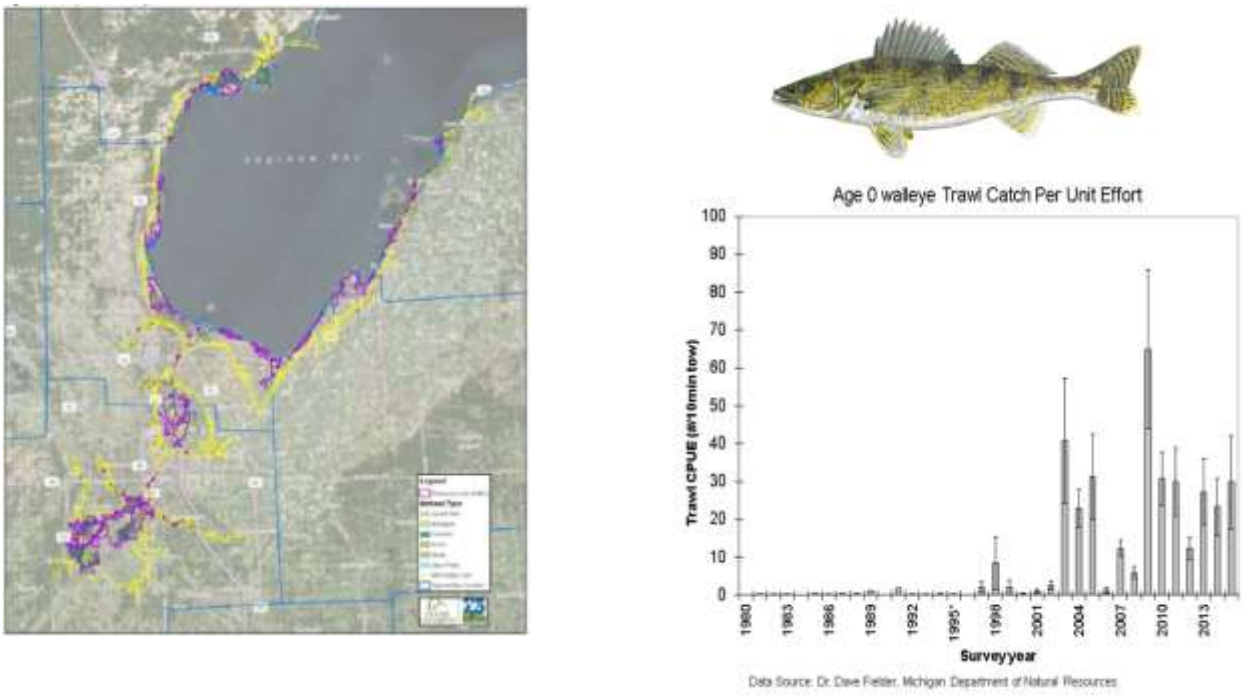

Figure 5.5.2
Map of Currently Protected Coastal Wetlands in the Saginaw Bay (left) area and walleye recruitment improvement at Saginaw Bay (right)

(Source, left: Refining and Updating the Wetland Protection Status in the Saginaw Bay Coastal Plain, Ducks Unlimited, 2013); (Source, right: Fielder, D. G., and M. V. Thomas, 2014. Status and Trends of the Fish Community of Saginaw Bay, Lake Huron 2005–2011. Michigan Department of Natural Resources (MDNR), Fisheries Report 03, and MDNR unpublished data).

The St. Clair-Detroit River System Initiative is an example of a binational local collaborative partnership with more than 30 organizations, including US and Canadian natural resource-related agencies, Tribes/First Nations, units of local government, industry and university partners, non-profit organizations and interested citizens. The partners share a common vision of restoring portions of southern Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River and western Lake Erie to a thriving ecosystem with science-based management and broad social support that provides environmental services for the region and the Great Lakes basin. Working with other partnerships, the St. Clair-Detroit River System Initiative has conducted fish spawning habitat restoration and developed a strategic restoration plan to be carried out into the future years (Figure 5.5.3).

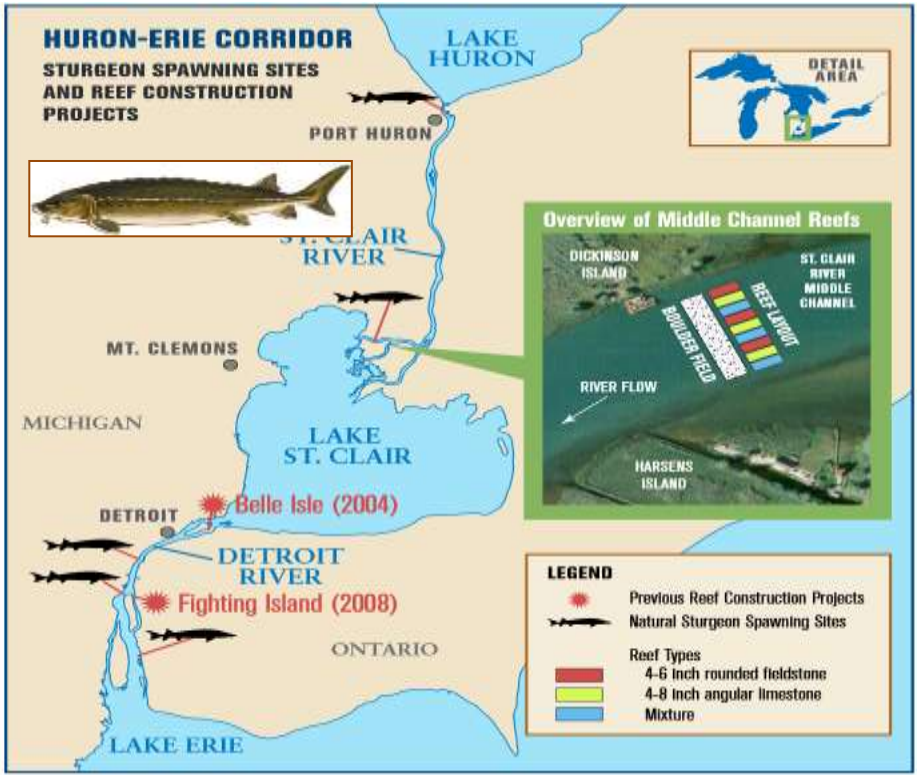

Figure 5.5.3
Huron-Erie Corridor Sturgeon spawning sites and Reef Construction projects
(Source: http://www.habitat.noaa.gov/pdf/restoring_fish_habitat_in_the_stclair_river.pdf)

The international waters that connect Lake Huron to Lake Erie provide habitat for more than 65 species of fish. The region, which includes the Ottawa National Wildlife Refuge and the Detroit International Wildlife Refuge, is part of the central Great Lakes flyway for millions of migratory waterfowl. It contains some of the largest and most diverse wetlands remaining in the region. The partners have implemented a plan to increase over eight hectares (20 acres) of fish spawning habitat. The pre- and post-construction monitoring demonstrated an immediate response by more than 14 native fish species, including spawning by the commercially important lake whitefish and the Michigan and Ontario listed threatened species lake sturgeon (Manny et al., 2015).

The lives of indigenous peoples are especially strongly linked to the Great Lakes. With the assistance of USGLRI grants from the Bureau of Indian Affairs, US Tribes have developed manoomin (wild rice) restoration plans and critical habitat inventories. Also, the Oneida Nation of Wisconsin is working to convert over 450 acres (about 180 hectares) of agricultural land to wetland, forest, and grassland habitat.

3. The Lake Ontario-St. Lawrence River Plan 2014

Water level change has a strong influence on Great Lakes coastal wetlands and other habitats. It is difficult, if not impossible, to protect and restore Great Lakes wetlands and other habitat without restoring water levels to their near-natural regime.

The patterns of water-level change of the Lake Ontario-St. Lawrence River system are the driving force that determines the overall diversity and condition of wetland plant communities and the habitats they provide for a multitude of invertebrates, amphibians, reptiles, fish, birds and mammals, imparting a direct linkage to the social and economic wellbeing in the region. After 14 years of scientific study and public engagement, the IJC recommended the Lake Ontario-St. Lawrence River Plan 2014 (Plan 2014) to the governments of Canada and United States in 2014 as the preferred option for regulating Lake Ontario-St. Lawrence River water levels and flows (IJC, 2014b) (Figure 5.5.4).

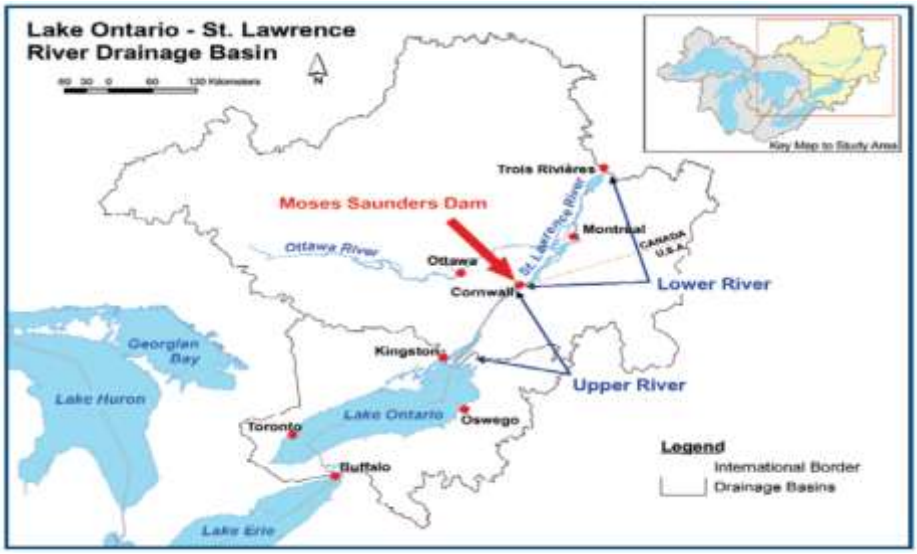

Figure 5.5.4
Lake Ontario-St. Lawrence river drainage basin to show the impacted area of the Plan

(Source: IJC, 2014b)

Plan 2014 is a result of extensive scientific studies and public engagement supported by more than $20 million provided by the Governments of Canada and the United States. It is expected that the Plan will significantly improve the health of Lake Ontario and the upper St. Lawrence River system by improving the diversity and function of the coastal wetlands that cover 26,000 hectares (64,247 acres), filter runoff, reduce erosion and provide habitat for hundreds of fish and wildlife species. The plan was developed based not only on the analysis of environmental factors, but also on how water level regulation may affect basin interests of coastal property, recreational boating, commercial shipping, hydropower and other social-economic factors. The plan was based on: the analyses of 32 environmental performance indicators that are sensitive to water levels and representative of ecosystem health; evaluation of potential effects to property using a parcel database of buildings and shore protection structures, building elevations, 40 years of hourly wave height and direction data and historical erosion rates; and estimation of potential effects to recreational boating using an inventory of all marinas and launch ramps, as well as surveys of boaters and charter and tour boat operators.

Plan 2014 is designed to provide more natural variations of water levels of Lake Ontario and the St. Lawrence River that are needed to restore ecosystem health. It will continue to moderate extreme high and low levels, better maintain system-wide levels for navigation, frequently extend the recreational boating season and slightly increase hydropower production. More year-to-year variation in water levels improves coastal wetland habitats to support highly valued recreational opportunities, filter polluted run-off and provide nurseries for fisheries and wildlife.

The Parties informed the IJC in December of 2016 that they concurred with Plan 2014. The IJC implemented the plan in January of 2017 and looks forward to it contributing significantly to the achievement of Objective 5.

4. Great Lakes Ecological Reserve System

As the Parties continue to facilitate collaborative partnerships, there are also opportunities for facilitating new binational collaborative actions to reduce the loss of native species and habitat, recover populations of native species at risk, and restore degraded habitat. This is in line with commitments in the Habitat and Species Annex of the GLWQA and the eventual achievement of the objective of supporting "healthy and productive wetlands and other habitats to sustain resilient populations and native species."

A potential further binational collaborative action would be to support the Great Lakes Ecological Reserve System (GLERS), which was proposed by the United States–Canada Great Lakes Islands Project to span international, state and provincial boundaries and to serve as a basin-wide system of ecological reserves to protect and restore Great Lakes habitat and biodiversity (Vigmostad, 2016).

GLERS focuses on the islands and coastal wetlands that are significant holders of species and habitats to maximize opportunities for biodiversity conservation. The GLERS is a way of connecting areas representing vital habitats to protect endangered, rare and threatened species. GLERS would enable the Parties to ensure a vibrant, biologically diverse, Great Lakes ecosystem over the long run.

GLERS would begin by linking managers of existing protected areas of biological diversity to address their specific species and habitat challenges. GLERS would be built manager-to-manager to address on-the-ground challenges shared by US and Canadian federal parks, conservation areas, refuges, sanctuaries, forests, recreation areas and other entities. An initial pilot project could link several Canadian and US federal managers, expanding over time to include the holdings of federal, state, provincial managers and non-governmental organizations.

Forexample,aconcerninLakeSuperioristheprotectionoflaketroutvariantsfoundamong IsleRoyale's450islands. Scientists couldinvestigatewhethersimilaroradditional laketrout variantsoccuramong the1,000 islandsintheLakeSuperiorNationalMarineConservationArea anddevelopajointmonitoringandmanagementplan.Themanagersmightdeterminethey neednewscientificstudies,additionalinventories,literaturereviewsor helpfromother expertstoidentifyandmanagelaketroutvariants.

The GLERS would ultimately create a basin-wide ecological reserve network spanning national and agency boundaries, authorities and cultures. This would have the potential to protect a percentage of the Great Lakes ecosystem that sustains the ecosystem function and biodiversity. GLERS could also inspire future Canadian National Marine Conservation Areas and US Great Lakes National Marine Sanctuaries to consider and plan for the conservation of habitat and species in addition to their other goals and authorities.

Governments are already taking actions to expand the range of protected Great Lakes freshwater and related terrestrial habitats. In Canada, the Lake Superior National Marine Conservation Area will soon be recognized as one of the largest protected areas of fresh water in the world. Additional such designations in both US and Canadian waters could help in the achievement of this objective.

The GLERS proposal would use existing staff and budget resources and create an information-sharing network without requiring additional resources (Vigmostad, 2016).

5.5.5 Section Summary

- Addressing the water quality objectives for such a complex and spatially extensive system as the Great Lakes presents serious challenges. Important progress has been made by the Parties on addressing Objective 5 and implementing the Habitat and Species Annex in line with its purpose. Building on many years of experience, the Parties have made considerable effort to assess the status and trends of the health of the Great Lakes related to this objective and prepare useful SOGL information.

- The SOGL 2017 report (ECCC and USEPA, 2017a, and 2017b) concludes that the overall health of coastal wetlands is relatively stable. No individual lake assessments have been conducted for three sub-indicators and aquatic habitat connectivity is the only sub-indicator showing improvement for all five lakes. In addition, the overall trend of the food web is relatively stable with some sub-indicators improving and some deteriorating. The bottom food-web component sub-indicators (phytoplankton and Diporeia) show a deteriorating trend; lake sturgeon populations are improving in all five lakes.

- Data collection and management is a key challenge to strengthening future assessments of progress towards Objective 5. Weaknesses in the current approach relate to: a reliance on short-term monitoring programs, which are vulnerable to being discontinued; a lack of standardized assessment and reporting methods among authors; a lack of continuity and transparency in data collection; and a lack of coordination among various individuals and agencies responsible for data collection, analysis and reporting.

- Lake-wide habitat and species protection and restoration conservation strategiesestablished and implemented by the Parties have been an important achievement in support of Objective 5. In addition, the Parties have developed a consistent basin-wide approach to survey Great Lakes habitat and measure net habitat gain during the last three years. These achievements

meet the mandate of Objective 5 and the Habitat and Species Annex objective of the GLWQA.

- The concurrence of the Parties with the IJC's Plan 2014 for the regulation of flows and levels in Lake Ontario and the St. Lawrence River in late 2016has the potential to contribute significantly to the achievement of this objective.

- The Parties have facilitated a range of binational collaborative partnerships and programs in support of the GLWQA objectives and the Habitat and Species Annex along with domestic and local collaborative programs. These partnerships have engaged federal, state and provincial, tribal, First Nation, municipal, watershed management agencies and non-government organizations, which are critically important for achieving the GLWQA objectives.

- Recognizing the importance of maintaining existing wetlands and restoring degraded or lost wetlands, more efforts are needed to prioritize restoration activities, collaboration, and funding to ensure the coastal wetlands remain healthy.

- New opportunities are emerging to promote and support new binational collaborative actions to reduce the loss of native species and habitat, recover populations of native species at risk, and restore degraded habitat. One such initiative with great potential is the proposal to establish a basin-wide system of ecological reserves to protect and restore Great Lakes habitat and biodiversity.

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5.6 Nutrients

5.6.1 Introduction

1. Purpose

This section reviews and assesses progress toward achieving General Objective 6 of theGreat Lakes Water Quality Agreement (GLWQA). Objective 6 states that the waters of the Great Lakes should "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." The section presents an assessment of programs and other measures in support of this objective.

This assessment is based largely on the review of:

- data and information from the *2016 State of the Lakes* presentation by the Parties (GLPF, 2016);
- the **Progress Report of the Parties** (Governments of the United States and Canada, 2016); and
- Implementation measures undertaken in support of the GLWQA Annex 4: *Nutrients*.

2. Background

Nutrient management was a success story under the 1972 and 1978 iterations of the GLWQA. Total phosphorus loads and the occurrence of algal blooms decreased, particularly in Lake Erie, and target loads were reached by the mid-1980s. However, despite evidence that both total and soluble reactive phosphorous (or dissolved phosphorus) concentrations have stabilized since mid-1990s, there has been a resurgence of nuisance and harmful algal blooms (HABs).

Nuisance algal blooms, particularly of a type of algae called *Cladophora*, currently foul some beaches in four of the five Great Lakes. These blooms interfere with recreational beach and water uses and impair aesthetic values (ECCC and USEPA, 2016). Some species of algae can be harmful to human and ecosystem health. HABs often are composed of microorganisms known as cyanobacteria, some of which produce toxins that can cause adverse health effects in humans and animals through the contamination of waterways used for recreational purposes and as drinking water supplies. Cyanobacteria possess characteristics of algae, chlorophyll-a and oxygenic photosynthesis (USEPA, 2016). The primary toxins of concern associated with cyanobacteria in the Great Lakes are microcystin (more than 80 congeners),saxatoxin, anatoxin a, and cylindrospermopsin (USEPA, 2016). HABs have surged in the western basin of Lake Erie and are occurring in embayments in lakes Michigan, Huron and Ontario (ECCC and USEPA, 2016).

Excessive algal growth can result in hypoxia, or low oxygen content in the bottom layer of some highly productive regions of the Great Lakes, including the central basin of Lake Erie and in Green Bay in Lake Michigan (ECCC and USEPA, 2016). During the summer, excessive nutrient loadings and warm temperatures lead to excessive growth of algae; as organic matter such as algae decomposes, bacteria consume the algae, and as the bacteria flourish from the extra food source, their increased metabolism and respiration reduce oxygen levels in the water column, potentially leading to oxygen depletion. When levels are below 2.0 mg/l they are considered hypoxic and when all the oxygen is depleted, it is called anoxia. Hypoxic conditions also lead to the release of phosphorus from sediments, known as "internal loading," which also may contribute to the development of algal blooms (Matisoff et al, 2016). Human-induced nutrient enrichment has increased the duration and areal extent of hypoxia and anoxia, which can cause fish kills, shifts in fish species distribution, with potential long-term effects on the aquatic food web, along with taste and odor problems for municipal water treatment plants (ECCC and USEPA, 2016).

The effects of excessive nutrient enrichment, or eutrophication, have continued to cause the most significant damage to and most profound changes in the water quality of Lake Erie, Green Bay and Saginaw Bay. In Lake Erie, this worsening condition has manifested itself in three ways: a recurrence of cyanobacteria blooms primarily in the western basin; significant hypoxic conditions in the central basin hypolimnion; and the recurrence of major *Cladophora*nuisance blooms along the northern nearshore of the lake's eastern basin.

Of all the Great Lakes, Lake Erie is showing the greatest frequency and severity of symptoms associated with eutrophication. The increase in frequency and coverage of Lake Erie algae blooms has occurred despite stable total phosphorus loadings over the last 15 years (USEPA, 2015). However, the dissolved phosphorus fraction/component of the loadings has been increasing. Dissolved phosphorus is of concern because it is highly bioavailable to algae, fueling rapid algal growth. About 95 percent of dissolved phosphorus is bioavailable to algae, while only

about 30 percent of the particulate phosphorus attached to eroded sediment is bioavailable (Heidelberg University, 2016).

Phosphorus loads to Lake Erie are not distributed evenly across the basin. Using data from the 2003-2013 period, the western basin receives the highest loadings: around 60% of the total load entering the lake, while the central and eastern basins receive 28% and 12%, respectively. Two of the largest watersheds that contribute nutrients to the western basin of Lake Erie are the Maumee River in Ohio and the Thames River in Ontario, which discharges into Lake St. Clair upstream of the Detroit River. The Maumee River phosphorus concentration is substantially greater.

In general, climate change is increasing average lake temperatures and increasing the duration of vertical stratification, which are two integral physical factors affecting eutrophication (Paerl and Huisman, 2009). Climate change will likely also increase the intensity of storms in the Great Lakes basin, leading to greater nutrient runoff and delivery of nutrients beyond the spring freshet (Scavia et al., 2014). Consequently, climate change could increase the magnitude, duration, and frequency of algal blooms in the Great Lakes and thus increase hypoxia.

The proliferation of invasive zebra and quagga mussels has indirectly reduced the availability of phosphorus to the fish community. As filter feeders, the mussels filter algae from the water and the phosphorus in algal tissues is then excreted in a form that nuisance aquatic plants and algae close to shore can use (Ozersky, 2010) reducing the flow of nutrients to the offshore. This phenomenon is referred to as a nearshore shunt (Hecky et al., 2004). Phosphorus taken up in these nearshore areas and in deeper mussel beds is essentially trapped at the expense of the open water food chain.

Offshore concentrations of total phosphorus have continued to fall to the point that in Lake Michigan, Lake Huron, and Lake Ontario concentrations are as low as 50% of GLWQA targets and show declining trends (Dove and Chapra, 2015). The offshore total phosphorus concentrations and transparency in Michigan and Huron are similar to those of Lake Superior (Barbiero, et. al., 2012) in lakes Michigan, Huron and Ontario. Low offshore phosphorus levels caused by the mussels, limit the growth of algae in the open waters, undermining plankton and fish communities of the pelagic food web (Figure 5.6.1).

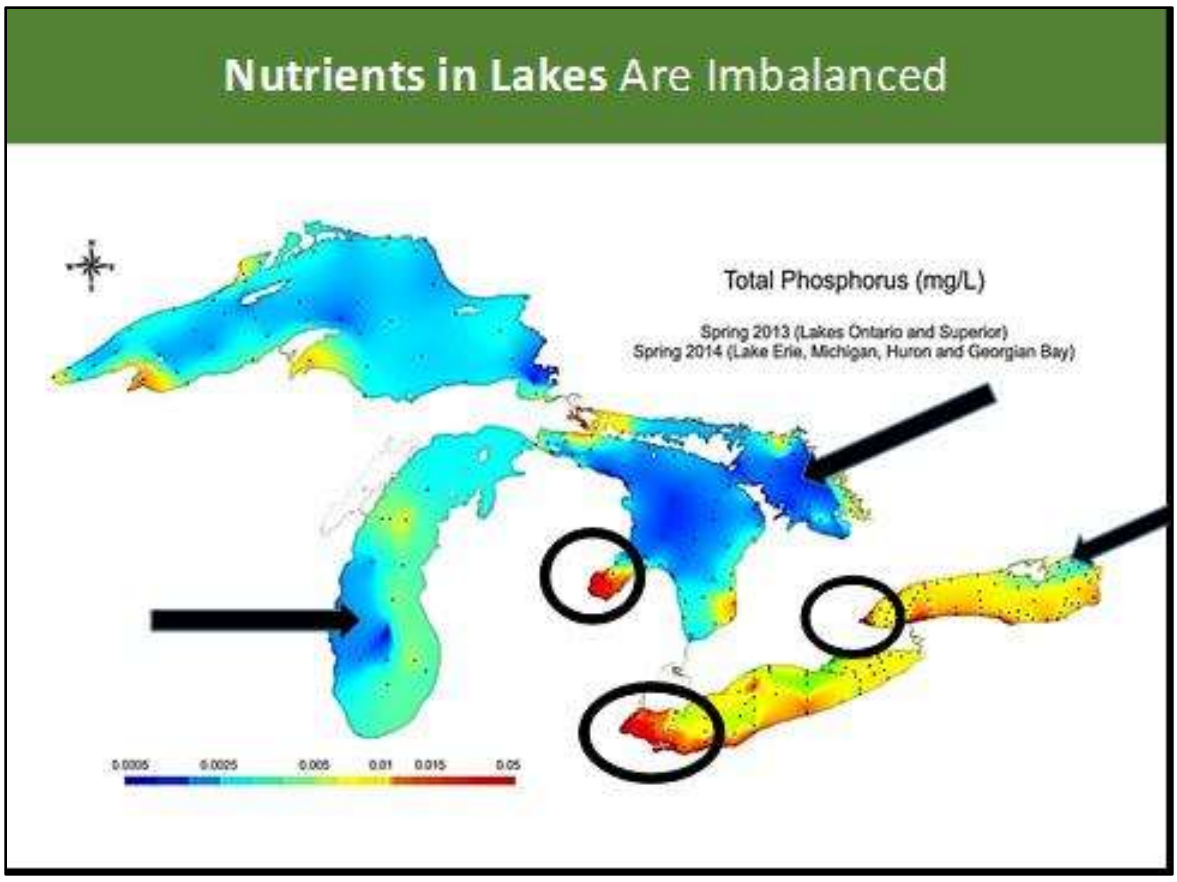

Figure 5.6.1 Imbalanced nutrient levels between and within lakes. Some areas are nutrient-rich (eutrophic) while others are nutrient-poor (oligotrophic). Differences have always existed, but they have been exacerbated recently. (Source: ECCC and USEPA. 2017b)

The IJC has studied the issue of nutrients in Lake Erie extensively and issued its report *A Balanced Diet for Lake Erie* (also known as the LEEP report) in 2014 (IJC, 2014). The discussion of nutrients in the IJC's triennial assessment of progress report, and this supporting technical appendix, draw extensively from that work.

5.6.2 Assessment of Annex Implementation

Annex 4 of the GLWQA, entitled Nutrients, addresses the General Objective of managing nutrients in the waters of the Great Lakes. Annex 4 calls for coordinated binational action to manage phosphorus (and other nutrients if warranted) with respect to concentrations in and loadings to the waters of the Great Lakes through coordinated binational action. The Parties established an Annex 4 subcommittee, chaired by the US Environmental Protection Agency (USEPA) and Environment and Climate Change Canada (ECCC), to carry out commitments in the Annex.

Created by the Parties in September 2013, the Annex 4 Objectives and Targets Task Team of the Nutrients Annex Subcommittee has been active in fulfilling commitments under the GLWQA. The task team convened a sub-team of modeling experts to compare and contrast the results from

a suite of existing Lake Erie models to quantify phosphorus load and eutrophication response relationships for the Lake Erie ecosystem. Using nine validated models the team evaluated the impact of a combination of load reduction strategies on western basin cyanobacteria blooms, central basin hypoxia, and eastern basin *Cladophora* (Binational.net, 2016).

The Annex 4 Task Team also considered the role of factors other than phosphorus loads and associated in-lake concentrations in governing eutrophication indicators. These other factors included nitrogen loads and concentrations, *Dreissenidae*densities and impacts, and variations in annual precipitation and tributary discharges. Additional considerations included the setting of in-lake phosphorus concentration objectives for nearshore areas and the role that phosphorus bioavailability plays in governing the response of eutrophication indicators to phosphorus loads. Its report (Annex 4 Objectives and Targets Task Team, 2015)recommended loading targets for total and dissolved phosphorus to address harmful algal blooms (HABs) in the Western Basin and hypoxia in the Central Basin. These targets were adopted by the Parties in 2016.

The Task team is also working on targets to address nuisance algal blooms in the Eastern Basin. They also identified 14 priority tributaries for nutrient reduction. Nutrient runoff from agriculture is the primary cause of the problems, but efforts to address this concern would need to deal with both agriculture and urban sources (Binational.net, 2016).

In addition to developing domestic action plans for Lake Erie, the subcommittee is working to establish phosphorus reduction targets to control nuisance algae in the eastern basin of Lake Erie, and will be addressing loading and concentration targets for Lake Ontario (Binational.net, 2016). To build upon the effort, there was a binational workshop held on January 26- 28th 2016, in order to determine the state of knowledge of *Cladophora* for the entire Great Lakes Basin and for individual lakes as well as areas within each lake individually. The findings of the workshop were used as a framework to develop a strategy to achieve the anticipated nutrient reduction targets in order to control *Cladophora* (GLWQA Progress Report, 2012).

To support the efforts of GLWQA the EPA is expected to provide about $600,000 to establish a sentinel monitoring sites in Lakes Michigan, Huron, Erie, and Ontario to measure *Cladophora* growth, biomass and water quality parameters (EPA, 2017). According to the IJC's LEEP report, the governments of United States and Canada should develop a domestic action plan including both regulatory and non-regulatory measures to reduce nutrient pollution in Lake Erie by 2018, to deal with *Cladophora* as a result of phosphorous loading (IJC, 2014).

5.6.3 Assessment of indicators

Nutrient indicators include harmful algal blooms (HABs), nutrients in lakes and *Cladophora*.

Table 5.6.1 Summary Conditions of the Great Lakes, by Nutrient Indicators
(Source: GLPF, 2016)

Great Lakes	Indicators of Progress		
	Harmful Algal Blooms	**Nutrients in Lakes**	***Cladophora***

Lake Superior	The status is **good** and the trend is **unchanged or undetermined**.	The status is **good** and the trend is **unchanging**. Targets have consistently been met	The status is **good** and the trend is **unchanging**. There is no historic occurrence of Cladophora on Lake Superior shorelines
Lake Michigan	The status is **fair** and the trend is **unchanging or undetermined**. There are eutrophic embayments such as Green Bay, Muskegon Bay and drowned river mouths along the western shore.	The status is **fair** and below target, the trend appears to be **deteriorating** further below targets.	The status is **poor** and the trend is **undetermined**. Cladophora remains to be an issue on beaches and is high in many parts of the lake.
Lake Huron	The status is **fair** and the trend is **unchanging off shore while deteriorating in some near shore regions**. The lake is generally oligotrophic but nearshore areas experience nuisance and HAB outbreaks, namely Saginaw Bay and Sturgeon Bay (Georgian Bay).	The status is **fair** and below target, the trend appears to be **deteriorating** further below targets. Offshore TP concentrations continue to decrease to values that may be too low to support a healthy level of lake productivity.	The status is **fair** and the trend is **undetermined**. Cladophora biomass approaches nuisance thresholds in localized areas over the Canadian shoreline. Over broader areas of the nearshore zone
Lake St Clair	The status is **poor** and the trend is **unchanging off shore while deteriorating in some near shore regions**.	No progress reporting provided	No progress reporting provided
Lake Erie	The status is **poor** and the trend appears to be **unchanging to deteriorating**. Toxic cyanobacteria blooms continue to occur throughout the western basin. Blooms in 2013, 2014 and 2015 were ranked as severe in a number of categories. The blooms in 2014 caused closure of the city of Toledo water supply and the 2015 bloom was the worst ever.	The status is **poor** and above target and the trend is **deteriorating**. TP and dissolved phosphorus targets continue to be exceeded and trends indicate possibly increasing concentrations. HABs have plagued the western basin and parts of the central basin	The status is **poor** and the trend is **undetermined**. Broadly distributed along much of the north shore and eastern basin Cladophora biomass is variable from year to year but continues at or above nuisance conditions at most sites sampled.
Lake Ontario	The status is **fair** and the trend appears to be **unchanging offshore to deteriorating/unchanging nearshore**. Offshore waters remain good; however, nearshore waters continue to experience nuisance algal blooms. Beach closures and toxic HABs have been reported in	The status is **fair** below targets and the trend appears to be **deteriorating** further below target. Offshore TP concentrations continue to decrease to values that may be too	The status is **poor** and the trend is **undetermined**. Biomass routinely exceeds nuisance conditions in the western end of the lake. Cladophora is widely distributed in

	several embayments on the New York (Sodus Bay and Port Bay) and Canadian side (Hamilton Harbour, Bay of Quinte).	low to support a healthy level of offshore lake productivity. Possibly fueled by locally high phosphorus discharges or in-lake nutrient cycling certain nearshore areas are experiencing recurrent nuisance algae.	Lake Ontario with recent surveys indicating nuisance conditions in both the vicinity of point source inputs and regions remote to known sources. Lack of consistent monitoring and inter-annual variability being comparable to that of Lake Erie and Michigan, assessment of trends is hindered.

5.6.4 Assessment of Lake Erie phosphorus objectives and targets

Annex 4 of the *Great Lakes Water Quality Agreement*(GLWQA) includes six Lake Ecosystem objectives adopted by the Parties in support of the purpose of the Annex:

1. minimize the extent of hypoxic zones in the Waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie;
2. maintain the levels of algal biomass below the level constituting a nuisance condition;
3. maintain algal species consistent with healthy aquatic ecosystems in the nearshore Waters of the Great Lakes;
4. maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the Waters of the Great Lakes;
5. maintain an oligotrophic state, relative algal biomass, and algal species consistent with healthy aquatic ecosystems, in the open waters of Lakes Superior, Michigan, Huron and Ontario; and
6. maintain mesotrophic conditions in the open waters of the western and central basins of Lake Erie, and oligotrophic conditions in the eastern basin of Lake Erie (GLWQA, 2012).

In Annex 4, the parties established interim substance objectives to achieve the Lake Ecosystem objectives for phosphorus concentrations for the open waters and nearshore areas of each Great Lake. The Annex 4 subcommittee was then charged with developing final substance objectives and loading targets. The subcommittee chose not to recommend final substance objectives for Lake Erie in part because phosphorus concentrations in the nearshore and open waters vary considerably over space and time, making them very difficult to track in a meaningful way (Annex 4 Objectives and Targets Task Team, 2015).

Canada and the United States in February 2016 adopted the following phosphorus load reduction targets (compared to a 2008 baseline) for Lake Erie (EPA and ECCC, 2016):

- *To minimize the extent of hypoxic zones in the waters of the central basin of Lake Erie:* a 40 percent reduction in total phosphorus entering the western and central basins of Lake Erie—from the United States and from Canada—to achieve an annual load of 6,000 metric tonnes (6,600 tons) to the central basin. This amounts to a reduction from the United States and Canada of 3,316 metric tonnes and 212 metric tonnes (3,648 tons and 233 tons) respectively.

- *To maintain algal species consistent with healthy aquatic ecosystems in the nearshore waters of the western and central basins of Lake Erie:* a 40 percent reduction in spring total and soluble reactive phosphorus loads from the following watersheds where algae is a localized problem: in Canada, the Thames River and Leamington tributaries; and in the United States, the Maumee River, River Raisin, Portage River, Toussaint Creek, Sandusky River and Huron River (Ohio).

- *To maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the waters of the western basin of Lake Erie*: a 40 percent reduction in spring total and soluble reactive phosphorus loads from the Maumee River in the United States.

Canada and the United States are working to develop domestic action plans that will outline strategies for meeting the new targets. The GLWQA calls for completion of the plans by February 2018.The Annex 4 subcommittee is workingto establish targets to minimize impacts from nuisance algae in the eastern basin of Lake Erie. The targets are expected to be set in 2017.

5.6.5 Assessment of Progress Report of the Parties

The Progress Report of the Parties (PROP) (reference) observes that the Parties have met, or are on track to meeting all Annex 4 commitments under the *Great Lakes Water Quality Agreement*(GLWQA). These commitments are:

- By2016,developbinationalsubstanceobjectivesforphosphorusconcentrations,loading targets,andloadingallocationsforLakeErie.
- By 2018,developbinationalphosphorusreductionstrategiesanddomestic actionplansto meettheobjectivesfor phosphorusconcentrationsandloadingtargetsin LakeErie.
- Assess,develop,andimplementprogramstoreducephosphorusloadingsfromurban,rural, industrialandagriculturalsources.Thiswillincludeprovenbestmanagementpractices,along withnew approachesandtechnologies.
- Identifyprioritywatershedsthatcontributesignificantlytolocalalgaedevelopment,and developandimplementmanagementplanstoachievephosphorusloadreductiontargetsand controls.
- Undertake and share research, monitoring and modeling necessary to establish, report on and assess themanagementof phosphorusandothernutrientsandimprovetheunderstandingofrelevantissuesassociatedwithnutrientsandexcessive algalblooms.

Substance objectives and loading targets

The Parties have met the commitment to develop substance objectives for phosphorus concentrations, loading targets and loading allocations for Lake Erie. These objectives were formally established in February 2016 on the schedule called for by the GLWQA. As part of the process, the Parties undertook a robust public engagement process to explain and justify the proposed targets.

Binational phosphorus reduction strategies and domestic action plans

Although the GLWQA deadline todevelopbinationalphosphorusreductionstrategiesanddomestic actionplansto meettheobjectivesfor phosphorusconcentrationsandloadingtargetsin LakeErie is not until February 2018, there are concerns about two developments in the process to date.

As of October 2017, the Annex 4 subcommittee has not considered the possibility of recommendations for new regulatory authorities in domestic action plans. Incentive-based programs supporting agricultural best management practices have achieved some success; as the Parties note, on the US side of the Great Lakes watershed, where an estimated 72.57 metric tonnes (80 tons) of phosphorus will be prevented from entering the Great Lakes annually as a result of projects in targeted watersheds, which include the Western Lake Erie basin (ECCC and USEPA, 2016). This, however, is only a small fraction of the reductions needed to achieve the Parties load reduction targetes. Further, Annex 4 envisions a regulatory component to phosphorus reduction strategies. Section D (3) commits the Parties to "assess and, where necessary, develop and implement regulatory and non-regulatory programs to reduce phosphorus loading from agricultural and rural non-farm point and non-point sources."

New authorities – or at least the option of new authorities – could be critical to domestic action plans. The general reliance on voluntary initiatives to reduce polluted (nonpoint) runoff from agricultural lands has over the past decade proven insufficient to control eutrophication of western Lake Erie in particular.

In 2015, the State of Ohio enacted an important new statutory requirement for the management of animal waste and chemical fertilizer in agriculture (Ohio Legislature 131st General Assembly, 2015). The new law bans, with some exceptions, the application of manure and chemical fertilizer on agricultural lands that are frozen, snow-covered, or saturated, or when significant rains are predicted. The statute is designed to prevent immediate runoff of phosphorus-rich animal waste in particular. Ontario's Nutrient Management Act, 2002, also prevents application of nutrients to agricultural land when the soil is snow-covered or frozen. The remaining states in the Lake Erie watershed could enact similar laws.

Second, the Annex 4 subcommittee has discussed endorsing plans developed by Ohio, Michigan and Ontario pursuant to their Western Basin of Lake Erie Collaborative Agreement as the state/provincial component of domestic action plans (State of Michigan, 2015). The idea that these plans, in all cases, are sufficient to achieve the 40 percent phosphorus load reductions envisioned in the three-party agreement and the Parties' targets(ECCC and USEPA, 2016)is not persuasive.

Domestic action plans to achieve phosphorus loading reduction targets need to include details on the timeline, who is responsible for each action, and expected deliverables, outcomes and quantifiable performance metrics to assure accountability.

Phosphorus management programs

The Parties state (ref?) that they are evaluating existingprogramsinCanadaandtheUnited States to identify opportunitiestomaximizephosphorusreduction and may proposenewprogramsor approachestomanagephosphorus loadings. The possibility of new programs is encouraging. Careful analysis ofagricultural programs, including promotion of voluntary adoption of best management practices, is critical. However, it is unclear that the reliance on existing voluntary efforts has improved western Lake Erie water quality, nor that of Green Bay and Saginaw Bay.

A significant proportion of corn grown in both the United States and Canada, and in the watershed of western Lake Erie, supplies a feedstock to meet renewable fuel mandates. The mandates, in turn, increase financial return to individual agricultural operators for planting the maximum feasible amount of corn, including the use of marginal cropland from which runoff may be excessive (USEPA, 2011). The IJC is currently reviewing the indirect effects of renewable fuel mandates on Lake Erie water quality in a special study.

Research, monitoring and modeling

The Parties have made a positive commitment to "Undertake and share research, monitoring and modeling necessary to establish, report on and assess themanagementof phosphorusandothernutrientsandimprovetheunderstandingofrelevantissuesassociatedwithnutrient sandexcessive algalblooms" (ECCC and USEPA, 2016). However, there is a lack of specificity in implementing the commitment. For example, the issue of characterizing and quantifying the influence of the Detroit River on HABs in the western Lake Erie basin remains of critical concern. So, too, is the issue of whether there is adequate monitoring and modeling to develop and evaluate conservation practices and best management practices to control non-point source nutrient pollution. A study conducted by the Northeast-Midwest Institute and the US Geological Survey found that monitoring was inadequate to evaluate the water quality impacts of agricultural best management practices and benefits for Lake Erie (Betanzo et al., 2015). The formation of the new Work Groups within the Annex 4 Task Team is promising and encourages the parties to develop strategies for long term support of the monitoring, modeling, and research needed to address the problems and prevent them from returning in the future.

Other issues

The western basin of Lake Erie experienced a particularly severe HAB in 2011. The IJC LEEP report (2014) noted that half of the loadings to Lake Erie that year came from tributaries draining agricultural areas and rural communities. One of the major sources of nonpoint loadings of phosphorus to Lake Erie is agricultural operations, including the application of fertilizers and manures to the land. Nutrient inputs to the western Lake Erie basin and Green Bay from concentrated animal feeding operations (CAFOs) and smaller animal feeding operations are not well documented but are a major concern. CAFOs house livestock inaconfinedspace,resultingintheconcentrationof manureinasmallarea. By one estimate, 146CAFOs arelocatedinthewestern Lake Erie basin, housingalmost12million dairy, hog and poultry animals. Their estimated waste output is over 2,385 million liters (630 million gallons) annually (Sierra Club, 2016). In the SPARROW modelling conducted by Robertson and Saad (2011) the highest yields (mass/area/time) of phosphorus and total nitrogen were found in areas having intense agriculture and large point sources of nutrients, such as CAFOs.

State regulatory agencies and not-for-profit environmental organizations disagree on the effectiveness of permitting and enforcement efforts by the agencies. For example, the Ohio Department of Agriculture, speaking of its livestock permitting program, observes that "Most farmers and agribusinesses hold themselves to the highest environmental standards. The State of Ohio now ensures the state's largest operations follow science-based guidelines that protect the environment while allowing the facility to be productive" (Ohio Department of Agriculture, 2016). By contrast, the Ohio Environmental Council, a nongovernmental organization, contends that livestock operations avoid regulation by housing a number of animals just under the

threshold where a permit would be required. “This means very big livestock operations are raising thousands of animals in Ohio with little oversight and few rules to follow” (Ohio Environmental Council, 2015). Given the significance of CAFOs as a nutrient loading source, the adequacy of the regulatory programs is not clear and merits further investigation. At a minimum, better measures are needed to ensure that the high volume of manure produced by CAFOs is not spread on cropland in excess of crop requirements.

The importance of wetlands in capturing and filtering pollutants is well-established. In northwestern Ohio, only 5 percent of Lake Erie’s original 124,238 hectares (307,000 acres) of wetlands remain, and similar patterns exist throughout the rest of the western basin of the lake (Doran and Kahl, 2014). Thedraining of coastalwetlandsand most of the 297,849 hectare (736,000 acre) GreatBlack swamp in the Maumee River and Portage River watersheds “eliminated mostof thecapacitytopreventpollutantsandsedimentsgeneratedin theuplandportionsof thewatershed fromenteringthelake.”The associated drainage systems and farmland that replaced the wetlandsled to increasederosion potentialand deliveryof sedimentandattachedpollutants toLakeErie (Ohio Department of Natural Resources, 2007).

Accelerated wetland restoration is an important issue for the Parties and state and provincial partners to consider in domestic action plans. Research suggests that a constructed wetland whose surface area is 4 percent of its catchment can retain about half of the catchment’s agricultural dissolved reactive phosphorus (DRP) load (Boles, 2016). This suggests that constructing and restoring wetlands as an agricultural best management practice can have significant water quality benefits.

Buffer strips are a technique for reducing agricultural runoff and have proven effective in many applications. Recently, as noted in the PROP, the State of Minnesota has legislated that landowners along public waters maintain a mandatory a 15.2-metre (50-foot) average width, 9.1-metre (30-foot) minimum width, continuous buffer of perennially rooted vegetation or comply with state shoreline standards and criteria promulgated by the State Commissioner of Natural Resources (2015 Minnesota Statutes). Buffers “slow runoff from fields, trapping and filtering sediment, nutrients, pesticides and other potential pollutants before they reach surface water” (Minnesota Department of Agriculture, 2016).

Another legally enforceable protection for western Lake Erie would be the establishment of a total maximum daily load (TMDL) under the United States*Clean Water Act*. As noted in the IJC’s 2014 report, *A Balanced Diet for Lake Erie*, the TMDL process entails calculation of the maximum amount of loading of pollutant(s) of concern that an impaired waterbody can receive and still meet water quality standards for that particular pollutant. The TMDL allocates the load to both point and non-point sources. Following development of a TMDL, implementation should proceed in a way that meets water quality standards and restores impaired waterbodies. States are required to develop TMDLs when a water body is listed under the United States Clean Water Act as being impaired.

There is no existing phosphorus daily load limit specific to the western basin of Lake Erie. The State of Ohio should, under the United States Clean Water Act, list the waters of the western basin of Lake Erie as impaired because of nutrient pollution. The State of Michigan has already done so. This designation by Ohio would trigger the development of a tri-state phosphorus

TMDL involving those two states as well as Indiana, with US EPA oversight. The TMDL provides timetables and accountability for implementing phosphorus reduction measures.

The PROP provides little detail on phosphorus reduction activities undertaken pursuant to the Canada-Ontario Agreement (COA) on Great Lakes Water Quality and Ecosystem Health, the federal-provincial agreement that supports the restoration and protection of the Great Lakes basin ecosystem, last updated in 2014. The report could provide additional description of COA-related actions to address nutrient pollution in the portion of the four Great Lakes under Ontario jurisdiction.

5.6.6 Assessment of Lake Erie Watershed Management Plans

The Legacy Issues Work Group of the Great Lakes Water Quality Board (WQB), the principal advisor to the IJC as set forth in the GLWQA, undertook a review of watershed management plans within the Lake Erie basin and other jurisdictions that could be used as best practice examples to achieve nutrient load reduction targets and aid in the restoration of Lake Erie (WQB 2016). The WQB recommended:

- The CanadianandUSgovernmentsaswell astheprovincial andstate governmentsshould ensurethatlake-widebasin, sub-basin, watershed andsub-watershedmanagementplans (including plans tomanage bays, islands andthe nearshore)aredeveloped fornutrientmanagementin Lake Erie.
- There areseveral keysuccess factors thattheCanadianand USgovernmentsaswell as theprovincial andstategovernments, shouldensureareincluded inthelake-widebasin, sub-basin, watershed, and sub-watershedmanagement plans for nutrientmanagement. These include science-based watershed characterization, clear goals and an adaptive management approach.
- TheCanadianandUSgovernments,aswell asthe provincial andstate governmentsaroundLakeErie,shouldensure thatfunding isavailabletosupportplanningactivities and implementationofwatershed management plansfornutrients.

IJC activities

While making commendable efforts to fulfill their commitment under the GLWQA with respect to monitoring and modeling of phosphorus and other nutrients in the Great Lakes and their tributaries and connecting rivers, the Parties could enhance modeling with the measurement of nutrients at critical locations and specific times of the year.

Through its Great Lakes advisory boards, the Commission is investigating several nutrient-related topics that will result in advice to governments in the next triennial period:

- The Science Priority Committee of the Science Advisory Board has just completed an analysis of the relative influence of different agricultural sources of phosphorus (including commercial fertilizers and manure) in the western basin of Lake Erie.
- The Water Quality Board is examining policies related to confined animal feeding operations.
- The Research Coordination Committee of the Science Advisory Board is analyzing how progress towards phosphorus reduction goals can be measured and communicated in an adaptive management framework.
- The Science Priority Committee of Science Advisory Board is studying the juxtaposition between nearshore nutrient enrichment and declining offshore lake productivity.

In addition, the IJC is examining the influence of ethanol policies on agricultural nutrient loadings.

5.6.7 Section Summary

- With the exception of Lake Superior, all Great Lakes are experiencing significant nutrient issues.
    - Open lake (or offshore) nutrients concentrations are below target and likely deteriorating in lakes Michigan, Huron and Ontario, likely due to changes in the food web caused by non-native species. This is undermining desirable fish populations.
    - Nutrient concentrations are above target in western and central basins of Lake Erie, and at target levels in the eastern basin.
- Although record algal blooms in western Lake Erie have captured the most public attention, excess nutrients also fuel harmful algal growth in localized areas such as Green Bay and Saginaw Bay and help to foster harmful algae, while nuisance algae affect nearshore areas of Lakes Erie and Ontario.
- The Parties have met the commitment to develop substance objectives for phosphorus concentrations, loading targets and loading allocations for Lake Erie. In doing so, the Parties undertook a robust public engagement process to explain and justify the proposed targets.
- Over the past ten to 15 years, governments at all levels have focused on incentive-based and voluntary programs to reduce nutrient loadings to the western basin of Lake Erie. These voluntary programs include funding and support for implementing best management practices on agricultural lands, the leading source of phosphorus in the western Lake Erie basin. However, frequent HABs in the last ten years suggest that the voluntary programs alone are not sufficient to achieve target loadings set by the Parties in 2016.

- The use of regulatory tools is needed to supplement voluntary initiatives to reduce phosphorus loadings in the western basin of Lake Erie.

5.6.8 References

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5.7 Invasive Species

This section reviews and assesses progress toward achieving general objective 7 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 7 states that the waters of the Great Lakes should "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."

This assessment includes a consideration of implementation measures undertaken in support of the GLWQA Annex 5: *Discharges from Vessels* and Annex 6: *Aquatic Invasive Species*. The assessment also reviews supplemental information from other management programs and activities carried out by governments, local governmental agencies and non-governmental organizations in Canada and the United States.

5.7.1 Background

Non-native species are organisms that enter an ecosystem beyond their native spatial range. More than 180 non-native species, also called nonindigenous species have become established in the Great Lakes due to human activities over the past 175 years.

Invasive species are non-native species to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (US Department of Agriculture (USDA), 2016), this includes both aquatic invasive species (AIS) and terrestrial invasive species. Invasive species represent one of the toughest challenges facing the Great Lakes basin.

García-Berthou et.al. (2011) found high rates of establishment of 123 aquatic species introduced into six contrasting European countries, where the average percentage established is 63%. Williamson and Fritter (1996) estimated that about 10% of introduced species become established and about 10% of those (or about 1/100) become invasive).Estimates of the frequency at which introduced species become invasive vary widely from about 1% to over 50% for fresh water species. For freshwater fish, mammals and birds, Jeschke and Strayer (2005) found high rates of establishment (50%) and invasiveness (50%), implying about 25% of introduced vertebrate species are invasive (IJC, 2013). A study conducted for the Great Lakes Mississippi River Interbasin Study (GLMRIS), *Non-Native Species of Concern and Dispersal*

Risk for the Great Lakes and Mississippi River Interbasin Study, concluded that the more alien species that are introduced to the Great Lakes or Mississippi River basins, the higher the probability that some of them will become invasive (USACE, 2011). The SOGL Technical Report reports that at least 31% of the nonindigenous species found in the Great Lakes are invasive because they have moderate to high environmental, socio-economic or economic impactConversely, roughly 70 percent of non-native species are not considered invasive and some may even be considered desirable. Rainbow Trout, Chinook and Coho Salmon are examples of non-native species that are not considered invasive in the Great Lakes.

AIS not only crowd out native species, but also have negative impacts on the spread of chemical contaminants and nutrients in the Great Lakes ecosystem (Governments of the United States and Canada, 2016a). The Great Lakes have suffered ecological damage and economic costs from a number of aquatic invasive species (AIS) that have successfully invaded this region (Mills et al., 1994). Rothlisberger et.al. (2012) estimated the median estimate of cost to the Great Lakes from invasive species that originate in the ballast water of ocean-going vessels at $138 million annually and possibly more than $800 million. Cost estimates vary, and the SOGL Technical Report places the cost of the overall economic impact of aquatic nonindigenous species at well over $100 million, accounting for impacts on power generation, recreational uses, commercial fishing, sea lamprey control and invasive aquatic weed removal. (ECCC and USEPA, 2017)

The IJC has been reporting on invasive species and providing a forum for binational collaboration on this issue for over 28 years. During this period the basin-wide impacts of Sea Lamprey (*Petromyzon marinus*), Zebra and Quagga Mussels (*Dreissena polymorpha* and *Dreissena rostriformis bugensis*), and other high-impact AIS (USACE, 2011) were documented. The impacts of terrestrial invasive species such as the Common reed (*Phragmites australis*) became very apparent as well. These are considered high-impact based on the history of wide-spread and costly impact they have inflicted upon ecosystems they have invaded. Sea Lamprey and Zebra Mussels alone have resulted in basin-wide harmful impacts to the Great Lakes and costs in the billions of dollars. IJC has consistently emphasized preventive action as the "first line of defense" in safeguarding the Great Lakes basin from the adverse ecological and economic impacts of an AIS infestation. IJC has also recognized the need for a "back-up plan" - a rapid response mechanism to quickly and decisively address AIS once an infestation has been reported (IJC, 2011), (IJC, Special Publication 2009-04).

General objective 7 of the GLWQA is directly linked to programs and measures undertaken in support of two of the annexes of the agreement:

- Annex 5 addresses the threat of aquatic invasive species (AIS) introduction and spread through vessels by means of biofouling and ballast water discharge.
- Annex 6 commits the Parties to establishing binational strategy to prevent the introduction of AIS, to control or reduce the spread of existing AIS, and to eradicate, where feasible, existing AIS within the Great Lakes basin ecosystem.

Objective 7 indirectly relates to a number of other GLWQA Annexes, including those relating to nutrients, habitat and species, climate change impacts and science. This relationship is clearly demonstrated by the far-reaching impacts that Zebra and Quagga mussels have had on the Great

Lakes ecosystem, where scientists have documented significant changes to the food web, the distribution of nutrients and toxic chemicals (Hecky et al.,2004), as well as the habitat and substrate available to other organisms. For the purposes of this assessment, only those programs and measures related to Annexes 5 (Discharges from Vessels) and Annex 6 (Aquatic Invasive Species) are addressed in this section.

The assessment of progress toward the invasive species objective in this section leads off with a discussion of the SOGL invasive species indicator and sub-indicators, followed by an assessment of actions reported in the Progress Report of the Parties, a review of annex implementation as it relates to the 2013 priorities for Annex 6 of the GLWQA, a review of action under Annex 5 - discharges from vessels, and an assessment of programs and measures.

5.7.2 Assessment of indicator

The overall Invasive Species indicator is assessed by the 2017 SOGL report as Poor and the trend is Deteriorating, due to the continuing spread and impact of previously established invasive species. The SOGL invasive species indicator has four sub-indicators that relate to General Objective 7 (ECCC and USEPA 2017):

- *Impacts of Aquatic Invasive Species* - total number and timing of new introductions of aquatic non-native species and the spread of previously established species. (Poor – and Deteriorating)
- *Dreissenid Mussels* - Abundance and Distribution (Fair/Deteriorating)
- *Sea Lamprey* – Abundance and Distribution (Fair/Improving)
- *Terrestrial Invasive Species* - Abundance and Distribution – (Poor/Deteriorating);
  A sub-indicator based on five species of interest – Asian longhorned beetle *Anoplophoraglabripennis*, Emerald ash-borer *Agrilusplanipennis*, Common reed *Phragmites*, Purple loosestrife *Lythrumsalicaria* and Garlic mustard *Alliariapetiolata*.

Sub-Indicators Supporting the Indicator Assessment					
Sub-Indicator	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Impacts of Aquatic Invasive Species	Deteriorating	Deteriorating	Deteriorating	Deteriorating	Deteriorating
Dreissenid Mussels	Unchanging	Deteriorating	Deteriorating	Improving	Deteriorating
Sea Lamprey	Improving	Improving	Improving	Improving	Unchanging
Terrestrial Invasive Species	Deteriorating	Deteriorating	Deteriorating	Deteriorating	Deteriorating

Status: GOOD | FAIR | POOR | UNDETERMINED

Table 5.7.1 Summary Table of Invasive Species Sub-Indicators (SOGL 2017)

Impacts of Aquatic Invasive Species – This sub-indicator reports on the number, distribution and impact of aquatic nonindigenous species in the Great Lakes.

The 2017 SOGL report shows that the overall rate of discovery of new aquatic nonindigenous species (ANS) in the Great Lakes has plummeted from an average of one new species discovered every 8 months, with over 70% attributed to ballast water discharges, to no new AIS discoveries attributed to ballast water discharges since 2006 (ECCC and USEPA, 2017). This is in large part due to the regulation of ballast water discharges from trans-oceanic ships discussed in Section 5.7.4.

On November 1, 2016, it was reported by the USEPA that samples taken from the western basin of Lake Erie in 2014 included non-native zooplankton species, *Thermocyclops crassus*. This small non-native copepod serves to illustrate the difference between non-native and invasive as well as the uncertainty associated with such discoveries.

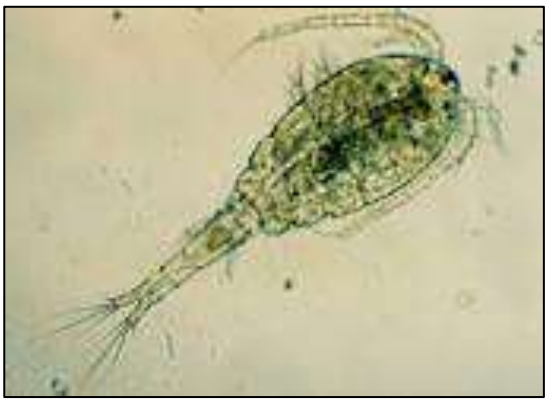


Photo Credit: USEPA

Joe Connolly of Cornell University discovered *Thermocyclops crassus* in water samples taken from western Lake Erie in 2014. Male and female specimens were found in low numbers, indicating that an established population exists in Lake Erie. Females are 0.8 to 1.1mm and males are about 0.7mm in length (Fischer 1853). They are similar to a native cyclopoid copepod *Mesocyclopsedax*, but slightly smaller. *Thermocyclops crassus* is present throughout Europe, Asia, Africa and Australia, but is generally considered Eurasian in origin (Ueda and Reid 2003). *Themocyclops crassus* has been found elsewhere in North America, including Lake Champlain (1991) so scientists are uncertain whether it was transported to the Great Lakes via ballast water or another pathway. It is recognized as non-native, but does not fit the USDepartment of Agriculture definition of an aquatic invasive, because it does not appear to cause harm to the ecosystem, the economy, or human health. Therefore, this latest discovery does not replace the Bloody red shrimp, *Hemimysis anomala,* reported in 2006, as the latest aquatic invasive species to enter the Great Lakes from ballast water discharges. (ECCC and USEPA, 2017)

However, while the rate of total new non-native species discovered in the basin has significantly declined over the past decade, previously established invasive species have continued to spread within the Great Lakes basin. Each of the Great Lakes has had at least one nonindigenous specie spread to its waters and establish populations during this same period. On the higher end, 19 species spread to Lake Superior and 30 to Lake Michigan. Factors linked to the spread of previously established non-native species include the presence of one ANS species facilitating the expansion of another (aka "invasional meltdown"), climate change, secondary shifts in native populations, removal of dams, and changes to fish habitat related to ANS. (Ricciardi, A. 2001); (ECCC and USEPA 2017).. As previously stated, estimates vary, but overall economic impact is over $100 million annually (ECCC and USEPA 2017). The spread of previously established ANS as well as their impact resulted in an SOGL assessment of Poor and a Deteriorating trend for this sub-indicator.

TheGreat Lakes Aquatic Nonindigenous Species Information System (GLANSIS) Map Explorerprovides a tool to show a graphical representation of the numbers of invasive species by lake basin (figure 5.7.1). The SOGL Technical Report states that the rate of invasion will also be measured as the number of new AIS arriving in the Great Lakes since the last assessment. Therefore if the data are maintained, output from the GLANSIS Map Explorer, shown in the 2017 SOGL report, could serve to effectively communicate trends in ANS expansion on a lake by lake basis in future SOGL reports.

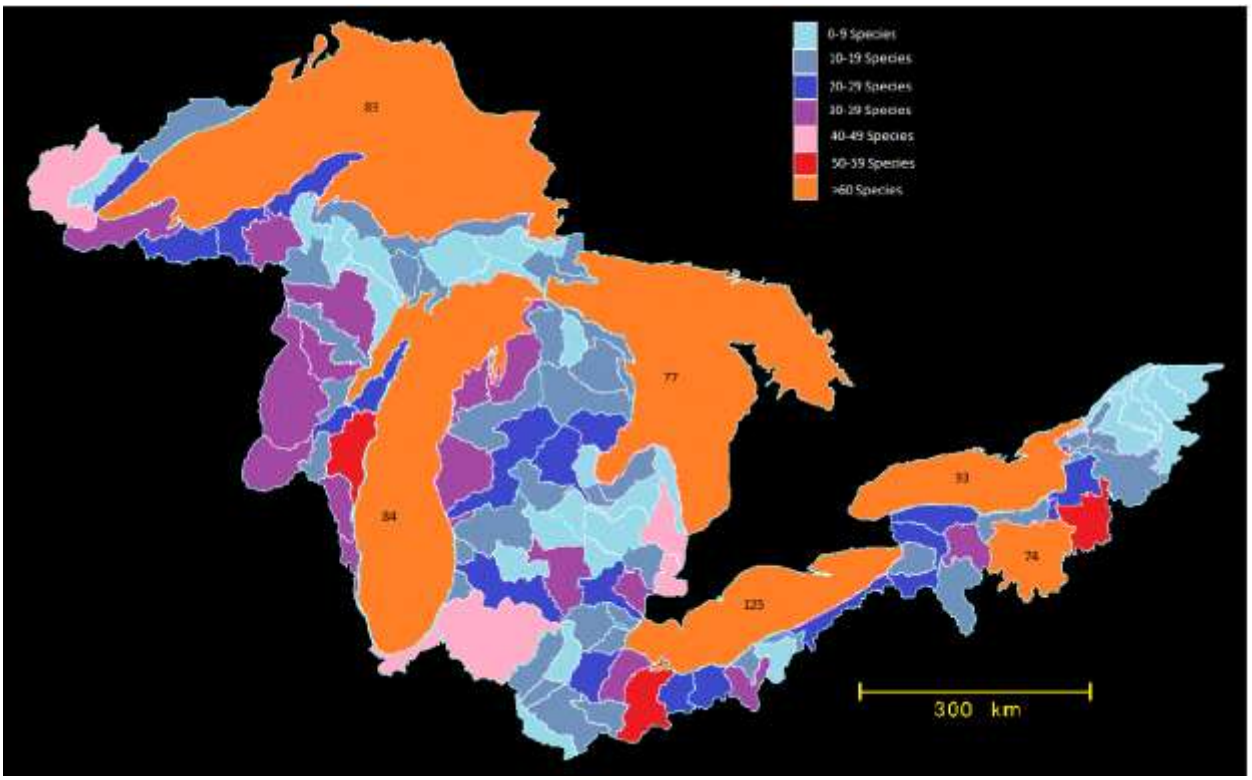


Figure 5.7.1 Invasive Species Distribution by Lake Basin, Source: NOAA – GLANSIS 2017

Dreissenid Mussels - This sub-indicator reports on the abundance and distribution of Zebra and Quagga mussels in the Great Lakes basin. The SOGL Technical Report provides a wealth of detailed information and rationale for the overall assessment of Fair with a Deteriorating trend for this sub-indicator. The population status varies widely depending on depth and the particular region of the lake. In Lakes Michigan, Huron and Ontario, Quagga mussels have replaced Zebra mussels everywhere except in shallow nearshore areas and are expanding populations in deep water (>90m). The status of Lake Superior is good and unchanging with small populations thought to be due to calcium concentrations that are too low to support larger populations. Populations in Lake Erie appear to have peaked and are not expanding.

Dreissenids have re-engineered the Great Lakes food web and altered nutrient and energy cycling Hecky et al., 2004). They promote nuisance algal blooms and benthic algae and either directly or indirectly cause harm to native species. They are linked to changes in the open water benthic community, decreases in native *Diporeia*, an important benthic food source as well as changes in phytoplankton abundance and composition (ECCC and USEPA, 2017).

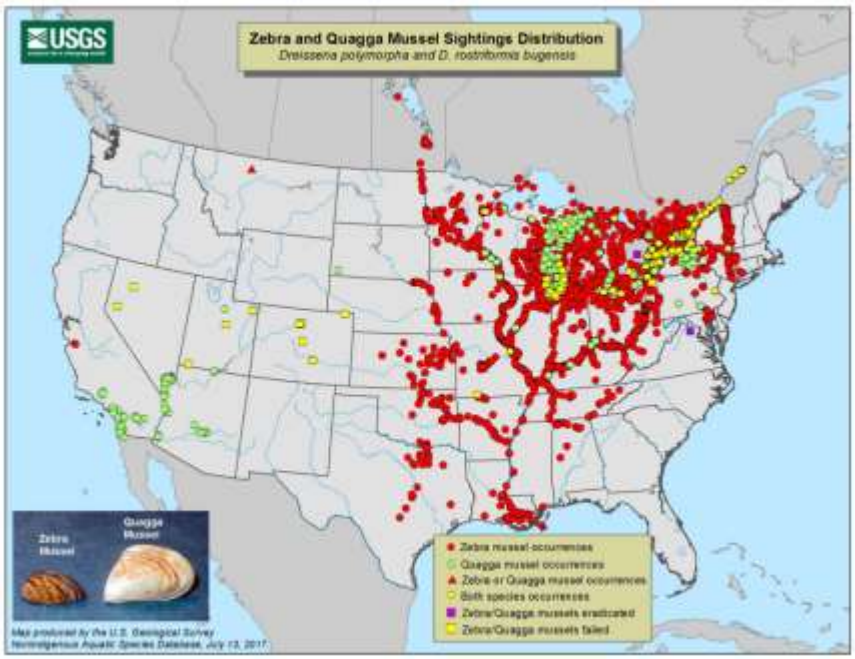


Figure 5.7.2 Distribution of Zebra and Quagga Mussels, Source: USGS

An important message that is clear from the SOGL Technical report is the importance of providing for sustained programs that conduct monitoring for dreissenids on a regular basis in all lakes in both the US and Canada. The report also calls attention to the need to assess mussel biomass as well as abundance and the importance of understanding how and when populations might become stable and at relative equilibrium with the environment. Improved understanding of the changes underway in Zebra and Quagga mussel populations will lead to predictive models and ultimately, improved Great Lakes resource management (ECCC and USEPA 2017).

Sea Lamprey – This sub-indicator reports on the abundance and distribution of sea lamprey. This sub-indicator has an overall assessment of fair and improving with sea lamprey abundance currently suppressed by about 90% from peak levels and Table 5.7.2 summarizes the most recent information from the Great Lakes Fishery Commission. The IJC Science Advisory Board (2016) identified sea lamprey abundance as one of eight sub-indicators that would be most effective for communicating with the public about the condition of the Great Lakes (SAB, 2016).

Credit: US Fish and Wildlife Service

Table 5.7.2.2016 Sea Lamprey and Lake Trout Abundance

Lake	Sea Lamprey Abundance	Wounds on Lake Trout	Lake Trout Abundance
Superior	Above target, decreasing	Above target, holding steady	Holding steady
Michigan	Meeting target, holding steady	Above target, decreasing	Holding steady
Huron	Above target, decreasing	Above target, holding steady	Holding steady
Erie	Above target, holding steady	Above target, holding steady	Holding steady
Ontario	Meeting target, holding steady	Meeting target, decreasing	Holding steady

Target levels for sea lamprey abundance range from less than 5000 for Lake Erie to over 50,000 for Lake Huron. (GLFC, 2017)http://www.glfc.org/status.php

Figure 5.7.3 displays the dramatic improvement resulting from sea lamprey control efforts.

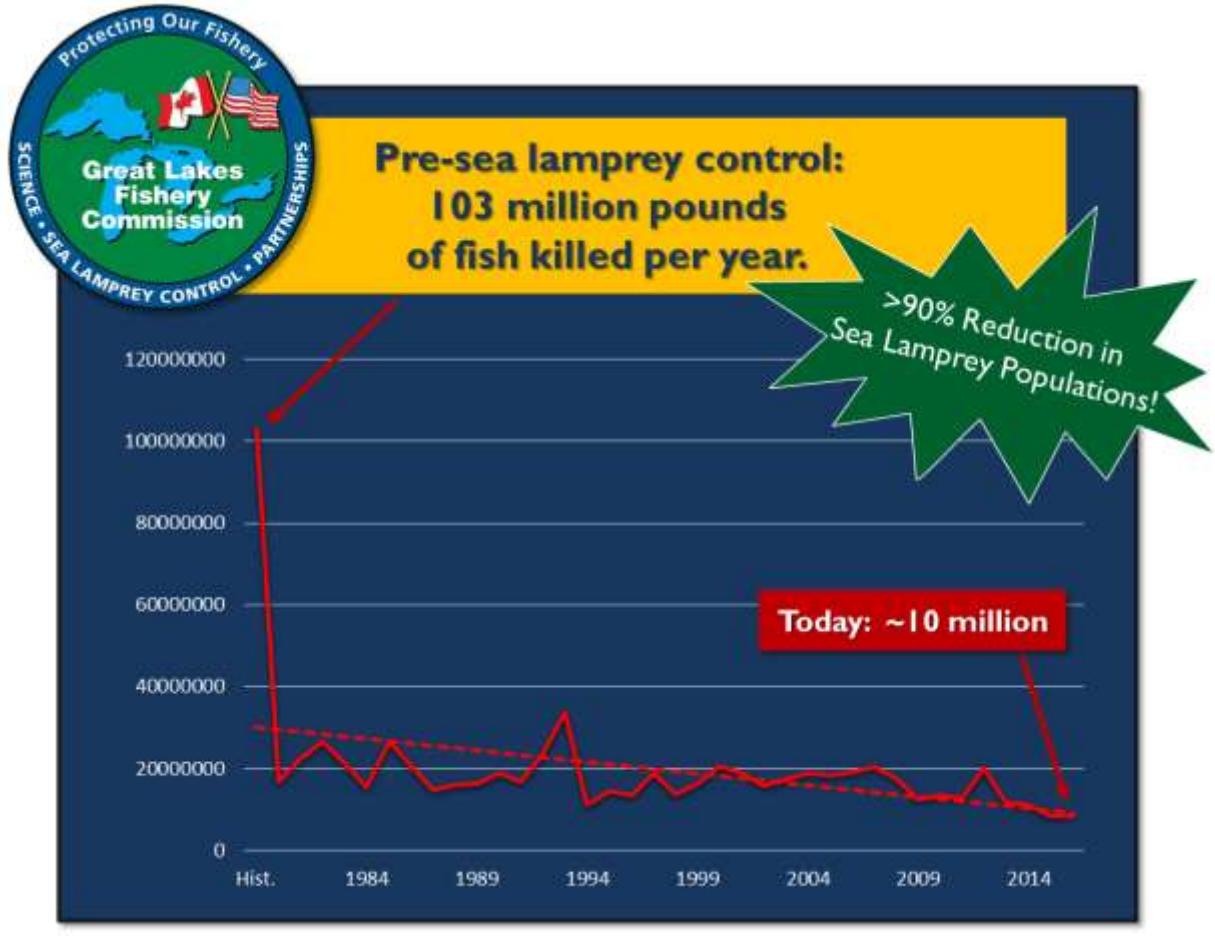


Figure 5.7.3 Reduction in fish killed as a result of a >90% reduction in Sea Lamprey Populations Associated with Control Actions.Source: GLFC, 2017

The SOGL Technical report identifies important management actions and areas where further effort is needed in the Great Lakes to reduce what is still a significant cause of native fish

mortality. Securing increased funding to continue and expand lampricide treatments, improve methods and find previously unidentified sources of sea lamprey in the Great Lakes watershed is identified as a key factor for advancing sea lamprey control (ECCC and USEPA 2017.

Terrestrial Invasive Species – This sub-indicator is based on five species of interest: Asian longhorned beetle, emerald ash borer, garlic mustard, *Phragmites*(Common Reed) and purple loosestrife. These five species were selected for this sub-indicator because of their significant and widespread impact on the Great Lakes. Terrestrial invasive species can cause an array of ecosystem impacts, including choking out native wetland plant species and deforestation which may lead to increased sediment, chemical and nutrient loading to the Great Lakes. Forests and wetlands play a key role in stabilizing soil and filtering run-off, serving to protect sources of public drinking water and native species habitats. The overall assessment of this sub-indicator is: Poor and Deteriorating.

The SOGL Technical Report provides a detailed lake-by-lake assessment of the impact and spread of the five species of interest. In general, it appears that two of the five species - the Asian longhorned beetle and purple loosestrife are being successfully controlled. The Asian longhorned beetle by quarantine and tree removal, andpurple loosestrife by the use of natural predators which selectively target the plant. In contrast, emerald ash borer, garlic mustard and *Phragmites* appear to be continuing to spread throughout the basin. These three pose a significant challenge and threat – Emerald ash borer is responsible for the degradation of just under 70,000 hectares of forest in Ontario between 2004 and 2012, garlic mustard is considered one of the most invasive non-native plants in North America. In 2005 Phragmites was branded the worst invasive plant species in Canada by Agriculture and Agrifood Canada (ECCC and USEPA, 2017).

These terrestrial invaders can significantly degrade habitat and adversely impact wetlands and water quality and the SOGL Technical Report provides a strong rationale for the lake-by-lake assessments.

Important take-home messages include the need for intensive collaboration on long term monitoring, the value of radar imagery as a means to detect the presence of large stands of *Phragmites* and the value of the Early Detection & Distribution Mapping System (EDDMapS). EDDMaps is used extensively in both the US and Ontario as a platform for gathering geographic information about the distribution of terrestrial and aquatic invasive species in Canada and the US (ECCC and USEPA 2017).

The distribution maps included in the 2017 SOGL report for the Common Reed *Phragmites*, figures 5.7.4 and 5.7.5 below, show a dramatic increase in distribution of this highly invasive plant since 1961. Trends shown by this sub-indicator and others addressed in the 2016 SOGL report illustrate the need to develop new methods and control technology to combat the spread of invasive species and reverse this trend. The use of herbicides is recommended as the primary control method for non-native *Phragmites* as part of a comprehensive integrated management program that uses chemical treatments along with other methods like fire, mechanical treatment or flooding. Control of Phragmites, especially large well-established infestations, will require multiple treatments using a combination of methods(MI DEQ 2014). Regulations on the use of

herbicides vary between States and Provinces and permits are required, additionally formulations and requirements change for use near or over water, in addition treatment timing will vary by region. In Canadian Provinces, no herbicides have been approved for use over water. (GLPC 2015)

Figure 5.7.4.*Phragmites* Observations in the Great Lakes (1948-1961)

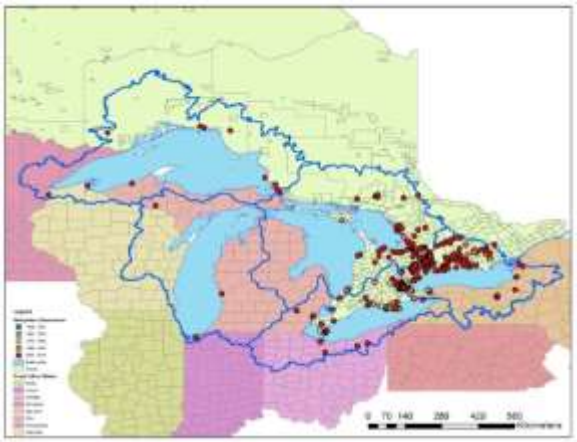


Figure 5.7.5 . *Phragmites* Observations in the Great Lakes (1948-2015) Source: ECCC and USEPA 2017 ;EDDMapS 2017

Phragmites Infestation

Photo - Leslie J. Mehrhoff, University of Connecticut, Bugwood.org

Common Reed (*Phragmites australis*) may grow as tall as 19 feet tall (6 meters) and can quickly crowd out native species by exuding a compound that kills the roots of neighboring plants. Its dense mass blocks light to other plants, changes wetland hydrology, alters wildlife habitat and increases fire potential. It spreads both by seed dispersal and by the spread of vegetative fragments of rizomes that break off and take root in new locations. It grows quickly, up to 4 cm a day vertically and can establish a root system that can measure several meters. (NOAA-GLANSIS 2017), (OMNR 2011)

The four sub-indicators of high-impact species found in the Great Lakes basin and the total number of non-natives in the Great Lakes strongly reflect the overall status and trend determinations for the AIS indicator. The testing of a framework for assessing the effectiveness of programs and other measures under the Great Lakes Water Quality Agreement completed for the IJC (Johns et al, 2016) showed increasing concern about the spread of previously established aquatic and terrestrial invasive species in the Great Lakes basin, and supports the assessment in the 2017 SOGL report. The _____ study also supports the notion of providing additional information regarding high-impact AIS like Sea Lamprey and Dreissenid Mussels. Hence, the sub-indicators selected by the Parties, taken into account with the narrative, effectively communicate progress on Objective 7 of the GLWQA.

5.7.3 Assessment of the Progress Report of the Parties

The discussion of invasive species in the PROP clearly reflects a strong emphasis on prevention, monitoring, response planning and risk assessment. It shows that significant research and development have been undertaken to develop control and eradication tools. As discussed in further detail below, all of the 2014-2016 priorities for science and action related to invasive species have been addressed and significant progress has been made. As previously noted, progress in these areas has been accompanied by setbacks with the spread of several previously established aquatic and terrestrial invasive species (ECCC and USEPA 2017).

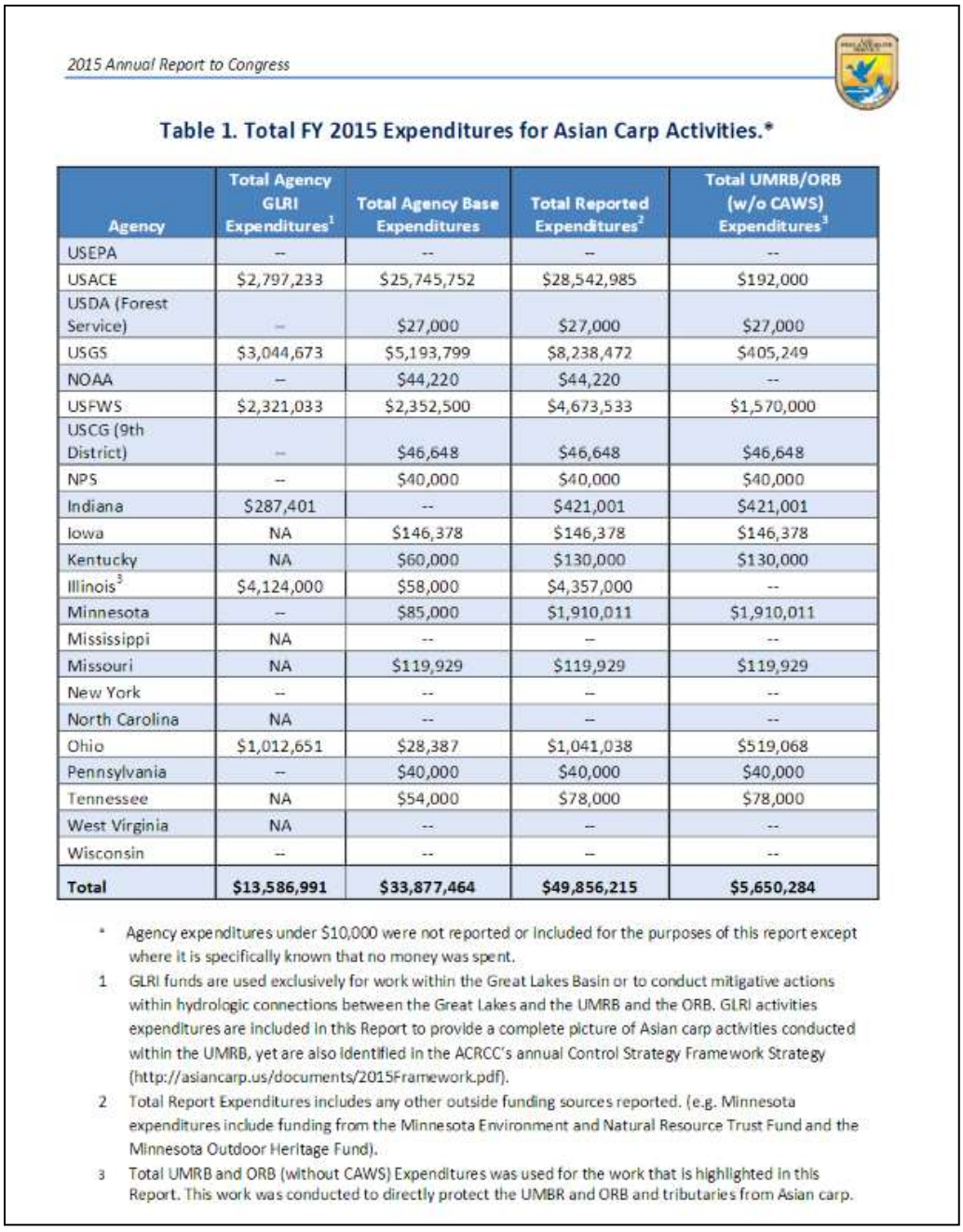
The Parties have taken the approach of making prevention of new AIS introductions the highest priority and emphasizing the need for risk assessment, sustained comprehensive monitoring for new invasive species and public outreach and education. The efforts of the Parties to establish the first basin-wide AIS early detection network are particularly noteworthy, as are new techniques that enable scientists to detect the genetic material from organisms though water samples.

The PROP demonstrates the positive impact of program funding towards AIS. Executed in 2010, the US Great Lakes Restoration Initiative (GLRI) designated invasive species as one of five major focus areas in its Action Plan, provided much needed funding to implement Great Lakes AIS programs and measures and enabled significant progress. This program is administered by the US Environmental Protection Agency (USEPA) Great Lakes National Program Office, which coordinates awards distributed and managed by numerous federal and state agencies, non-governmental and academic institutions. GLRI funding has supplemented base program funding throughout the reporting period and, because it is channeled through a single agency, GLRI funding data can be easily summarized from the GLRI geo-spatial database. For the first five years of the GLRI, total expenditures for AIS were $276.7 million for over 1,775 projects. This represents approximately 18 percent of GLRI funds channeled through the USEPA to federal partner agencies and grantees. GLRI-funded studies have been completed to assess the risk of introduction and establishment of AIS on the Great Lakes, the risk of AIS spread facilitated by domestic shipping and the potential impacts on Great Lakes food webs and fisheries (USEPA 2015).

During this reporting period, Canada has also made significant investments in AIS initiatives with departmental funding from Fisheries and Oceans Canada (DFO), Canada's Natural Science and Engineering Research Council, Environment and Climate Change Canada (ECCC), the Ontario Ministry of the Environment and Climate Change, the Ontario Ministry of Natural Resources and Forestry (OMNRF), the non-profit Invasive Species Centre and numerous other sources. Details of program expenditures for both US and Canadian AIS initiatives are described in the sections below.

The PROP provides much detail on the commitment of resources and results coming from efforts to prevent the introduction and to control the spread of Asian Carps through the Chicago area waterways and other physical connections to the Great Lakes. The term Asian Carp is very broad and includes the naturalized and abundant common carp, grass carp, black carp and the bighead & silver carps. For the purposes of the PROP and in this triennial assessment report, the term

Asian Carp is used to describe a smaller group that includes Bighead carp (*Hypophthalmichthysnobilis*), Silver carp (*Hypophthalmichthys molitrix*), Grass carp (*Ctenopharyngodonidella)* and Black carp (*Mylopharyngodonpiceus)* (USGS, 2016). The government's efforts directed at these species are highly effective and worthwhile.



2015 Annual Report to Congress

Table 1. Total FY 2015 Expenditures for Asian Carp Activities.*

Agency	Total Agency GLRI Expenditures[1]	Total Agency Base Expenditures	Total Reported Expenditures[2]	Total UMRB/ORB (w/o CAWS) Expenditures[3]
USEPA	--	--	--	--
USACE	$2,797,233	$25,745,752	$28,542,985	$192,000
USDA (Forest Service)	--	$27,000	$27,000	$27,000
USGS	$3,044,673	$5,193,799	$8,238,472	$405,249
NOAA	--	$44,220	$44,220	--
USFWS	$2,321,033	$2,352,500	$4,673,533	$1,570,000
USCG (9th District)	--	$46,648	$46,648	$46,648
NPS	--	$40,000	$40,000	$40,000
Indiana	$287,401	--	$421,001	$421,001
Iowa	NA	$146,378	$146,378	$146,378
Kentucky	NA	$60,000	$130,000	$130,000
Illinois[3]	$4,124,000	$58,000	$4,357,000	--
Minnesota	--	$85,000	$1,910,011	$1,910,011
Mississippi	NA	--	--	--
Missouri	NA	$119,929	$119,929	$119,929
New York	--	--	--	--
North Carolina	NA	--	--	--
Ohio	$1,012,651	$28,387	$1,041,038	$519,068
Pennsylvania	--	$40,000	$40,000	$40,000
Tennessee	NA	$54,000	$78,000	$78,000
West Virginia	NA	--	--	--
Wisconsin	--	--	--	--
Total	**$13,586,991**	**$33,877,464**	**$49,856,215**	**$5,650,284**

* Agency expenditures under $10,000 were not reported or included for the purposes of this report except where it is specifically known that no money was spent.

1 GLRI funds are used exclusively for work within the Great Lakes Basin or to conduct mitigative actions within hydrologic connections between the Great Lakes and the UMRB and the ORB. GLRI activities expenditures are included in this Report to provide a complete picture of Asian carp activities conducted within the UMRB, yet are also identified in the ACRCC's annual Control Strategy Framework Strategy (http://asiancarp.us/documents/2015Framework.pdf).

2 Total Report Expenditures includes any other outside funding sources reported. (e.g. Minnesota expenditures include funding from the Minnesota Environment and Natural Resource Trust Fund and the Minnesota Outdoor Heritage Fund).

3 Total UMRB and ORB (without CAWS) Expenditures was used for the work that is highlighted in this Report. This work was conducted to directly protect the UMBR and ORB and tributaries from Asian carp.

Table 5.7.3 Total FY 2015 Expenditures for Asian Carp Activities
Source: USFWS, USEPA 2015

The Asian carp program is a mature, well developed effort, supported by domestic regulations, that has influenced the development of strategic and tactical AIS response plans throughout the

region by demonstrating the effectiveness of unified incident response management. The 2016 Asian Carp Monitoring and Response Plan; and Upper Illinois River Asian Carp Contingency Response Plan serve as excellent examples. An extensive amount of information has been made available through a robust public outreach and education effort with both US and Canadian sites at www.asiancarp.us and www.asiancarp.ca.

As discussed in the PROP (Governments of the United States and Canada. 2016), the historical rate of discoveries of new non-native species increased to one new discovery every eight months up until about 2004 (ECCC and USEPA 2017) . The highest rate is observed to coincide with the period between the opening of the St. Lawrence Seaway and implementation of strict, mandatory ballast water management regulations. It is significant that, with increased vigilance, greater understanding of the impacts of AIS and improved monitoring, the number of non-native species in the Great Lakes has held steady at approximately 185 for the past decade. The proactive approach of the Parties to conduct AIS risk assessments and establish watch lists will improve understanding of the potential impacts of AIS that have not yet been discovered and help guide response actions if and when they are discovered. The success of ballast water management efforts discussed in the PROP and in subsection on Annex 5 below shows that sustained success in preventing new introductions of AIS is reflected in the rate of discovery and demonstrates the value of regulating pathways of introduction of invasive species.

The need for effective multi-organizational coordination of AIS response is an important issue that has been addressed by the Parties. This was highlighted by a 2012 study commissioned by the IJC showing that in just a small portion of the Great Lakes basin, there were 100 Canadian and US public and non-governmental organizations somehow involved with AIS response (Donahue et. al., 2013). Close cooperation with the Great Lakes Panel on Aquatic Nuisance Species (Governments of the United States and Canada, 2016) was a key element in harmonizing national and binational efforts. Communications have been enhanced by the network of contacts developed over the past 25 years by the ANS Panel. Effort and funding by the Parties has resulted in an impressive list of accomplishments over the past several years (Governments of the United States and Canada, 2016).

5.7.4 Assessment of Annex implementation

1. Annex 6 – Aquatic Invasive Species

Review of 2014-2016 priorities for science and action

The 2014-2016 Science Priorities for Annex 6 – Aquatic Invasive Species (Governments of the United States and Canada, 2016b) include:

- undertake ecological assessments of AIS prevention programs;
- develop and evaluate early AIS detection technologies and methods;
- research and develop technologies and methods for control and eradication of AIS;
- determine the effects of habitat and climate change on risks of AIS establishment; and
- implement and evaluate risk assessments of species, pathways, and vectors of AIS.

The process for conducting ecological assessments of AIS prevention programs has been initiated by the Parties by establishing performance measures and strategic outcomes for key programs. These metrics may be compared with the conditions reported in the State of the Great Lakes report to assess progress. For example, the Fisheries and Oceans Canada Report on Plans and Priorities for 2016-2017(2016) shows that performance measures have been established relative to communicating AIS related science, Sea Lamprey abundance, monitoring and early detection of Asian carps. Similar program metrics have been established by US agencies, for example, the Great Lakes Restoration Initiative Action Plan has established metrics including the number of: GLRI-funded projects that help block pathways through which aquatic invasive species can be introduced to the Great Lakes ecosystem, number of tributary miles protected, early detection monitoring activities conducted, Great Lakes rapid responses or exercises conducted, new technology field tested and information-sharing collaboratives developed. If both countries establish comparable program measures, the Parties could enable program assessment by comparing programmatic trends with indicator trends reported in the SOGL report. By providing for sustained monitoring and reporting of these measures over successive triennial cycles, the Parties may demonstrate a commitment to the guiding principles of accountability, adaptive management, science-based management and sustainability as specified in Article 2 of the GLWQA.

AIS detection, monitoring, eradication and control for numerous species have benefitted from the emphasis placed on Asian carp during this triennial reporting period. Monitoring efforts for many different species have benefitted from the investments made in developing techniques for detecting genetic markers for Asian Carp. New control technology includes seismic pressure "water guns" and carbon dioxide that have been tested as a means to both block and herd Asian carp and other fish. New nets and methods for deploying nets that have proven successful in China have been tested. These methods to direct and concentrate fish may be used in tandem with other technologies to improve gear efficiency. The level of effort and funds spent on Asian carp control are well-justified given the potential impacts these carp can cause and by the extent to which the response procedures and control technology developed for Asian carps may be applied to the eradication and control of many other species.

In addition to developing early detection technologies and methods, the need to effectively report detections and share that information among all the agencies conducting AIS monitoring is critically important to informed management decisions. Significant progress has been made in this aspect as demonstrated in the response to detections of Grass Carp in the Great Lakes during this reporting period.

Information sharing has been greatly enhanced through the use of geo-spatial databases and the US Geological Survey (USGS) maintains a Nonindigenous Aquatic Species (NAS) database, which includes records of diploid and triploid Grass Carp (in addition to hundreds of other species). The data are accessible at: http://nas.er.usgs.gov/. The advanced version of the site allows users to access either collection information or generate a map, which can be examined from fine to coarse scale. The database information relies on voluntary submissions, and would be incomplete if agencies did not cooperate in regularly providing data. These include the Aquatic Nuisance Species (ANS) task force and several Great Lakes ANS Panel agencies, including USGS, OMNRF, DFO and several state agencies. The NAS database has become the

primary database for depositing their collection data and scientists from these key agencies appear to be equally committed to ensuring this database is up-to-date. This results in a database with only minor gaps. For example, the Grass Carp data are largely complete, and as of August 2016 the only missing data were about several fish captured in the Hudson River. An example map of Grass Carp observations is provided in Figure 5.7.6.

Figure 5.7.6 Map of Grass Carp Observations from NAS Database, USGS 2017

Another excellent example of information sharing as well as the potential that exists in "citizen science" is a geographic information system that employs volunteered information that has proven instrumental in mapping terrestrial invasive species in the Great Lakes region. EDDMapS is supported by the National Park Service, US Forest Service, the Ontario Federation of Anglers and Hunters and a number of other organizations. Although there are some limitations, efforts are instituted to provide a measure of quality assurance and efforts such as this need to be further developed and improved to provide a greater understanding of the extent of terrestrial invasive species. The potential of this approach was also highlighted during public comments at the 2016 Great Lakes Public Forum. Such tools will be critically important for increased understanding about how climate change and other factors affect the spread of terrestrial invasive species. More information about this initiative is provided at the following link: https://www.eddmaps.org/ontario/.

Other significant advances have been made in applied AIS research related to control and eradication. These include the synthesis and testing of Sea Lamprey pheromones for the purpose of increasing efficiency of control measures, the use of a highly targeted compound from a dead soil bacterium that kills Zebra and Quagga mussels while sparing native mussels and other organisms, methods to deliver piscicides and molluscicides in a highly targeted manner, and "gene silencing" technology which has the potential to control the spread of invasive Phragmites (USEPA, 2015). Field testing and proving all these new technologies has been assigned a high

priority by the Parties, which is appropriate, given the great potential benefits (Governments of the United States and Canada, 2016).

However some obstacles remain. Specifically, the approvals and permits to use chemical control agents vary greatly between the United States and Canada. Given that the challenge of AIS cuts across geographical boundaries, it is important to institute effective and consistent control strategies throughout the Great Lakes. Effective and consistent control strategies could include finding common ground on the safe and environmentally responsible use of all types of control measures, harmonizing permitting, removing administrative barriers and adopting an integrated approach to AIS management.

Significant progress has been made on risk assessments, which also incorporate to some extent the over-arching issues of habitat and climate change. The US Fish and Wildlife Service (USFWS) has made 63 screening risk assessments of high-risk fish, crustaceans and mollusks available at: https://www.fws.gov/fisheries/ans/species_erss_reports.html, in addition to assessments of organisms considered low or uncertain risk. Also, the Canadian Centre of Expertise for Aquatic Risk Assessment provides easy access to more than 70 AIS risk assessments for plants and animals and provides an extensive list of references on methods.

Review of time-bound commitments

The GLWQA included time-bound commitments in the AIS Annex which have been met by the United States and Canada. Progress the Parties have made in large part resulted from leveraging the existing, extensive network of federal, state, provincial, and local government agencies and non-government organizations with a depth of AIS related experience. More details of these existing programs are provided in part 5.7.5. These commitments are:

Within two years of entry into force of the GLWQA, develop and implement an early detection and rapid response initiative that:

- develops species watch lists;
- identifies priority locations for surveillance;
- develops monitoring protocols for surveillance;
- establishes protocols for sharing information;
- identifies new AIS; and
- coordinates effective and timely domestic and, when necessary, binational response actions to prevent the establishment of newly detected AIS.

Significant progress was reported by the two Parties related to these time-bound commitments and documented in the December 2015 List of EDRR Achievements and Activities presented to the Great Lakes Executive Committee. The following accomplishments were reported by the Parties:

- Priority locations in the United States to undertake surveillance for the potential introduction of species on the watch list have been identified, and sampling locations were developed in partnership with states and Tribes.

- Hotspots of historical invasions resulting from ballast water discharge were identified based on ecological niche modeling and using sampling techniques developed for a study in Lake Superior by (Grigorovichet al.,2003).
- Connections with the Mississippi River system (http://glmris.anl.gov/).
- Locations near major cities, where live bait, live food, aquaculture, aquarium pet, water garden, biological supply, and water-related recreation are concentrated.

These priority surveillance locations have been identified based on history of invasions in the Great Lakes, risk assessments that describe potential points of invasion into the Great Lakes, and cities where human-mediated invasional pathways are most concentrated. Those pathways include the live bait, live food, aquaculture, aquarium pet, water garden, biological supply, and water-related recreation. Locations sampled for Asian carps were developed based on associations with projected spawning habitats.

In the United States, monitoring and surveillance protocols were developed in partnership with states and tribes. Schloesser and Quinlan (2015) provide a detailed summary of eDNA methods and results related to US sampling that are available at http://www.fws.gov/midwest/fisheries/eDNA.html.

The US Fish and Wildlife Service is monitoring the fish community to detect any new non-native fish in several locations in Lake Superior including the St. Louis River, Upper St. Marys River, Thunder Bay, and Chequamegon Bay (USFWS 2014).

In the United States, protocols for sharing information were developed, which include information being shared among the Fish and Wildlife Service and each state, and also under the aegis of the Great Lakes Fishery Commission's Lake and Technical Committees.

With the possible exception of the previously unreported non-native invertebrate zooplankton species *Thermocyclops crassus* in the western basin of Lake Erie, described above, no new non-native species have become established in the Great Lakes since 2006, well before the start of the 2012 GLWQA. Some specimens of Grass carp have been collected in the Lake Erie system and are reproducing but fishery scientists do not consider the population to be proven as established and self-sustaining (Embke et al. 2016).

Canada and the United States continue to undertake activities such as the coordination of plans and preparations for any response actions necessary to prevent the establishment of newly detected AIS and to be prepared in the event of the identification of newly detected AIS in the Great Lakes. All of the activities listed below are enhancing the ability of agencies to respond to newly detected AIS in the Great Lakes:

- *Cooperative State and Ontario/Canada Asian Carp Response Plans* are in place in Ohio and Michigan. All eight Great Lakes states have AIS Management plans in place(http://www.anstaskforce.gov/stateplans.php), and all of those plans include AIS response plans that can be implemented for Asian carps and other AIS.

- *Governors' and Premiers' Mutual Aid Agreement* (MAA); Link: http://www.cglslgp.org/media/1564/ais-mutual-ai d-agreement- 3-26-15.pdf is in place to: prevent the introduction and spread of AIS in the Great Lakes; foster mutual aid among the Great Lakes states and provinces to respond to serious threats to the Great Lakes Basin from AIS; and encourage further cooperative actions by the parties to combat AIS. One of the projects recently initiated under the MAA is an innovative pilot program by Michigan, Ohio and Ontario to harmonize approaches to address AIS risk, and further cooperation among those three jurisdictions (http://www.cglslgp.org/medi a/1591/ais-harmonization- resolution-6-13-15.odf).

- *Incident Command System training* has been delivered in various venues, including the "Table-top" exercise convened by the AIS Annex Subcommittee and its partners. Table-top response exercises for Asian carp and other species have been conducted within and among jurisdictions to enhance preparedness for a possible detection of additional AIS in the Great Lakes. Those exercises evaluate plans and procedures, clarify roles and responsibilities, develop effective agency relationships, assess resources and capabilities, and identify needs and solutions. One such exercise was convened under a partnership of the AIS Annex Subcommittee, Michigan, Ohio, Ontario, the IJC, and others. The After Action Report from the exercise will summarize the test scenario process and any lessons learned. Another such exercise was convened under the newly created Great Lakes Interstate Management Plan. Individual states continue to conduct exercises that include cross-agency relationships, assessing resources and capabilities, and identifying needs and solutions.

Under the Council of Great Lakes Governors and Premiers MAA:
- Illinois and Indiana convened a *Ruffe Detection Exercise* in 2015. Other Great Lakes states were invited to participate.
- Michigan and Ohio convened a *Grass Carp Detection exercise* in Lake Erie. That exercise was convened as the result of Grass Carp detections in the Lake Erie system.
- DFO and OMNRF coordinated a *Grass Carp response* along with partners, executing a full Incident Command Response to complete intensive surveys. A laboratory analysis was undertaken on the samples to determine fertility, origin, and age testing. The work was coordinated with USGS experts and indicated that all Grass Carps found were large adults originating from ponds, two were found to be sterile (triploid) and six were fertile (diploid).

The USUSFWS and OMNRF undertook a number of detection and response initiatives to prevent the spread of AIS throughout the reporting period. For example, 2015 reports to the Great Lakes Executive Committee include:
- USFWS eDNA sampling for Bighead carps conducted in 2015 - From the 5,028 water samples collected, none were eDNA positive.
- OMNRF eDNA sampling in 2015 - From the 848 water samples collected, two positive samples were found however no fish were found. eDNA sampling from Bay of Quinte and Toronto area were added after discoveries of Grass carp (see bullet below).
- USFWS 2015 sampling included:
    - 348 invertebrate samples in Lakes Superior, Michigan, and Erie
    - 248 samples of newly hatched fishes in Lakes Superior in 2015. From the 35 Early Detection locations sampled across Lakes Huron, Erie, Superior and Ontario (800

field sampling sites) Grass Carp was discovered in Lake Ontario and Lake Erie during July to September, 2015.

Up to date details of sampling are provided by the USFWS at the following link: https://www.fws.gov/midwest/fisheries/eDNA.html

In November 2016, the Grand Traverse Band of Ottawa and Chippewa Indians (GTB) developed an AIS Management Plan aimed at preventing and/or minimizing the impact of AIS on the natural resources critical to the Grand Traverse Band. Additionally, other Tribes have developed Great Lakes Tribal Aquatic Invasive Nuisance Species Management Plans through US GLRI grants.

During public consultation on the draft Triennial Assessment of Progress report and the PROP in 2017 the IJC received comments that questioned the costs and benefits of invasive species of rapid response and eradication. The IJC studied a wide range of aspects regarding AIS rapid response in a series of board reports and biennial reports over the past 20 years, including GLRI funded reports on AIS rapid response completed in 2013. The GLRI funded work included a jurisdictional analysis and pilot rapid response plan that were discussed during the 2017 International Association for Great Lakes Research (IAGLR) Conference in Detroit. Those studies recognized that prevention of invasive species needed to remain a top priority, but that early detection and rapid response capacity was a necessity in the event that invasive species prevention efforts failed. The collaborative efforts and response actions that occurred during the implementation of the 2012 GLWQA have shown significant progress in developing and exercising the capacity for early detection, response and eradication of invasive species. (Donahue et. al. 2013)

2. Annex 5 Discharges from Vessels

The two governments have long standing regulatory programs and measures, supported by domestic legislation, to address discharges from vessels. International shipping conventions are enforced by both governments, and legislation such as the Federal Water Pollution Control Act, the Comprehensive Environmental Response Compensation, and Liability Act, the Clean Water Act, National Aquatic Invasive Species Control Act, and the Canada Shipping Act provide a solid foundation for regulatory programs. As reported in bi-annual reports by the USCG, USEPA, Transport Canada and DFO between 1988 and 2012, both countries have greatly reduced ship-source pollution. This has been accomplished through internationally consistent regulation of all aspects of the commercial shipping industry including the ship's design, operating requirements, inspection and certification as well as licensing of crew members.

Key commitments in Annex 5 relating to the AIS general objective relate to ballast water discharges.

The International Maritime Organization's (IMO) 2004 Ballast Water Management (BWM) Convention, met the requirements for entry into force on September 8, 2016, when Finland ratified the convention. The convention stipulates that it will enter into force 12 months after ratification by a minimum of 30 States, representing 35 percent of world merchant shipping

tonnage. Finland's accession brought the combined tonnage of contracting States to the treaty to 35.1441 percent, with 52 contracting Parties. As a result, the BWM Convention will enter into force on September 8, 2017.

The BWM Convention was adopted in 2004 by the IMO, the United Nations specialized agency with responsibility for developing global standards for ship safety and security and for the protection of the marine environment and the atmosphere from any harmful impacts of shipping. The convention reflects the input of science to reduce risk and is influenced by the Great Lakes region. Canada chairs the IMO ballast water review group (IMO, 2016).

Canada provided a position paper to the IMO 68th session of the Marine Environment Protection Committee in March 2015 addressing details of implementation and will move forward with implementing the provisions in its domestic legislation. Unlike Canada, which acceded to the convention on April 8, 2010, the United States has not signed on to the IMO convention. However, in March 2012 the US Coast Guard (USCG) adopted the same discharge standard in its regulations.

Joint ballast water management efforts conducted by the United States and Canada are described in the annual summary of the Great Lakes Seaway Ballast Water Working Group. The group is composed of representatives from the St. Lawrence Seaway Development Corporation, St. Lawrence Seaway Management Corporation, Transprot Canada – Marine Safety and Security and the USCG. Consistent with previous years, the 2015 report shows that 100 percent of ships entering the Great Lakes received ballast management exams on each Seaway transit. In total, all 8,361 ballast tanks were assessed during the 455 vessel transits. Regulations require all ships entering the Great Lakes St. Lawrence Seaway from outside the Exclusive Economic Zone (a zone extending out up to 200 nautical miles from the territorial sea) to conduct ballast water exchange or flushing. Both governments have coordinated enforcement programs to achieve nearly 100 percent compliance. Ships that did not exchange their ballast water or flush their ballast tanks at sea were required to either retain the ballast water and residuals on board, treat the ballast water in an environmentally-sound and approved manner, or return to sea to conduct a ballast water exchange. Ships that were unable to exchange their ballast water/residuals were required to retain them onboard. Verification exams conducted on outbound voyages of ships exiting the Seaway and 100 percent screening of ballast water reporting forms indicated that there was no non-compliant ballast water discharged in the Great Lakes Seaway system in 2015. Continued high vessel compliance rates for the 2016 navigation season are anticipated.

The spread of AIS already in the lakes may be exacerbated by ships that pick up ballast water at one port in the Great Lakes and travel to another port and then discharge ballast water. To address the spread of AIS by this pathway, the regulation of ballast water discharges from "Lakers", ships that remain within the Great Lakes, is being considered by Transport Canada as well as several States. Lakers are currently exempt from US Coast Guard ballast water management requirements although they are required to report ballast water practices and keep ballast water records. When the USCG published their rules in 2012, in the preamble to the rule they stated their intent to revisit the decision to exempt Lakers from ballast water management requirements. At that time, the USCG conducted a Laker engineering evaluation and found that

using a ballast water management system or discharging to shore would be relatively impracticable at the time.

In the 5 years since the USCG rules were established, there has been significant progress in developing new treatment systems, type-approved systems exist and it may eventually become practicable to treat ballast water discharges from Lakers despite several characteristics that makes ballast treatment challenging. Such characteristics include ballast capacity that may be three times larger and ballast pumping rates over 10 times faster than salt water ships (see Figure 5.7.7), short voyages that are a matter of days, lack of tank coatings and less than one day in port. Lakers currently adhere to a set of best management practices required by USEPA's vessel general permit and founded on practices developed by the industry in 1993. (LCA 2016; Rayburn 2016). Regulations also would need to consider the risk associated with Laker operations, for example there are some Lakers that transit the seaway to the Gulf of St. Lawrence and do not always remain within the lakes. In the 2017-2019 priorities for science and action, the two governments have agreed to seek consistency and compatibility between US and Canadian ballast water requirements and this should provide a path towards compromise and harmonious joint implementation for both Lakers and seagoing vessels.

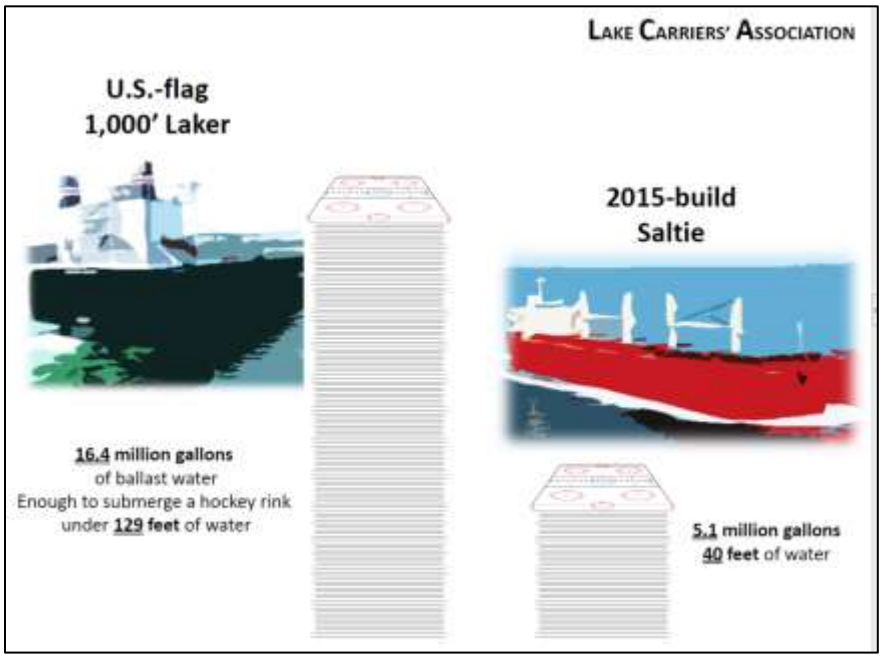


Figure 5.7.7 Comparison of Laker and Saltie, Rayburn 2016

In 2010, Canada allocated $4 million per year to DFO for the implementation of the Invasive Alien Species Strategy for Canada. The strategy was developed in 2004 by the federal, provincial and territorial Canadian Council of Fisheries and Aquaculture Ministers. A Canadian Action Plan to Address the Threat of Aquatic Invasive Species developed under the strategy, calls for the prevention of unwanted introduction, early detection of potential invaders, rapid response to prevent the establishment of aquatic invasive species, and management to contain those species that have already become established. Some of this funding has been used for ballast water management (IAS Strategy, 2004).

US GLRI funding and agency program funds have also provided for developing and refining new procedures for testing the efficacy of ballast water treatment systems in the Great Lakes. Several promising ballast water management systems were performance tested, with many tests conducted at the Great Lakes ballast water testing facility in Superior, WI operated by the Great Ships Initiative. Under US regulations the manufacturer of a Ballast Water Management System approved by a foreign administration can request a USGS determination that its system complies with US ballast water management regulations as an Alternate Management System (AMS) and as of August 2016, the USCG has accepted 65 ballast water treatment systems as AMS. As of July 2016, 38 letters of intent were received by the USCG for systems being submitted for USCG type approval. As of July 2017, the USCG has approved four ballast water treatment systems, marking significant progress in the process of identifying practicable systems for salt water vessels entering the Great Lakes.

The regulatory playing field in the United States is complicated by the fact that as the result of a court decision, the USEPA also regulates ballast water discharges under the Clean Water Act with its Vessel General Permit program, which is implemented in partnership with the states. The current permit program has also adopted the IMO discharge standard, with the additional requirement for vessels entering the St. Lawrence Seaway to continue mandatory ballast water exchange/tank flushing. Transport Canada has also recommended continuation of the practice, although it is not required by federal regulations once the IMO ballast water treatment requirements become instituted by domestic legislation. Mandatory exchange and flushing of ballast water tanks would also no longer be required under the current USCG rules once approved treatment systems are installed. As the "gate keepers" for entry into the Great Lakes, the seaway authorities have made ballast water exchange and flushing a mandatory requirement for entry into the Saint Lawrence Seaway; and have the authority to keep this requirement in place.

The patchwork of requirements and implementation dates has been reduced significantly since 2009 when the US Saint Lawrence Seaway Development Corporation initiated the Great Lakes Ballast Water Collaboration in conjunction with the IJC. The Collaborative fostered improved communication and collaboration between industry, state and federal regulators, and key stakeholders on the issue of ballast water and reducing the risk of invasive species in the region. During this period most state and federal requirements became more consistent, however the complex regulatory regime has created much uncertainty for ship owners. Both countries have stated that they will cooperate in enforcement of BWM regulations and the details of implementation will eventually be worked out over the coming years. However this uncertainty has caused some vessel owners to delay installation of ballast water treatment systems. Other vessel owners, such as FedNav,Canada's largest ocean-going dry-bulk shipowning and chartering group, have already begun installing ballast water treatment systems on newly constructed saltwater vessels under the assumption that the treatment systems will eventually be granted type approval by the USCG.

Harmonizing BWM requirements between the United States and Canada is a stated priority of the Parties for action in the upcoming triennial reporting cycle under the GLWQA. Accordingly, swift action by the two governments to act on this priority and provide clear direction to all segments of the marine industry will facilitate uniform compliance and protect the Great Lakes.

In the meantime, current requirements for 100 percent ballast water exchange of tanks with ballast and salt water flushing of all empty ballast tanks continue to be in effect. These requirements have been effective, as is evidenced by the fact that, with the possible exception of the previously unreported non-native invertebrate zooplankton species *Thermocyclops crassus* in the western basin of Lake Erie described above, no new non-native species has been discovered in the Great Lakes that can be attributed to ballast water discharges since 2006. These requirements are considered the most stringent ballast water management inspection regime in the world and provide a "safety net" protecting the Great Lakes from ship-mediated AIS introductions.

The Ballast Water Working Group concluded that:

"*For any regulatory regime to be effective, the Great Lakes and the St. Lawrence Seaway must be treated as a single system. The only way to ensure consistent ballast discharge regulations across the Great Lakes Seaway system is to have strong federally mandated standards managed by unified federal agency coordination between Canada and the United States in partnership and consultation with the States and Provinces."* (BWWG, 2016)

A strict enforcement regime of mandatory ballast water exchange and flushing could provide an effective backstop to the new treatment requirements.

5.7.5 Assessment of key programs and measures

Numerous programs and measures have been established at all levels of government which support the general objective of preventing the introduction and spread of AIS. For the most part, existing programs have been sustained and new measures implemented in support of the GLWQA. Key programs and measures related to the programs and measures listed in Annex 6 are highlighted below.

1. Great Lakes Panel on Aquatic Nuisance Species

This panel and several others around the country were established by the United States in 1991 by the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (P.L. 101-646). Its purpose is to facilitate collaboration between the national ANS Task Force and state and local government partners on ANS prevention and control programs. The legislation was reauthorized in 1996 as the *National Invasive Species Act* (NISA, Public Law 104-332). Its mission is to "coordinate the development of education, research and policy to prevent new aquatic invasive species from entering the Great Lakes basin and to control and mitigate those AIS populations already established." The panel is staffed by the Great Lakes Commission and draws its membership from US and Canadian federal agencies, Great Lakes states, the provinces of Ontario and Québec, regional agencies, user groups, local communities, First Nations and tribal authorities, commercial interests, and the university/research community. Details about the panel may be found on its website.

Over the past 25 years, the panel has become a mainstay for binational, regional collaboration on policy, research and operational protocols to stop the establishment and spread of AIS. The panel has identified Great Lakes priorities, assisted with the national ANS Task Force, coordinated AIS program activities in the region and advised public and private interests on control efforts. With the growing concerns regarding AIS as reflected in the 2012 Protocol to the GLWQA, the panel has taken on an important role, promoting actions to support the goals set in the Annex 6. The panel continues to make a vital contribution with collaboration on United States – Canada AIS risk-assessments, species-based binational collaborative groups such as the Grass Carp Ad Hoc committee, information sharing, priority species list, and research recommendations.

Organizational relationships and professional contacts established over the many years have a direct, positive impact on the speed and effectiveness of AIS early detection and rapid response. Unfortunately, funding for the panel has declined in real terms. Its funding has never been adjusted for inflation and decreased from $50,000 per year to $40,000 per year in 2012 by sequestration. With the added workload associated with implementation of the 2012 GLWQA, the Great Lakes Panel clearly requires increased funding to sustain its operations. Although direct funding for the Great Lakes ANS Panel has come from the United States, given the benefits of binational cooperation facilitated by the Panel both governments should consider contributing funding. This issue has been brought to the attention of the ANS Task Force by multiple regions and the need is well documented, for further information see: http://glc.org/files/projects/ais/GLP-ltr-regional-panel-funding-10312014.pdf and http://projects.glc.org/ans/documents/ANS%20Panels%20Letter%20to%20ANSTF%20March%203%202009.pdf.

2. Great Lakes Fishery Commission (GLFC)

The GLFC was established by the 1955 Convention on Great Lakes Fisheries to: formulate a coordinated fishery research program between the United States and Canada; make recommendations to governments; formulate and implement a program to control the invasive, noxious Sea Lamprey in the Great Lakes; and establish working arrangements among the fishery management agencies, including provincial, state, tribal and federal authorities.

The GLFC is made up of eight Commissioners (four from each country). Its work is supported by an institutional structure that includes the Board of Technical Experts and the Sea Lamprey Research Board to advise on science, the Sea Lamprey Control Board and committees of citizen advisors. To maintain working arrangements, the GLFC facilitates the implementation of "A Joint Strategic Plan for Management of Great Lakes Fisheries," a multijurisdictional agreement among the basin's fishery management agencies. Through the Joint Strategic Plan, the members work together to develop and implement shared fishery objectives and to harmonize their policies. The process occurs through several Joint Strategic Plan committees including a lake committee for each lake, technical committees, a basin-wide Council of Lake Committees, the Law Enforcement Committee, and the Great Lakes Fish Health Committee.

On June 9, 2016, the Government of Canada announced increases in funding for Sea Lamprey Control. At the Annual Meeting of the Great Lakes Fishery Commission, officials announced that the Government of Canada is making an investment of an additional $8 million over two

years to the Great Lakes Fishery Commission for Sea Lamprey control. This new infrastructure funding will be used to improve physical barriers to prevent Sea Lamprey from gaining access to suitable spawning and nursery habitats in tributaries of the Great Lakes and in new infrastructure to help prevent the spread of invasive Sea Lamprey in the Great Lakes and their tributaries. The investment will be directed towards the maintenance and improvement of low-head physical barriers, as well as the rehabilitation of dams built for other purposes that also serve an important role in Sea Lamprey control.

Sea Lampreys are a highly destructive invasive species. Since entering Lake Ontario over 200 years ago, Sea Lampreys have inflicted significant economic damage and harm to the fishery and ecosystem. Canada's Sea Lamprey Control Program (SLCP) uses several techniques to target Sea Lampreys during different stages of the life cycle including lampricides, physical barriers and trapping. The SLCP has been effective in controlling this aggressive and resilient invasive species, and remains critical in restoring balance to the Great Lakes ecosystem.

3. Canadian Aquatic Invasive Species Network

The Canadian Aquatic Invasive Species Network , funded by the Canadian Natural Science and Engineering Research Council , focused on early detection, rapid response, and reducing uncertainty in prediction and management action success. The network received $400,000 in research council funding from 2013 through 2015 and contributed to efforts in several areas including assisting industries affected by AIS, developing government policy and advancing early detection methods and control technology, but this program has not been continued.

4. Great Lakes Phragmites Collaborative (GLPC)

The GLPC is a partnership established to improve communication and collaboration and lead to more coordinated, efficient and strategic approaches to management of the Common Reed *Phragmites,* restoration of native habitat and research across the Great Lakes basin in both the United States and Canada. The GLPC serves as an effective communication conduit via an interactive website, a webinar series and social media outlets to facilitate access to information and resources, and encourages technology transfer and network building among habitat managers, governmental agencies, and private landowners. This initiative is led by a core team supported by staff from USGS – Great Lakes Science Center and the Great Lakes Commission with oversight and input from a regional Advisory Committee which includes representatives from the public and private sector in the United States and Canada. This effort is part of a broader USGS project funded through the Great Lakes Restoration Initiative and has become a model for effective collaboration across multiple jurisdictions.

*Phragmites*australis was branded the worst invasive plant species in Canada by Agriculture and Agri-food Canada and, as shown in the State of the Great Lakes reports, there has been a dramatic increase in the distribution of this highly invasive plant around the Great Lakes basin since 1961.

The need for further binational collaboration on measures to control its spread becomes apparent when comparing United States and Canadian efforts to control invasive aquatic plants an also shows the utility of the GLPC. While many chemical control agents are approved for use in the United States, only one is approved for use in Canada. Similarly, binational aquatic invasive species control efforts lack a shared or integrated approach to the safe and environmentally responsible use of all types of chemical, physical and biological control measures among jurisdictions. The GLPC is an effective mechanism for identifying common ground on the safe and environmentally responsible use of all types of these measures. This would inform and assist the governments to harmonize permitting and regulations, remove administrative barriers, adopt integrated hazard assessment and implement critical path controls. For *Phragmites* in particular,chemical control used in the United States is not permitted in Canada, though trials are currently underway to evaluate chemical use. In the meantime, this leaves manual cutting and drowning as the primary tools for control in Canada. New control technologies and methodologies identified by a focused effort on *Phragmites*, could be extended to control and eradicate other invasive plants.

5. Invasive Mussel Collaborative

The collaborative was established by USGS, NOAA, GLFC and GLC to advance scientifically sound technology for invasive mussel control. It provides a species-specific framework for communication and coordination. This collaborative has enhanced communications related to response actions and lessons learned, helping responders to new infestations more effectively implement effective control actions.

6. Asian Carp Regional Coordinating Committee

The Asian Carp Regional Coordinating Committee, representing 28 Federal, State/Provincial, Municipal, non-profit and binational organizations from the United States and Canada is a model of multi-jurisdictional collaboration. Asian Carp management activities have transitioned to a more sustainable funding model, with more than 73 percent of 2015 funding coming from Agency base expenditures in the United States and 27 percent provided by grants from the GLRI (Table 3.7.1). Canadian agencies have made significant contributions to this effort, sharing the results of research and initiatives directed at risk assessments, monitoring, early detection and rapid response efforts. The committee has overseen comprehensive monitoring, risk assessment, control and eradication efforts. These efforts have not only added to the knowledge base regarding Asian carp, but have significantly increased the capacity to detect and control other AIS, such as snake head, Sea Lamprey, Eurasian Ruffe, and Zebra Mussels.

7. Invasive Species Centre

The Invasive Species Centre is a Canadian non-profit organization that builds partnerships and supports collaborative projects in natural and applied science, policy research, outreach and education to protect Canada's forests, fields, gardens, waterways and cities from the damaging effects of invasive species. Founded in Ontario, the Invasive Species Centre has a global reach to

address invasive species issues across Canada. Its main source of revenue is from the OMNRF. The Centre provides a well-organized communications platform for other "nested" Canadian programs including: Asian Carp Canada, Forest Invasives Canada and the Early Detection & Rapid Response (EDRR) Network Ontario project.

8. Centre of Expertise for Aquatic Risk Assessment

The objectives of the Canadian Centre of Expertise for Aquatic Risk Assessment were to develop a national standard for conducting biological risk assessments of AIS; educate practitioners on the risk assessment process; develop a process for prioritizing risk assessment needs; provide advice to headquarters on national priorities for risk assessments; coordinate and track progress of national risk assessments and ensure that deliverables are met. As discussed above, the centre contributed significantly to the development of AIS risk assessments supporting Annex 6 goals; however the program was not continued.

9. Ontario detailed-level risk assessment guidelines

The OMNRF finalized this guidance in 2011. The regulation classifies 16 species identified on the Conference of Great Lakes and St. Lawrence Governors and Premiers "Least Wanted Aquatic Invasive Species List" and all species in the family Channidae (Snakeheads) as prohibited under the *Invasive Species Act, 2015*. (Fish: Bighead Carp, Silver Carp, Grass Carp, Black Carp (these four species of carp are commonly known as Asian carp), Snakehead, Stone Moroko, Zander and Wels Catfish. Aquatic Invertebrates: Killer Shrimp, Yabby (crayfish), Golden Mussel. Aquatic Plants: Hydrilla, Brazillian Elodea, Water Soldier, European Water Chestnut, Parrot Feather).

This guidancefollows the 2013 commitment to block these species from entering the Great Lakes basin; and, classifies Phragmites, Dog Strangling Vine and Japanese Knotweed as restricted species under the *Invasive Species Act, 2015*.

10. Great Lakes Aquatic Nonindigenous Species Information System

This is a web-based database consisting of three lists: species nonindigenous to the Great Lakes basin (not native to any part of the basin); range expansion species (native only to a portion of the basin); and a watch list (species not currently found in the Great Lakes but considered to be of high risk). These lists provide an up-to-date accounting of nonindigenous species and have been enhanced during the reporting period link with the USGS NAS system described above. This linkage provides an effective portal for detailed information about the species as well as its distribution and impact.

11. Internet trafficking in AIS

The Great Lakes Commission, with funding from the GLRI and USEPA, developed the Great Lakes Detector of Invasive Aquatics in Trade in 2016. This tool enables users to better understand the risk of AIS being traded on the internet in the Great Lakes region. It also facilitates outreach to internet-based sellers, with information about relevant regulations and potential risks or impacts associated with AIS. The July 2015 phase 1 report is available at the following links: Report, Appendices.

12. Great Lakes Mississippi River Interbasin Study (GLMRIS)

GLMRIS is a US Army Corps of Engineers study that presents a range of options and technologies to prevent ANS movement between the Great Lakes and Mississippi River basins through canals. The study examined 18 other potential connections in addition to the Chicago Area Waterways. This extensive study released several reports during the GLWQA triennial reporting period and added significant information to the understanding of Great Lakes aquatic connections. The final report was released in January 2014 and presents options for addressing or mitigating the impact of the hydraulic connection between the two basins. These options range from a complete physical separation of the Mississippi and Great Lakes basins to options that would maintain a physical connection while creating an ecological separation. Ecological separation is defined as no inter-basin transfer of aquatic organisms via the Chicago Area Waterway System at any time, and the prohibition of movement or inter-basin transfer of aquatic organisms between the two basins. Since the Chicago Area Waterway System serves as a conduit for treated wastewater, provides flood control and an important transportation link there are many factors to consider. The eight alternatives reported in the GLMRIS included a wide range of options for structural and non-structural controls, new technologies, buffer zones and hydrologic separation schemes as well as rough estimates of cost which ranged from $68 M dollars to more than $18 B dollars.

US Army Corps of Engineers costs for the GLMRIS study and the related studies for Eagle Marsh and the Brandon Road Lock and Dam started in US fiscal year 2013 and projected through US fiscal year2019 amount to over $19 M dollars. The Brandon Road Lock and Dam is located downstream of the junction between the Des Plaines River and the Chicago Sanitary and Ship Canal and is a site where effective barriers and other control measures are considered feasible. The draft Brandon Road study report was released for public comment on August 7, 2017. It (describe the report and findings) (USACE 2017 – provide reference and hyperlink report title to web page.)
Further details of the Brandon Road project are available at: Brandon Road Lock Project website.

13. Chicago Area Waterway System Advisory Committee

This advisory committee provides significant support for implementing measures identified by the 2010 Chicago Area Watersways study and GLMRIS follow-on work. This includes testing new AIS control technology that may create a barrier at the Brandon Road Lock and Dam as described in the preceding section.

14. Ontario Conservation Authorities

Ontario has 36 Conservation Authorities - resource management agencies that operate on the basis of local watersheds. Conservation Authorities provide science-based advice and services within their watersheds, undertake biological and fish monitoring and are instrumental in AIS monitoring, removal, and restoration activities, especially for the lower-Great Lakes. They are funded primarily through municipalities (48%) and self-generated revenues (40%). Additional sources of funding for Conservation Authorities are provided by the Province (10%) and Federal government (2%) (2014). In 2012, they engaged 495 landowners and provided $5.9 million in grants to carry out rehabilitation and restoration projects with wetlands, habitats, shorelines and stream & fish habitat. 127 projects were aimed at invasive species.

15. Ontario's Invading Species Awareness Program

The Ontario Federation of Anglers and Hunters , runs a joint program with the Ontario Ministry of Natural Resources and Forestry (OMNRF) called "Ontario's Invading Species Awareness Program" (www.invadingspecies.com). Established in 1992, the program has worked cooperatively to prevent the introduction of invasive species through multiple pathways, including recreational watercraft, use of live bait, and the aquarium, water garden, live food fish, and horticulture industries. The program includes invasive species outreach, monitoring, and stewardship activities. It promotes early detection of new species through citizen reports to the Invading Species Hotline and the Early Detection and Distribution Mapping System (EDDMapS) within North America, the Great Lakes, and Ontario's inland waters.

Potential gaps - The Environmental Commissioner of Ontario (ECO) 2015/2016 Environmental Protection Report (2016), Volume 2, chapter 2 addressed invasive species management in Ontario. It recommended the Ministry of Natural Resources and Forestry take actions to restrict known pathways of invasive species spread; tackle invasive species in provincial parks; establish advisory panels with scientific expertise and local and Aboriginal knowledge to propose species for regulation; and to report publicly on progress to manage invasive species regulated under the Invasive Species Act, 2015. The report also called for an increased program funding and less reliance on grants. Another potential gap noted on the Canadian side, is that there do not appear to be invasive species policies or procedures in place for dealing with invasive algae. The OMNRF addresses aquatic plants and animals, but not algae. The Ontario Ministry of Environment and Climate Change (MOECC) handles algal bloom issues, but does not have any management strategy for non-native algae such as Starry Stonewort (*Nitellopsisobtusa*), which has been increasing in abundance in the lower Great Lakes.

5.7.6 Section Summary

- The United States and Canada have fully developed mature AIS prevention programs in place that are institutionalized in domestic legislation and regulations. Every Great Lakes State and Province has instituted and exercised rapid response plans and Governors and

Premiers have established a mutual aid compact. Significant progress has been made in the areas of monitoring, prevention and risk assessment during the reporting period.

- The spread of existing AIS within the basin was highlighted at the GLPF and in the SOGL highlights report as a serious concern resulting in an overall *poor – deteriorating* status.

- The Parties have selected AIS sub-indicators for the AIS indicator that effectively communicate progress on General Objective 7 of the GLWQA in the 2016 SOGL.

- Significant progress has been made by the Parties on all 2014-2016 priorities for science and action on AIS. The Great Lakes Panel has placed emphasis on collaboration, coordination and information sharing.

- Over the past 25 years, the Great Lakes Regional Panel on ANS has become a mainstay for binational coordination and regional collaboration on policy, research and operational protocols to stop the establishment and spread of AIS. It provides an important forum for activities related to Annex 6 of the GLWQA.

- The United States and Canada have consistent ballast water management programs in place that take into account the international ballast water discharge standard issued by the IMO. The joint efforts of the two governments strictly enforce ballast water exchange and flushing requirements for vessels entering the Great Lakes through the St. Lawrence Seaway.

  A strictly enforced regime of mandatory ballast water exchange and flushing currently in place has proven effective and research sponsored by the Canadian government indicates that treatment to the IMO discharge standard in addition to ballast water exchange and flushing will further reduce the risk of introduction.

- The regulation of ballast water discharges from "Lakers", ships that remain within the Great Lakes, is being considered by Transport Canada as well as several States as a means to address the spread of AIS, from one port to another within the lakes. The two governments have agreed to seek consistency and compatibility between US and Canadian ballast water requirements and this could provide a path towards harmonious joint implementation for both Lakers and seagoing vessels.

- Given that the challenge of AIS cuts across geographical boundaries, it is important to institute effective and consistent control strategies throughout the Great Lakes. The Parties could find effective and consistent control strategies on the safe and environmentally responsible use of all types of control measures, harmonize permitting, remove administrative barriers and adopt an integrated approach to AIS management.

- Efforts by the Parties to control the spread of Asian Carps and prevent their introduction to the Great Lakes are commendable. The Asian Carp Regional Coordinating Committee,

representing 28 federal, state/provincial, municipal, non-profit and binational organizations from the United States and Canada is a model of multi-jurisdictional collaboration. The US has provided for more sustainable and predictable funding by moving a greater percentage of funding from grants to agency program funds. The level of effort and funds spent on Asian carp control are well-justified by the program results and by the extent to which the response procedures and control technology developed for Asian carps may be applied to the eradication and control of many other species.

- Significant progress has been made in sharing key information to support of management decisions among all the agencies conducting AIS monitoring, as demonstrated in the response to detections of Grass Carp in the Great Lakes during this reporting period.

- The GLMRIS, Chicago Area Waterways and Brandon Road Lock studies have identified options for effectively separating the Mississippi River and Great Lakes basins.
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- The spread of invasive *Phragmites australis*, aindicator terrestrial species selected to assess the state of the Great Lakes by the Parties, is the focus of a broad collaborative effort. Given additional support, this collaborative effort may serve to improve binational collaboration and identify new Agreements and tools to eradicate *Phragmites*. New tools and Agreements developed in this process may in turn be used to control and eradicate other invasive plants.

- The process for conducting ecological risk assessments of AIS invasion potential has been initiated by the Parties by establishing performance measures and strategic outcomes for key programs.

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5.8 Contaminated Groundwater

This section reviews and assesses progress toward achieving General Objective 8 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 8 states that the waters of the Great Lakes should "be free from the harmful impact of contaminated groundwater."

This assessment includes a consideration of implementation measures undertaken in support of the GLWQA Annex 8: *Groundwater* and other key programs related to groundwater.

5.8.1 Background

Groundwater in the Great Lakes basin is a critical part of the region's water resources, providing direct input and indirect streamflow to the Great Lakes. Groundwater and surface waters are inextricably linked in terms of both quality and quantity (Figure 5.8.1). Reductions in groundwater quantity, due to over-pumping for example, can reduce base flow to streams negatively impacting surface waters and degrading groundwater dependent habitats and ecosystems. If groundwater contaminant levels are higher in surface waters than groundwater, then groundwater ultimately discharged to receiving waters can deteriorate surface water quality. For instance, surface waters of the Great Lakes can be affected by leaking underground storage tanks, animal feeding operations, failing septic systems, or other sources of groundwater contamination. Sometimes, groundwater transported to surface waters can be of higher quality than the receiving waters, resulting in improved surface water quality.

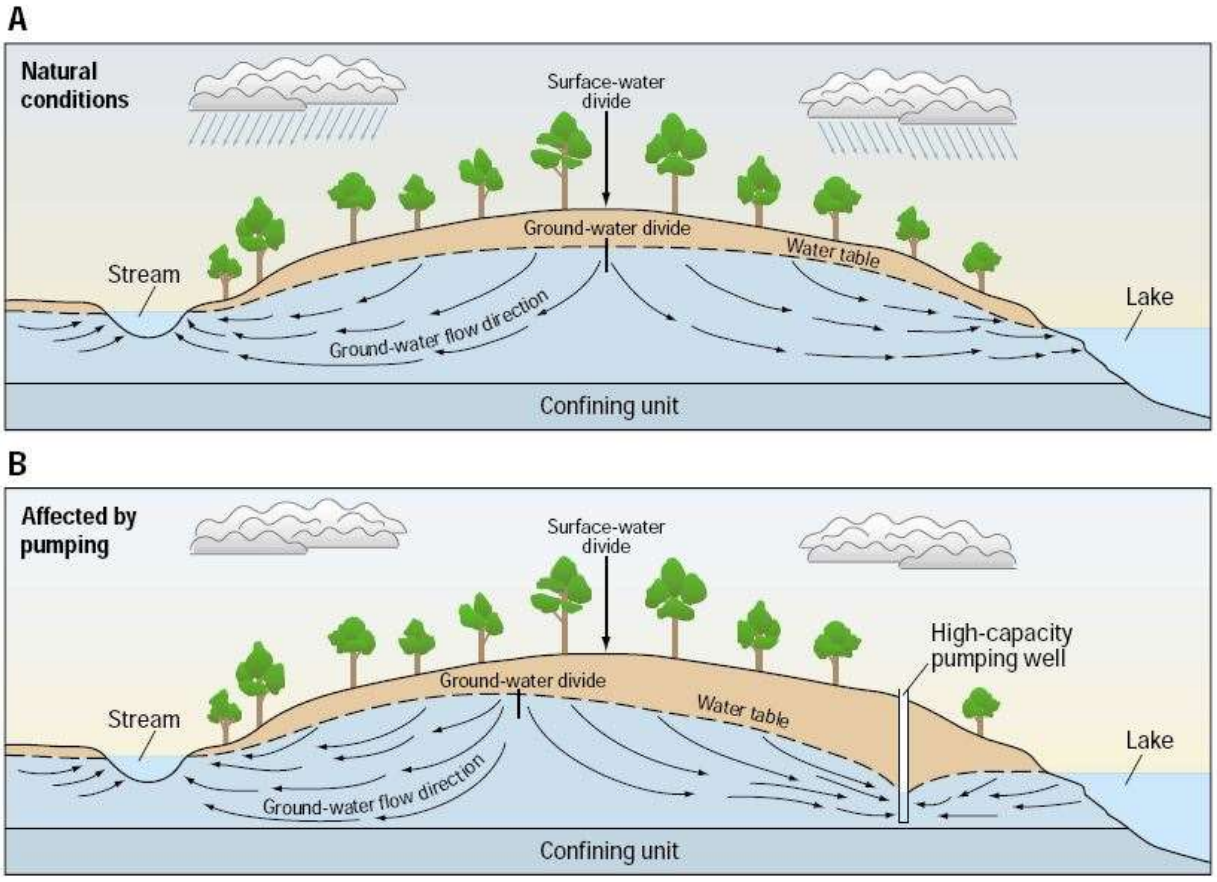

Figure 5.8.1 – Generalized Groundwater - Surface Water Interactions (A) under natural conditions and (B) affected by pumping (*Source: USGS, 2000*)

The role of groundwater and its impacts on the Great Lakes were not fully recognized in the establishment of the original GLWQA in 1972. The 1978 GLWQA introduced the "ecosystem approach", recognizing the interconnectedness of all components of the environment, and created Annex 16 to address pollution from contaminated groundwater. The 2012 GLWQA establishes Annex 8, an updated groundwater Annex that recognizes the interconnection between groundwater and the waters of the Great Lakes and that preventing groundwater contamination is critical in protecting the physical, chemical and biological integrity of the Great Lakes. Annex 8 seeks to support the achievement of Objective 8 by promoting the coordination of groundwater science and management actions.

5.8.2 Assessment of indicators

1. Assessment

The 2017 SOGLHighlights Report (Governments of Canada and the United States, 2017) includes a groundwater quality indicator to assess the general status of the quality of shallow groundwater in the Great Lakes basin. Previous 2011 SOGL reporting did not include a groundwater quality indicator, but rather a "Base Flow due to Groundwater Discharge" indicator. The SOGL 2017 indicator reportson two key groundwater contaminants – chloride (representative of urban contamination from the use of salt for de-icing) and nitrate (representative of rural contamination from agricultural practices). In regions of the Great Lakes basin where there is more development(such as the basins of Lakes Michigan, Erie and Ontario) the lakes are assessed as "fair". Those regions of the Great Lakes basin that are less developed (such as the basins of Superior and Huron) are assessed as "good". However, this assessment is for the groundwater throughout the basin and does not necessarily reflect what is discharged to the lakes. The SOGL Highlights report notes the need for a better understanding of the impacts and interaction of contaminated groundwater with the surface waters of the Great Lakes.

Overall, the groundwater quality indicator for the Great Lakes basin is assessed with a status of "fair" with an "undetermined" trend. It is a challenge to try to accurately assess the quantity and quality of groundwater across the basin because thereare limited data to determine groundwater status and trends.

2. Improvements for indicator reporting

The IJC suggested that the groundwater quality indicator be expanded to measure several chemical and physical parameters, representative of agricultural and urban areas (IJC, 2014). Besides nitrate and chloride (already in SOGLR 2017) the expansion should include: water level and/or flow, temperature, pH, Total Dissolved Solids,, nitrate, chloride, sulfate, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, total chlorinated compounds, benzene, toluene, ethylbenzene, xylenes, arsenic, cadmium, zinc, phosphorus and triazine herbicides.

A report of the IJC's Science Advisory Board's Research Coordinating Committee (SAB-RCC) with suggestions to improve SOGL reporting found that the data for some of the additional measures proposed by IJC for the groundwater indicator already exist and if analyzed and reported would improve the SOGLR (SAB-RCC, 2016). However, SAB-RCC also notes that the level of effort and time required to resolve all the issues with this indicator is high (for example, developing the methods to calculate the metrics) and resource constraints the Parties may not be able to adopt every suggested measure. This highlights the challenges in assessing progress towards the groundwater Objective. This is further underscored by the delay in the development of the 2017 SOGL groundwater qualityindicator.

5.8.3 Assessment of Progress Report of the Parties

1. Assessment

The Parties established the following Binational Priorities for Science and Action for 2014-2016 to guide their work under Annex 8 of the GLWQA:

- By 2015, publish a Groundwater Science Report of available groundwater science to understand and manage groundwater and its impacts on the waters of the Great Lakes.
- Identify science gaps and research needs concerning groundwater impacts to the waters of the Great Lakes.
- Analyze contaminants, such as nutrients, and other factors, such as climate change, that affect groundwater's impact on the waters of the Great Lakes.
- Undertake surveillance of groundwater quality for priority areas.
- Coordinate binational groundwater activities under the GLWQA with domestic groundwater programs to assess, protect and manage groundwater impacting the waters of the Great Lakes.

The Parties, through the Annex 8 subcommittee, released the draft report *Groundwater Science Relevant to the Great Lakes Water Quality Agreement: A Status Report* in late 2015 for public comment, with the final report completed in May 2016 (Granneman and Van Stempvoort, 2016). The release of this report meets the first three of the five Binational Priorities for Science and Action noted above. The report also meets the commitments of the Parties under the "science" mandate outlined in Annex 8 of the GLWQA. The PROP indicates that discussion with other Annex subcommittees, via the Annex 8 subcommittee, will be undertaken to determine if there needs to be a focus on coordinating specific binational groundwater activities and to determine the need for surveillance of groundwater quality in priority areas.

2. Publication of groundwater science report and Identification of Science Priorities

The Annex 8 subcommittee report examines threats and stresses to groundwater quality as well as the impacts of groundwater quantity and flows on the lakes. The scope of the report also informs and supports the efforts of other GLWQA Annexes. The report discusses the effects of groundwater in nearshore regions of the lakes (Annex 2); the storage, transport and discharge of nutrients (Annex 4); the dependency of Great Lakes habitats on groundwater (Annex 7); and the

current understanding of climate change on groundwater and its potential impacts on Great Lakes water quality (Annex 9).

Many priority science gaps are identified throughout the report and are grouped into eight overarching categories:

- assessing regional-scale groundwater discharge to surface water;
- assessing the geographic distribution of known and potential sources of groundwater contaminants relevant to Great Lakes water quality, and the efficacy of mitigation efforts;
- monitoring and surveillance of groundwater quality in the Great Lakes basin;
- advancing research on local-scale interaction between groundwater and surface water;
- developing better tools for monitoring, surveillance and assessment of groundwater/surface water interactions;
- advancing research on the role of groundwater in aquatic habitats in the Great Lakes basin;
- improving the understanding of effects of urban development on groundwater; and
- developing scale-up models of regional effects of groundwater on Great Lakes water quality.

The priority science needs identified in the Annex 8 groundwater report were used to help identify the Parties' 2017-2019 Binational Priorities for Science and Action, in consultation with other Annex subcommittees. Of the eight broad science priority needs identified in the report, the first three are reflected in the draft 2017-2019 Binational Priorities for Science and Action (identified as priority actions to address the science priority needs) listed below:

- develop better tools to assess groundwater – surface water interaction and use them to advance assessment of regional-scale groundwater discharge (quantity) to surface water in the Great Lakes basin;
- undertake a focused assessment of the geographic distribution of known and potential sources of groundwater contaminants relevant to Great Lakes water quality; and
- advance monitoring, surveillance, and assessment of groundwater quality in the Great Lakes Basin.

The GLWQA states that binational priorities will be established based on an evaluation of the state of the Great Lakes, public input and recommendations of the Commission. The IJC's Science Advisory Board (SAB), in its review of the draft 2017-2019 Binational Priorities for Science and Action, concluded that a better understanding of how groundwater influences the nearshore is needed to improve the management of that zone.However, the PROP does not specify why these particular items were selected as priorities for action noris it clear when (or how) the remaining priority science needs identified in the Annex 8 report will be addressed.

The priority science needs identified in the Annex 8 report are consistent with previous recommendations made in several recent IJC and IJC Board reports including, *the IJC's 15th and 16th Biennial Reports on Great Lakes Water Quality* (IJC, 2011; IJC, 2013) the IJC's Science Advisory Boards'sScience Priority Committee report that selected *Key Recommendations from the last two IJC Biennial Reports* (SAB-SPC, 2016), the IJC's report on *Protection of the Waters of the Great Lakes (IJC, 2015)* , and the IJC's Science Advisory Board's *Groundwater in the Great Lakes Basin* report (SAB, 2010). In general, these reports all identify the need for

improved groundwater research and monitoring to better understand and manage groundwater quality and subsequently its impacts on surface waters of the Great Lakes. This includes groundwater quantity and its connection to surface waters, which is not well understood. Below are excerpts of the recommendations from those reports:

> "Designate a lead agency with responsibility for compiling and regularly reporting to the Commission on relevant research, monitoring and program information on key groundwater issues because of the importance of groundwater quality to human and ecosystem health". (IJC, 2011 and SPC, 2016)

> "Federal, state and provincial research should continue to improve mapping and understanding of groundwater aquifers in the basin, determining where groundwater supplies may be degraded in the future, identifying management methods for avoiding these problems, and achieving an improved understanding of the relationship among land uses and groundwater and surface water quality and stream habitat." (IJC, 2015)

> "Recognize and reflect the relationship between the quantity and the quality of groundwater and the interactions between groundwater and surface water in respect to both quality and quantity."(SAB, 2010)

5.8.4 Assessment of key government programs

1. Assessment

Achieving the objectives of the GLWQA requires coordination and collaboration among federal, state and provincial, Tribal, First Nations and municipal governments, watershed management agencies and non-government organizations, both domestically and binationally. Table 5.8.1 provides examples of programs and initiatives that support the protection of groundwater in the Great Lakes through improving the understanding of groundwater quality and quantity and prevention efforts.

In Canada, the provinces have direct responsibility for managing groundwater, unless there is a "significant national interest in the water resource management" (per the *Canada Water Act, 1985*), such as international boundary waters with the United States. In such cases the federal government would share the responsibility of managing these waters with the provinces. In the United States, groundwater allocation and use are regulated by individual states, whereas ground water quality protection is a mixture of state and federal laws.

Table 5.8.1Examples of programs contributing to the protection of groundwater in the Great Lakes

Program	Year
Canada	
Natural Resources Canada Groundwater Geoscience Program - Groundwater Information Network	**2002**
Canada Water Act	**1985**
Ontario Provincial Groundwater Monitoring Network	**2000**
Ontario Low Water Response Program	**2001**
Ontario Water Resources Act	**1961**
Ontario Clean Water Act	**2006**
Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health	**2014**
Ontario Great Lakes Strategy	**2012**
United States	
Underground Storage Tank Program (Resource Recovery and Conservation Act)	**1988**
Underground Injection Control Program (Safe Drinking Water Act)	**1977**
Wellhead Protection Program (Safe Drinking Water Act)	**1986**
Great Lakes-St. Lawrence River Basin Sustainable Water Resources Compact	**2008**
Eight Great Lakes States - groundwater monitoring programs	
Binational	
Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement	**2005**

2. Groundwater quantity

Groundwater quantity and quality impacts the water quality of the Great Lakes and its use and withdrawal are regulated by individual states and provinces, with requirements varying among jurisdictions. Some jurisdictions regulate groundwater withdrawals through permit requirements, while others require registration of withdrawals for specified thresholds (SAB, 2010). With the enactment of the 2008 Great Lakes St. Lawrence River Basin Sustainable Water Resources Compact (Great Lakes Compact) and Great Lakes St. Lawrence River Basin Sustainable Water Resources Agreement, all ten Great Lakes states and provinces are called upon to develop a program to regulate new and increased water withdrawals, including a registration and reporting

requirement for all withdrawals in excess of 378,541 liters (100,000 gallons) per day (for both surface waters and groundwater) (Schulte, 2013).

The IJC has commended the states and provinces for the enactment of the Great Lakes Compact and the parallel Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement and concludes that if fully and rigorously implemented, the measures will provide a solid foundation for managing Great Lakes diversions and consumptive uses into the future (IJC, 2015). The IJC's Protection of the Waters of the Great Lakes report (IJC, 2015) discussed the impact of groundwater withdrawals on groundwater supply. The report also considered the impact of withdrawals on groundwater quality. Over-pumping of aquifers can degrade groundwater quality by pulling in contaminants, such as naturally occurring radium or fluoride, from adjacent aquifers. The report recommended that Great Lakes states and provinces should fully factor the adverse ecological and water quality impacts of groundwater withdrawals into both water use permitting procedures and decisions regarding consumptive use.

The state of Michigan, for example, has developed a Water Withdrawal Assessment Tool to determine the potential impacts of large quantity water withdrawals on nearby water sources, including potential impacts to fish habitats and populations (MDEQ, http://www.michigan.gov/deq/0,4561,7-135-3313_3684_45331-201102--,00.html, Accessed September 2016). This tool has been used by Michigan since 2009 to regulate large quantity withdrawals and is required to be used by anyone proposing to make new or increased large water withdrawals from either surface water or groundwater in the state. This tool is currently being evaluated by other Great Lakes states for potential implementation (Governments of Canada and the United States, 2016).

At the end of 2016, Ontario announced that it would be taking action to protect the province's water resources from new or expanded groundwater withdrawals from bottled water companies. This was prompted by Ontarians' concerns over water security and specific concerns on the use of groundwater for bottling in communities that rely on that same groundwater for drinking water. A two year moratorium was put into place on January 1, 2017 that would prohibit the issuance of new permits for groundwater withdrawals for water bottling facilities or the authorization of increased groundwater withdrawals for water bottling facilities under their existing permits (https://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MTMwMjU1&statusId=MTk4OTEw&language=en, accessed June 2017). This was followed by a proposed regulation that would impose a new charge on water bottlers that take groundwater (https://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MTMxNTQw&statusId=MTk5NDkw, accessed June 2017). The proposed regulation would apply to permitted facilities and establishes a fee increase of $500 per million liters used per year, from the current annual fee of $3.71 per million liters used. The regulation further notes that the funds gathered from this increased charge would be used to gain a better understanding of and more effectively manage groundwater takings by bottled water facilities. The Canadian Bottled Water Association feels that the Ontario government has unfairly singled out the bottled water industry, by increasing fees for bottled water facilities, but exempting other commercial groundwater users, such as golf courses (http://watercanada.net/2017/ontario-bottled-water-policy-and-public-opinion-at-odds/, accessed June 2017). Further, permits for bottled water facilities account for 0.001% of the total permitted

volume of water withdrawals in Ontario (http://www.canadianbeverage.ca/news-media/press-releases/statement-regarding-new-bottled-water-charges-in-ontario-from-canadian-beverage-association-cba/, accessed June 2017). The government of Ontario argues bottled water is unique from other commercial uses because almost all the groundwater goes into the product and is then removed from the local watershed. However, the government recognizes that they will need to take a broader look at the regulations governing water withdrawals in Ontario to ensure that both surface and groundwater are protected by taking into account the cumulative effect all water withdrawals may have on a watershed.

3. Groundwater quality

The quality of groundwater used for public drinking water supply is well regulated in the United States and Canada (Ontario). The US Environmental Protection Agency (USEPA) has several programs for the protection of groundwater from contamination sources, including the Underground Injection Control program (UIC), Wellhead Protection program and Underground Storage Tank program (UST). The UIC program regulates the underground injection of fluids and fluid wastes through wells to protect underground sources of drinking water. The Wellhead Protection program requires states to develop a program that will minimize pollution of public water supply wells by identifying and managing potential contaminant sources in the area that contributes water to a well. The UST program includes requirements for tank inspections and reporting of leaks. Leaking underground storage tanks were identified as a serious threat in the SAB's (2010) groundwater report and IJC's 15th Biennial Report (IJC, 2011). In 2015, the USEPA strengthened its UST regulations to include, among other provisions, secondary containment and interstitial monitoring (*i.e.,* leak detection) requirements for new and replaced tanks.

In Ontario, the Ministry of the Environment and Climate Change has programs in place to protect groundwater including, regulation of the construction and abandonment of wells and Environmental Compliance Approvals to regulate releases of pollutants to the environment and source water protection. At the end of 2015, Ontario completed the development of Source Water Protection Plans (SWPP) for the protection of drinking water, including groundwater, in watersheds throughout the province. These plans identify sources vulnerable to contamination and actions to protect them. The plans include legally binding policies to mitigate source water threats, to be implemented by various bodies (such as ministries/government agencies, municipalities, and Conservation Authorities). Conservation authorities are local watershed agencies established to ensure the conservation, restoration and responsible management of Ontario's water, land, and natural habitats. The mitigation policies used by all these bodies can include land-use planning, regulations, and stewardship (such as education and best management practices). Once a SWPP is in place, municipalities or planning authorities cannot undertake any activity that conflicts with that plan.

4. Groundwater monitoring, mapping and research

In Canada, the Groundwater Information Network provides web access to national standardized groundwater information, including groundwater monitoring data, well databases and maps. Collaboration with the US Geological Survey (USGS) is also underway to enable cross-border

sharing of information. Ontario, which is also a collaborator with the network, has a Provincial Groundwater Monitoring Network that provides access to information on groundwater levels and chemistry data from monitoring wells.

In 2016, Natural Resources Canada, through its Groundwater Geoscience Program, completed a study to determine a strategy for a regional water resources modeling platform for the Great Lakes basin and Southern Ontario (Frey et al., 2016). The report notes that such a platform, which integrates groundwater and surface water systems for the Great Lakes basin, can be utilized as a decision-support tool for surface water and groundwater sustainability and Great Lakes water quality. The report also notes there are limitations in the availability of data needed to develop the model at the scale of the Great Lakes basin. However, identified data gaps help to inform field-data collection and monitoring needs. This need for additional data, particularly that of the role of groundwater-surface water interactions in the Great Lakes, is underscored by the science priority needs identified in the Annex 8 report.

In the United States, the USGS has continuing groundwater studies in the Great Lakes region to evaluate the groundwater quantity and quality, which can subsequently impact the surface waters of the Great Lakes. For example, the USGS is currently undertaking the Glacial Aquifer System Groundwater Availability Study, which includes areas of the Great Lakes basin. The USGS (2016) study, is intended to provide information on the status of groundwater resources in the system, how they have changed over time and how they will respond to future changes in environmental and anthropogenic conditions (USGS, http://mi.water.usgs.gov/projects/WaterSmart/, Accessed September 2016). Additionally, the USGS, through the National Water Data Information System, provides access to national water resource data on quantity, quality, distribution and movement of surface water and ground water. Each of the Great Lakes states also maintains groundwater monitoring networks and databases of information on groundwater levels and quality. This includes the collection of groundwater withdrawal data as part of their responsibilities under the Great Lakes Compact.

5.8.5 Section Summary

- The Parties are undertaking many activities to improve the understanding of groundwater quality and its connectivity to surface waters along with the relationship between quantity and quality. This is reflected through their activities under Annex 8, the establishment of their Binational Priorities for Science and Action, as well as their domestic programs.

- The Parties established five Binational Priorities for Science and Action for 2014-16. Three of these five priorities were accomplished with the release of their report on *Groundwater Science Relevant to the Great Lakes Water Quality Agreement: A Status Report* (Granneman and Stempfort, 2016), which examines threats and stresses to groundwater quality as well as the impacts of groundwater quantity and flows on the lakes. This report also meets the Parties' commitments under the "science" mandate outlined in Annex 8 of the GLWQA. The two remaining Binational Priorities for Science and Action are expected to be addressed by the end of 2016.

- The Parties' groundwater report identifies eight over-arching priority science needs, which encompasses the need for improved groundwater research and monitoring to better understand and manage groundwater quality and subsequently its impacts on surface waters of the Great Lakes, including groundwater quantity and its interactions with surface waters. Three of these priority science needs are reflected in the draft 2017-19 Binational Priorities for Science and Action for groundwater. However, it is not clear when (or how) the remaining priority science needs will be addressed. As noted in several IJC and SAB reports (SAB, 2010; IJC, 2011; SPC, 2016), a better understanding of how groundwater influences the nearshore is needed to improve the management of that zone.

- The IJC has commended the work of the Great Lakes states and provinces for the enactment of the Great Lakes Compact and the parallel Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement to protect the waters of the Lakes from the potentially harmful effects of consumptive uses and diversions. However, the impacts of groundwater withdrawals on groundwater quality, and ultimately surface waters and the lakes, are increasingly important. The Great Lakes states and provinces should fully factor the adverse ecological and water quality impacts of groundwater withdrawals into both water use permitting procedures and decisions regarding consumptive use.

- The status of groundwater quality in the Great Lakes basin is undergoing assessment through the development of a groundwater quality indicator under the SOGL report. The expected 2017 groundwater indicator will more appropriately report progress toward the achievement of Objective 8 of the GLWQA by reporting on the quality of shallow groundwater in the basin, and specifically the contaminants chloride and nitrate. Future reporting of this indicator would be improved by expanding the number of parameters to be analyzed

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5.9 Other Substances, Materials and Conditions

This section reviews and assesses progress toward achieving general objective 9 of the *Great Lakes Water Quality Agreement* (GLWQA). Objective 9 states that the waters of the Great Lakes "should 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".

Objective 9 captures topics not covered by the other GLWQA objectives. Specifically, these topics include: Areas of Concern (AOCs) (Annex 1); Lakewide Management (Annex 2); Climate Change Impacts (Annex 9); the Cooperative Science and Monitoring Initiative (part of Annex 10); Great Lakes adaptive management; and microplastics.

5.9.1 Assessment of progress on Areas of Concern

1. Background

The 1987 GLWQA established 43 AOCs throughout the Great Lakes basin. The AOC program has been continued in the 2012 version, which includes an Annex specifically related to AOCs. Annex 1 of the 2012 GLWQA requires that the Parties designate AOCs and for each AOC, Remedial Action Plans (RAP) must be developed and implemented to address each of the beneficial use impairments(BUI) that apply to the AOCs. There are 14 types of BUIs.

A BUI is a reduction in the chemical, physical or biological integrity of the waters of the Great Lakes sufficient to cause restrictions on fish and wildlife consumption, tainting of fish and wildlife flavour, degradation of fish and wildlife populations, fish tumours or other deformities, bird or animal deformities or reproduction problems, degradation of benthos, restrictions on dredging activities, eutrophication or undesirable algae, restrictions on drinking water consumption or taste and odour problems, beach closings, degradation of aesthetics, added costs to agriculture or industry, degradation of phytoplankton and zooplankton populations, loss of fish and wildlife habitat.

The GLWQA specifies that AOC remediation plans adopt "…a systematic and comprehensive ecosystem approach to restoring beneficial use". More information on the AOC process, BUIs, status of progress and additional information can be found in Annex 1, or at the IJC's website at http://ijc.org/en_/aoc, or the Parties' AOC websites at http://www.ec.gc.ca/raps-pas/ and https://www.epa.gov/great-lakes-aocs.

Annex 1 commits the Parties to triennial reporting on the status of BUIs in each AOC, the actions completed, and the remaining actions required, for each AOC. The PROP includes this information, and presents the status of actions to address each BUI (actions complete at 100 percent, 75 percent and more, 50 percent and more/less levels).

The 2014-2016 Priorities for Science and Action developed by the Parties committed the Parties to completing two AOC-related actions: to develop AOC guidance documents to provide

additional knowledge and tools to enhance and advance the restoration and delisting of AOCs; and to develop practices or mechanisms (such as RAP reports, lessons learned, or BUI information) for sharing information among AOC communities and the broader public. In August 2016, two Annex 1 task team reports were released by the Parties – a situational analysis and guidance related to AOCs in recovery. Those reports were distributed via various sources including the Great Lakes Information Network list called GLIN-announce, a widely used subscriber list server hosted by the Great Lakes Commission. However as of October 2017, these reports do not appear to be posted to websites maintained by the Parties.

The experience with AOCs serves as a strong reminder of the principle of prevention included in the GLWQA. Over the last 30 years, hundreds of millions of dollars have been spent cleaning up legacy pollutants and other degradation in AOCs, requiring a significant additional investment of volunteer and agency staff time. These investments could have been directed to other activities had degradation of AOCs been better anticipated and prevented in the first instance.

2. Assessment of indicators

Many indicators discussed elsewhere in this report also relate to this section of the report. The one indicator that is not discussed elsewhere is Remediating Contaminated Sediments which is presented in the 2011 State of the Great Lakes report (ECCC and USEPA, 2014). The indicator notes an increasing trend in remediation between 1997 and 2010, which should be expected, as remediation projects in AOCs that were planned and permitted earlier in remedial action plan (RAP) processes were implemented during the period being examined. This indicator was not reported in SOGL 2017.

3. Assessment of progress of the Parties

Progress Towards AOC Remediation and Restoring Beneficial Uses

Between 2013 and 2016 the following progress has been made towards AOC delistings and Beneficial Use Impairment removals/redesignations:

As of 2013 (from IJC, 2013):

- US - 33 of 255 BUIs removed, 1 AOC delisted and 1 AOC in Recovery out of 26 AOCs
- Canada (at May, 2011) - 54 of 154 BUIs removed, 3 AOCs delisted and 2 AOCs in Recovery out of 12 AOCs
- Binational – 0 of 5 AOCs delisted

As of 2016 (from Situation Analysis Task Team, 2016):

- US - 62 of 255 BUIs removed, 4 out of 26 AOCs delisted
- Canada - 65 of 146 BUIs removed, 3 AOCs delisted and 2 AOCs in Recovery out of 12 AOCs (note: the total number of Canadian BUIs is different between 2013 and 2016 (146 vs. 154) due to changes in the way Environment and Climate Change Canada reported BUIs requiring further assessment. Additional refinements to BUI accounting is expected in ECCC's forthcoming Canadian Environmental Sustainability Indicator – Restoring the Great Lakes Areas of Concern
- Binational – 0 of 5 AOCs delisted

Since the Parties' AOC programs were codified in the 1987 Agreement, seven AOCs have been delisted and two have been designated as Areas in Recovery. Three of those delistings (all in the United States) occurred since the current version of the GLWQA was signed by the Parties in 2012 (two of them since it came into effect in 2013), which illustrates the accelerated progress that has occurred in the United States since the Great Lakes Restoration Initiative was initiated in 2010. Of the remaining 34 AOCs, 22 are in the United States, seven are in Canada and five are binational. A further 13 AOCs are expected to have all management actions completed and/or be delisted within the next five years. The Parties' priority AOCs are as follows (from Situation Analysis Task Team, 2016 and Governments of the United States and Canada,2016):

- *United States* – Management actions have been completed at SheboyganRiver, AshtabulaRiver, WaukeganHarbor and St. Clair River. By 2019, management actions will be completed at River Raisin, St. Marys River, Menominee River, Rochester Embayment, BuffaloRiver, ClintonRiver, ManistiqueRiver, MuskegonLake and Black River.
- *Canada* – By 2019, priority actions will be completed at NipigonBay, PeninsulaHarbour, Niagara River, Bay of Quinte, and St. Lawrence River (Cornwall).

Progress since 2010 in US Areas of Concern has been accomplished primarily through the US Environmental Protection Agency's (USEPA) Great Lakes Restoration Initiative (GLRI). The initiative relies on partnerships and in some cases matching funding with other federal and state agencies and other organizations. Approximately $1.9 billion has been invested in Great Lakes restoration from fiscal years 2010-2015, with nearly $600 million going directly towards AOC cleanup (Table 5.5.4 Annex 1 Situation Analysis (Situation Analysis Task Team, 2016).

Additional investments in wastewater and stormwater infrastructure are also occurring. Direct investments have led to a rapid acceleration of BUI removal, completion of cleanup actions for several AOCs, and the delisting of two AOCs in 2014. Completion of cleanup actions for eight additional AOCs is expected in the next few years, subject to continued funding from the GLRI.

Progress in the Canadian AOCs has been accomplished through Environment and Climate Canada's (ECCC) Great Lakes Action Plan, which included a direct investment of $16 million for 2010-2012 to clean up AOCs. The PROP includes additional financial information on wastewater and stormwater spending in AOCs through infrastructure programs not tied directly to AOCs.
Canada has made significant recent investments at the Hamilton Harbour AOC (CDN $139 million, over approximately eight years for sediment remediation and CDN $484 million, over approximately ten years, for wastewater treatment infrastructure) and the Port Hope Harbour AOC (CDN $1.28 billion, over ten years for contaminated sediment remediation).
Progress on AOCs is also being made through the Government of Canada's partnership with the Province of Ontario, as described in the *Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health*, and partnerships and matching funding with other organizations. Completion of cleanup actions in five Canadian AOCs is expected by 2019. Base funding for AOC remediation through the Government of Canada's Great Lakes Action Plan is less than that of the United States, when measured on a per capita and per AOC basis. While the federal governments are making the largest investments in AOC cleanup, the aggregate investments of state/provincial and local organizations in AOC remediation is substantial.

Annex 1 is one of a small number of the Annexes that focuses on multiple activities. AOCs are strongly founded on interrelationships among scientific questions -- assessment of conditions to characterize BUIs, ecological risk assessments, monitoring to confirm ecosystem response following implementation of management actions (all of which must be done an appropriate spatial scale to capture local conditions (Yurista et al., 2016)), implementation (management actions to address one or more of the 14 BUIs) and community engagement (establishing and supporting Public Advisory Councils [PACs]).

Thus, interaction between the organizations associated with these activities is important and necessary to ensure that current scientific approaches and best practices related to remedial projects and community engagement are shared. This also holds true for RAP practitioners working on similar issues at different locations across the basin. Although there are many opportunities for this to occur at a domestic level (see text box), opportunities at a binational level are limited, in large part because Annex 1 is the only Annex without an associated Great Lakes Executive Committee structure. For each of the other nine Annexes, the Annex Committees and Extended Subcommittees provide regular and recurring opportunities for agency staff from multiple levels of government, academics, NGOs, consultants, and others with a professional interest in the Annex topic to discuss Annex-related issues. This opportunity does not exist on a binational basis for AOCs.

For the five binational AOCs - St. Marys River, St. Clair River, Detroit River, Niagara River and St. Lawrence River - two parallel domestic processes are in place. Progress towards completion of management actions in these binational AOCs is generally uneven between the two domestic

processes. This is inconsistent with the ecosystem approach principle included in the GLWQA. Further, there is only limited formal and contemporary guidance for binational AOCs to inform BUI removals and AOC delisting across the boundary. Meanwhile, the need for such guidance is great because management actions have been completed on one side of several of the binational AOCs, and therefore delisting approaches are under active consideration. This includes the possibility of designating one side of a binational AOC to an AOC in Recovery designation while management actions continue to be implemented on the other side of the same AOC.

The most urgent need to coordinate activities is in those binational AOCs where progress towards delisting is most uneven despite active domestic RAP programs. Examples include the St. Lawrence River AOC, where ECCC has determined that all management actions have been completed in the Cornwall, ON area, while actions are ongoing in the Massena, NY area; and the St. Clair River AOC, where the USEPA has determined that all management actions have been completed in the Port Huron, MI area, while actions are ongoing in the Sarnia, ON area.

Sharing Areas of Concern Best Practices and Technical Transfer

There are many excellent examples of opportunities for interested residents and those with a professional interest in AOCs to learn more about science, implementation, community engagement and related topics. A few examples are highlighted below:

- Many individual RAP teams hold regular events to discuss themes of local relevance, and expand local interest in the AOC. For example, the Detroit River Canadian Cleanup holds an annual Detroit River Evening which includes a status update on the beneficial use impairments in the AOC, and a guest speaker discussing a topic of particular interest in the AOC. On the US side, the Friends of the Detroit River hold an annual Shiver on the River event to increase awareness about the river.

- The Michigan Public Advisory Council (MPAC) is comprised of the Chair and Vice Chair (or designates) of each of the state's AOC PACs. The MPAC meets about twice per year to share information about the status and priorities of individual AOCs, and best practices. One MPAC meeting typically occurs in the state capitol, which includes a breakfast meeting with state legislators.

- The annual US AOC conference organized by EPA includes concurrent sessions on a range of science, management, and community engagement topics for US AOCs. The last conference was held in March, 2017.

- Environment and Climate Change Canada hosts regular Canadian AOC conferences, which explore a range of themes related to Canadian AOCs. The last conference was held in February, 2014.

4. IJC activities

The AOC program was recommended by the IJC's Water Quality Board (WQB, 1985) and incorporated by the Parties into the 1987 version of the Agreement.. Since the AOC program was established by the Parties through the 1987 Agreement, the IJC has periodically reported on progress towards restoring AOCs. In 2003, the IJC completed a special report which examined how much has been done in restoring beneficial uses in AOCs, and offered a number of recommendations (IJC, 2003). The 16th IJC biennial report included an account of the number of AOCs delisted and the numbers of beneficial use impairments removed (IJC, 2013).

Annex 1 (AOCs) of the 2012 GLWQA requires that the Parties solicit a review and comments from the IJC and others prior to the designation of an AOC in Recovery and prior to the removal of a designation as an AOC or an AOC in Recovery. Since the 2012 GLWQA came into effect in 2013, the IJC has reviewed and commented on Delisting Reports for Deer Lake AOC (MI) and White Lake AOC (MI), and a draft Delisting Report for Nipigon Bay AOC (ON). The IJC's comments are available at:http://www.ijc.org/en_/Reports_and_Publications. Although each report addressed a specific AOC, several themes were relevant to all AOCs:

- The importance of ongoing monitoring to ensure no slippage on environmental conditions, which is consistent with the anti-degradation principle included in the GLWQA. This may require monitoring activities that extend beyond reliance on the ongoing monitoring programs of federal and state/provincial agencies. The IJC included recommendations to the Parties on this topic in its advice on the Parties' 2017-19 Priorities for Science (http://ijc.org/files/publications/SAB_advice_on_Parties_science_priorities.pdf).

- The importance of Public Advisory Councils (PACs) preparing for the transition to the post-delisting era so that community momentum gained through the RAP process can continue. This will have several benefits, including the possibility of greater community involvement in the lakewide management process (LAMP) associated with an AOC. Federal and/or state/provincial support for this transition improves the likelihood it will be successful. This is consistent with the public engagement principle included in the Agreement.

- Delisting reports should clearly summarize and reference available science and related information that demonstrates that all reasonable actions have been taken to eliminate local sources of contamination. In some cases, contaminants or influences from outside the AOC may prevent full remediation of beneficial uses (for example, fish consumption advisories related to mercury contamination from atmospheric sources).

The considerable resources being directed to implementation of remedial actions should logically lead to an eventual outcome of delisting for all AOCs. However, once the cleanup is complete, communities are faced with the question of how to maintain the remediated site and continue community participation in environmental stewardship, which prior to delisting often occurred through the AOC's PAC or equivalent. A report completed for the IJC included an initial

assessment of issues related to 'life after delisting' (Mandelia, 2016), and found that several challenges exist. These include a loss of momentum following delisting due to the loss of a tangible reason to organize, diffuse sources of funding for stewardship projects with uneven eligibility requirements (some funding sources require an AOC designation to qualify), and less frequent environmental monitoring than existed prior to delisting, which makes it more difficult to detect any worsening of environmental conditions. The report found that many PACs that were able to successfully transition to 'life after delisting' did so by including a focus on economic revitalization associated with their environmental projects, pursuing funding from a broader range of funding sources (in one case by incorporating as a charitable not-for-profit), and shifting from a reliance on agency monitoring programs to partnerships with universities and citizen scientists to ensure no backsliding of environmental conditions. The initial assessment also found that there is little awareness by the public of the larger lakewide management context where their AOC is situated and little involvement in the LAMP.

Delisting reports prepared for the AOCs delisted (or proposed for delisting) since the current GLWQA came into effect describe how environmental conditions at delisted AOCs will be characterized moving forward through ongoing long-term monitoring programs of the Parties and other agencies. It is generally the case that the intensity of monitoring activities in an AOC diminishes substantially once an AOC is delisted. Thus, there is a risk that deterioration of conditions in an AOC following delisting may not be detected in a timeframe that is appropriate. Given that the Parties plan to complete management actions and/or delisting numerous AOCs in the coming years, the importance of this issue is likely to increase.

5.9.2 Assessment of progress on lakewide management and cooperative science and monitoring

1. Background

Annex 2 (Lakewide Management) of the GLWQA commits the Parties to "(assess) the status of each Great Lake, and (address) environmental stressors that adversely affect the Waters of the Great Lakes which are best addressed on a lakewide scale through an ecosystem approach". Specific program commitments include establishing lake ecosystem objectives, undertaking science and monitoring activities, developing binational strategies to address substance objectives, developing an Integrated Nearshore Framework by 2016, and documenting and coordinating necessary management actions through the development of LAMPs.

Directly related to the Annex 2 commitments, Annex 10 (Science) includes a commitment to "implement a cooperative science and monitoring initiative for each of the Great Lakes on a five-year rotational basis. The Parties shall focus monitoring activities on the science priorities identified through the Lakewide Management Process. The Parties will coordinate these activities across government and non-government organizations."

Thus, the LAMP and Cooperative Science and Monitoring Initiative (CSMI) processes are inextricably linked in an iterative cycle of advancing the science needed to inform management decisions, which once implemented, alter system conditions that can be measured and quantified

through a subsequent cycle of science activities. The CSMI coordinates binational priority science and research activities in the Great Lakes basin with an emphasis on enhanced monitoring and research field activities, which are conducted on the basis of one lake per year on a five-year rotating cycle. Such coordination reduces monitoring costs and improves data collection efforts. The CSMI is intended to complement ongoing monitoring conducted by the Parties in coordination with state/provincial agencies and others for various environmental components, including nearshore and offshore water quality, sediment quality and fish tissue contaminant concentrations

The 2014-16 Priorities for Science and Action for Annex 2provided additional, time-bound details on the Agreement commitments, and included (but were not limited to) the following:

- Identify and address lake-specific priorities for science through the CSMI and LAMP processes. CSMI-focused science and monitoring field work occurs in 2013 in Lake Ontario, 2014 in Lake Erie, 2015 in Lake Michigan, 2016 in Lake Superior, and 2017 in Lake Huron.
- Draft lake ecosystem objectives for each Great Lake as benchmarks to measure status and trends, including a guidance document by July 2014 and draft objectives for Lake Erie by July 2015.

The Annex 2 section of the PROP includes a summary of the actions and outputs related to lakewide management for 2014-16. Many of the commitments and timelines included in Annex 2 have been met.

2. Assessment of indicators

The State of the Great Lakes 2011 report (Environment and Climate Change Canada and US Environmental Protect Agency, 2014) included an indicator on hardened shorelines, which was also included as a sub-indicator in the Watershed Impacts and Climate Trends section of the State of the Great Lakes 2017 Highlights report (ECCC and USEPA, 2017a). Due to data limitations in the 2014 report, this indicator included an assessment of only Lake Ontario. No other comprehensive datasets other than the sets used for Lake Ontario were identified in the preparation of this report. Binational hardened shoreline assessments for Lake Erie including its upstream (Huron-Erie corridor) connecting channel, as well as for southwest Lake Michigan and eastern Lake Huron would be helpful in understanding the condition and trends along the most intensively developed sections of Great Lakes shoreline. This indicator was not reported in the State of the Great Lakes 2017 report.

3. Assessment of progress on lakewide management

The work of the Parties has served to elevate the prominence of lakewide management under the GLWQA. The 2012 Agreement includes lakewide management as a stand-alone Annex, and assigned ambitious programs and measures to that Annex. Through that action, the Parties

appear to share the IJC's view that LAMPs have "the potential to be the core instrument to engage a broader array of governments, agencies and programs in the watershed and in nearshore and offshore waters of the Great Lakes Basin Ecosystem" (IJC, 2009, 12).

Progress on lakewide management in the United States has been largely resourced at a federal level through the US GLRI. The GLRI was launched in 2010 to accelerate efforts to protect and restore the largest system of fresh surface water in the world. Since then, GLRI has funded 3,455 projects totaling over $1.7 billion directed towards restoration work in highly contaminated AOCs, nutrient reduction, invasive species control and habitat restoration (US EPA, 2017a). Based on the lack of publicly available data, it is difficult to determine what level of investment is being specifically directed to LAMP priorities. This is also the case in Canada, where ECCC's resourcing for LAMP priorities is evidently diffuse and not centrally reported. It is important to note that in addition to federal investments in LAMP priorities, substantial support is provided by other project partners, including state and provincial governments.

In 2014, the Parties confirmed the LAMP and CSMI reporting rotational schedule where CSMI reporting occurs two years prior to the LAMP so that science findings can be used to inform management prescriptions (Table 5.9.1).

Table 5.9.1LAMP and CSMI Schedule*

Year	CSMI					LAMP
	Year 1: Priority Setting	**Year 2: Cruise Logistics**	**Year 3: Sampling**	**Year 4: Data Analysis**	**Year 5: Management Synthesis/Reporting**	
2016	Ontario	Huron	Superior	Michigan	Erie	Huron
2017	Erie	Ontario	Huron	Superior	Michigan	Ontario
2018	Michigan	Erie	Ontario	Huron	Superior	Erie
2019	Superior	Michigan	Erie	Ontario	Huron	Michigan
2020	Huron	Superior	Michigan	Erie	Ontario	Superior
2021	Ontario	Huron	Superior	Michigan	Erie	Huron
2022	Erie	Ontario	Huron	Superior	Michigan	Ontario

*Per Annex 2 of the Agreement, the associated connecting channel is included in the CSMI and LAMP activities related to the applicable lakes - Lake Huron includes the St. Mary's River, Lake Erie includes the St. Clair River, Lake St. Clair and the Detroit River, and Lake Ontario includes the Niagara River and the St. Lawrence River to the international boundary.

In 2015, the Parties released the draft Lake Superior LAMP for input, which was the first LAMP issued under the current GLWQA. The final Lake Superior LAMP was issued in September, 2016.The Lake Superior LAMP does an excellent job describing lakewide threats. These include aquatic invasive species, climate change, legacy chemicals, the eight established chemicals of mutual concern, and additional substances of concern (e.g. pharmaceuticals). The LAMP also discusses other threats including mining, oil transportation, and coastal development.

In May, 2017 the IJC provided its advice and recommendations on the LAMPto the Parties after consulting with its Great Lakes Advisory Boards. Those comments noted that available science information was well reflected in the LAMP, though the IJC highlighted the need for greater specificity in identifying priority projects, including details related to project objectives, lead organization, timelines, required resources and resource provision. The IJC also noted that the Lake Superior LAMP would benefit from a more detailed discussion of engaging relevant constituencies and communities; indeed, this is something that all subsequent LAMPs should do as well.

It is notable that almost four years after the 2012 Agreement came into effect, the LAMP partnerships have only recently begun to establish work group outreach and engagement subcommittees. It has been observed that while Tribes are engaged in LAMPs in the United States, the participation of First Nations in Canada is limited.

First Nations, tribes and other organizations with local knowledge have much to offer and could substantially improve the LAMPs. Engaging with indigenous, minority and subsistence communities that consume Great Lakes fish in greater quantities than the rest of the population is particularly important to include in these discussions.

In 2015, the IJC also provided its input to the Parties regarding their proposal to restructure the Lake Superior Binational Program (LSBP) into the Lake Superior Partnership. The LSBP's most important contribution to the quality of the water of the Great Lakes is arguably the Zero Discharge Demonstration Project (ZDDP), which has made important progress towards achieving zero discharges of the nine designated persistent, bioaccumulative toxic substances in Lake Superior. Because only two of the nine ZDDP critical pollutants have been designated by the Parties as Chemicals of Mutual Concern, the Parties need to clarify how the remaining seven ZDDP critical pollutants will be addressed through the Annex 3 process or through processes unique to Lake Superior. Additionally, the IJC recommended that the Parties report on the progress made towards each of the individual policy and action commitments contained in the LSBP, and which goals, policies and actions would be continued through the Lake Superior LAMP.

Annex 2 of the 2012 GLWQA included a new requirement that LAMPs include a lake's associated connecting channel, where one exists (Lake Huron and the St. Marys River, Lake Erie and the St. Clair River, Lake St. Clair and Detroit River, and Lake Ontario and the Niagara River and the St. Lawrence River to the international boundary). This provision applies to the Lake Huron LAMP, which was released in draft form for consultation in July, 2017. An expanded focus on the connecting channels is expected to result in a description of stressors and priority management actions which allow for greater integration of AOCs and LAMPs where connecting channels include AOCs, since both address similar stressors at different spatial scales within the same geographic areas. It will also bring greater focus to the influence of connecting channels on the physical, chemical and biological integrity of downstream waters.

<u>Development of an Integrated Nearshore Framework</u>

In accordance with their Annex 2 commitments in the GLWQA, in September 2016 the Parties published an Integrated Nearshore Framework (Canada and United States, 2016). The framework reflects considerable effort by the Parties and its partners, and builds on the IJC's earlier analysis and recommendations (IJC, 2011). The guiding principles included in the report are appropriate and comprehensive. The Lake Partnerships should play a central role in influencing the actions of individual agencies' projects and the voluntary actions of communities, and the Parties should commit to providing resources for the restoration or protection priorities for sections of coastline, as identified in the framework. The Parties could also play a larger role in centralizing information on nearshore stressors, consistent with the view expressed at an IJC workshop: "Although there are exceptions, there is no coordinated or easily accessible database to monitor and tabulate loadings of pollutants from direct dischargers and from diffuse and land-based sources. Data dealing with shoreline development, remediation and land use change are not centralized or provided in an inventory. Hence, understanding progress or priorities in nearshore areas is difficult" (IJC, 2009, 7).

Progress in this area is consistent with the coordination principle included in the GLWQA. A comprehensive and coordinated approach to tracking nearshore stressors would also assist with an assessment of the cumulative effects of multiple stressors, which is referenced in the nearshore framework but not discussed in detail.

4. Cooperative Science and Monitoring Initiative

The development of LAMP management activities relies heavily on science information developed through the CSMI. The program was established by the Parties in 2002 to coordinate monitoring, and in 2006 that program was expanded to include research coordination. Connecting channels were added in 2009, where those connecting channels affect the downstream lake. The CSMI was designed to coordinate binational priority science and research activities in the Great Lakes basin with an emphasis on enhanced monitoring and research field activities which are conducted on one lake per year on a five-year rotating basis.

In the 2012 GLWQA, the CSMI was formalized in Annex 10 which states "Lake-Specific Science and Monitoring: In addition to ongoing science and monitoring activities that are routinely carried out by the Parties and other government and non-government entities, the Parties shall implement a cooperative science and monitoring initiative for each of the Great Lakes on a five-year rotational basis. The Parties shall focus monitoring activities on the science priorities identified through the Lakewide Management process. The Parties will coordinate these activities across government and non-government organizations."

The Parties' PROP includes a useful description of the CSMI activities for the reporting period. The Parties reporting would be enhanced if the PROP could describe how the science information completed through the CSMI was used to inform management decisions, using specific examples to illustrate the science-management linkage on which the CSMI is founded.

In addition to the CSMI, ongoing monitoring is conducted by the Parties in coordination with state and provincial agencies and others for various environmental compartments, including

nearshore and offshore water quality, sediment quality and fish tissue contaminant concentrations. Temporally- and spatially-extensive monitoring activities completed by the Parties and others outside of CSMI are critical to understanding the status and trends of conditions in the lakes. Analysis completed by the IJC's Science Advisory Board on the Parties' open lake water quality monitoring, including ECCC's Great Lakes Surveillance Program ,which monitors open lake water quality for each binational lake every other year during spring and fall, and the USEPA-GLNPO's Open Lake Water Quality Survey, which currently surveys Lake Michigan annually in spring and summer, found that data from the Canadian side are generally comprehensive for a number of contaminants, including legacy contaminants, and to some extent chemicals of emerging concern. Data collection dates back to the mid-1980s, providing long-term coverage. However, data are lacking from the United States due to the termination of the USEPA's chemicals in water monitoring program in the late 2000s. This limitation mainly affects Lake Michigan, as ECCC continues to monitor the other four lakes for contaminants (IJC, 2016). Additionally, there are challenges in comparing Lake Michigan to the other lakes due to differences in survey techniques between ECCC and the USEPA (Roth et al.,2016).

The CSMI supplements the Parties' ongoing monitoring activities. Under Annex 2, individual Binational Lake Partnerships identify research, monitoring and other science priorities to assess threats to water quality and support management actions. To address these priorities, the Annex 10 CSMI Task Team works with governmental and academic scientists to develop, coordinate, and allocate resources for specific research activities for each lake on a five-year rotating basis.

The CSMI process relies on comprehensive and binational planning and reporting at two points in the CSMI cycle. Workshops are typically held: during the 'priority identification' phase (year 1 of the five-year CSMI cycle) when key agencies, organizations and researchers meet to assist the lake partnerships in finalizing lake-wide science and monitoring priorities; and at the 'reporting out' phase (year 5 of the five-year CSMI cycle) when key organizations and researchers present their key findings, which are used to inform LAMP reporting and the identification of required management actions for the next cycle. Through its Science Advisory Board's Research Coordination Committee, the IJC supports priority identification CSMI workshops, which helps fulfill the IJC's role described in Article 7.1(d) of the GLWQA. The Great Lakes Sea Grant Network also supports reporting out workshops which helps fulfils its extension mandate.

The CSMI program expands the range of science activities for a specific lake which are primarily funded by federal, state and provincial agencies. For example, for the last CSMI cycle for Lake Ontario for which comprehensive reporting is available (2008), investigations focused on the nearshore, including an assessment of nearshore/offshore gradients for multiple parameters under the influence of three different land use patterns, and an estimation of the biomass of *Cladophora,* dreissenid mussels, cyanobacteria and round gobies and investigation of the factors influencing those species (Richardson et al.,2012). The Parties' PROP notes that 2013 priorities for Lake Ontario include lower food web assessment, nutrient loadings and nearshore to offshore movement of nutrients. In November, 2016 a CSMI workshop was held to identify priorities for Lake Ontario's next monitoring year, scheduled for 2018.

A review of completed and planned CSMI activities suggests that the CSMI is focusing primarily on the lakes proper, with only limited focus on the associated connecting channels. Given that connecting channels can act as sources of stressors to the downstream lake and/or modify in-lake processes, the Binational Lake Partnerships and Annex 10 Cooperative Science and Monitoring Task Team could strengthen their assessments by increasing efforts on the connecting channels in the CSMI cycle. The IJC notes that connecting channels did receive attention at the November 2016 Lake Ontario CSMI priority identification workshop.

The IJC has heard from different groups with different interests that the CSMI has significantly improved coordination amongst federal science agencies and that some progress has been made coordinating involvement with state/provincial agencies. This encouraging progress towards research and monitoring coordination could be built upon in other areas, including academic partner involvement. Where coordination with academic researchers has occurred, it has tended to be through contractual relationships between federal agencies and universities. In some cases, CSMI resources have been used to leverage additional resources from non-CSMI funders to increase the amount of activity accomplished in support of CSMI priorities. The Lake Ontario CSMI is a good example where a strong lead role has been played by several universities and academic institutions. Continued efforts to expand the coordination role of CSMI to include universities either through continued contractual relationships or through expanded efforts to ensure university researchers understand CSMI priorities and, as appropriate, address them through their research activities could reap rewards. Greater academic involvement in the CSMI is likely to enrich the pursuit of priority science activities and/or appropriately adjust recurring CSMI activities. Similarly, greater emphasis on joint agency-academic activities would enlarge the network of experts focusing on advancing science related to the Great Lakes.

Broader engagement in the CSMI is expected to evolve with the relatively recent involvement of the Great Lakes Sea Grant Program and the International Association for Great Lakes Research (IAGLR) in CSMI-related activities.

The IJC has also heard during various consultations that reporting associated with CSMI often extends well beyond the reporting year (year 5 of the CSMI cycle) and is widely diffuse across agency reports, peer-reviewed journals and conference presentations. Sample processing, data analysis and the science report peer-review process takes time. However, the consolidation of preliminary CSMI findings is required on a timely basis, particularly for management decisions which must be made immediately following the CSMI cycle for a particular lake. The management synthesis report could incorporate results of previous CSMI cycles to identify trends and highlight long term accomplishments.

A key challenge related to the CSMI is the management and flow of information resulting from the process. The IJC's Science Priority Committee is conducting an analysis of issues related to information coordination and flow, which was informed by an expert workshop held in March 2016. Preliminary findings from that analysis found that there are many organizations that play a role in the data collection and information delivery continuum, and there is a need to have an overarching institution to play a coordination role. The Data Management and Sharing Task Team of the GLWQA's Annex 10, Great Lakes Blue Accounting, the IJC's Information Coordination and Flow Workgroup, the Great Lakes Observing System through the Data

Management and Communications (DMAC) subsystem, and EPA's Great Lakes Advisory Board's Science and Information Subcommittee are examples of such an institution. The Parties could participate in future efforts to improve the Great Lakes information flow from goal setting through information management and delivery.

The year 2016 marks the ten-year anniversary of the CSMI program being expanded to include research coordination. Two cycles of the CSMI have occurred during this period. Therefore, it is an opportune time to review the program and assess the success of the program and the extent to which the initiative has provided new data and information otherwise lacking or absent from 'off year' monitoring. As noted in the IJC's advice on the Parties' 2017-19 Priorities for Science, this assessment should include an examination of:

- What assets have been employed, and how are they deployed differently than off years?
- Are under-sampled periods (*e.g.*, winter conditions) or regions (*e.g.*, nearshore) or processes (*e.g.*, air-water exchange, nitrogen biogeochemistry) being identified and addressed?
- Does a five-year cycle make the most sense? To what degree does this preclude an examination of certain dynamics, such as comparisons across five years within an individual lake across a large range of processes?
- How can the focus on the connecting channels and St. Lawrence River be improved?
- How much is being invested in the CSMI effort and how is it apportioned?
- Is there a readily available repository of CSMI data and results?
- Is there merit in considering a 'Comparative Science and Monitoring Initiative' that examines processes and issues across the basin rather than on a lake-by-lake basis?

5.9.3 Assessment of progress on climate change

1. Background

Annex 9 of the GLWQA commits the Parties "to identify, quantify, understand, and predict the climate change impacts on the quality of the Waters of the Great Lakes," and to "sharing information that Great Lakes resource managers need to proactively address these impacts." Specific program commitments include:

- taking into account climate change impacts on the chemical, physical and biological integrity of the waters of the Great Lakes;
- using their domestic programs to address climate change impacts to achieve the objectives of the GLWQA; and
- communicating and coordinating on a binational basis.

The Annex also commits the Parties to coordinating actions where appropriate with water quantity management actions taken by or in conjunction with the IJC. There are additional science commitments, including:

- develop and improve regional-scale climate models to predict climate change in the Great Lakes basin ecosystem at appropriate temporal and spatial scales;
- link projected climate change outputs from the regional models to chemical, physical, biological models that are specific to the Great Lakes;
- enhance monitoring of relevant climate and Great Lakes variables to validate model predictions and to understand current climate change impacts;
- develop and improve analytical tools to understand and predict the impacts, and risks to, and the vulnerabilities of, the quality of the waters of the Great Lakes from anticipated climate change impacts; and
- coordinate binational climate change science activities (including monitoring, modeling and analysis).

Changes observed in the Great Lakes over the last several decades have been linked to climate change, including reduced winter ice cover, altered stratification patterns, increased summer temperatures, and more frequent and intense storms (Sterner et al., 2017). Climate change has emerged as a stressor to fish populations in large lakes, driven by processes including warmer temperatures throughout the water column, less ice cover, longer periods of stratification, and increased bottom hypoxia (Collingsworth et al., 2017). Biodiversity in general is being affected by climate change by shifting many species' distributions, and outpacing their adaptive capacities (Staudinger et al., 2013).

Although there is near unanimous scientific consensus that climate change is occurring and its effects are already being observed across the Great Lakes basin (McDermid et al., 2015) there continues to be uncertainty in establishing cause and effect linkages with climate change, and quantifying climate-induced effects is one of the grand challenges for Great Lakes research (Sterner et al., 2017).

2. Climate change Sub-indicators

Several sub-indicators developed by the Parties are signals of climate change. The USEPA observes that "water level and water temperature are two important and interrelated indicators of weather and climate change in the Great Lakes. Water level (the height of the lake surface above sea level) is influenced by many factors, including precipitation, snowmelt runoff, drought, evaporation rates, and people withdrawing water for multiple uses. Water temperature is influenced by many factors, too, but most directly by air temperature" (USEPA, 2017b). Assel(1999) observes, "The ice cover is also a sensitive indicator of climate change integrating fall, winter and spring energy exchanges between the lake and the planetary boundary layer.

- Surface Water Temperatures: *Increasing*. The Parties use the onset of stratification as the indicator. All three upper lakes have experienced earlier stratification, Lake Superior onset of stratification has occurred 4 +/-2 days earlier since 1979 and both Lakes Michigan and Huron onset of stratification has occurred 5+/-2 days earlier since 1980. The trend is undetermined for Lakes Erie and Ontario because of insufficient data.

- Water levels: Water level conditions have historically varied, and continue to vary considerably across each of the Great Lakes. Using the 1985 to 2015 period as the basis for measurement, there was a decreasing trend in levels on four of the five Great Lakes. However, for 2011-2015 levels show an increasing trend for some lakes.

- Ice cover: *Declining*. The basin-wide loss of average ice cover from 1973 to 2015 was 26 percent.

At the Great Lakes Public Forum, the Parties reported on climate change in the Great Lakes and presented its impact on ice cover (Figure 5.9.1).

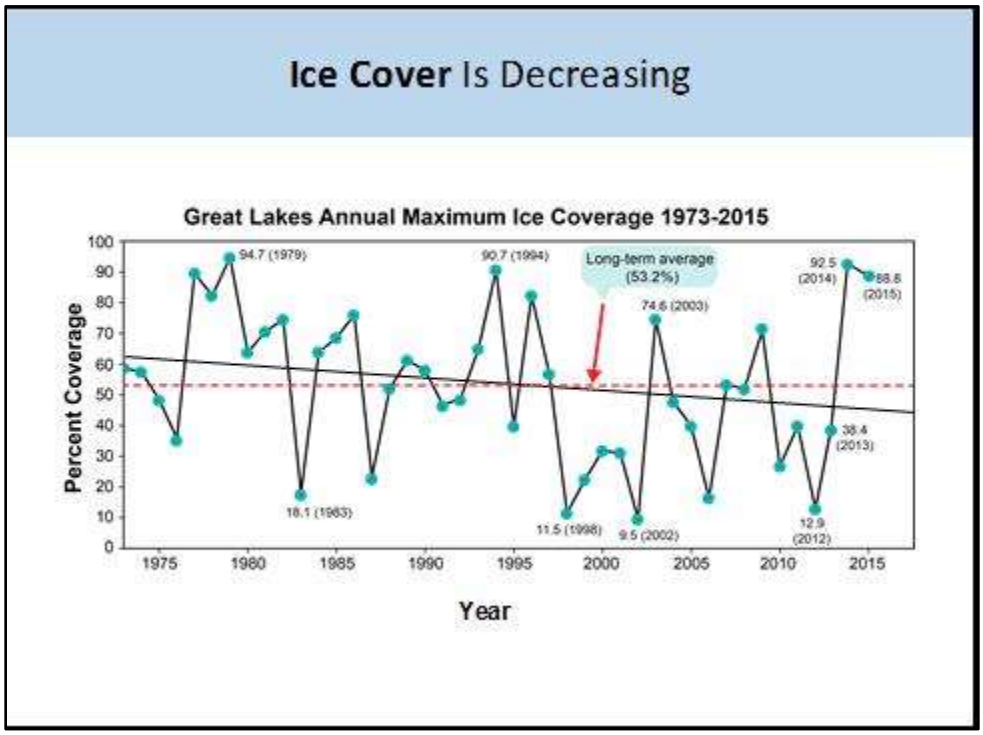

Figure 5.9.1 Ice coverage of the Great Lakes fluctuates from year to year but there is a downward trend over the past 40 years, possibly due to global climate change. Source: Draft SOGL as presented at the Great Lakes Public Forum.

The SOGL 2017 Highlights Report (ECCC and EPA, 2017a) includes reporting for the climate trends indicator (which is in turn based on five sub-indicators). The report summarizes data collected over the past 30-40 years that shows increases in temperature, precipitation, and reduced ice cover. The report acknowledges that climate information is not assessed in the same manner as other indicators – the assessment includes climate trends, but not climate status. Since scientific certainty is high (and increasing) that climate change will affect the condition of the lakes and their myriad processes, an approach to assessing climate status would be a useful addition to subsequent SOGL reports. The IJC notes that variability in the regional climate has caused levels of the Great Lakes to fluctuate greatly in recent decades (Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, 2017). As the State of the Great Lakes

2017 Technical Report notes, discerning any trend in lake levels depends upon the period of record selected (ECCC and USEPA, 2017b).

While the SOGL reports a significant decreasing trend for the 1985-2015 period on four of the lakes, using the 1987 to 2017 period as the basis for measurement, there was no significant trend in levels on any of the five Great Lakes. Recent variability in lake levels is more notable. Record-setting high levels occurred on lakes Superior, Michigan-Huron and Erie in 1985-86. Record-setting monthly low levels occurred on Lake Superior in 2007 and on Lakes Michigan-Huron in 2013. In 2017, the levels of all the Great Lakes were the highest they've been in decades, with Lake Ontario levels surpassing the previous record high set in 1952.

In addition, the Commission has heard that climate change may be impacting the traditional range of manoomin (wild rice) in the Great Lakes due to warming winters and changing water levels, affecting Indigenous Peoples' culture, health and well-being.

3. Assessment of the Progress Report of the Parties

The Parties note that five items included in the binational priorities for science and action released on March 10, 2014 correspond to Annex 9 commitments. These are:

Science

- Compile existing knowledge on Great Lakes climate change.
- After compiling Great Lakes climate change knowledge, assess and identify critical information needs and develop strategies to address those gaps.

Action

- Address the needs of other GLWQA annexes for improved climate change science (*e.g.*, understanding positive and negative impacts predicted under climate scenarios, monitoring of climate variables, improving tools for the analysis of climate change).
- Communicate and share climate change information with key user groups throughout the Great Lakes basin.
- Refine existing "Great Lakes Climate Summaries and Outlooks" factsheets with enhanced binational collaboration to produce and deliver climate information on a regular basis.

In the PROP, the Parties identify a variety of initiatives to carry out the priorities. For example, to enhance understanding and compile knowledge on Great Lakes climate change, the Great Lakes Evaporation Network has deployed *in situ* measurements – including offshore eddy flux towers, buoy-based sensors, and vessel-based platforms – through binational collaboration to reduce uncertainties in the Great Lakes water balance, provide a more robust basis for short- and long-term projections, and fill a significant gap in over-lake flux measurements, including evaporation and water temperatures, and related meteorological data.

Another example of compliance with Agreement priorities is the *Quarterly Climate Impacts and Outlook: Great Lakes Region*, jointly prepared by the US National Oceanic and Atmospheric Administration (NOAA) and ECCC. Published approximately four weeks after the end of each

season, it summarizes the latest season's weather and water level conditions and impacts over the Great Lakes and provides an outlook for the upcoming quarter.

Perhaps the most important action was the *State of Climate Change Science in the Great Lakes Basin Report*, (released in October 2015) which will support Annex 9 commitments. The report captures available science on impacts of climate change in the Great Lakes Basin and inventories the climate change assessment methods applied in the region (McDermid et al., 2015). This report includes a companion database with summaries of more than 250 recent climate change studies.

The Progress Report of the Parties also identifies a significant number of domestic actions taken in fulfillment of GLWQA commitments on climate change. For example, Canada is developing Regional Climate Change models for the Great Lakes – St. Lawrence River system. Fisheries and Oceans Canada, Hydro-Quebec, Centre of Water Expertise of Quebec, Ouranos, and ECCC are conducting a coordinated evaluation of the impacts of climate change on the levels and flows of the St. Lawrence River from 1961-2100.

The NOAA GLERL developed and released a basin wide Water Level Dashboard in 2014. The dashboard is an interface for visualizing projected, measured, and reconstructed surface water elevations on the earth's largest lakes. The dashboard reflects relationships between hydrology, climate, and water level fluctuations in the Great Lakes.

Actions reported by the Parties strongly emphasize physical and chemical parameters associated with climate change. Only two of the eight actions identified by the Parties are associated with potential biological impacts.

The Parties have satisfactorily addressed the science commitments made in Annex 9, cooperating successfully on numerous measurement and communications projects and meeting timelines. However, the Parties have not implemented some of the program commitments in Annex 9.

To better understand the capacity of governments to confront the realities of climate change, a project completed under the auspices of the IJC's Great Lakes Water Quality Board (Innovolve Group, 2016) looked at climate projections and their likely environmental impacts in the Great Lakes region. The project also examined the preparedness of governments for adaptation and resilience. Analysis from the project found that although most jurisdictions have a climate change policy or plan in place, mitigation is more common than climate change adaptation or resiliency planning. Newer plans are placing greater focus on adaptation measures and their implications for water quality. In most cases, adaptation planning remains a distinct activity, not fully integrated into broader government planning. Most adaptive actions are not adopted in light of climate change alone. It is therefore important to integrate climate change adaptation initiatives with other programs, such as resource management and sustainable development, coastal zone management, watershed management, and community development.

Municipalities in particular will face formidable water quality challenges resulting from climate change. With more frequent and intense storms, municipal combined sewer overflows can be expected to increase, promoting eutrophication and hypoxia and exposing the public to pathogens through recreational contact or drinking water. The Water Quality Board found that

stormwater management is not advancing with sufficient speed across all jurisdictions to address the changing climate. The importance of preventing combined sewer overflow discharges to the Great Lakes and their tributaries will only increase in the coming decades as the climate changes due to historic and ongoing greenhouse gas emissions. Governments need to invest in solutions that either increase storage within combined sewer systems or result in sewer separation.

The Water Quality Board project also showed the likelihood of increasing variability in lake levels and frequency of extreme precipitation events related to climate change. These events could lead to loss of valued ecosystem services from coastal damage, pose challenges to the integrity of coastal water infrastructure and degrade wetlands and other nearshore habitats. The IJC, as part of its mandate on water levels and flows in the Great Lakes through the Boundary Waters Treaty, has a record of making recommendations to governments related to the wise management of shoreline and coastal land use as the principal component of mitigation strategies meant to alleviate the adverse consequences of constrained water level fluctuations. This includes consideration of land use planning and zoning as ways to safeguard shoreline and coastal regions and provide protection to fish and wildlife habitat from development that would negatively impact estuaries and wetlands.

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4. IJC activities

The IJC's Great Lakes Adaptive Management (GLAM) Committee commissioned a physical surveillance report (Mortsch, 2016) which built on the analysis reported by McDermid et al. (2015) by focusing on climate effects on additional physical conditions including storms, winds and waves, ice cover, and coastal and riverine processes. Insights gained on these conditions are expected to be useful to the GLAM Committee as its undertakes the monitoring, modeling and assessment needed to support ongoing evaluation of the regulation of Great Lakes water levels and flows.

The IJC's Great Lakes Water Quality Board undertook a review of government policies associated with climate change resiliency in the region (Water Quality Board, 2017). The board sought to identify roles and actions that US. and Canadian jurisdictions can undertake to: reduce the impact of climate change and/or support adaptive capacity within existing authorities; identify gaps in the regulatory framework leading to degradation of water quality, failure to achieve GLWQA objectives, or resulting in negative ecosystem effects; and identify roles that non-government actors and sectors can play to complement government action in addressing these issues.

The board's report included a summary of climate-related projections in the Great Lakes region and their likely environmental impacts, as summarized in Table5.9.2.

Table 5.9.2 CLIMATE PROJECTIONS AND LIKELY ENVIRONMENTAL IMPACTS IN THE GREAT LAKES REGION

Climate-related Projections in the Great Lakes Region	Likely Environmental Impacts
Warmer air temperatures (esp. warmer nights; warmer winters; even *warmer* water temperatures)	• Less ice cover; less stratification and oxygen distribution in the lakes • More lake evaporation year-round (trending to lower lake levels) up by 25 percent since 1980 • More favorable conditions for algae and bacteria • Loss of habitat and/or increased stress for cool and cold-water fish • Increased likelihood of heatwaves and urban heat-island effects; heat-related illnesses • More warm weather pests, including invasive species • Stress on livestock and crops; reduced productivity • Loss of valued ecosystem services (flood buffers, water filtration, erosion stabilization, coastal habitat including nesting/nursery areas) from coastal erosion, damage to streamside habitat; loss of important populations • Challenges to coastal water infrastructure (drinking water intake and discharge disposal infrastructure not easily adaptable to high lake level variability) • Exposed contaminated areas from lower levels, dredging harbors to support shipping in low water years • Risks for coastal development during low water years and "hardening" shorelines
More precipitation and more extreme precipitation events	• Increased polluted runoff, especially from intense spring storms • Sediment and nutrient "flushes;" rapid increased loading in Great Lakes watersheds and the lakes themselves • Algal blooms, oxygen depletion, dead zones, cyanobacteria • Loss of safe drinking water supplies • Degraded wetlands and coastal habitat
More extreme swings between periods of drought and drench	• Loss of valued ecosystem services (flood buffers, water filtration, erosion stabilization, coastal habitat including nesting/nursery areas) from coastal erosion, damage to streamside habitat; loss of important populations • Challenges to coastal water infrastructure (drinking water intake and discharge disposal infrastructure not easily adaptable to high lake level variability) • Exposed contaminated areas from lower levels, dredging harbors to support shipping in low water years • Risks for coastal development during low water years and "hardening" shorelines
Increasing variability in lake levels	• Loss of valued ecosystem services (flood buffers, water filtration, erosion stabilization, coastal habitat including nesting/nursery areas) from coastal erosion, damage to streamside habitat; loss of important populations • Challenges to coastal water infrastructure (drinking water intake and discharge disposal infrastructure not easily adaptable to high lake level variability) • Exposed contaminated areas from lower levels, dredging harbors to support shipping in low water years • Risks for coastal development during low water years and "hardening" shorelines
Changes in vitality and distribution of cold-climate-dependent	• Changes in species range and relative abundance, especially for cool and cold-water fish • Likely range expansion for warm-weather invasive species, including diseases,

species--both aquatic and terrestrial	crop pests, expanded ranges for zebra and quagga mussels • Changes in terrestrial tree and plant species along coastal areas and Great Lakes tributaries that will likely alter wildlife species distribution
Nutrient and invasive species challenges exacerbated	• Polluted runoff from extreme storms enriches nutrient and bacteria loadings into near-shore waters • Zebra and quagga mussels filter nearshore waters, increasing light penetration; • Sunlight penetration and warmer air temperatures warm the waters faster, deeper, and to higher temperatures • Sunlight and warm water supports growth of algae and other phytoplankton • With plenty of nutrients, warm water and sunlight, algae growth "explodes" • Massive blooms die off and use up dissolved oxygen=dead zones
Changes in seasonal wind directional (vector) patterns	• Reduced exchange between waters in bays with low oxygen levels and open lake waters; potential increase in dead zones, especially Green Bay, Western Lake Erie
Negative Synergies from multiple effects	• Polluted runoff from extreme storms enriches nutrient and bacteria loadings into near-shore waters • Zebra and quagga mussels filter near-shore waters, increasing light penetration • Sunlight penetration and warmer air temperatures warm the waters faster, deeper, and to higher temperatures • Sunlight and warm water supports growth of algae and other phytoplankton • With plenty of nutrients, warm water and sunlight, algae growth "explodes" • Massive blooms die off and use up dissolved oxygen=dead zones

Source: IJC WQB Emerging Issues Work Group, Climate Change and Adaptation in the Great Lakes (2017)

The board's report provides recommendations to the IJC corresponding to the tasks above, including:

- The IJC should advise the Canadian and US governments to demonstrate global leadership by jointly developing a Binational Approach to Great Lakes Climate Change Adaptation and Resilience in the Great Lakes.
- The IJC should advise the governments that investments in research, information sharing and knowledge management are needed to carry out a Vulnerability Assessment, to engage stakeholders and rights holders, and to identify priorities for responsive actions in the Great Lakes region.
- The IJC should recommend to governments that they create a staff-supported *Network of Networks* (or augmentation of an existing network) to collect, aggregate and share information that can support climate adaptation response strategies at federal, regional, state/provincial, and local scales.

Another concern of climate change is increased stormwater runoff. Future climate conditions in the Great Lakes basin are expected to lead to warmer temperatures, as well as precipitation events of increased intensity and frequency (Collingsworth et al., 2017). With more frequent and intense storms, municipal combined sewer overflows can be expected to increase, with concomitant implications for environmental quality (e.g., eutrophication and hypoxia) and human health (e.g., pathogens and risk of exposure through recreational contact or drinking

water). Analysis completed by the IJC's Water Quality Board (Innovolve Group, 2016) found that most jurisdictions have addressed stormwater management, although stormwater management is not advanced across all jurisdictions. The importance of preventing CSO discharges to the Great Lakes and their tributaries – for example, through increased storage within the combined system, or sewer separation – will only increase in the coming decades as climate changes due to historic and ongoing greenhouse gas emissions.

5.9.4 Assessment of progress on adaptive management

1. Background

In outlining principles and approaches to be employed in the implementation of the GLWQA, Article 2(4)b defines adaptive management as "implementing a systematic process by which the Parties assess effectiveness of actions and adjust future actions to achieve the objectives of this Agreement, as outcomes and ecosystem processes become better understood."

There are two specific mentions of adaptive management elsewhere in the document. Annex 3(b)(6) seeks progress "toward the sound management of chemicals of mutual concern using approaches that are accountable, adaptive, and science-based." Annex 7(b)(2) calls for "lakewide habitat and species protection and restoration conservation strategies that use adaptive management approaches."

Assessing the deployment of an approach like adaptive management is difficult to do across the full range of the GLWQA and its Annexes. The integration of adaptive management with discrete tasks is only measurable after the fact. However, several examples illustrate the efforts of the Parties with respect to implementing adaptive management measures in support of the GLWQA objectives.

The Interagency Task Force implementing the USEPA's GLRI has developed a conceptual framework for science-based adaptive management as guidance for the GLRI Action Plan II.

The framework consists of the following elements:

- Conduct annual planning (*i.e.*, the five-year GLRI Action Plan) to identify projects to address priority ecosystem problems;
- Fund projects in accordance with the GLRI Action Plan and annual planning process;
- Assess project effectiveness on multiple scales and use this information in the annual planning process;
- Assess Great Lakes ecosystem health and identify ecosystem problems and use this information in the annual planning process;
- Communicate the GLRI progress through a number of outreach strategies; and
- Prioritize ecosystem problems to be targeted through GLRI in the annual planning process.

The Task Force has developed a GLRI Adaptive Management Implementation Pilot for Western Lake Erie Basin as an extension of the *Science-based Adaptive Management Process for GLRI Action Plan II* described above. A US federal interagency task team will test an adaptive management framework and refine processes and methods for multi-agency coordination of science to improve restoration outcomes for western Lake Erie.

The Parties are also applying adaptive management to the setting of phosphorus reduction targets for Lake Erie. The USEPA is currently working with other federal, state and Canadian partners to develop a long-term plan that will identify the monitoring, data and analyses needed to support implementation and evaluation of these nutrient reduction goals as part of an ongoing, adaptive management approach.

In the latest iteration of the 2014 Canada Ontario Agreement regarding the Great Lakes, the federal and provincial governments agreed to: "enhance knowledge of existing and future impacts of climate change in relation to the Great Lakes"; and "shareinformationaboutclimatechangeimpacts,advancethe integrationof thisinformationinto Great Lakesmanagementstrategiesand promoteadaptationactions" (COA, 2017).

2. IJC activities

In March2012,theInternational UpperGreat LakesStudy(IUGLS) Board concluded a five-yearstudy reviewing theregulation ofwater levelsontheupperGreatLakes. TheIJC then issueda directivetotheInternational GreatLakes-St. LawrenceRiverAdaptiveManagementTaskTeam(TaskTeam)todevelop an Adaptive ManagementPlan fortheGreat-LakesSt. LawrenceRiversystem. In April 2013,theIJC providedits report to governmentsregarding theIUGLSand endorsedtheimplementation ofa comprehensiveAdaptiveManagementapproach supportedby scienceand monitoring (IJC, 2009). The Task Team's 2013 AdaptiveManagementPlan proposed twointerconnected initiatives:

1. Ongoing reviewand evaluationof theeffectivenessofthe IJC's regulationplan rulesatmeeting their intended objectives;and
2. Collaborationon developing and evaluating solutionstoproblemsposed byextremewater level conditionsthatcannot besolved through lakeregulation alone.

The IJC shared the Task Team's report and proposed AM plan with the Parties. As the first of these proposed initiatives related to the Commission's existing orders of approval, the IJC in January of 2015 launched the Great Lakes – St. Lawrence River Adaptive Management Committee (GLAM) as an ongoing body to apply an adaptive management approach to the Commission's Great Lakes - St. Lawrence water level regulation responsibilities. The GLAM Committee will monitor, model and assess conditions to provide on-going information on how the regulation of water levels and flows affects socio-economic interests and the environment. As more is learned, and as climate and other conditions change over time, this information will help determine whether the IJC should consider changes to the methods used to regulate flows and levels.

5.9.5 Assessment of progress on microplastics

1. Background

Numerous studies havedocumented plasticdebris, such asplasticbags, bottles, boxes,fibers, microbeads, and cigarettebutts, in marine andfresh waters, includingthe GreatLakes. This larger plastic debriscan degradeinto smaller particles. Particles that are smaller than 5-mm in diameter are known as microplastics.There are several categories of microplastics, including preproduction plastic pellets and flakes, microfibers, breakdown materials from larger plastics and microbeads. Microbeads, the most well-known of these categories, are small plastic beads that are added as an abrasive to personal care products, including cosmetics, face washes, toothpastes, deodorants, hair coloring, shaving creams and sunscreens.

Thesesmaller plastic particles, the microplastics, areof particular concern.Theycan beeasilyingested byaquaticorganisms. Little is known about the fate of these smaller plastic particles, and there is concern about their potential impacts on environmental and human health. Laboratory studies have shown that chemicals, such as PCBs and PBDEs, can bioaccumulate in the tissues of fish that have consumed microplastic particles (Rochman et al., 2013; Wardrop et al., 2016).

Microplastics became a significant concern for the Great Lakes in 2013 with the publication of research by a team from the State University of New York – Fredonia that found high volumes of plastic pollution in the open waters of the Great Lakes. Microplastics comprised 98 percent of the plastic items captured, a proportion much higher than that found in the world's oceans (Eriksen et al., 2013).

The Province of Ontario has undertaken research to examine the sources and composition of microplastics in and entering the Great Lakes and to determine what happens to them when they enter the Great Lakes -- whether they wash up on shore, settle to the bottom, or remain in the water. In 2014, staff from Ontario's Ministry of the Environment and Climate Change (MOECC) collected surface water samples from nearshore areas in Lake Erie downstream of Detroit-Windsor, near the mouth of the Grand River, and near Fort Erie. Samples from Lake Ontario were collected in Hamilton Harbour, Humber Bay near Toronto, and in Toronto Harbour. Up to 6.7 million particles of plastic per km^2 (17.35 million per $mile^2$) were found with the highest count occurring in Humber Bay of Toronto. Greater amounts of microplastics were present after rainstorms, indicating that runoff of debris from the landscape through storm water is an important source to the lakes. Microbeads were present in wastewater effluent samples, comprising up to 30 percent of the microplastics found in the effluent samples.

Cooperative Canadian research to determine whether microplastics reach bottom sediments found that microplastic particles are present in sediment cores from the center of Lake Ontario and from near the Niagara River, but that microbeads are not present in these samples. Polyethylene was the most abundant polymer type, even though it typically floats rather than sinks to bottom sediments. Sampling of sediments in the St. Lawrence River found that microplastics, and specifically microbeads, were present in samples ranging from as little as 7

beads per m^2 to as high as 136, 926 beads per m^2, where areas received municipal and industrial effluent discharges (Castaneda et al., 2014).

2. Assessment of activities of the Parties

No Annex or specific provision of any Annex in the GLWQA explicitly addresses microplastics. However, one of the principles and approaches outlined in the GLWQA, the precautionary approach, does have implications for addressing microplastics. The GLWQA defines precaution as set forth in the Rio Declaration on Environment and Development: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." The potential impacts of microplastics on the Great Lakes ecosystem are significant enough to warrant measures be taken at the earliest possible opportunity.

The Parties have undertaken a number of activities related to marine debris, including researching, understanding and developing program and policy options to deal with microplastics.

The NOAA operates the Marine Debris Program, which supportsmarine debrisprojectsin partnershipwithstateandlocalagencies,tribes,non-governmental organizations,academia,andindustry (https://marinedebris.noaa.gov/). Theprogramalsospearheadsnationalresearcheffortsand workstochangebehaviorinthepublicthroughoutreachandeducationinitiatives.Inaddition,the NOAAMarineDebrisProgramsupports locally-drivenmarinedebris preventionandremoval projectseachyear. Within the Marine Debris Program is a Great Lakes specific, “Great Lakes Land-based Marine Debris Action Plan” that establishes goals, objectives, and strategies to promote coordinated action to address the threats posed by land-based marine debris, in the Great Lakes from 2014 through 2019. This comprehensive framework for action is meant to ensure that the Great Lakes, its coasts, people, and wildlife are free from the impacts of marine debris.

The USEPA Trash Free Waters program focuses on understanding the different types, sources and conveyances of marine debris throughout a watershed. The program addresses improper disposal of waste on the water and onshore, trash entering waterways through storm drains and when sewers overflow, promotion of proper trash disposal and recycling, and monitoring of debris trends in the environment. The program has a goal of approaching zero-loading of trash into US waters within ten years.

The US Geological Survey studied the quantity of plastics in 29 Great Lakes tributaries and found that 98 percent of the plastic particles were microplastics (Baldwin et al., 2016). Fibers and lines were the most common item found and this differs from lake studies that found fragments to be more common. That may be because fibers and lines may settle when they get to the more lentic lake waters. This project is another example of Great Lakes work funded by the GLRI through the USEPA’s Great Lakes National Program Office.

ECCC administers several federal laws and programs promoting sound waste and wastewater management, provides funding opportunities for community activities such as beach clean-ups, and waste and wastewater infrastructure and technology innovation, and collaborates with the other jurisdictions through the Canadian Council of Ministers of the Environment to improve waste diversion and management, including an action plan for Extended Producer Responsibility. ECCC has also made international commitments including theG7Action PlantoCombatMarineLitter, which identifies15priorityactionstoaddressmarine litterin fourkeyareas:land-basedsources;sea-based sources;removal;andresearch,outreachandeducation.

On December 28, 2015, the *Microbeads-Free Waters Act*became law in the United States. The act eliminates the uncertainty over biodegradability. It defines microbeads as "any solid plastic particle that is less than 5 millimeters in size," pre-empts all state laws and removes the biodegradable loophole. It prohibits soaps, body washes, toothpaste and other personal care products from containing the traditional plastic or biodegradable plastic beads as of July 1, 2017. The law also prohibits the sale of products containing microbeads as of July 1, 2019, which means all existing stock of products with microbeads must be eliminated from store shelves by that date.

3. IJC activities

The IJC is concerned about the potential ecological and human health impacts of microplastics in the Great Lakes. To explore the issue, the IJC convened a two-day workshop in April 2016 to develop recommendations for the IJC to consider forwarding to the governments of Canada and the United States to help address the challenges posed by microplastics pollution in the Great Lakes. This as an opportunity for the governments to implement the principles of "prevention" and "precaution" that guide them in achieving the objectives of the GLWQA.

Workshop participants agreed that the presence of plastics, in any form, is not acceptable in the environment and therefore needs to be properly managed. It was also clear from the workshop that the science and knowledge on microplastics is evolving, particularly for freshwater systems and the Great Lakes specifically. Governments will need a better understanding of the issue in order to make informed decisions on policies and programs to effectively manage plastics and ultimately microplastics. As a result, IJC sent a letter to the governments and posted recommendations (IJC, 2017) on how to reduce prevention of plastic debris in the Great Lakes. The IJC recommended that prevention of microplastic and plastic pollution should be accomplished through binational planning that combines various approaches and tools, including science and research, policy, market-based instruments and education and outreach.

5.9.6 Section Summary

Objective 9 of the GLWQA addresses a wide range of important current and emerging challenges to the quality of the waters of the Great Lakes.

Areas of Concern

- The experience with AOCs serves as a strong reminder of the principle of prevention included in the GLWQA as many millions of dollars needed to be spent on clean-up that might have been avoided.

- Progress on AOCs has been substantial in the triennial period, particularly in the United States, with three more ACOs delisted and over 20 BUIs removed, due to USEPA's GLRI funding. For example, the GLRI has helped implement RAPs. Canada has also made progress, include large investments in Hamilton Harbour and Port Hope Harbour AOCs. Increased ongoing investments on the Canadian side to parallel increased ongoing US investments would accelerate binational progress on AOCs.

- Additional technical transfer between AOCs, and coordination between the domestic processes occurring on both sides of binational AOCs, also are required.

- Annex 1 is the only Annex in the GLWQA without an associated Great Lakes Executive Committee structure. For each of the other nine Annexes, the Annex Committees and Extended Subcommittees provide regular and recurring opportunities for agency staff from multiple levels of government, academics, NGOs, consultants, and others with a professional interest in the Annex topic to discuss Annex-related issues. This opportunity does not exist on a binational basis for AOCs.

Lakewide Management and Cooperative Science and Monitoring

- Progress in lakewide management has been mixed. In the triennial period, the Parties developed an Integrated Nearshore Framework and have initiated a pilot project to apply it. The first LAMPs were prepared, though it is still uncertain whether agencies and communities are sufficiently invested in the LAMPs, and whether their recommended actions are sufficiently prescriptive, for them to serve as the lens through which management actions are planned and implemented.

- Public consultation and outreach related to the LAMPs is currently underdeveloped. The Parties need to reaffirm their commitment to the principles and approaches of public participation and accountability in carrying out activities in support of lakewide management.

- The CSMI is a key mechanism to achieve the science priorities identified through the lakewide management process. The CSMI has significantly improved coordination among federal science agencies, and notes progress at the state/provincial level as well. This progress could be built upon by better engaging academic partners.

- Progress in the timely reporting and dissemination of preliminary CSMI findings that can inform the management decisions that must be made immediately following the CSMI cycle for a particular lake, but before full peer-reviewed science reports are published, is encouraged.

Climate Change

- There is near unanimous scientific consensus that climate change is occurring and its effects are being observed across the Great Lakes basin.

- The Parties have satisfactorily addressed the science commitments made in Annex 9, cooperating successfully on numerous measurement and communications projects and meeting timelines. However, greater emphasis on climate change adaptation and resiliency planning and action is required.

- Land use planning and zoning are useful tools for safeguard shoreline and coastal regions and provide protection to fish and wildlife habitat from extreme storm events and variability in water levels associated with climate change.

Adaptive Management

- The Parties have made considerable effort to incorporate adaptive management into key Great Lakes programs, including the GLRI and the Canada Ontario Agreement respecting the Great Lakes (COA).

Microplastics

- Microplastics are an emerging and challenging issue in the Great Lakes basin. The presence of plastics is not acceptable in the environment and therefore sources of plastics into the environment and plastics already in the environmentneed to be properly managed.

- The science and knowledge on microplastics, including their impacts on the ecosystem and human health is evolving, particularly for freshwater systems and the Great Lakes specifically.

- Binational planning to prevent microplastic pollution is needed and should include monitoring and research, pollution prevention, and education and outreach.

5.9.7 References

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Chapter 6 Other Advice

6.0 Introduction

Chapter 6 assesses key challenges that are critically important for making progress toward achieving the objectives of the Great Lakes Water Quality Agreement (GLWQA) but that are not directly addressed in any of the preceding Chapters. Specifically, this chapter seeks to:

- identify future improvements to the Great Lakes indicators used for decision making;
- evaluate Great Lakes indicator data availability and accessibility for making recommendations to the Parties on monitoring and information synthesis;
- review how governments and society could strengthen efforts to prevent future harm to the Great Lakes ecosystem; and
- discuss the importance of coordination and public engagement principles in GLWQA implementation and the reporting of their implementation.

6.1 Great Lakes indicators

6.1.1 Background

Article 7 of the GLWQA charges the IJC with the responsibility of assessing and reporting upon the progress of the governments of Canada and the United States in their implementation of the agreement. It calls for the IJC to provide other advice and recommendations as appropriate. Recognizing the importance of indicators in assessing progress, as well as managing and communicating data and information, the IJC has undertaken efforts to identify improvements and refinements to Great Lakes indicators (IJC 2013, IJC 2014a, HPAB 2014, SPC 2016, SAB-RCC 2016). Chapter 4 discussed improvements to indicators used for communicating status and trends to the public. This chapter discusses improvements for the indicators used for decision making.

As better monitoring data become more available and improvements to indicators can be instituted over time, increased understanding of the Great Lakes ecosystem will provide well-informed management decisions. This will also ensure that the IJC is well placed to fulfill the assessment and reporting responsibilities assigned by the GLWQA.

During the past three years, the IJC, through its Water Quality Board (WQB), Science Advisory Board (SAB), and Health Professionals Advisory Board (HPAB), has conducted extensive scientific analyses and consultations with experts in the Great Lakes region from both countries with a view of improving existing indicators for measuring the health of the Great Lakes. This effort is built on the many years of experience and products accumulated from the indicator development process of the State of the Lakes Ecosystem Conference of the governments of the Canada and the United States. As a result of this effort, the IJC recommended 16 ecosystem and five human health indicators, each consisting of multiple measures, to the Parties in 2014 (IJC, 2014a, HPAB, 2014). These indicators provide good coverage of the GLQWA objectives with a

small number of indicators. In recommending these indicators, the IJC recognized that data are not available for some of the indicators but believes that most of the recommended indicators can be used as sub-indicators in the Parties' State of the Great Lakes reporting (SOGLR).

After determining how indicators recommended by the IJC could be applied or "operationalized", the Parties included,in their SOGLR, those indicators for which there are readily available data, along with additional climate and human population indicators (ECCC and USEPA, 2017a). As a result, the Parties usednine high-level indicators and 44 sub-indicators. For the purposes of assessing progress on the GLWQA, the nine indicators are aligned to the nine General Objectives. A sub-indicator is defined by the Parties as a measurable feature that provides outcome-oriented, managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality (ECCC and USEPA,2017a). For the purpose of this chapter, what the IJC refers to as "indicators" and "measures" can be considered to be equivalent to what the Parties refer to as "sub-indicators."

To fulfill its assessment and reporting responsibilities assigned by the GLWQA, the IJC has recognized the need for continuous improvement of indicators for future assessments of progress reports beyond 2017. Since the SOGL will only use indicators with available data, additional indicators and their associated measures that currently have partial or no data may be useful to improve the assessment and reporting responsibilities. Given that data collection is expensive and time-consuming, evaluation of the necessity of the additional indicators and measures proposed by IJC iscritical.

TheIJC's Science Advisory Board, Research Coordination Committee (SAB-RCC) led a workgroup consisting of members from the IJC's SAB, HPAB, and WQB to assess potential improvements to the set of indicators to be used in SOGLR 2017 (ECCC and USEPA, 2017a) for reporting progress toward achieving the GLWQA objectives and identified additional indicators needed to fill those gaps (SAB-RCC, 2016).

6.1.2 Indicator gaps

After consultation with Great Lakes regional indicator experts who are familiar with the GLWQA objectives, it was found that the sub-indicators used by the Parties in SOGL 2017 reporting generally well represent the nine GLWQA General Objectives (Table 6.1). However, the SAB-RCC work group identified four areas that could potentially be enhanced for future SOGL reporting (SAB-RCC 2016). The IJC supports all the recommendations in the SAB-RCC report. This section discusses the proposed recommendations and the next section focuses in on the data availability and accessibility aspects.

Table 6.1.Proposed IJC indicators and measures (from RCC 2016) with recommended additions to SOGLRidentified in boldand italic

GLWQA General Objectives	IJC

	Indicators	Measures
Objective 1: Be a source of safe, high-quality drinking water	Biological hazards of***source water***	*E. coli*
		Nitrate
		Turbidity
	Chemical integrity of***source water***	Atrazine
		Estrogenicity
		Cyanotoxins
Objective 2: Allow for swimming and other recreational use, unrestricted by environmental quality concerns	Illness risk at beaches	95th percentile of numbers of *E. coli* per 100 ml at beaches
	Source of risk at beaches	Percent of beaches with beach sanitary survey
Objective 3: Allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants	Contaminate levels in edible fish species	Concentrations of PCBs, DDT, mercury, chlordanes, toxaphane, mirex in edible portions of lake trout, walleye, yellow perch, whitefish, and smallmouth bass
Objective 4: 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	PBT in biota	PBT in whole fish
		PBT in herring gull eggs and bald eagle
	Chemicals of Mutual Concern in water	Chemical of Mutual Concern in water
	Atmospheric deposition of toxic chemicals	Atmospheric deposition of toxic chemicals
	Abundance and distribution of fish-eating and colonial nesting birds population status and health status	Population status
		Health status
Objective 5: Support healthy and productive wetlands and other habitats to sustain resilient populations of native species	Coastal wetland extent, composition and quality	Coastal wetland invertebrates
		Coastal wetland fish
		Coastal wetland plants
		Coastal wetland amphibians
		Coastal wetland birds
		Coastal wetland area and extent
	Shoreline alteration index	Shoreline alteration index
	Lower food web productivity and health	Phytoplankton biovolume
		Zooplankton biomass; ***Mysis biomass***
		Benthos abundance
		Preyfish biomass and diversity index
	Fish species of interest (recruitment and abundance)	Lake trout and whitefish
		Walleye
		Lake sturgeon
		Nearshore predators (largemouth/smallmouth bass, northern pike)
Objective 6: Be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts 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	Phosphorus loads and in-lake concentrations	In-lake Water TP and DRP concentrations
		Nearshore water TP, DRP, and nitrate concentrations
		Tributary TP and DRP loadings
	Harmful and nuisance algae	Harmful algal blooms
		Nuisance algal blooms
Objective 7: 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	Aquatic invasive species (invasion rates and impacts)	Rates of invasion
		Status and impacts of ***invasive plankton, Asian carp, round goby, ruffe, sea lamprey, Dreissenid mussels***

the quality of the waters of the Great Lakes		
Objective 8: Be free from the harmful impact of contaminated groundwater	Contaminants in groundwater	Measure of chemical and physical parameters from agricultural and urban watersheds
Objective 9: 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	Water level	Water level variability
		Timing of water level minimum and maximum
		Magnitude of seasonal rise and decline
	Water temperature	Summer average
		Stratification date
		Turnover date
		Maximum and average ice concentrations
	Land cover and fragmentation status	Land conversion rate
		Land fragmentation
	Tributary physical integrity	Hydrologic alteration (flashiness index)
		Tributary connectivity to Great Lakes
		Sediment-turbidity measure

1. Drinking water indicators

The GLWQA General Objective 1 states that the Great Lakes should "be a source of safe, high-quality drinking water," while the Parties used the sub-indicator of treated drinking water. Because this objective specifies the Great Lakes to be a "source" of safe, high quality drinking water,the SAB-RCC recommends ***using the HPAB (2014) proposed indicators of biological hazards and chemical integrity of source water*.** Since the purpose of the GLWQA is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes, reporting progress on the condition of sources of drinking water, rather than treated drinking water, is more appropriate. Additionally, with the highly advanced technology and associated cost, even sewage water can be treated to reach drinkable standards. Hence, measuring treated drinking water does not measure progress in protection and restoration of the health of the Great Lakes.

2. Nutrient indicators

The GLWQA General Objective 6 states that the Great Lakes "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." The Parties used the indicator of nutrients in lakes, which includes the concentrations of total phosphorus, dissolved reactive phosphorus, and nitrate in open water. The SAB-RCC suggests ***measuring concentrations of total phosphorus, dissolved reactive phosphorus, and nitrate in the nearshore and offshore***. Due to the invasion of Dreissenid mussels, the nutrient concentrations in four of the Great Lakes in offshore regions have been decreasing, which has been a concern for fisheries productivity (Hinderer et al., 2011). In contrast, the nutrient concentrations in some nearshore areas have been increasing due to watershed and coastal human activities. Given the difference in the trend in nutrient

concentrations between nearshore and offshore, the IJC suggests reporting on nutrient concentrations not only from offshore but from nearshore areas, as well.

The major nonpoint source nutrients for the Great Lakes waters are from tributaries. As a result, reporting on the trend of nutrient loading from tributaries is critically important for identifying pollutants' sources and developing effective management practices and policies in controlling such sources. Hence, the SAB-RCC recommends adding an additional sub-indicator to report on ***loadings of total phosphorus and dissolved reactive phosphorus from the major Great Lakes tributaries***.

3. Food web indicators

The GLWQA General Objective 5 states that the Great Lakes "support healthy and productive wetlands and other habitats to sustain resilient populations of native species." Because this objective includes both physical and biological aspects of the ecosystem, this objective is associated with the largest number of indicators. Although preyfish is used to indicate the health of wetlands, and preyfish and predators are used to indicate food web health in the offshore area, certain aspects of the nearshore food web indicator are missing. Hence, the SAB-RCC recommends ***adopting the IJC measure of recruitment and abundance of nearshore predators*.** This is because the nearshore area is the most productive and ecologically diverse zone of the Great Lakes, and is the most vulnerable zone to anthropogenic disturbances. The health of the food web in this area provides good signals of progress to restore and maintain the chemical, physical, and biological integrity of the Great Lakes.

4. Aquatic invasive species

GLWQA General Objective 7 states that the Great Lakes shall "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." The indicators used by the Parties include a host of measures (sub-indicators), including aquatic invasive species rate of invasion and status and impacts of sea lamprey and Dreissenid mussels. In addition to these measures, the SAB-RCC suggests also ***reporting on the status and impacts of Asian carp***since those species pose a major threat to the Great Lakes ecosystem and economy. Addressing Asian carp status and impacts in the SOGLR would also provide context and support for the Progress Report of the Parties, which addresses prevention and control programs (Governments of the United States and Canada, 2016).

6.2 Data availability and accessibility

6.2.1 Background

Under the GLWQA, the Parties are required to assess progress toward achieving the general objectives. Hence, the selected indicators must have adequate quantitative data for reporting progress consistently over time to enable tracking changes of the Great Lakes health. The SOGLR used only indicators with available data and was not able to use additional indicators identified by the IJC to improve reporting because data were not available. Accordingly, there is

a need to identify the resources necessary to fill indicator data gaps for future improvements in data collection, synthesis, sharing, and management.

Additionally, the SOGLR and the previous State of the Lake Ecosystem Conference (SOLEC) reports have been synthesized by authors who have subject expertise from government agencies, academia institutions, and non-government organizations. Those authors are either the data holders or they synthesize data from others who have access to them. After writing the reports, the data stay with the authors and are not stored and managed by a data-system that can be accessed by other users or updated. This may hinder consistency in data synthesis, summary, and interpretation for future SOGL reporting when the same indicators were reported by different authors in different reporting years.

6.2.2 Indicator reporting improvements

In consultation with more than 150 scientists, managers, and human health experts in the Great Lakes region, the SAB-RCC conducted a detailed analysis and assessment on data availability and data accessibility for the ecosystem and human health indicators and their associated measures that were recommended to the Parties (SAB-RCC, 2016). Based on the analysis and assessment of SAB-RCC, the IJC identified the following key areas related to data availability and accessibility that could be enhanced in the future.

1. Sub-indicators in use but need additional data

The majority of the sub-indicators for the draft SOGL have reasonable data coverage for status assessment, while some sub-indicators do not have sufficient data for detecting long-term trends. Two sub-indicators are of particular importance:

- *Coastal wetlands extent and composition sub-indicator*
  Mapping and estimation of the areal coverage of the Great Lakes coastal wetlands was done in 2004. As there has not been a complete update to the estimation of areal extent in over 10 years, the status and trend are undetermined for this sub-indicator. Hence, a complete update of such data is essential.

- *Harmful algal bloom sub-indicator*
  There are few long-term data collected on harmful algal blooms and more specifically, toxins, in the Great Lakes, making trend analysis difficult. The data sources presented in the SOGL (ECCC and USEPA,2017a) are varied and in many cases used different sampling and analytical methods. Monitoring in Lakes Erie and Ontario is generally good but monitoring in Lakes Michigan, Huron, and Superior is sparse and largely reactive to algal blooms. Well planned systematic sampling is needed.

2. Sub-indicators recommended and needed data

Integrating, synthesizing, or collecting data for the following sub-indicators that are not used in the SOGL are critically important for meeting the responsibility of assessing progress identified by the GLWQA.

- *The biological hazards and chemical integrity of source water*
  The data for these indicators currently are collected by municipal or state agencies using inconsistent methods and temporal intervals, although the Ontario Ministry of the Environment and Climate Change has monitored most drinking water plants across the province in a more consistent sampling frequency and approaches. Hence, readily available data for indicator calculation or trend detection are limited. Efforts are needed to harmonize municipal or state future sampling methods, and to integrate and synthesize existing data for detecting trends. The current use of treated water to assess status and trends of drinking water in the SOGL does not meet the requirement of assessing progress toward achieving the GLWQA objective of "The Waters of the Great Lakes should: be a source of safe, high-quality drinking water."

- *Illness risk at beaches and source of risks at beaches*
  These two indicators consist of calculating 95th percentile of numbers of *E. coli* per 100 ml at beaches and percentage of beaches with beach sanitary survey. Both US and Canada waters have available data, but efforts are needed to assemble and synthesize such data into consistent forms for indicator calculation or trend detection. The SOGL used beach advisories to assess status and trends, which may not be adequate for assessing progress toward achieving the GLWQA objective because the criteria of beach advisories have not been standardized among Great Lakes states of US and between Canada and the United States.

- *Tributary total phosphorus and soluble reactive phosphorus loadings*
  Tributary total and soluble reactive phosphorus loadings have been considered controlling factors for the harmful algal bloom in the Great Lakes and IJC recommended them as additional sub-indicators to fill the assessment gaps. Currently, such loading data are available for the major tributaries of Lake Erie, but limited data are available for the other lakes. Efforts are needed to monitor the long-term trend of total and soluble reactive phosphorus loadings from all the major tributaries of the Great Lakes.

- *Nearshore total phosphorus and soluble reactive phosphorus concentration*
  The SOGL (ECCC and USEPA,2017a) reported that while phosphorus concentrations were elevated throughout many parts of the Great Lakes in the past, problems of excess phosphorus are largely confined to some nearshore areas and parts of Lake Erie. In Lakes Michigan, Huron, and Ontario, the offshore total phosphorus concentrations may be too low and may negatively impact lake productivity. Nearshore nutrient enrichment persists in some locations of the Great Lakes, and nutrient targets are frequently exceeded and conditions are deteriorating for Lake Erie. Given that nearshore nutrient concentrations are much more influenced by local pollutant discharges and the offshore and nearshore nutrient concentrations show opposite trends in many parts of the lakes, there is a need to report on the status and trends of nearshore nutrient concentrations. Many federal and local programs have collected such data. However, these data are spread across many agencies and data collectors, and a consistent and coordinated effort to synthesize and integrate them is needed.

6.2.3 Data accessibility

There is not a central repository or single data portal for the data synthesized in the SOGLRor the previous State of the Lake Ecosystem Conference (SOLEC) reports. As a result, the data cannot be accessed for analysis or reporting by anyone other than the authors of the reports themselves. The authors for the SOLEC(2014) report and the 2017 SOGLR have changed substantially, which may hinder the consistency in data synthesis, summary, and interpretation for future SOGLRs. Hence, the IJC encourages the Parties to store the summarized data for the calculation of the sub-indicators into a centralized system, or an accessible distributed database that has public access and can be updated periodically, at least every assessment cycle. This system would improve transparency of the SOGLR and enhance scientific understanding and management decision making.

The majority of the indicator data are from federal programs, and the data management of these programs has not been integrated. The open data system effort of Canada and the data harvesting portals of the US Geological Survey, the Illinois-Indiana Sea Grant, the Great Lakes Observing System, the Great Lakes Aquatic Habitat Framework, and the US Environmental Protection Agency Great Lakes Environmental Database are promising initiatives. However, these initiatives are inconsistent, non-integrated, and sometimes redundant, and do not reflect the principles of accountability, coordination, and innovation established in the GLWQA.

A considerable portion of critical indicator data has been collected by local programs. This includes the human health source of drinking water data that have been collected by municipal or state programs. It will require sustained, binational efforts to synthesize, integrate, and harmonize these data to make them accessible and easily interpreted.

Overall, there is an urgent need to store and better manage the summarized data used by the SOGLR at a centralized location or a single database portal that can be accessed by others in the future (SAB-RCC, 2016). There is a need to establish a binational effort to synthesize and harmonize the needed indicator data that have been collected or will be collected by municipality and other local programs and to store the data in a publicly-accessible central location. These accessible data will not only increase the efficiency, consistency, and transparency of the assessment of progress, but also enhance the effectiveness of information delivery for public awareness and science-based policy and management decision making.

6.2.4 Funding for Great Lakes Monitoring and Restoration

The United States and Canada need to initiate and maintain long-term funding for the restoration of the Great Lakes. As was noted in previous sections of this report, much progress over the past few years has been credited to new investments from programs in the United States and Canada, especially the US Great Lakes Restoration Initiative (GLRI). The GLRI was launched in 2010 to accelerate efforts to protect and restore the Great Lakes and was the largest investment in the Great Lakes in two decades by the US. In 2010, a task force of 16 federal agencies and many of the region's governors released the GLRI Action Plan for US fiscal years 2010-2014 covering five "focus areas": 1) Cleaning up toxics and areas of concern; 2) Combating invasive species;3) Promoting nearshore health by protecting watersheds from polluted run-off; 4) Restoring wetlands and other habitats; and 5) Tracking progress, education, and working with partners

During US fiscal years 2015-2019, US federal agencies continue to use GLRI funding to target threats to the Great Lakes ecosystem and to accelerate progress toward long term goals. Implementation is guided by the GLRI Action Plan which has been updated for US fiscal years 2015-2019 to focus on:1)Cleaning up Great Lakes Areas of Concern;2) Preventing and controlling invasive species;3) Reducing nutrient runoff that contributes to harmful/nuisance algal blooms; and 4)Restoring habitat to protect native species.

One example of the advantages of the GLRI is the work cleaning up Areas of Concern. Many individual beneficial use impairments (BUI) have been removed at a number of sites that have been partially remediated. Canada made its greatest progress towards removing BUIs in the 1990s, while the pace of remediation of the US sites has picked up in recent years because of increased investment and effort under the US GLRI and the Great Lakes Legacy Act.

The 2014 Canada-Ontario Agreement provides a long-term framework for coordinated action on the Great Lakes. The Parties agree to create opportunities for others to contribute resources, as appropriate, to achieving the purpose of the Agreement.Ontario's Great Lakes Strategy 2016 progress report outlines some of the key accomplishments and new scientific findings established during the first three years of Ontario's Great Lakes Strategy. It represents the actions across 14 different Great Lakes ministries and numerous partners, including First Nation and Métis communities, municipalities, conservation authorities, environmental organizations, the science community, and the industrial, agricultural, recreational and tourism sectors.

In addition to the base funding for core programs across all ministries, Ontario invests an additional $15 million annually toward projects that directly benefit the Great Lakes. Since 2007, Ontario has invested more than $140 million into 1,000 local Great Lakes protection projects that have reduced harmful pollutants, restored some of the most contaminated areas and engaged hundreds of partners and community groups to protect and restore the health of the Great Lakes. Since 2007, Ontario has also invested more than $660 million in upgrades to municipal wastewater and stormwater infrastructure in the Great Lakes Basin.

Funding for monitoring - A small set of binational indicators is needed for effectively communicating with the public on whether the water quality of the lakes are improving or getting worse. However, additional binational monitoring data and indicators are needed to make better informed decision on Great Lakes Restoration and management strategies. For instance, monitoring data are needed to restore and delist Areas of Concern, to help ensure the pre-existing conditions do not return. Monitoring data are needed to understand the linkages between heavy rainfall, agricultural and urban runoff, combined sewer overflows, and harmful algal blooms in order to develop mitigation strategies such as green infrastructure. As the IJC noted in its 16th Biennial Report (IJC, 2013), perhaps the most conspicuous example of a monitoring gap is the absence of comprehensive binational lakewide, long-term monitoring of phosphorus loadings to the Great Lakes including Lake Erie, Lake St. Clair and portions of the other Great Lakes. The monitoring gap has complicated the selection of prevention and remediation measures. The parties need to understand the role of various sources of phosphorus into Lake Erie, Lake St. Clair and the other lakes to develop and implement effective management strategies

Therefore, it is critically important for the US and Canadian governments to fund and maintain a comprehensive binational water quality monitoring program within the Basin that includes indicators (or sub-indicators) designed to convey status and trends to the public and government resource managers and scientists.

6.3 Prevention of harm to the Great Lakes

6.3.1 Anticipation and prevention of emerging threats

Governments have had to devote significant resources to correct or remediate damage to the Great Lakes ecosystem for decades. Examples include newly introduced chemicals that cause unforeseen impacts, the arrival of invasive species such as zebra and quagga mussels that have altered the aquatic food web, and the sharp increase in runoff of bioavailable dissolved reactive phosphorus that has contributed to an unexpected rise in harmful algal blooms in western Lake Erie.

The need for anticipatory mechanisms to consider potential ecological threats has been noted. In 1995, the USEPA Science Advisory Board issued a report, *Beyond the Horizon: Using Foresight to Protect the Environmental Future*, which recommended, among other things, that the agency create a "look-out panel" with members from both inside and outside government to provide the USEPA and the nation with an early warning of environmental issues that may emerge in the future (USEPA, 1995). Other studies and documents have highlighted the need for greater anticipatory capacity to protect the Great Lakes through prevention.

Prevention is one of the principles and approaches in the 2012 GLWQA, which also charges the Great Lakes Water Quality Board, the principal advisor to the IJC, with "identifying emerging issues and recommending strategies and approaches for preventing and resolving the complex challenges facing the Great Lakes." The IJC's Great Lakes SAB advises the Water Quality Board and the IJC on the science underpinning Great Lakes matters.

During 2017 and 2018, the SAB, in partnership with the IJC's Great Lakes Water Quality Board, will explore the issue of emerging threats and advise the IJC. The SABwill synthesize current knowledge and evaluate existing approaches that may be suitable for anticipating and preventing potential threats to the Great Lakes. The Board is also expected to provide a report identifying potential environmental threats to the health of the Great Lakes ecosystem. The IJC, in turn, will advise the Parties as appropriate.

6.3.2 Public trust principles

The courts ofboththeUnited States andCanada have embraced common lawprinciples regardingwater useandmanagement founded, explicitly or implicitly, on the public trust doctrine. Under thelawsof both countries, the doctrine prohibits alienation, subordination and/or interferenceor material harmto basic publicuses of navigablewaterslikeTheGreatLakes. It also imposes an affirmative obligation on government as trustee to protect the integrity of these waters and the associated ecosystem.

Publictrust principles (Olson, 2014) thatapplyto navigablewaters like theGreatLakes, connectingwaters, and tributarywatersinclude:

- Publictrust waters andprotected uses cannot be alienated bygovernment and maynever betransferredor controlled forprivatepurposes; that is, a public purposeis required.
- A proposed diversion oruse cannot materiallyimpair the flow, level, integrity orqualityof publictrustwater, tributarywater, orpublictrust resources or protected public uses.
- Thesubstantial valueofpublictrust waters, natural resources, anduses is presumed, and the burden of proofis on those who seek to useoralter the publictrust commons or uses.
- Thereis no *De Minimis* harm that is exemptfrom the publictrust doctrine. Cumulativeeffects must be accounted for.
- Government hasa continuingdutyto determinethat therewillbeno impairment or harm to the flows, levels, quality, and integrityof publictrust waters, uses,and ecosystem beforeitapproves ordenies agovernmental or private action.
- Government as trustee and affected interestsmustbalancecompetinguses such that the public trust is notimpaired and publictrust uses arenot subordinated to privateuses. Private uses, whilelawful if reasonable, arecorrelative but cannotoverride the publictrust in these waters, natural resources,or thepublicuses dependent on them.

Publictrust principles can betracedfrom Rome to the present through the common lawsystems of both Canada and the United States (Sohm, 1970). As a resultof theheritageof Roman Justinian codes that deemed watera *juspublicum*, alimitation was established on the Crown's broad powers over publicwaters and natural resources ofaspecial or unique characterthat served substantial public needs. Generally, then,the waters of the GreatLakes arein thepublicdomain in thename ofthe Crown in Canadaand held or owned bythe sovereign state forthe benefit and welfareof its citizens in theUnited States.

In 1892, theUnited States Supreme Court, in*Illinois CentralRail Road Co.v. Illinois*, ruled that allof theGreatLakes weresubject to the public trust doctrine and a navigational servitudeinfavor of thefederalgovernment. The courtsin all eight GreatLakes states in theUnited States and the two Canadian provinces making upthe basin haverecognized the public trust doctrine, either expresslybynamingthe GreatLakes and theconnected ortributarywaterssubject to apublictrust or through application ofthe public's paramountright and useof publicor navigablewaters. Protection of public waters for public purposes has been called by a Michigan court "a high, solemn, and perpetual trust, which it is the duty of the state to forever maintain" (Collins *v.* Gerhardt, 1926).

More recently, the Canadian courts havebegun to recognizethe potential ofpublictrust principles, and several Canadian waterlawand policyexperts haveurged the adoption of explicit publictrust principles bythe courts orthe provincial governments. Canadian federal and provincialgovernments also havebegun to explorethe incorporation ofpublictrust principles into specific water andnatural resourcelaws. Thedoctrinealsohas been applied bythe courts ofother countries to protect common bodies of waterfrom abuseor private control.

Despite the expansive and court-backed authority of common law public trust principles, governments have occasionally been reluctant to apply them to prevent harm to public trust resources such as navigable waters and Great Lakes bottomlands, relying instead on specific

statutory enactments. Public trust principles underlie some of these statutes but the statutes are at times narrow in scope and do not fully empower governments to prevent harm.

In a time of unprecedented and uncertain changes resulting from the complex interaction of climate change, non-native species, water demands and other factors, public trust principles could play a significant role in preventing harm to the Great Lakes ecosystem. For example, in considering first-time proposals to use open waters of the Great Lakes for net-pen aquaculture, governments have not only the option, but also the duty of acting as a trustee of these waters for the public. If the effects of such a use are not fully understood or it is clear that the intended occupancy or subordination of an area of public waters would be for primarily private purposes, governments are obliged to deny the proposed use under public trust principles. If such a use would materially impair the flow, level, integrity or quality of public trust waters, tributary waters, or public trust resources, then governments are also obliged to deny that use. In this way, public trust principles can support and promote a *first, do no harm* management ethos to the world's largest freshwater ecosystem.

The IJC has previously encouraged Great Lakes jurisdictions to consider applying a public trust framework to the protection of Lake Erie (IJC, 2014b) and to the protection of the Great Lakes from potential harm caused by water withdrawals and consumptive uses (IJC, 2016). Support for a public trust framework was also expressed during the public engagement session at the Great Lakes Public Forum by those opposed to what are perceived as unsustainable commercial withdrawals of Great Lakes ground water.

6.4 Section Summary

- The SOGL report could be improved by including the indicators, sub-indicators, or measures proposed by the SAB-RCC, specifically,
  - biological hazards and chemical integrity of source water, proposed by HPAB (2014);
  - concentrations of total phosphorus, dissolved reactive phosphorus, and nitrate in the nearshore and offshore,
  - recruitment and abundance of nearshore predators, and
  - status and impacts of Asian carp.

- There is an urgent need to improve the storage and management of data used in SOGL. More accessible data will increase the efficiency, consistency, and transparency of the assessment of progress toward the objectives of the GLWQA, as well as enhance the effectiveness of information delivery for public awareness and science-based policy and management decision making. Specific needs include: strengthening storage and management of summary data at a centralized and accessible location; and establishing a binational effort to synthesize and harmonize indicator data that have been collected or will be collected by municipalities and other local programs.

- It is critically important for the US and Canadian governments to fund and maintain a comprehensive binational water quality monitoring program within the Basin. This

information will identify emerging water quality issues and show changes in trends for key ecological and human health parameters.

- The courts ofbothCanada and theUnited Stateshave embraced common lawprinciples regardingwater useandmanagement founded on the public trust doctrine. Under thelawsof both countries, the doctrine prohibits alienation, subordination and/or interferenceor material harmto basic publicuses of navigablewaterslikeTheGreatLakes. It also imposes an affirmative obligation on government as trustee to protect the integrity of these waters and the associated ecosystem. In a time of unprecedented and uncertain changes resulting from the complex interaction of climate change, non-native species, water demands and other factors, public trust principles could play a significant role in preventing harm to the Great Lakes ecosystem.

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Glossary

4Rs NUTRIENT STEWARDSHIP PROGRAM – A nutrient stewardship program created by the agricultural industry, state agri-business associations, The Nature Conservancy, The Ohio State University, Michigan State University, state farm bureaus, state agencies and others. The program promotes best practices through the 4Rs, which refers to using the Right Source of Nutrients at the Right Rate and Right Time in the Right Place. Definition derived from the Fertilizer Institute.

ADAPTIVE MANAGEMENT – A planning process that can provide a structured, iterative approach for improving actions through long-term monitoring, modeling and assessment. Through adaptive management, decisions can be reviewed, adjusted and revised as new information and knowledge becomes available or as conditions change.

ALGAE – Aquatic plants that survive through photosynthesis; they can range in size from microscopic organisms to large algae, like *Cladophora*.

ALGAL BLOOMS – An excessive and relatively rapid growth of algae on or near the surface of water. It can occur naturally as the result of a change in water temperature and current or as a result of an excess of nutrients in the water.

ANNEX COMMITTEE – A committee appointed by the Great Lakes Executive Committee to implement actions to achieve the general and specific goals of an annex of the Great Lakes Water Quality Agreement.

AQUATIC INVASIVE SPECIES (AIS) – As defined in the Great Lakes Water Quality Agreement, AIS refers to any non-indigenous species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that threatens or may threaten the diversity or abundance of aquatic native species, or the ecological stability, and thus water quality, or water quality of infested waters, or commercial, recreational, or other activities dependent on such waters.

AREA OF CONCERN (AOC) – A location designated by the Parties under the Great Lakes Water Quality Agreement where environmental impairments resulting from local human activities prevent certain uses of the lakes. These impacts are termed beneficial use impairments, or BUIs.

ASIAN CARP – A type of fish native to Asia that has been introduced to the United States. Asian carp are regarded as highly invasive species in the US and Canada and capable of causing severe economic, ecological or human health harm. They include the following species: bighead carp (*Hypophthalmichthysnobilis*), black carp (*Mylopharyngodonpiceus*), grass carp (*Ctenopharyngodonidella*) and silver carp (*Hypophthalmichthys molitrix*). Hybrids of silver and bighead carp also exist. Definition derived from the Michigan Department of Natural Resources.

BALLAST WATER – Liquid water carried or brought onboard and stored in tanks aboard a vessel to increase the draft, change the trim, regulate the stability or maintain safe stress loads on a ship.

BASIN – The region or area of which the surface waters and groundwater ultimately drain into a particular course or body of water.

BENEFICIAL USES – Uses and benefits of Great Lakes water quality and ecosystem resources, as identified in the Great Lakes Water Quality Agreement. They include fish and wildlife health and habitat, drinking water, and recreation.

BENEFICIAL USE IMPAIRMENT (BUI) – Under the Great Lakes Water Quality Agreement, a BUI is a reduction in the chemical, physical or biological integrity of the waters of the Great Lakes sufficient to cause any of the 14 identified impairments. These impairments include: restrictions on the human consumption of fish and wildlife; eutrophication or undesirable algae; restrictions on drinking water consumption; and beach closings.

BIOACCUMULATIVE – The accumulation of a substance, such as a toxic chemical, in the tissues of a living organism. Bioaccumulation takes place within an organism when the rate of intake of a substance is greater than the rate of excretion or metabolic transformation of that substance. Definition derived from The American Heritage Science Dictionary.

BLUE FLAG CERTIFICATION – An international certification for beach, marina or sustainable boating tourism operators created by the Foundation for Environmental Education. Certification criteria include standards for water quality, safety, environmental education and information and general environmental management criteria. Definition derived from the Foundation for Environmental Education.

BOUNDARY WATERS TREATY OF 1909 – The agreement between the United States and Canada that established principles and mechanisms for the resolution of disputes related to boundary waters shared by the two countries. The International Joint Commission was created as a result of this treaty.

CHEMICALS OF MUTUAL CONCERN – Under the Great Lakes Water Quality Agreement, the Parties agree to mutually determine those chemicals, coming from human-made sources that are potentially harmful to human health or the environment, and to take cooperative and coordinated measures to reduce the release of these chemicals.

CLADOPHORA – A genus of green algae found growing attached to rocks or timbers submerged in lakes and streams. *Cladophora* grows in the form of a tuft or ball with filaments that may range up to 13 cm (5 inches) in length.

CLIMATE CHANGE – A change of climate that is attributed directly or indirectly to human activity, that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods.

CYANOTOXINS – Toxins which are produced and contained within cyanobacterial (blue-green algae) cells. Toxins are released during death or cellular rupture, including mechanical or chemical reactions. Cyanotoxins can be produced by a wide variety of cyanobacteria including Microcystis, Anabaena and Planktothrix. Definition derived from the USEPA.

DIOXIN – A group of toxic chemical compounds that share certain chemical structures and characteristics. Dioxins are formed in the production of some chlorinated organic compounds, including some herbicides. Dioxin compounds break down very slowly and persist for long periods of time in the environment. Dioxins are known to cause cancer, reproductive and developmental problems, damage the immune system, and interfere with hormones. Definition derived from the USEPA.

DECHLORANE PLUS – A polychlorinated chemical flame retardant used in electronic wiring and cables, automobiles, hard plastic connectors and plastic roofing materials. Dechlorane Plus has been detected in the air, fish, and sediment samples within the Great Lakes region. Definition derived from the Government of Canada.

DEEP GEOLOGICAL REPOSITORY (DGR) – An underground storage cavern excavated within a stable geologic formation to store waste products from the production of energy using nuclear power. Facilities are built with the objective of achieving long-term isolation of radioactive material.

DOMESTIC ACTION PLAN – Plans developed by the United States and Canada to combat the growing threat of toxic and nuisance algal development in Lake Erie. In 2012, through the Great Lakes Water Quality Agreement, the two governments agreed to establish binational phosphorus load reduction targets for Lake Erie by February 2016, and to develop domestic action plans that will outline strategies for meeting the new targets by 2018.

DRINKING WATER ADVISORY – Public health protection messages issued by regulatory authorities to inform consumers about actions they should take to protect themselves from real or potential health risks related to their drinking water supply. Advisories are generally precautionary, and typically take three forms: Do not consume, Do not use and Boil water. Definition derived from Environment and Climate Change Canada.

ECOSYSTEM – A biological community of interacting organisms and their physical environment, including the transfer and circulation of matter and energy.

EDGE-OF-FIELD-MONITORING – Voluntary water quality monitoring programs that measure the amount of nutrients and sediment in water runoff from a field, and compare the improvements under different conservation systems. Monitoring allows agricultural producers and scientists to quantify the impacts of conservation work on water quality. Definition derived from the United States Department of Agriculture.

ENVIRONMENT – Air, land or water; plant and animal life including humans; and the social, economic, cultural, physical, biological and other conditions that may act on an organism or community to influence its development or existence.

ENVIRONMENTAL JUSTICE – environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Definition from the USEPA.

EUTROPHICATION –The process whereby water bodies become over-nourished either naturally by processes of maturation or artificially by excessive nutrient enrichment.

EXTENDED PRODUCER RESPONSIBILITY (EPR) – A policy approach under which producers are given a significant responsibility – financial and/or physical – for the treatment or disposal of post-consumer products. Such practices provide incentives for manufacturers to prevent waste and may promote product design which is environmentally conscious, thereby achieving sustainable recycling and materials management goals. Definition derived from the Organisation for Economic Co-operation and Development.

FIRST NATION – A Canadian term used to describe an indigenous Native American community officially recognized as an administrative unit by the federal government or functioning as such without official status. Definition derived from the Government of Canada.

FISH CONSUMPTION ADVISORY – A recommendation to limit or avoid eating certain species of fish or shellfish caught from specific water bodies or types of water bodies (such as lakes, rivers or coastal waters) due to chemical contamination. Advisories may be issued for the general public or specific groups of people at risk, such as subsistence anglers, the elderly and pregnant or nursing women. Definition derived from the USEPA.

GENERAL OBJECTIVES – As defined in the Great Lakes Water Quality Agreement, General Objectives refer to the broad descriptions of water quality conditions consistent with the protection of the level of environmental quality the Parties seek to secure and which provide a basis for overall water management guidance. The Agreement identifies nine categories of General Objectives.

GREAT LAKES BINATIONAL TOXICS STRATEGY – The 1978 Great Lakes Water Quality Agreement committed Canada and the United States to virtually eliminate inputs of persistent toxic substances to the Great Lakes system in order to protect human health and to ensure the continued health and productivity of living aquatic resources and their human use. On April 7, 1997, Environment Canada and the United States Environmental Protection Agency signed the Great Lakes Binational Toxics Strategy, which set forth a process to work in cooperation with their public and private partners toward the goal of virtual elimination of persistent toxic substances resulting from human activity from the Great Lakes basin.

GREAT LAKES VITAL SIGNS – A defined set of measures that were selected by the IJC based on their ability to inform the public about the status of the Great Lakes and whether the Great Lakes are getting better or worse. Relative to State of the Great Lakes reporting, Great Lakes vital signs are a subset of existing sub-indicators and proposed new sub-indicators.

GREAT LAKES WATER QUALITY AGREEMENT – The Agreement expresses the commitment of Canada and the United States to restore and maintain the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem. The most recent protocol amending the 1978 Agreement was signed in 2012.

HARMFUL ALGAL BLOOMS (HABS) – HABs result from the proliferation of blue-green algae (including cyanobacteria) in environmentally stressed systems, where conditions favor opportunistic growth of one or more noxious species, displacing more benign ones. The blooms are considered harmful because excessive growth can harm ecosystems and produce poisons (or toxins) that can cause illness in humans, pets, livestock and wildlife.

HEXABROMOCYCLODODECANE (HBCD) – A brominated chemical flame retardant often used in furniture, automobile textiles, mattresses and polystyrene foam. Humans and animals may be exposed to HBCD from products and dust in the home, workplace and the environment. Definition derived from Natural Resources Defense Council.

HYDRAULIC FRACTURING – A chemical and mechanical method of drilling by forcing open fissures in subterranean rocks by introducing liquid at high pressure, especially to extract oil or gas. Also called "fracking." Definition derived from the USEPA.

HYPOXIA – A condition of low or depleted oxygen in a water body, leading to regions where life cannot be sustained. Hypoxia occurs most often as a consequence of human-induced factors, especially nutrient pollution.

INDICATOR – As defined in State of the Great Lakes Technical Report, an indicator is a piece of evidence, (e.g. data or measures) that informs about current conditions. Watching the evidence over time gives an indication of trends. Doctors use specific measures such as blood pressure and temperature to assess one's health. To assess large, complex ecosystems such as the Great Lakes, environmental indicators are a useful and accepted approach. Great Lakes indicators are used to:

- Assess conditions and track changes in the ecosystem;
- Understand existing and emerging issues;
- Guide programs and policies needed to prevent or address harmful environmental problems; and,
- Provide information to set priorities for research and program implementation.

Reporting on a suite of Great Lakes indicators produces a big picture perspective on the condition and trends of the complex ecosystem. Indicators have been used to report on Great Lakes ecosystem components since the first State of the Lakes Ecosystem Conference (SOLEC) in 1994.

INTERNATIONAL JOINT COMMISSION (IJC) – International independent binational agency formed in 1909 by the United States and Canada under the *Boundary Waters Treaty* to prevent and resolve boundary waters disputes between the two countries. The IJC makes decisions on applications for projects such as dams in boundary waters, issues Orders of Approval and regulates the operations of many of those projects. It also has a permanent reference under the Great Lakes Water Quality Agreement to help the two national governments restore and maintain the chemical, physical, and biological integrity of those waters.

LAKERS – Bulk carrier vessels or ships which carry cargo exclusively within the Great Lakes basin.

LAKEWIDE ACTION AND MANAGEMENT PLAN (LAMP) – Under the Great Lakes Water Quality Agreement, a LAMP is an action plan for cooperatively restoring and protecting the ecosystem of a Great Lake. LAMPs are developed and implemented in consultation with US state governments and the province of Ontario and may include participation from local government agencies. LAMPs are in place for lakes Superior, Michigan, Erie and Ontario.

LAKE SUPERIOR ZERO DISCHARGE DEMONSTRATION PROGRAM – A program designed to achieve zero release of certain designated persistent, bioaccumulative toxic substances in the Lake Superior basin.

MERCURY – A naturally-occurring chemical element found in rock in the crust of the earth, including in deposits of coal. Mercury becomes a problem for the environment when it is released from rock and ends up in the atmosphere and in water bodies. Human activities are responsible for most of the mercury pollution that is released into the environment, often by burning coal, oil, waste products and wood. Definition derived from the USEPA.

MÉTIS – A person of mixed Native American and Euro-American ancestry; in particular, one of a group of such people who in the 19th century constituted the Métis Nation in the areas around the Red and Saskatchewan rivers. Definition derived from the Government of Canada.

MICROCYSTIN – A naturally-occurring, potent liver toxin produced by the cyanobacteria Microcystis. Microcystin toxins are the most widespread cyanobacterial toxin and can bioaccumulate in common aquatic vertebrates and invertebrates such as fish, mussels and zooplankton. Definition derived from the USEPA.

MICROPLASTICS – Plastic particles that are smaller than 5-mm in diameter, such as preproduction plastic pellets and flakes, microfibers, breakdown materials from larger plastics and microbeads. Microbeads, the most well-known of these categories, are small plastic beads that are added as an abrasive to personal care products, including cosmetics, toothpastes, deodorants, shaving creams and sunscreens. Microplastics can be ingested by aquatic organisms, leading to a range of potential impacts including the transfer of plastics and associated toxins along the food web, potentially to humans.

NEARSHORE – As defined in IJC's 15th Biennial Report on Great Lakes Water Quality, the nearshore includes the relatively warm shallow areas near the shores, coastal wetlands that are dependent on lake levels, the connecting channels and virtually all of the major embayments of the system. This area is estimated to include approximately 90 percent of shallow Lake Erie, 25 percent of each of lakes Michigan, Huron, and Ontario, but only five percent of Lake Superior, which has deeper waters. The definition also describes the nearshore zone as including the land areas that are affected by the waves, wind, ice and temperature. In general, the nearshore zone extends about 16 kilometers (ten miles) into both land and water.

NITROGEN – A nutrient essential for plant and animal growth and nourishment which may exist in the forms of nitrate, nitrite, or ammonium. Excess nitrogen can cause the rapid growth of aquatic plants and algae.

NUTRIENT – A food or any nourishing substance assimilated by an organism and required for growth, repair, and normal metabolism. For example, phosphorus and nitrogen are nutrients for algae.

ONTARIO CLEAN WATER ACT – Ontario legislation to ensure access to safe drinking water. The act requires creation and execution of plans to protect the sources of municipal drinking water supplies. Local communities must evaluate the existing and potential threats to their water and set out and implement the actions necessary to reduce or eliminate significant threats. Definition derived from the Government of Ontario.

ONTARIO DRINKING WATER SURVEILLANCE PROGRAM (DWSP)–A program that monitors water quality at selected municipal drinking water systems for scientific and research purposes. DWSP is a voluntary partnership that compliments the regulatory monitoring that must be done by the drinking water systems. DWSP monitors for inorganic, organic and radiological parameters. Definition derived from the Government of Ontario.

ONTARIO SAFE WATER ACT – An Ontario law that dictates owners and operators of drinking water systems that supply water to the public have responsibilities to ensure the water is safe to drink. Definition derived from the Government of Ontario.

ONTARIO SOURCE WATER ASSESSMENT PROGRAM – A program that includes source protection plans which contain policies that either recommend or require that actions be taken to address activities identified as threats in the science-based assessment reports. Definition derived from the Government of Ontario.

OUTFALL – Any pipe or conduit used to carry water and either raw sewage or treated effluent to a final point of discharge into a body of water. Definition derived from the Organisation for Economic Co-operation and Development.

PARTICIPATE IJC – A website created by the IJC to fulfill its duties under the Boundary Waters Treaty to take into consideration views of all interested parties before the IJC makes decisions or recommendations.

PARTIES – The parties or signatories to the Great Lakes Water Quality Agreement. That is, the Governments of Canada and the United States.

PHOSPHORUS – A nutrient essential for plant and animal growth and nourishment, which exists in particulate or soluble reactive forms. The element used in a wide range of agricultural, industrial and domestic products. It is a key nutrient limiting the amount of phytoplankton and attached algae in the Great Lakes and most freshwater bodies.

PHRAGMITES – Genus of four species of perennial wetland grasses found in temperate and tropical regions. Specific reference to *Phragmites* in this document refers to *Phragmites australis*, a Eurasian genotype that can grow over 6 meters tall (19 feet) and can quickly crowd out native species by exuding a compound that kills the roots of neighboring plants and by blocking out light to other species.

POLYCHLORINATED BIPHENYLS (PCBs) – A group of human-made organic chemicals consisting of carbon, hydrogen and chlorine atoms. Because of their non-flammability, chemical stability, high boiling point and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications. PCBs were domestically manufactured from 1929 until manufacturing was banned in 1979. Definition derived from the USEPA.

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) – A class of chemicals that occur naturally in coal, crude oil, and gasoline. They also are produced when coal, oil, gas, wood, garbage, and tobacco are burned. PAHs can bind to, or form small particles in the air. Definition derived from the USEPA and US Centers for Disease Control.

PROGRESS REPORT OF THE PARTIES (PROP) **–** Under the Great Lakes Water Quality Agreement, the Parties agree to prepare a triennial progress report documenting actions taken domestically and binationally in support of the Agreement. The government production of the PROP and the IJC review of it is a key government accountability feature under the Agreement.

PUBLIC INFORMATION AND ENGAGEMENT – A proactive, coordinated process of informing the public throughout the course of a study and providing opportunities to interested individuals and organizations to make their views known and to review and comment on preliminary findings.

RADIONUCLIDES – An atom which has excess nuclear energy making it inherently unstable. Energy is typically released in the form of radiation. Radionuclides occur naturally, but they can also be produced artificially in nuclear reactors, cyclotrons, particle accelerators or radionuclide generators. They have a number of commercial and medical uses (i.e. radioisotopes).

REMEDIAL ACTION PLAN (RAP) – Under the Great Lakes Water Quality Agreement, plans designed to restore beneficial uses that have become impaired due to local conditions at Areas of Concern. Developed and implemented in cooperation with state and provincial governments, RAPs include: an identification of BUIs and causes; criteria for restoring beneficial uses, established in consultation with the local community; and remedial measures to be taken.

STATE OF GREAT LAKES REPORTING (SOGLR) – A process in which the governments of Canada and the United States regularly report on progress towards achieving the overall purpose of the Great Lakes Water Quality Agreement through reporting on ecosystem conditions and trends.

STORMWATER MANAGEMENT – Practices that help to minimize the impact of polluted agricultural and urban runoff flowing into lakes and streams, and reduce the impact of such runoff on water bodies.

TRIBES – A group or community of Indigenous peoples that the United States recognizes in a government-to-government relationship and exists politically in a "domestic dependent nation" status. Federally recognized Tribes possess certain inherent powers of self government and entitlement to certain federal benefits, services, and protections because of the special trust relationship. Definition derived from the Government of the United States of America.

US BEACHES ENVIRONMENTAL ASSESSMENT AND COASTAL HEALTH ACT (BEACH ACT) – The Beach Act addresses pathogens and pathogen indicators in coastal recreation waters.

US SAFE DRINKING WATER ACT – A US federal law that protects public drinking water supplies. Under the SDWA, the EPA sets standards for drinking water quality and with its partners and implements various technical and financial programs to ensure drinking water safety. Definition derived from the USEPA.

VULNERABILITY ASSESSMENT –Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity to climate change, and its adaptive capacity.Adaptation actions are needed to eliminate or reduce the vulnerability of systems to the impacts of climate change.Vulnerability Assessments can support adaptation planning in several ways: identify areas most likely to be impacted by projected changes in climate; build an understanding of why these areas are vulnerable, including the interaction between climate change, non-climatic stressors, and cumulative impacts; assess the effectiveness of previous coping strategies in the context of historic and current changes in climate; and identify and target adaptation measures to systems with the greatest vulnerability. Definition derived from Ontario Centre for Climate Impacts and Adaptation Resources.

WETLAND – Areas of land where water saturates the soil at or near the surface all year or for varying periods of time. Wetlands support aquatic and terrestrial plants and animals. Examples of wetlands include swamps, marshes and meadows.

ZERO DISCHARGE – Concept which aims to eliminate toxic liquid, solid or gaseous substance releases into an aquatic, atmospheric or terrestrial environment.

ZONING – Regulations and laws designed to implement developed land use plans used by municipalities. Zoning can be used to control development, improve safety and protect resources. Zoning can be divided into different categories of development which include residential, commercial, agricultural or industrial zones. Specific laws may regulate requirements for residential or commercial buildings, transportation and utilities.