Lake Erie

2019-2023 LAKEWIDE ACTION & MANAGEMENT PLAN

LAKE ERIE

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The 2019-2023 Lake Erie Lakewide Action and Management Plan (LAMP) was developed by member agencies of the Lake Erie Partnership.

Lake Erie Partnership Agencies, 2019

Environment and Climate Change Canada (ECCC)
Essex Region Conservation Authority
Fisheries and Oceans Canada (DFO)
Michigan Department of Environmental Great Lakes and Energy (EGLE)
National Oceanic and Atmospheric Administration (NOAA)
Ohio Lake Erie Commission (OLEC)
Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)
Ontario Ministry of the Environment, Conservation and Parks (OMECP)
Ontario Ministry of Natural Resources and Forestry (OMNRF)
Pennsylvania Department of Environmental Protection (PADEP)
New York State Department of Conservation (NYSDEC)
Upper Thames River Conservation Authority
U.S. Army Corps of Engineers (USACE)
U.S. Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS)
U.S. Environmental Protection Agency (USEPA)
U.S. Fish and Wildlife Service (USFWS)
U.S. Forest Service (USFS)
U.S. Geological Survey (USGS)

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USGS (middle right)

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ACRONYMS AND ABBREVIATIONS

AIS	Aquatic Invasive species
AOC	Area of Concern
AOCiR	Area of Concern in Recovery
BCS	Biodiversity Conservation Strategy
BMP	Best Management Practice
BUI	Beneficial Use Impairment
CCME	Canadian Council of Ministers of the Environment
CFU	Colony Forming Units
CMC	Chemical of Mutual Concern
CRRA	Community Risk and Resiliency Act
CSMI	Cooperative Science and Monitoring Initiative
CSO	Combined Sewer Overflow
E. coli	*Escherichia coli*
EDM	Early Detection and Monitoring
FEQG	Federal Environmental Quality Guidelines
GLEI	Great Lakes Environmental Indicator Program (1 & 2)
GLMRIS	Great Lakes and Mississippi River Interbasin Study
GLRI	Great Lakes Restoration Initiative
GLSLS	Great Lakes St. Lawrence Seaway
GLWQA	Great Lakes Water Quality Agreement
GO	General Objectives
HABs	Harmful Algal Blooms
LAMP	Lakewide Action and Management Plan
LEMN	Lake Erie Millennium Network
LEOs	Lake Ecosystem Objectives
NRTMP	Niagara River Toxics Management Plan
P	Phosphorus
Phragmites	*Phragmites australis* subsp. australis
PRISM	Partnership for Regional Invasive Species Management
SAV	Submerged aquatic vegetation
SCDRS	St. Clair-Detroit River System
SDWA	Safe Drinking Water Act (Ontario)
SDWA	Safe Drinking Water Act (U.S.)
SOGL	State of the Great Lakes
SRP	Soluble Reactive Phosphorus
TEK	Traditional Ecological Knowledge
TEQs	Toxic Equivalents
TP	Total Phosphorus
UNESCO	United Nations Educational, Scientific and Cultural Organization
Ww	wet weight

Chemicals

Σ2DDC-CO	Dechlorane plus expressed as the sum of *syn*- and *anti*- isomer
DDT	Dichlorodiphenyltrichloroethane
Dioxins and furans	Polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran;
HBCD	Hexabromocyclododecane
LC-PFCAs	Long-chain perfluorinated carboxylic acids
OCPs	Organochlorine Pesticides
PAH	Polycyclic Aromatic Hydrocarbons
PBDEs	Polybrominated Diphenyl Ethers (Flame Retardants)
PCBs	Polychlorinated Biphenyls
PCDD/F	Dioxin/Furans
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
SCCPs	Short-Chain Chlorinated Paraffins
TCDD	Tetrachlorodibenzo-*p*-dioxin (usually in reference to congener 2,3,7,8-)

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Learn about the actions government agencies are taking to address key environmental issues – and ways that you can help.

Learn about how researchers are supporting management actions through a better understanding of the Lake Erie ecosystem.

Learn about the role you can play in protecting, restoring, and conserving Lake Erie.

EXECUTIVE SUMMARY

Lake Erie is socially, economically, and environmentally significant to the Great Lakes region and the nations of the United States and Canada. Lake Erie is a source of inspiration, recreation, rejuvenation, discovery and raw materials. It is also an important element in the heritage of many cultures and individuals. While it is the smallest Laurentian Great Lake by volume, it is the 15th largest freshwater lake in the world by volume. It consists of three distinct, but interacting water bodies (Western Basin, Central Basin, and Eastern Basin). Its upstream connecting river system, the St. Clair – Detroit River System (SCDRS), encompasses the Detroit River, Lake St. Clair and the St. Clair River and connects Lake Huron to Lake Erie.

Parts of the Lake Erie watershed are rural and dominated by agricultural uses, owing to highly fertile soils and moderate temperatures, while other parts are highly urbanized. Lake Erie's watershed is the most densely populated watershed of the Great Lakes basin, with over 12.5 million people living within the basin. Lake Erie's moderating effects on climate influence the human culture, outdoor activities, agriculture and the health of adjacent coastal areas. Lake Erie is an important source of drinking water and its waters and coasts offer many types of recreational opportunities including sandy swimming beaches, nature preserves, scenic vistas and prime fishing spots.

Lake Erie has been, and continues to be, dramatically degraded and challenged by human endeavors. Individual and collective efforts are being made to restore the lake and its resources. While restoration challenges still exist, the coordinated restoration planning for Lake Erie is used as a representative model for environmental management and regional and international cooperation.

In keeping with the Great Lakes Water Quality Agreement (the Agreement), the governments of Canada and the United States have committed to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes. This 2019-2023 Lake Erie Lakewide Action and Management Plan (LAMP) fulfills a United States and Canadian commitment of the Agreement to assess ecosystem condition, identify environmental threats, set priorities for research and monitoring, and identify further actions to be taken by governments and the public that address the key threats to the waters of Lake Erie and the SCDRS.

GENERAL OBJECTIVE		STATUS
1.	Be a source of safe, high quality drinking water.	Good
2.	Allow for unrestricted swimming and other recreational use.	Fair
3.	Allow for unrestricted human consumption of fish and wildlife.	Fair
4.	Be free from pollutants that could harm people, wildlife or organisms.	Fair
5.	Support healthy and productive habitats to sustain our native species.	Poor-Good
6.	Be free from nutrients that promote unsightly algae or toxic blooms.	Poor
7.	Be free from aquatic and terrestrial invasive species.	Poor-Fair
8.	Be free from the harmful impacts of contaminated groundwater.	Fair
9.	Be free from other substances, materials or conditions that may negatively affect the Great Lakes.	NA

Table i. Status of Lake Erie in relation to the 2012 GLWQA General Objectives. NA = not assigned (refer to section 4.9).

The LAMP was developed by members of the Lake Erie Partnership, a collaborative team of natural resource managers led by the governments of Canada and the United States, in cooperation and consultation with State and Provincial Governments, Tribal Governments, First Nations, Metis, Municipal Governments, and watershed management agencies.

STATE OF LAKE ERIE

Lake Erie's ecosystem is in Poor condition and the trend is Unchanging based on assessments described in State of the Great Lakes Technical Report (ECCC and U.S. EPA 2019). Lake Erie continues to be a good source of high-quality drinking water and has beaches and nearshore areas that continue to provide opportunities for swimming and recreational use. Canadian monitored beaches have shown an increase in the number of days that beaches are open and safe for swimming. Toxic chemicals continue to decline in the environment, however, fish consumption advisories continue to be in effect for some toxic chemicals. Prey fish diversity and the proportion of native prey fish species have declined, but despite a changing prey fish community, Lake Erie supports the largest self-sustaining Walleye population in the world. Lake Trout abundance has increased, due in part to declines in Sea Lamprey populations, but there is no evidence of natural reproduction. Self-sustaining populations of Lake Sturgeon are found in the St. Clair, Detroit and Upper Niagara rivers. Increased aquatic habitat connectivity due to dam removal and mitigation projects is further supporting the increasing predator and prey fish populations in the lake. Coastal wetland conditions range from Fair to Poor. Harmful algal blooms resulting from excessive nutrients occur regularly in Lake St. Clair and the western basin of Lake Erie during the summer months. Excessive growth of *Cladophora* continues to be a problem in the eastern basin of the lake. Invasive species, particularly Sea Lamprey, are still causing harm to predatory fish. The status of nitrate and chloride in groundwater is Fair for areas of the basin that were assessed. Land-based stressors continue to impact Lake Erie. Shifts in climate trends such as earlier onset of stratification and decreases in ice cover, also have ecosystem implications. (See Table i).

Based on these findings, the Lake Erie Partnership has identified five priority threats to the waters of Lake Erie and the SCDRS, including:

- Nutrients and bacterial pollution;
- Chemical contaminant pollution;
- Loss of habitat and native species;
- Invasive species; and
- Climate change impacts.

The active threats identified above are the focus of this plan, while recognizing that there are also risks to water quality from possible spills or accidents. Other new or emerging threats may also impact the basin beyond the timeframe of this LAMP, 2019-2023. Assessing and managing those risks fall under the regulatory purview of the various jurisdictions around the lake and thus are subject to their consulting and permitting processes.

PRIORITY SCIENCE AND MONITORING ACTIVITIES

Management priorities that would benefit from additional scientific study are identified by the Lake Erie Partnership with input from stakeholders and the public. Partnership agencies undertake routine research and monitoring on the Great Lakes, and through a Cooperative Science and Monitoring Initiative (CSMI), conduct a focused binational effort for each lake on a five-year rotational basis.

The CSMI is a joint United States and Canadian effort implemented under the Great Lakes Water Quality Agreement. CSMI provides environmental and fishery managers with the science and monitoring information necessary to make management decisions on each Great Lake. The intensive CSMI field year follows a five-year rotating cycle in which the lakes are visited one per year. The emphasis on a single lake per year allows for coordination of science and monitoring activities focused on information needs not addressed through routine agency programs, and cooperation on specific science assessments.

The Lake Erie CSMI field year is 2019, with data interpretation, analysis and reporting occurring in subsequent years.

Lakewide priorities for 2019 include the following:

- Improved understanding of nutrient dynamics (sources, sinks, pathways and loadings) and nutrient-related issues (harmful algal bloom toxicity, nuisance algae growth, and hypoxia);
- Assessment of critical habitats for species, as well as how lower food web health, invasive species, harmful algal blooms and hypoxia impact fish production; and
- Characterization of chemical contaminant loading and cycling.

LAKEWIDE ACTION AND MANAGEMENT

Over the next five years, members of the Lake Erie Partnership will undertake 41 actions to address priority environmental threats to water quality and the ecosystem health of Lake Erie and the SCDRS. Management actions are organized by environmental threat in Table ii along with the responsible agencies.

IMPLEMENTATION AND ACCOUNTABILITY

Members of the Lake Erie Partnership are committed to advancing the binational protection and restoration of the Lake Erie and SCDRS ecosystem through the implementation of this five-year plan. Members of the Partnership will work with watershed management agencies, local public agencies and the public, and indigenous people to implement the management actions. Coordination of efforts will be assisted by regular communication among the Lake Erie Partnership agencies. Tracking and reporting by the Partnership agencies will help in the assessment of progress and support accountability.

Table ii. Lake Erie Partnership strategies and actions that address key environmental threats.

#	LAKE ERIE PARTNERSHIP STRATEGIES AND ACTIONS 2019-2023	AGENCIES INVOLVED
	CHAPTER 5.1 NUTRIENTS AND BACTERIAL POLLUTION	
1	**Strategies to Reduce Phosphorus Loadings from Agricultural Sources** Continue to encourage and incentivize farmers to adopt on-farm best management practices, emphasizing a "systems approach" (combinations of management practices) to comprehensively address concerns at the farm scale Adopt 4R's Nutrient Stewardship Certification or similar programs Avoid nutrient applications on frozen or snow-covered ground Implement and enforce fertilizer and manure application requirements where they apply Prevent agricultural runoff by improving soil health and managing drainage systems to hold back or delay delivery of runoff to receiving waterbodies. Reduce the impact of effluent releases from greenhouses on Lake Erie	U.S Federal and State Domestic Action Plan agencies; Canada-Ontario Domestic Action Plan agencies
2	**Strategies to Reduce Phosphorus Loadings from Municipal Sources** Optimize wastewater infrastructure Encourage investments in green infrastructure Identify and correct failing home sewage treatment systems Enable water quality trading as a potential future tool for managing phosphorus	U.S Federal and State Domestic Action Plan agencies; Canada-Ontario Domestic Action Plan agencies
3	**Watershed Based Planning and Restoration Efforts** Develop or refine local watershed plans to meet the phosphorus reduction goals for the lake Target watershed restoration efforts to areas most prone to phosphorus losses Establish ecological buffers for rivers, streams, and wetlands to intercept and infiltrate runoff and prevent streambank erosion	U.S Federal and State Domestic Action Plan agencies; Canada-Ontario Domestic Action Plan agencies
4	**Science, Surveillance and Monitoring** Enhance in-lake monitoring of algae and hypoxic conditions Improve monitoring of nutrient loads in tributaries and watersheds Invest in research and demonstration initiatives to improve knowledge and understanding of the effectiveness of BMPs	U.S Federal and State Domestic Action Plan agencies; Canada-Ontario Domestic Action Plan agencies
5	**Outreach and Education** Undertake outreach and education on local and regional scales to increase the understanding of water quality condition and management challenges, nearshore and beach health, and best management practices and policies.	U.S Federal and State Domestic Action Plan agencies; Canada-Ontario Domestic Action Plan agencies

CHAPTER 5.2 CHEMICAL CONTAMINANTS

ADDRESSING POINT SOURCE CHEMICAL CONTAMINANTS

6	Federal, provincial, state and regulatory partners monitor and ensure compliance with clean water laws and regulations (see Table 20 above).	USEPA, OEPA, NYSDEC, EGLE. OMECP
7	Provide support and funding assistance for municipal wastewater infrastructure programs/improvements.	OEPA, NYSDEC, EGLE

ADDRESSING SEDIMENT CHEMICAL CONTAMINANT REMEDIATION

8	Superfund and AOC specific actions, including sediment remediation activities in the Canadian St. Clair River AOC and in the U.S. Detroit River AOC and Rouge River AOC.	USEPA, ECCC, OMECP, EGLE
9	Proper management of sediment dredged from federal navigation channels in Lake Erie, as well as non-federal/recreational harbor areas.	USACE, OEPA, NYSDEC, EGLE

ADDRESSING NON-POINT SOURCE CHEMICAL CONTAMINANTS

10	Implement efforts to reduce NPS pollution from brownfields/remedial sites (via groundwater migration) and stormwater (e.g., via green infrastructure projects) are also covered.	EGLE, States

ADDRESSING CHEMICAL CONTAMINANT SCIENCE, SURVEILLANCE AND MONITORING

11	Continue monitoring and periodic reporting on atmospheric pollutant deposition at Great Lakes stations.	ECCC, USEPA, OMECP
12	Continue long-term monitoring of Lake Erie and SCDRS water and sediment contaminants to examine legacy organics, PAHs, trace metals, mercury, and selected new and emerging compounds.	ECCC, USEPA, OEPA, EGLE, OMECP, NOAA
13	Conduct fish contaminant monitoring between 2019 and 2023.	MDHHS, EGLE, OEPA, ODNR, PADEP, USEPA, OMECP, OMNRF, NYSDEC
14	Conduct annual Herring Gull monitoring in each year between 2019 and 2023 at sampling locations within the Lake Huron basin.	ECCC, EGLE
15	Support the development and implementation of the Chemicals of Mutual Concern binational strategies	ECCC, USEPA

CHAPTER 5.3 AQUATIC HABITAT AND NATIVE SPECIES

16	**Spawning Reefs:** Increase functional river spawning habitat for native species in the main channel and tributaries of the Detroit and St. Clair Rivers.	OMNRF, MDNR, USGS, USFWS
17	**Aquatic Habitat Protection and Restoration:** GLFC Habitat Task Group is developing a Priority Management Area exercise to help identify priority areas. Implementation of the Niagara River AOC (U.S.) Habitat and Species Restoration Plan Implement SCDRS Initiative projects identified to achieve the habitat connectivity-related priority objectives by 2023 Continued monitoring of terrestrial and aquatic invasive species, Implementation of boat launch stewards. Promote on-farm habitat restoration around streams, wetlands and woodlots through development and implementation of environmental farm plans	OMNRF, ODNR, MDNR, PADNR NYSDEC, USACE, U.S.EPA, USFS NYSDEC, Erie County (NY), ODNR SCDRS agencies (NOAA, USFWS, USGS, MDNR, EGLE, USEPA) OMAFRA
18	**Stream Connectivity:**	USACE, NYSDEC, Erie County (NY)

	Lowering and modification of the Springville (Scoby) Dam on Cattaraugus Creek (New York) Assess options for remediating impacts of Dunnville Dam on Grand River (Ontario) Ballville Dam Removal (Ohio) SCDRS Initiative projects identified to achieve connectivity-related priority objectives of the Initiative Promote North Atlantic Aquatic Connectivity Collaborative road-stream crossing assessments and support implementation projects at priority sites Install 2 aquatic organism passage structures within the Western Lake Erie/Lake St. Clair Focus Area (Great Lakes Coastal Program 5-year Target)	OMNRF, ECCC ODNR USFWS, MDNR, EGLE, USFWS, NOAA, USGS, USEPA USFWS, NYSDEC USFWS
19	**Species Recovery:** Implementation of the Great Lakes Fishery Commission Strategic Plan for the Rehabilitation of Lake Trout in Lake Erie, 2008-2020 Maumee River Lake Sturgeon restoration (Ohio) SCDRS Initiative projects identified to achieve the rare species-related priority objectives of the Initiative	NYSDEC, OMNRF, MDNR, ODNR, USFS USFWS, ODNR USFWS, USGS, NOAA, DFO, MDNR, OMNRF
20	**Coastal Wetlands:** Sandusky Bay Initiative Woodlawn Beach (NYS) Wetland Enhancement Continued shoreline softening and coastal wetland restoration projects in connecting channels and embayments Restoration of hydrologic connectivity between coastal wetlands and Lake Erie SCDRS Initiative projects identified to achieve the coastal wetland-related priority objectives of the Initiative Assess coastal wetland health and vulnerability to climate change Restore/Enhance 110 acres of coastal wetland within the Western Lake Erie/Lake St. Clair Focus Area (Great Lakes Coastal Program 5-year Target)	ODNR, OEPA NYSDEC US EPA, OMNRF, USGS, USFWS, USFS USACE, USFWS USFWS, NOAA, USACE, USGS, MDNR, ODNR, EGLE ECCC, OMNRF USFWS
21	**Dunes and Bluffs:** Development of a decision-support tool/technical guidance for natural and nature-based features shoreline management along NY's Great Lakes. Implementation of State Coastal Management Programs and efforts to promote the use of natural and nature-based features shoreline protection and stabilization techniques.	NYSDEC NYSDEC, ODNR, NOAA
22	**Islands:** Support protection and restoration of Lake Erie and SCDRS islands, particularly unique habitats and globally rare or endemic species	USFWS, ECCC, EGLE, States and Province
	CHAPTER 5.4 AQUATIC AND TERRESTRIAL INVASIVE SPECIES	
23	**Ballast Water:** Establish and implement programs and measures that protect the Great Lakes basin ecosystem from the discharge of AIS in ballast water, consistent with state and federal authorities and commitments made by the Parties through Discharges from Vessels Annex of the Agreement.	Transport Canada, USCG, USEPA, States
24	**Organisms in Trade:** Prevent the introduction of invasive species through management and trade (e.g. bait, aquaculture, internet, pet shops) by improving and implementing laws and rules, using science-based risk assessment to inform prohibited species lists, and coordinating efforts across jurisdictions	USFWS, USDA, DFO, States and Province
25	**Early Detection and Rapid Response:**	DFO, USFS, USFWS, SCDRS agencies, States and Province

	Implement an ‘early detection and rapid response initiative’ with the goal of finding new invaders and preventing them from establishing self-sustaining populations. Conduct Lakewide benthic assessments of Dreisennid mussels through the Agreement’s Science Annex Cooperative Science and Monitoring Initiative. Improve detection and assessment by developing surveillance monitoring for non-native species in the SCDRS.	NOAA, USEPA, USGS MDNR, EGLE, USGS, USFWS, USEPA
26	**Canals and Waterways:** Through the Asian Carp Regional Coordinating Committee, prevent the establishment and spread of Bighead and Silver Carp in the Great Lakes.	USEPA, USFWS, USACE, ODNR, MDNR
27	**Grass Carp:** Use an adaptive management framework to guide response actions in western Lake Erie based on current knowledge. Response **efforts** include but are not limited to partnering with commercial fishers to remove fish and gain biological data from those captures, conducting targeted removal efforts with traditional fishing gears, determining the seasonal habitat use and movements to inform response actions, and evaluating novel removal approaches. Specific actions include: Conduct targeted inter-jurisdictional response actions Evaluate the feasibility of seasonal barriers in identified spawning tributaries Inform seasonal habitat use and movement patterns via acoustic telemetry Provide bounty to commercial fishers for grass removals Develop, implement, and evaluate novel control methods	USFWS, USGS, DFO, MDNR, States and Province
28	**Sea Lamprey:** • Control the larval Sea Lamprey population in 11 regular producing tributaries in Lake Erie (Grand River (OH), Big Otter Creek (ON), Big Creek (ON), Youngs Creek (ON), Conneaut Creek (PA), Crooked Creek (PA), Raccoon Creek (PA), Canadaway Creek (NY), Buffalo Creek (NY), Cattaraugus Creek (NY), and Big Sister Creek (NY)) with selective lampricides. Continue operation and maintenance of existing barriers and the design of new barriers where appropriate. • Implement a spot treatment of the St. Clair River in 2020 Advance sea lamprey management through development and implementation of new control techniques	GLFC Sea Lamprey Control Program (DFO, USFWS as control agents, USACE)
29	**Control of Terrestrial and Aquatic Invasive Species:** Maintain terrestrial, coastal and nearshore aquatic habitat diversity and function through appropriate control of Phragmites and other detrimental invasive species including monitoring, mapping, and control efforts guided by science-based BMPs. Actively respond to Red Swamp Crayfish invasion in Southeast Michigan. Use collaborative measures to implement and evaluate response/control actions at infested locations using novel approaches. Conduct inspections at known sources of introduction (e.g., live food markets, biological supply, etc.) in states within the basin where the species is prohibited. Coordinate Phragmites control efforts and share BMPs through the Ontario Phragmites Working Group, Great Lakes Phragmites Collaborative and the Phragmites Adaptive Management Framework. Implement coordinated prioritized invasive species control efforts using an adaptive management framework to ensure support of multiple uses (e.g. recreational boating, hunting, water intake, non-motorized vehicles), limit the spread of invasive species to new areas, and mitigate impacts of AIS to aquatic ecosystems. Better understand and assess vulnerability of high-quality areas to the introduction of invasive species.	Parks Canada, USDA-NRCS, USEPA, USFS, USFWS, USACE, CAs, States and Province EGLE, MDNR
30	**Regional efforts:** Implement strategic actions identified in Terrestrial Invasive Species State Management Plans and Aquatic Invasive Species State	States

	Management Plans approved by the ANS Task Force including regional and local priorities.	
SCIENCE, SURVEILLANCE, AND MONITORING		
31	Develop implementable control strategies for Dreissenid Mussels.	Invasive Mussel Collaborative (led by GLC, GLFC, USGS, NOAA, USACE)
32	***Improve understanding of invasive species impacts to inform management efforts:*** • *Role of mussels in HABs toxicity and the invasion curve*: More data needed to inform ecosystem models and understand where Lake Erie mussels are on the invasion curve. *Impacts of Round Goby on the food web:* Enhance assessment methods and technology to better understand Round Goby population density/distribution. *Causes of botulism outbreaks:* Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl.	States, Province, USGS, NOAA
33	***Pathway monitoring*** Conduct surveillance, compliance inspections, and enforcement actions to identify and minimize risk of transporting and introducing invasive species associated with key industries and pathways (e.g. bait, fish market, aquarium, recreational boating).	USFWS, USDA, States
34	Continue to use invasive species databases and mapping tools to support invasive species management, survey, and outreach efforts.	States, Province
35	Conduct aquatic plant (e.g. *Hydrilla*) surveys as needed in NY's portion of the Lake Erie basin	USACE, NYSDEC
OUTREACH AND EDUCATION		
36	**Communication:** Undertake aquatic invasive species prevention outreach and education, including discussions with key industries (e.g. water garden, aquarium, shipping) and natural resource user groups (e.g. recreational boaters and lake access site signage), and to local law enforcement to support State efforts.	DFO, USFS, CAs, States and Province
37	Support and participate in Invasive Species Awareness Week.	States
	CHAPTER 5.5 CLIMATE TRENDS Actions identified for nutrient sand bacterial pollution and loss of habitat and native species will help to maintain ecosystem function and enhance resilience to the impacts of climate change	
38	***Watershed Resilience***: Continue efforts that engage landowners and the public to protect and enhance the function and resilience of watershed headwater features, streams, forests, and wetlands to maintain and enhance resilience to climate change impacts, including Conservation Authority Climate Change Strategies and Action. Reduce inland vulnerability to extreme weather events by promoting wetland protections in flood-prone areas and expanding green infrastructure and urban forests to slow storm runoff. Adapt to threats caused by climate change by restoring ecosystem biodiversity, increasing habitat connectivity, and supporting resiliency initiatives for natural and built environments, including flood mitigation studies for priority flood-prone Lake Erie tributaries. Improve in-field infiltration practices to reduce runoff from agricultural fields	Conservation Authorities, MDNR, OMECP, USDA NRCS, USFS, EGLE, MOGL, OMAFRA States, EGLE, OMAFRA NYSDEC, EGLE NRCS, OMAFRA, MDARD, EGLE

39	***Critical Community Infrastructure:*** Plan and implement LID initiatives that are suited to future extreme weather events via watershed work that increases green space and green infrastructure. • Michigan Low Impact Development manual (section 319 funding supporting Michigan non-point source grant programs) • Ontario Low Impact Development manual, in development Ohio Balanced Growth Program Protect critical infrastructure in coastal communities by using natural and engineered measures to improve resiliency where possible. Strengthen drinking and wastewater infrastructure to reduce vulnerability to flooding, drought, and other extreme weather events.	Conservation Authorities, OMECP, USFS, MDEQ, MOGL OLEC NYSDEC, ODNR NYSDEC
40	***Coastal Resilience:*** Develop Great Lakes coastal restoration and resilience strategies to alleviate flood and erosion impacts to build and natural shorelines and improve overall coastal ecology, and promote improved shoreline stewardship through technical assistance.	NYSDEC, ODNR, EGLE
OUTREACH AND EDUCATION		
41	***Communications:*** Publish Great Lakes *Quarterly Climate Summary* that addresses trends and forecasts Host state by state Climate Services Workshops Undertake and support outreach and education to stakeholders and the public on the impacts of climate change to the Great Lakes and Lake Erie through fact sheets, newsletters and other means. Encourage municipalities and landowners to implement flood mitigation actions (e.g., soil health practices, natural infrastructure, wetland restoration/protection, etc.) to reduce peak flows in high-risk streams. Undertake community-based stewardship and education activities (e.g., coastal debris prevention, habitat restoration, etc). Promote living shorelines and coastal/riparian stewardship on public and private lands to improve aquatic habitat and enhance coastal resiliency. Develop and implement nature-based shoreline certification programs	NOAA NOAA Conservation Authorities, ECCC, USFS, OMECP States (NYSDEC, ODNR) & Partner Agencies/Organizations, OMAFRA EGLE EGLE ODNR

1.0 INTRODUCTION

The Lake Erie Lakewide Action and Management Plan (LAMP) is a binational, five-year ecosystem-based strategy for restoring and protecting the water quality of Lake Erie and the St. Clair-Detroit River System.

The Lake Erie LAMP fulfills a United States and Canadian commitment under the 2012 Great Lakes Water Quality Agreement (the Agreement) to assess ecosystem conditions, identify environmental threats and appropriate actions to address these threats, and set priorities for research and monitoring. The Agreement recognizes that the best approach to restore the Lake Erie ecosystem and improve water quality is for the two countries to adopt common objectives, implement cooperative programs, and collaborate to address environmental threats.

The LAMP is a world-recognized model for cooperation among governmental jurisdictions and their management agencies. It represents a shared understanding of the health of Lake Erie and a means for coordinating and documenting management actions. It sets out mechanisms to guide and support the work of natural resource managers, decision-makers, stakeholders, and the public in a collaborative management approach for protecting and restoring the water quality of the Great Lakes and connecting river systems.

The geographic scope of this LAMP includes Lake Erie, the St. Clair – Detroit River System (or SCDRS, which encompasses the Detroit River, Lake St. Clair and the St. Clair River and connects Lake Huron to Lake Erie), and the Upper Niagara River[1] (Figure 1).

The LAMP is a resource for anyone interested in the Lake Erie ecosystem, its water quality, and the actions that will help restore this unique Great Lake.

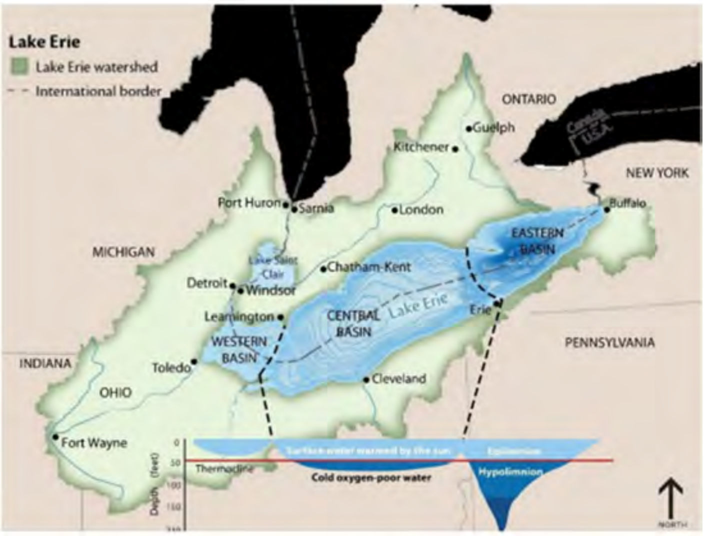

Figure 1. Map of the Lake Erie Basin. (Source: Environment and Climate Change Canada).

1.1 THE GREAT LAKES WATER QUALITY AGREEMENT and LAKEWIDE MANAGEMENT

Since 1972, the Agreement has guided U.S. and Canadian actions to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes. In 2012, the United States and Canada amended the Agreement, reaffirming their commitment to protect, restore and enhance water quality and to prevent further degradation of the Great Lakes Basin ecosystem.

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

Table 1. Annexes of the Great Lakes Water Quality Agreement.

The Agreement commits the United States and Canada to address 10 priority issues through specific 'Annexes' (Table 1). The Lake Erie LAMP integrates information and management needs from each of these Annexes, with a focus on Lake Erie-specific management needs to maintain, restore and protect water quality and ecosystem health. The commitment to develop LAMPs is specified in the Lakewide Management Annex

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[1] Under the 2012 Agreement, the Niagara River falls within the geographic scope of Lake Ontario. However, in recognition of ongoing binational efforts and agency programs that often combine Lake Erie and the Upper Niagara River for ecological assessment and priority-setting purposes, the Lake Erie LAMP describes some habitat actions for the Upper Niagara River. Refer to the Lake Ontario LAMP at https://binational.net/2019/04/15/lolamp-paaplo/ to learn more about actions to improve water quality in the Niagara River and Lake Ontario.

(Annex 2); this includes a commitment to integrate nearshore information and management actions into the LAMPs. A historical perspective on binational lakewide management efforts in Lake Erie is provided in Appendix A.

1.2 THE LAKE ERIE PARTNERSHIP

The LAMP was developed by member agencies of the Lake Erie Partnership, a collaborative team of natural resources managers led by the governments of the United States and Canada, in cooperation and consultation with State and Provincial Governments, Tribal Governments, First Nations, Métis, Municipal Governments and watershed management agencies. The LAMP supports an adaptive management approach (Figure 2) for restoring and maintaining Lake Erie water quality and will guide activities by management agencies for the years 2019 to 2023.

The Partnership facilitates information sharing among members, supports collaborative assessment of the state of the lake, sets priorities, and assists in coordinating binational environmental protection and restoration activities. It consists of a Management Committee, whose members are senior-level representatives of organizations with decision-making authority, and a Work Group that establishes task groups or sub-committees as required to focus on lake issues that need to be addressed.

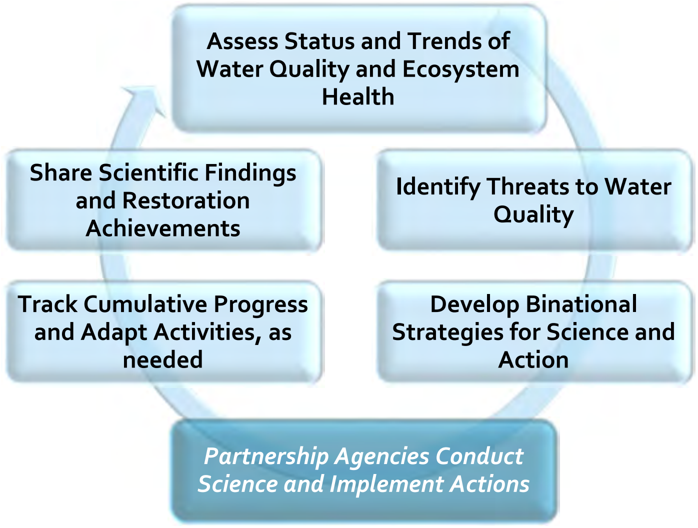


Figure 2: An adaptive lakewide management approach for Lake Erie.

Over the next five years, members of the Lake Erie Partnership will undertake key actions to address priority environmental threats to Lake Erie water quality and ecosystem health. These actions and the agencies implementing them are identified in Table ii. Chapter 5 discusses these actions in more detail. During the implementation of this LAMP, member agencies of the Lake Erie Partnership will assess the effectiveness of actions and adjust future actions to achieve the objectives of this plan, as outcomes and ecosystem processes become better understood.

ACTIONS THAT EVERYONE CAN TAKE

Public awareness and appreciation of water quality issues are important aspects of this LAMP. There are many opportunities to get involved in protecting Lake Erie water quality and ecosystem health.

Look for other '*Actions that Everyone Can Take*' information in the Chapter 5 of this LAMP; also refer to Chapter 7 (Outreach and Engagement). Local watershed organizations also work to improve water quality - contact one near you to learn more or volunteer.

1.3 ALIGNMENT WITH OTHER INTERNATIONAL RESOURCE MANAGEMENT EFFORTS

The Lake Erie Partnership actively works to ensure that management actions identified in this LAMP are complementary to other international management efforts established under various binational treaties, agreements, and programs, which also work within the Lake Erie ecosystem.

International Joint Commission Activities: The 1909 Boundary Waters Treaty (BWT) provides principles for Canada and the United States to follow in using the waters they share. The International Joint Commission (IJC) is a binational organization established under the BWT that works to prevent and resolve boundary waters disputes between Canada and the United States. The IJC serves as an independent and objective advisor to the two governments and is an important mechanism for binational dialogue and planning related to implementation of the Agreement. The IJC is advised by more than 20 binational boards and task forces, including the Great Lakes Water Quality Board, which assists the IJC in administration of the Agreement, and the Great Lakes Science Advisory Board, which advises the Commission and the Great Lakes Water Quality Board on scientific and research matters related to Great Lakes water quality. The IJC also provides oversight of efforts to regulate water levels and flows in some of the Great Lakes and connecting channels. However, there currently are no such efforts to control water levels or flows in Lake Erie. Downstream of Lake Erie, the International Niagara Control Works (INCW) control structure is used to partition Niagara River waters between the Horseshoe and American Falls and the hydroelectric power facilities in the United States and Canada.

Water Withdrawals Management: The Great Lakes-Saint Lawrence River Basin Sustainable Water Resources Agreement details how eight Great Lakes states and the provinces of Ontario and Quebec manage and protect their water supplies. The Great Lakes-St. Lawrence River Basin Water Resources Compact is a legally binding interstate compact and a means to implement Great Lakes-St. Lawrence River Water Resources Regional Body commitments (http://www.glslregionalbody.org/index.aspx, http://www.glslcompactcouncil.org/). The Water Resources Regional Body was created by the Great Lakes and St. Lawrence Governors and Premiers, who work as equal partners to grow the region's $6 trillion economy and protect the world's largest system of surface fresh water (http://www.gsgp.org).

Fishery Management: The Great Lakes Fishery Commission (GLFC) facilitates cross-border cooperation of state, provincial, tribal, and federal fishery management agencies for the improvement and preservation of the fisheries under the Joint Strategic Plan for Great Lakes Fisheries Management (GLFC 2007). The Lake Erie Committee of the GLFC is a binational committee comprised of senior officials from state and provincial fishery management agencies. It is tasked with sustainably and cooperatively managing lake Erie's fisheries resources and the fish community, considering issues and problems of common concern to the jurisdictions, developing and coordinating joint state/provincial/federal fisheries programs and research projects, and making recommendations on fisheries management issues affecting Lake Erie. The Lake Erie Committee also has developed and maintains shared fish community objectives, establishes appropriate stocking levels and harvest targets, sets law enforcement priorities, and formulates management plans. http://www.glfc.org/lake-erie-committee.php

(Ohio Lake Erie Commission)

2.0 THE INHERENT VALUE, USE, AND ENJOYMENT OF LAKE ERIE

Lakewide management is guided by a shared vision of a healthy, prosperous, and sustainable Great Lakes region in which the waters of Lake Erie are used and enjoyed by present and future generations.

The Lake Erie watershed is currently home to almost 13 million people (10 million in the United States and 2.7 million in Ontario) and has been used and enjoyed by people for thousands of years. We continue to recognize the inherent natural, social, spiritual, and economic value of the Lake Erie basin ecosystem. Sound management and use will benefit present and future generations.

The following provides a brief cultural description of the earliest inhabitants and how resource use supports the regional economy.

2.1 INDIGENOUS PEOPLE AND TRADITIONAL ECOLOGICAL KNOWLEDGE

For thousands of years, Indigenous peoples have lived in and travelled through the Lake Erie watershed, making use of the region's natural resources for food, clothing, and raw materials, and for spiritual and cultural practices. Certain locations around the lake have been used as Indigenous gathering places for millennia. For example, the Aamjiwnaang First Nation, on the St. Clair River, draws its name from an Ojibwa word for "important gathering place". A network of trails ran along the north and south shores of the lake, connecting the peoples of Lake Erie with settlements as far away as the Mississippi River and Chesapeake Bay.

The name "Erie" is derived from *erielhonan*, the Iroquoian word for "long tail", reflecting the lake's tail-like shape. Historically, an Iroquoian group known as the Erie people occupied a large territory on the south shore of Lake Erie, ranging from western New York through most of northern Ohio.

Today, four major Indigenous cultural groups are present within the Lake Erie watershed in Canada: the Anishinaabe, Haudenosaunee, Lenape, and the Métis. These are represented in nine First Nations in Ontario: Aamjiwnaang First Nation (St. Clair River); Bkejwanong (Walpole Island First Nation) (Lake St. Clair); Chippewas of the Thames First Nation (Thames River); Oneida Nation of the

Thames (Thames River); Munsee-Delaware Nation (Thames River); Eelünaapéewi Lahkéewiit (Delaware Nation at Moraviantown) (Thames River); Caldwell First Nation (western Lake Erie); Six Nations of the Grand (Grand River); and the Mississaugas of the New Credit (Grand River).Three Mètis Nation of Ontario communities are located in the watershed: the Grand River Mètis (centered in Kitchener), the Thames Bluewater Métis (centered in London), and the Windsor-Essex-Kent Métis (centered in Windsor). U.S. federally recognized tribes in the Lake Erie watershed include the Seneca Nation of Indians (eastern Lake Erie watershed) and the Tonawanda Band of Seneca Indians (Upper Niagara River watershed) (for map see Appendix B).

2.2 NATURAL RESOURCES AND THE REGIONAL ECONOMY

Lake Erie is the southernmost of all of the Great Lakes. A moderate climate and fertile watershed soils support a strong regional economy that includes water-based industries, commercial and recreational fishing, commercial shipping, a charter boat industry, agriculture, nature-based tourism and recreation, and natural gas and oil extraction. In addition to these major sectors, the basin supports a variety of other industries typical of the Great Lakes Basin, including finance, services (health, education, religion), transportation, communications, and manufacturing, including automotive and steel.

Water Use and Water-Based Industries: Over 12.5 million people get their drinking water from Lake Erie (US EPA 2018). In 2017, the six jurisdictions that share the watershed – Indiana (IN), Michigan (MI), New York (NY), Ohio (OH), Ontario (ON) and Pennsylvania (PA) – collectively withdrew 26,142 million liters of water per day (6,906 million gallons/day) from the watershed, excluding in-stream hydroelectric water use, which accounted for an additional 202,989 million liters/day (53,624 million gallons/day) (Great Lakes Commission 2018). This amount is a six percent decrease from the 2016 total withdrawal amount of 27,869 million liters /day (7,362 million gallons/day). Aside from water used for hydroelectric power generation purposes, the primary water uses were thermoelectric power generation, both once-through and recirculated cooling (14,733 million liters/day or 3,892 million gallons/day), public water supply (6,170 million liters/day or 1,630 million gallons/day), and industrial use (4,853 million liters/day or 1,282 million gallons/day). Lake Erie surface water was the source of 80% of these water withdrawals (Great Lakes Commission 2018).

Commercial fishng boats in Wheatley Harbour (L. Cargnelli)

Commercial and Recreational Fishing: The warm waters of Lake Erie support the most productive fishery in the Great Lakes. The Lake Erie fishery is managed through a quota system. Ontario allocates most of its quota to commercial fishing, while in the United States the quota is allocated almost exclusively to sport fishing. As a result, more than 80% of commercial fishing occurs in Ontario waters (ECO 2011), with the principal commercial fish species being Walleye (*Sander vitreus*), Yellow Perch (*Perca flavescens*), Rainbow Smelt (*Osmerus mordax*) and White Bass (*Morone chrysops*). In 2015, the landed value of the Lake Erie fish harvest in Ontario alone exceeded $30 million, not including the value of associated food processing, packaging, and shipping industries (Governments of Canada and Ontario 2018). A recent study commissioned by the Ontario Commercial Fisheries' Association suggests that the economic impact of Ontario's commercial fisheries was at least $244 million in 2015, and created 913 direct jobs, 1,490 jobs overall, and estimated annual tax revenues of more than $20 million (MNP 2015).

Known for its world class Walleye fishery, Lake Erie supports a sportfishing industry valued at over $1 billion (U.S.) per year and a charter boat industry that is one of the largest in North America (American Sportfishing Association 2013).

Commercial Shipping: Lake Erie forms part of the Great Lakes St. Lawrence Seaway (GLSLS), which extends from the Atlantic Ocean into central North America and moves over 181 million tonnes (200 million tons) of cargo every year between its 85 ports. Cargoes shipped in the GLSLS include iron ore, coal, cement, limestone, salt, sand and grain, as well as chemicals, petroleum, finished products and containerized cargo to a lesser extent (U.S. Department of Homeland Security 2014). Lake Erie has more commercial shipping ports than any other Great Lake. In 2015, two Lake Erie ports (Cleveland, OH and Detroit, MI) were among the top 10 Great Lakes ports in terms of millions of short tons of cargo handled (Blue Accounting, 2018a). Commercial shipping between Lake Erie and Lake Ontario is via the Welland Canal, which allows ships to bypass Niagara Falls. In 2017, over 38 million tonnes (41.9 million tons) of cargo were moved through the canal (St. Lawrence Seaway Management Corporation 2018). In 2017, Lake Erie saw 53.5 million short tons (MST) of cargo, headed to or from U.S. harbors, move on its water (reference). Commercial shipping between Lake Huron and Lake Erie moves through the SCDRS. An average of 59 million tonnes (65 million tons) of cargo transit the SCDRS annually (average from 2006-2010), generating $1.83 billion (U.S.) and supporting 41,000 jobs (US Army Corps of Engineers 2013).

Commercial cargo ship docked in the St. Clair River (ECCC)

Agriculture: Within the Lake Erie watershed, agriculture is an important contributor to the economy on both sides of the border, with approximately 75% of the land in both the Ontario portion of the basin (Governments of Canada and Ontario 2018) and the US portion of the basin (USGS 2000) in agricultural production. In the United States, there are approximately 2.9 million hectares (4.1 million acres) of farmland and 2.5 million hectares (3.3 million acres) of cropland in the Lake Erie basin (2012 data, USDA 2012). In Canada there are approximately 1.7 million hectares (4.1 million acres) of farmland and 1.4 million hectares (3.5 million acres) of cropland in the Lake Erie basin (2011 data, ICOA 2013). Soybeans, corn, winter wheat, and hay are the four dominant crops within the Lake Erie watershed. Soybeans and corn make up approximately 90% of the production in the United States, with over 50% and 39% of the acreage, respectively (U.S. EPA 2018) while in Canada soybean is 34% and corn is 28% of the cropland acreage, respectively (ICOA 2013).

The Leamington-Kingsville area of Ontario supports the largest concentration of greenhouse vegetable growers in North America, with over 612 hectares (1600 acres) of greenhouses producing tomatoes, cucumbers, peppers, and nursery flowers (ICOA 2013). In the United States, the Lake Erie region is home to the largest grape-growing territory outside of California, with thousands of acres of vineyards along the “Lake Erie Grape Belt” in western New York, Pennsylvania, and Ohio. In Ontario, Lake Erie’s North Shore and Pelee Island Designated Viticultural Areas cover approximately 405 hectares (1,000 acres).

Nature-based Tourism and Recreation: The waters and shores of Lake Erie provide plentiful opportunities for recreation, and support a wide variety of ancillary industries, including tourism, which in 2015 was valued at $14.1 billion for Ohio’s Lake Erie region alone (Great Lakes Commission 2017). In-water activities include swimming, boating, and recreational fishing. Thousands of shipwrecks dot the lake’s bottom, attracting recreational divers from all over the world.

Although the Lake Erie watershed is highly altered by human activity, many wild places remain, and there are hundreds of parks and conservation areas throughout the watershed. Ecotourism continues to be a growing part of the regional economy, attracting hundreds of thousands of visitors every year. Birdwatching is particularly popular along the Lake Erie shoreline, especially at parks and refuges like Point Pelee National Park, Long Point Provincial Park, Maumee Bay State Park, Metzger Marsh, and Ottawa National Wildlife Refuge.

(Pennslyvania Sea Grant)

Natural Gas and Oil Extraction: Issuing federal or state permits for new directional, slant, or offshore drilling operations in or under the U.S. portions of the Great Lakes was banned in the Energy Policy Act of 2005 (P.L. 109-58, §386). Canada prohibits offshore oil drilling but does allow on-shore (directional) drilling for oil under the Great Lakes as well as offshore natural gas drilling. In Ontario’s Lake Erie watershed, oil production has occurred since 1858 (North America’s first commercial oil well was in Oil Springs, ON) and natural gas drilling has occurred since the early 1900s. Natural gas production in the Ontario waters of Lake Erie has occurred since the 1950s, with wells drilled on the bottom of Lake Erie to access pockets of natural gas deep beneath the lake.

3.0 THE LAKE AND ITS WATERSHED: AN IMPORTANT CONNECTION

The Lake Erie watershed is the area of land that drains rain and snow into streams that flow into the lake. Home to more than one-third of the entire population of the Great Lakes Basin, it is the most populated watershed. The water quality of Lake Erie depends on the health of its watershed.

The Lake Erie and St. Clair-Detroit River System's watersheds together cover 78,000 km² (30,140 mi²), the second smallest watershed of all the Great Lakes. Due to the high degree of urban, agricultural, and industrial land uses in the watershed, Lake Erie is vulnerable to water quality impacts that can originate in the watershed.

This chapter begins with a brief description of the large volumes of water that move through the watershed including the St. Clair-Detroit River System. Water movement from the headwaters through inland lakes and wetlands and into the streams that flow to the lake is then described to illustrate how Lake Erie's water quality is affected by activities throughout its watershed and along its shoreline. The chapter concludes by describing how a healthy watershed is critical to ensuring healthy coastal wetlands, nearshore, and offshore waters and provides regional examples of the variety of protected areas along the shores and islands of Lake Erie.

3.1 LAKE ERIE WATER SOURCES AND FLOWS

Lake Erie is located downstream of Lake Huron and upstream of Lake Ontario (Figure 1), with an average depth of only 19 m (62 ft). Although it is the smallest Laurentian Great Lake, on a global scale Lake Erie is the 15th largest freshwater lake in the world (Sturtevant and Domske 2012). On average, Lake Erie holds about 484 trillion litres (127 trillion gallons) of water, depending on the various flows into and out of the lake in a given year, as described below.

If you emptied the water in Lake Erie onto the land of its watershed, it would cover the land to a depth of over 6 meters (20 feet).

Each hour, approximately 19.3 billion litres of water (~5 billion gallons) flows into Lake Erie from Lake Huron through the St. Clair and Detroit Rivers. The water flowing through the St. Clair and Detroit Rivers represents about 80% of average total inflows into Lake Erie. Precipitation accounts for 11% of the total inflow, and runoff from the watershed, including tributary flows, accounts for about 9% of total inflows (Nace 2017). Major tributaries to the lake include the Maumee, Sandusky, Cuyahoga, Raisin, and Huron Rivers in the United States and the Thames (via Lake St. Clair) and Grand Rivers in Canada (Figure 1). Water leaves the lake through consumptive uses, evaporation, and downstream flows. Every hour, about 2.7 billion litres (722 million gallons) of water evaporate from the lake into the atmosphere. An additional 21 billion litres (5.55 billion gallons) of water per hour exit through the Niagara River, eventually flowing into Lake Ontario.

Lake Erie's shallow depth and significant flow volume means that water entering the lake requires only 2.6 years on average to flow out of the lake (referred to as a 2.6 year "retention time"), which is a fraction of Lake Superior's 191-year retention time. This means that water in Lake Erie courses relatively quickly through the lake into the Niagara River and Lake Ontario.

3.2 LAKE ERIE WATERSHED

The Lake Erie watershed is comprised of a diverse collection of habitat types, each playing a critical role in maintaining water quality. The following sections describe some of the major habitat types and how a healthy watershed functions.

Headwaters and Uplands

Headwaters include surface drainage features, groundwater seeps, and springs that are the sources of water to streams and small watercourses. Headwater streams are the smallest parts of river and stream networks but make up the majority of river miles in a watershed. Headwaters are intrinsically linked to downstream water quality through their influence on the supply, transport, and fate of water and solutes in watersheds.

Upland areas encompass the majority of the watershed land areas and include both natural habitats and developed areas. Well-functioning uplands allow water to infiltrate into the soil, which minimizes stormwater runoff, reduces potential for extreme flooding, and recharges aquifers.

Forests cover 19% of the Lake Erie basin area (ECCC and US EPA, 2019) and are largely temperate deciduous and mixed forests, with small remnants of Carolinian forest. The warm, humid climate supports a wide variety of tree species including Sugar Maple (*Acer saccharum*), American Beech (*Fagus grandifolia*), White Oak (*Quercus alba*), Red Oak (*Quercus rubra*), Shagbark Hickory (*Carya ovata*), Black Walnut (*Juglans nigra*), and Butternut (*Juglans cinerea*), with Eastern Cottonwood (*Populus deltoids*), Black Ash (*Fraxinus nigra*), Tulip Tree (*Liriodendron tulipifera*), Sycamore (*Platanus occidentalis*), and Bitternut Hickory (*Carya cordiformis*) on moist sites and Black Oak (*Quercus velutina*), resprouting American Chestnut (*Castanea dentate*), and Chinquapin Oak (*Quercus muehlenbergii*) in drier regions. Lake Erie's forests and woodlands provide habitat for many species of wildlife. The deep, organic soils and uneven terrain of forest ecosystems protect source water by slowing runoff and preventing soil erosion. The forest canopy shades riparian areas and is instrumental in moderating stream temperatures. Only 31% of streams within the Lake Erie basin have forested riparian zones (ECCC and US EPA, 2019).

Agricultural lands account for approximately 75% of the Lake Erie basin watershed, most of which are artificially drained. Agricultural soils provide important ecosystem functions and can be managed to protect downstream water quality. Nutrient and pesticide management, drainage management, and the use of conservation practices like cover crops, furrow dikes, grassed waterways, buffer strips, two-stage ditches, and water/sediment control basins help to minimize flooding, soil erosion, and nutrient loss.

Lakeplain Prairies consist of rich and deep soil on which a variety of tallgrasses and flowers grow. Most of the Great Lakes St. Lawrence *Lakeplain Prairies* have been converted to agriculture due to their rich soils. However, important vestiges of lakeplain prairies are still found in the Lake Erie basin within the St. Clair River Delta, along the Michigan shores of Detroit River, and Ohio's Lake Erie shores. The extensive root systems of these plant communities lock soil particles together, helping to prevent soil erosion and water pollution. These sites also support a number of amphibian and reptile species as well as several species of grassland songbirds.

Alvars are globally rare habitats found in areas dominated by exposed limestone or dolomite bedrock, with little or no soil cover. Originally created by glacial activity, alvars are flat and usually flood throughout the spring but are dry in summer. Alvars support rare plant and animal species that have adapted to these extreme conditions. Alvars occur at a variety of locations around Lake Erie, including the North Shore Alvar on Kelley's Island, Ohio, where unusual species include Northern Bog Violet (*Viola nephrophylla),* an endangered species), Balsam Squaw-weed (*Senecio pauperculus)*, Kalm's Lobelia (*Lobelia kalmia)*, and Pringle's Aster (*Symphyotrichum pilosum pringlei)*. Alvars on Pelee Island, Ontario, support at least four plant species (Navel-shape Corn-salad (*Valerianella umbelicata)*, Downy Wood Mint (*Blephilia ciliate)*, Yellow Horse Gentian (*Triosteum angustifolium)* and Leavenworth's Sedge (*Carex leavenworthii*) that occur nowhere else in Canada.

Shoreline in the eastern basin of Lake Erie (ECCC)

Urban Centers contain a higher percentage of hard surfaces compared to natural areas, including roofs, roads, and parking lots. This prevents or significantly reduces stormwater infiltration. The inability of stormwater to infiltrate into the ground increases risk of flooding and allows pollutants to directly enter waterways through stormwater runoff/conduits. Well-designed urban centers reduce flooding and runoff risks via incorporation of sufficient green space and green infrastructure. Green spaces can include vegetated urban areas such as parks, playing fields, community gardens, and cemeteries. Green infrastructure best

The Cleveland, Ohio waterfront (Great Lakes Commission)

management practices include rainwater harvesting systems, rain gardens, green roofs, permeable pavement, tree planting and other stormwater management
techniques that soak up, store, and slow the movement of water.

Inland Lakes and Wetlands

Inland lakes, wetlands and ponds occur throughout the Lake Erie watershed. These waterbodies offer many recreational opportunities including swimming and fishing and can slow and store water moving through the watershed, reducing the risk of flooding. They also act as filters to prevent excess nutrients and sediment from reaching Lake Erie. Many different kinds of *inland wetlands* occur in the Lake Erie basin, including swamps, marshes, wet prairies, bogs and fens. These wetlands provide diverse habitat for aquatic and terrestrial wildlife, absorb nutrients like phosphorus and nitrogen from water, capture sediment, store carbon, enable groundwater recharge and help to minimize impacts of flooding via retention during high water events.

Wetland (Steven Gratz)

Streams

Streams are the arteries of the larger watershed systems, allowing connections between the headwaters and the lake. They provide important spawning habitat for fish and other aquatic species. There are 64,503 total kilometers (40,080 total miles) of streams in the Lake Erie basin (46,032 kilometers (28,603 miles) in the United States, 18,471 kilometers (11,477 miles) in Canada; Source: NHDPlus Version 2 and Ontario Integrated Hydrology Data: Enhanced Watercourse Dataset, as compiled by Vouk et al. 2018). Both cold- and warmwater streams occur within the Lake Erie basin. Warmwater streams, which predominate, support species like bass, sunfish and crappie while coldwater streams support species such as trout and sculpin. Development and the construction of dams and other physical barriers have created obstacles to fish migration/passage and have degraded stream habitat, including important spawning areas and riparian corridors, and have altered flow and sediment transport regimes.

Coastal Shorelines

Coastal shorelines are where most people interact with Lake Erie, through recreational activities like swimming, fishing and boating, and a variety of commercial uses. Natural coastal systems provide unique habitats for both terrestrial and aquatic fauna. They are the last line of defense for the lake, trapping pollution in water runoff before it enters the lake. Lake Erie's shoreline is 1,402 km (871 mi) long (Environment Canada and U.S. EPA 1995) and the St. Clair-Detroit River System shoreline is 636 km (395 mi) long (U.S. Census Bureau 2012).

Approximately half of Lake Erie's shoreline has minimal (<15%) hardening, while 20% of the shoreline has excessive (>70%) hardening (GLEAM 2012). The geology of the coast changes as you circle the lake. Lake Erie's northern and southern shores boast sand beaches, dunes and sandy bluffs, while its western and eastern shores are composed of rocky cliffs of exposed bedrock, marshes and wetlands and low floodplains. Coastal erosion can have a major impact on the lake's coastal geography, as well as economic and societal impacts to lakefront landowners, public parks, swimmers, boaters, anglers, utilities, and infrastructure. Natural and responsibly developed shorelines provide protection against erosion while also supporting water quality and ecosystem health.

3.3 WATERS OF THE ST. CLAIR-DETROIT RIVER SYSTEM AND LAKE ERIE

The waters of the Lake Erie watershed form a delicate network supporting human activities as well as plant and animal life. Changes to one part of the network can be felt throughout the whole. Maintaining healthy waters in all parts of the watershed is necessary to ensure continued use and enjoyment of Lake Erie.

As water moves through the watershed, it ultimately flows into the "waters of Lake Erie" that include the St. Clair and Detroit Rivers, Lake St. Clair, and the interconnected zones of the lake and its associated coastal wetlands, nearshore waters, and open waters, as described below (Figure 1). The health of the waters of Lake Erie has a direct impact on humans as well as on plant and animal species. Pollutants entering these waters are very difficult to remove and have the potential to contaminate waters downstream, including the Niagara River, Lake Ontario, and the St. Lawrence River. The health of the Lake Erie watershed maintains the health of the waters of Lake Erie, as well as downstream systems.

The St. Clair River

The St. Clair River connects Lake Huron to Lake St. Clair, and together with Lake St. Clair and the Detroit River, forms the international boundary between the United States and Canada. At the outlet of Lake Huron, the river runs fast with an average discharge of 5,200 m^3/s (182,000 ft^3/s), with numerous wetlands and islands along its length. As it enters Lake St. Clair, the river flows into the largest freshwater delta in North America, the St. Clair River Delta.

The 65.2 km (40.5 mile) length of the St. Clair River forms part of the boundary between Ontario and Michigan. For centuries, the St. Clair River has been an important trade route for Indigenous peoples. In the late 17th century, French coureurs des bois and voyageurs used the route in the fur trade. By the 19th century, the river had become important for moving rafts of lumber and by the 20th century it was carrying shipments of grain and metal ores. Today, the river is an important transport link on the St. Lawrence Seaway, allowing ships to travel between Lake Huron and Lake Erie.

Five endangered or threatened fish species occur in the St. Clair River, including the endangered Northern Madtom (*Noturus stigmosus*), an extremely rare benthic catfish found in the lower St. Clair River, and the threatened Lake Sturgeon (*Acipenser fulvescens*). Although Lake Erie's Sturgeon populations continue to be well below historic levels, stocks in the SCDRS are robust.
The St. Clair River and Detroit Rivers provide important Lake Sturgeon spawning habitat. The upper St. Clair River near Port Huron, Michigan contains one of the largest spawning populations of Lake Sturgeon in the Great Lakes, with an estimated 15,000 individuals. Recent habitat restoration efforts to create additional spawning sites through artificial reef construction are now underway in the St. Clair and Detroit Rivers, resulting in three new spawning sites so far.

Along the river, intensive industrial activity, waste disposal sites, landfills and agricultural and residential land use have contributed loads of PCBs, mercury, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and phosphorus that have impaired the ecosystem. As a result of impacts resulting from past loadings of these contaminants, in 1987 the St. Clair River was designated an Area of Concern (AOC) under the Agreement. Since that time considerable work has been done to remediate issues and improve conditions in the river.

Lake St. Clair

Like the St. Clair River, Lake St. Clair formed part of an important navigation system for many Indigenous peoples, and it remains an important shipping route today. The lake provides drinking water, and the lake is also home to a number of boat clubs and public beaches. Its varied coastal landscapes and extensive coastal wetlands provide habitat for diverse plant and animal species, including many species at risk. Lake St. Clair is shallow with an average depth of 3.7 m (12 ft). An 8.2 m (27 ft) deep shipping channel is maintained within the lake to allow large lake freighters to travel between the St Clair and Detroit Rivers. Its total surface area is approximately 1,100 km^2 (430 mi^2). The outflow of Lake St. Clair enters the Detroit River, which in turn drains into Lake Erie. Lake St. Clair's residence time is 7-10 days because of its relatively modest volume (3.4 trillion liters/902 billion gallons) relative to its high outflow rate

(Gibb 2012). Besides the St. Clair River, Ontario's Thames River is the largest Canadian tributary and the Clinton River is the largest United States tributary to Lake St. Clair.

Walpole Island is a part of the St. Clair River delta, which is the largest delta in the Great Lakes. Walpole Island Marshes, Fen and Prairies, an Area of Natural and Scientific Interest, is an important wetland area, and one of the most extensive wet prairies in North America. It is home to a number of protected species, including the King Rail (*Rallus elegans*), the Lake Chubsucker (*Erimyzon sucetta*) and the Dense Blazing Star (*Liatris spicata),* a perennial wildflower. Walpole Island is part of the territory of the Walpole Island First Nation.

The Detroit River

The Detroit River is the outlet of Lake St. Clair and flows 51 km (32 mi) south to Lake Erie, carrying approximately 5,300 m^3/s (188,000 ft^3/s) of water into Lake Erie, and forming another part of the international boundary between the United States and Canada. A number of islands occur along the length of the river, especially close to its outflow into Lake Erie. At the head of the Detroit River lie the major urban areas of Detroit, Michigan and Windsor, Ontario. Like the St. Clair River, the Detroit River has been the focus of intensive industrial and urban development over the last two centuries. These activities contributed discharges of organic and inorganic pollutants, bacteria, and oils and grease to the river, causing ecosystem impairments resulting in the Detroit River being designated an AOC in 1987 under the Agreement.

Docks on the Detroit River (Detroit River Canadian Cleanup)

Although the Detroit River is relatively short, it is home to some of the busiest ports in the Great Lakes basin and several major international border crossings, including the Ambassador Bridge, North America's busiest international border crossing that connects Detroit, Michigan with Windsor, Ontario. In recent years, the establishment of several conservation areas and nature reserves along its shores has led to the return of some native species that had been displaced by human activities. Water quality improvements and the construction of artificial reefs have improved spawning habitat in the river to the point that Lake Sturgeon, Walleye, Lake Whitefish and 12 other native fish species are once again spawning in the river.

The Detroit River International Wildlife Refuge is located on the western shore of Lake Erie and the Detroit River and is the only international wildlife refuge in North America. It includes the last undeveloped mile of shoreline along the United States mainland of the Detroit River, as well as marshes, shoals, wet meadows, islands and waterfront lands. It is unique in being located inside a major metropolitan area, and provides a refuge for numerous mammal, fish, and bird species, many of which are now returning to the area after decades of habitat disturbance through human activity.

Coastal Wetlands

Coastal Wetlands formerly occurred throughout Lake Erie, but were especially abundant in the Western Basin, Lake St. Clair, and along the shores of the Detroit River, St. Clair River, and the Upper Niagara River. In many of these areas, wetland losses have been significant with losses as high as 95%. Substantial and highly diverse coastal wetlands remain in the Lake Erie basin, with prime examples at the Lake St. Clair Delta, Long Point Bay, Rondeau Bay Coastal Wetlands, Dunnville Marshes at the mouth of the Grand River, and Point Pelee in Ontario; Lake St. Clair (Ontario and Michigan); and in several public and private wetlands in the Western Basin. Together these wetlands cover approximately 2,790 km^2 (689,000 acres).

Although reduced in size and in some cases only partially connected to the lake, these wetlands still serve many important ecosystem functions. For example, over 65 species of fish, 16 of which are threatened or endangered, use the St Clair-Detroit River System wetlands during critical life stages. This system is also part of the central

Great Lakes flyway for millions of migratory birds and is recognized as part of a globally significant shorebird stopover area.

Coastal wetlands are essential for supporting critical life stages of aquatic-dependent species.

Lake Erie

Lake Erie is naturally divided into three distinct basins that differ in shape, depth, hydrology, and biological productivity (Figure 1). The Western Basin is the smallest and shallowest, with an average depth of 7.4 m (24.1 ft). The Central Basin is the largest and has an average depth of 18.5 m (60.1 ft).

The Eastern Basin has the greatest average depth at 24.4 m (79.3 ft). Although Lake Erie overall is considered mesotrophic (moderate biological productivity), some areas in the shallow western basin are eutrophic (high productivity), and much of the deep eastern basin is oligotrophic (low productivity). Productivity of central-basin waters generally follows a gradient between the western and eastern basins, declining from west to east. Productivity also decreases from shallow inshore areas to deep offshore areas in all basins (Markham and Knight 2017).

Nearshore Waters

Nearshore waters are shallow, productive environments that link the coastal ecosystem to the deeper waters of the open lake. Most species of Great Lakes fish use nearshore waters for one or more critical life stages or functions. As a result, the nearshore area hosts the highest diversity of fish species. The Agreement recognizes that nearshore waters must be restored and protected because communities rely on this area for safe drinking water, recreational activities such as swimming, fishing and boating, and water withdrawals for industry and power generation. The nearshore is the hydrological and ecological link between watersheds and the open waters. Prevalence of seasonal harmful algal blooms in the western basin and nuisance algae *Cladophora* in the eastern basin are of particular concern for resource managers.

The quality of the shallow, nearshore waters is primarily determined by land use. A sustainable and prosperous Great Lakes economy is dependent upon a healthy nearshore system.

Lakeside Daisy State Nature Preserve on Ohio's Marblehead Peninsula was founded to help protect the only natural population of the endangered Lakeside Daisy (*Tetraneuris herbacea*) in the United States. These bright yellow flowers require dry, alkaline soils, which are inhospitable for many other species. The Lakeside daisy grows primarily in alvars, a globally rare ecosystem characterized by flat limestone plains with little or no soil.

The Lake Erie Bluffs, one of the Lake Metroparks in Lake County, Ohio, permanently protect wetland, meadow and mostly undeveloped lakefront habitat used by rare and common plant and animal species. The landscape contains a mix of 12 meter- (40 foot-) high beach bluffs and 2,743 meters (9,000 feet) of open sandy and cobble beach shoreline.

Point Pelee National Park is located on both the small peninsula that is the southernmost point in mainland Canada as well as Middle Island in Lake Erie. Point Pelee National Park offers "Carolinian" forest, a unique southern Ontario ecosystem rich in plant and animal species more typical of the southern United States. The park has many species that are rare in other parts of Canada, including Tulip Tree (*Liriodendron tulipifera*), Sassafras (*Sassafras albidum*), Five-lined Skink (*Plestiodon fasciatus*) and Eastern Fox Snake (*Pantherophis gloydi*). Point Pelee is a United Nations Educational, Scientific and Cultural Organization (UNESCO) "Wetland of International Significance" and provides an important stop-over for many migrating birds. Over 390 species of birds have been recorded in the park's birding area.

The shoreline of Abino Bay in the eastern basin of Lake Erie (ECCC).

Like Point Pelee National Park and Presque Isle State Park, Long Point Provincial Park lies on a sandy point jutting out into Lake Erie's eastern basin. It is an important site for migratory birds, with 383 different species recorded in the park. It is located within a UNESCO World Biosphere reserve and is home to protected species like the Fowler's toad (*Bufo fowleri*). The park includes important wetlands and tracts of Carolinian forest as well as providing opportunities for recreational activities and ecotourism.

Three Canadian National Wildlife Areas (NWAs) are located in the Lake Erie watershed: St. Clair NWA, Big Creek NWA and Long Point NWA. All are significant in size, offering a diversity of important habitats for migrating bird, fish, reptiles, amphibians, and rare species of plants.

Presque Isle State Park is a sandy Peninsula stretching into Lake Erie that is Pennsylvania's only 'seashore'. The park is subject to constant change and reshaping due to rain and wind, providing an excellent opportunity to study ecological succession. Due to its unique situation and the number of different habitat types it contains, the park is home to many endangered, threatened and rare species, including the Cerulean Warbler (*Setophaga cerulea*). As part of a transcontinental migration route, it is an important stopover for migratory birds.

Open Waters

The open waters of Lake Erie support a robust and resilient fishery. Important preyfish species include Rainbow Smelt, Gizzard Shad (*Dorosoma cepedianum*); juvenile White Bass, White Perch (*Morone americana*), Yellow Perch, Emerald Shiner (*Notropis atherinoides*), Spottail Shiners (*Notropis hudsonius*), and Round Goby (*Neogobius melanostomus*). Major predators in the open waters of the lake are Rainbow Trout (*Oncorhynchus mykiss*), White Bass, Smallmouth Bass (*Micropterus dolomieu)*, Lake Trout (*Salvelinus namaycush*), Walleye, Burbot (*Lota lota*), and the invasive, parasitic Sea Lamprey (*Petromyzon marinus*).

Ongoing challenges to the Lake Erie food web present challenges for resource managers. Invasive species compete with native species for food and habitat. Examples include the invasive Sea Lamprey, which have had dramatic impacts on the Lake Erie fish populations and require the expenditure of millions of dollars annually to control. Another food web stressor is the dead zone (an area of low oxygen in the water) that develops at the bottom of the central basin of Lake Erie in summer. By influencing the distribution of Yellow Perch and Rainbow Smelt populations, the dead zone may cause changes in species' feeding and growth rates. The dead zone may also affect fishery catch rates by altering the amount of available habitat and, therefore, the distribution or density of targeted species (Kraus et al. 2015).

Maumee River at Waterville (Ohio Lake Erie Commission)

4.0 STATE OF LAKE ERIE

Lake Erie is the shallowest, warmest, and most productive Great Lake. Although its overall condition has improved significantly since the 1970s, threats still exist. Chemical contaminants, nutrient and bacterial pollution, loss of habitat and native species, and the spread of non-native invasive species impact the health and use of Lake Erie and the St. Clair - Detroit River System (SCDRS).

The United States and Canada have made significant progress toward restoring and maintaining water quality of Lake Erie and the SCDRS since first signing the Agreement in 1972. Over the past four decades, management agencies and the public have worked to reduce chemical contamination, protect habitats and native species, and rehabilitate degraded areas, resulting in a cleaner, healthier Lake Erie.

This chapter provides the public and resource managers with an assessment of current conditions and ongoing threats to water quality, habitats and native species within Lake Erie and the SCDRS. Many sources were used to inform this assessment including, but not limited to, the following:

- State of the Great Lakes Indicator Reports (ECCC and U.S. EPA 2019)
- Returning to a Healthy Lake Erie: An International Biodiversity Conservation Strategy for Lake Erie (Pearsall et al. 2012)
- Canada-Ontario Lake Erie Action Plan for Reducing Phosphorus Loads (2018)
- U.S. Lake Erie Action Plan (2018)
- Lake Erie Millennium Network State of Lake Erie Workshop Report (LEMN 2017)
- Literature reviews and information from scientists and research managers
- Great Lakes Fishery Commission Lake Erie Committee and Task Groups

Information in this chapter is organized by each of the nine General Objectives of the Agreement (Table 2). Each section includes background information and methods used to determine the current status and trends. A discussion using the supporting data and science-based indicators is provided along with an assessment of threats. Given that conditions often vary spatially within Lake Erie, in some cases demonstrating clear west to east gradients, the current environmental impacts for most of the General Objectives are organized by four major lake basins/geographic regions around the Lake Erie watershed: SCDRS, Western Basin, Central Basin, and Eastern Basin (Figure 3).

GENERAL OBJECTIVES	
1.	Be a source of safe, high-quality drinking water.
2.	Allow for unrestricted swimming and other recreational uses.
3.	Allow for unrestricted human consumption of the fish and wildlife.
4.	Be free from pollutants that could harm people, wildlife or organisms.
5.	Support healthy and productive habitats to sustain our native species.
6.	Be free of nutrients that promote unsightly algae or toxic blooms.
7.	Be free from aquatic and terrestrial invasive species.
8.	Be free from harmful impacts of contaminated groundwater.
9.	Be free from other substances, materials or conditions that may negatively affect the Great Lakes.

Table 2. The General Objectives of the 2012 Agreement

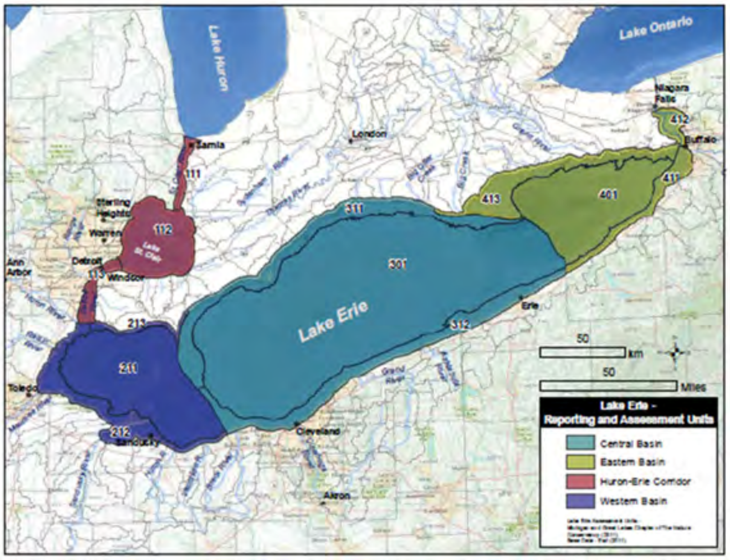


Figure 3. Lake basins/geographic regions of Lake Erie (from Pearsall et al. 2012).

What Are State of the Great Lakes Indicators?

The State of the Great Lakes indicators are used to track progress toward achieving the General Objectives. These indicators are comprised of nine high-level indicators and 45 supporting sub-indicators. Taken together, the indicators allow for consistent and comprehensive ecosystem assessments with repeatability. The indicator reports provide status (assessed as Good, Fair, Poor) and/or trend (assessed as Improving, Unchanging, Deteriorating) for the Great Lakes overall and where possible, on an individual lake basin level. Each three-year reporting cycle, Great Lakes experts prepare assessments using data that in most cases come from Great Lakes basin-wide, long-term monitoring programs.

4.1 BE A SOURCE OF SAFE, HIGH QUALITY DRINKING WATER

Lake Erie continues to be a safe, high quality source of water for public drinking water systems.

4.1.1 BACKGROUND

Over 12.5 million people get their drinking water from Lake Erie (ECCC and MOECC 2018; US EPA 2018). Protecting drinking water and water resources from pollutants is a priority for all levels of government and a shared responsibility involving many partners and communities.

Lake Erie is a source of drinking water for over 12.5 million people.

4.1.2 HOW IS DRINKING WATER MONITORED?

The Ontario Ministry of the Environment, Conservation and Parks (OMECP), the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Ohio Environmental Protection Agency (OEPA), Pennsylvania Department of Environmental Protection (PADEP) and New York State Department of Health (NYSDH) require municipal drinking water systems (treated water) to be regularly tested for many contaminants including inorganic (arsenic, cadmium, lead, nitrate/nitrite nitrogen), organic (benzene, perchloroethylene, nitrilotriacetic acids, certain pesticides and PCBs), microbial (bacteria), and radiological (tritium and other radiological compounds) parameters.

For more information on the Provincial and State programs, see:
www.ontario.ca/page/drinking-water
www.michigan.gov/drinkingwater
http://www.epa.ohio.gov/ddagw/drinkingandgroundwaters.aspx
http://www.dep.pa.gov/business/water/bureausafedrinkingwater/pages/default.aspx
https://www.health.ny.gov/environmental/water/drinking/

4.1.3 STATUS AND SUPPORTING DATA

When Lake Erie is used as a source of water, the status of municipal treated drinking water quality within the Great Lakes Basin is in 'good' condition with an 'unchanging' trend for the years 2012 to 2017 (ECCC and U.S. EPA 2019). Exceedances of treated drinking water quality targets are rare in both the United States and Canada (Tables 3 and 4; Figure 4).

State	Percent of Community Water Systems providing water that met all health-based standards (2017)	Total Population Served
MI	97.4%	7,366,271
NY	95.3%	18,229,585
OH	95.8%	10,273,349
PA	90.6%	11,382,605
Total	95.5%	47,251,810

Table 3. Percent of U.S. Community Water Systems that met all health-based standards in 2017.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arsenic	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%
Atrazine	100%	100%	100%	100%	100%	---	---	---	---	---	100%
Barium	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Fluoride	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
Lead	99%	99%	100%	100%	99%	100%	100%	100%	99%	100%	100%
Microcystin-LR*	100%	100%	100%	100%	100%	100%	100%	100%	94%	94%	100%
Nitrilotriacetic acid	100%	98%	100%	100%	100%	100%	100%	100%	100%	---	---
Nitrate	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Nitrite	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Selenium	99%	99%	99%	99%	99%	99%	99%	99%	100%	100%	100%
Trichloroethene	97%	99%	98%	98%	98%	98%	98%	99%	99%	98%	98%
Uranium	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Tritium	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Other radiological	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 4. Percent of Ontario drinking water systems that met Ontario Drinking Water Quality Standards in years 2007-2017. * Only one system had microcystin-LR levels above the standard. Source: OMECP Drinking Water Surveillance Program.

Ontario's regulated treatment systems provide high quality drinking water to its residents. The 14 drinking water systems that use Lake Erie for their source water met Ontario Drinking Water Standards 99.84% of the time in 2016-2017 based on 12,659 tests prescribed by regulatory analysis of the treated drinking water (OMOECC 2017).

In the states of Michigan, New York, Ohio and Pennsylvania over 95% of the total population received treated drinking water from community water supply systems that were in compliance and

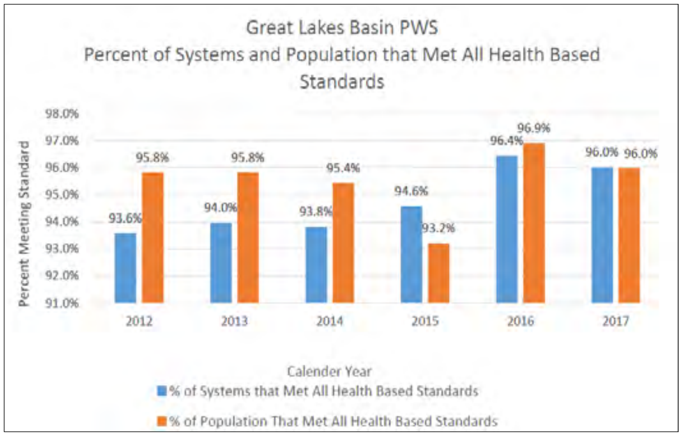


Figure 4. Percent of Great Lakes Basin primary water systems and population served that met all health-based standards in years 2012-2017. Source: U.S. EPA Safe Drinking Water Information System.

met health-based drinking water quality standards in 2017 (U.S. EPA Government Performance and Results Act Reports https://obipublic11.epa.gov/analytics/saw.dll?PortalPages&PortalPath=/shared/SFDW/_portal/Public&Page=Summary).

4.1.4 THREATS

Lake Erie provides a safe source of drinking water when treated. Potential threats include: cyanotoxins from harmful algal blooms; over application of fertilizers, manure and pesticides that can enter groundwater and surface water; stormwater and wastewater sources, especially during and after extreme storm events; failing household sewage treatment systems that leach nutrients and pathogens; chemicals of emerging concern, and chemical spills within the watershed and directly to Lake Erie. Continued progress toward addressing these issues will help to protect Lake Erie water quality and its use as a source of drinking water.

4.1.5 IMPACTED AREAS

There currently are no areas within the waters of Lake Erie that have significant and year-round problems that impact the safety of drinking water supplies.

Some areas in the Western Basin of Lake Erie experience recurring harmful algal blooms (HABs) in late summer/early fall that pose potential intermittent threats to source water intakes for drinking water plants. These HABs have the potential to produce toxins that must be monitored and treated by the public drinking water systems. Examples of cyanotoxin monitoring and reporting can be found on the City of Toledo's water quality dashboard (http://toledo.oh.gov/services/public-utilities/water-treatment/water-quality/) and the Township of Pelee's Algal Toxin Monitoring Results Page (http://www.pelee.org/community-2/blue-green-algae/water-test-results/).

The EGLE is currently conducting a proactive statewide public water supply sampling effort, to create an understanding of the extent of impact for per- and polyfluoroalkyl substances (PFAS) on the state's supplies of drinking water (see Chapter 5.2 *Strategies to Prevent and Reduce Chemical Contaminant Pollution* for more details).

The SCDRS is the drinking water source for over four million people in Michigan. For Canada, SCDRS provides water to 14 drinking water treatment facilities owned by 12 local communities and the Great Lakes Water Authority, which serves 127 communities. To help reduce risks to drinking water quality posed by potential contaminants from point and nonpoint sources in the SCDRS, the EGLE and Southeast Michigan Council of Governments partnered with the 14 drinking water facilities to establish a real-time drinking water monitoring network. Additional monitoring equipment and a linked online reporting platform at the 14 plants will help provide early detection of changes in source water flowing into the drinking water intakes and provide advanced notice to downstream plants. This is critical given the SCDRS's fast flow rate and variable response times to address contamination events at downstream facilities.

4.1.6 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Ongoing agency programs under the U.S. Safe Drinking Water Act and the Ontario Safe Drinking Water Act, including the associated monitoring and reporting components, will be required by the states and Province to ensure continued attainment of this General Objective. Actions that will support these programs and help protect Lake Erie as a source of drinking water can be found under Chapter 5.1 – *Strategies to Prevent and Reduce Nutrient and Bacterial Pollution* and Chapter 5.2 - *Strategies to Prevent and Reduce Chemical Contaminant Pollution.*

4.2 ALLOW FOR SWIMMING AND OTHER RECREATIONAL USE, UNRESTRICTED BY ENVIRONMENTAL QUALITY CONCERNS

Lake Erie's beaches offer ample swimming and recreational opportunities but have been increasingly impacted by rural and urban stormwater.

4.2.1 BACKGROUND

Lake Erie beaches provide tourism and recreational opportunities for millions of people in Canada and the United States. However, these frequently visited beaches are also prone to pollution from stormwater runoff, deficient wastewater infrastructure such as septic systems, and other watershed sources, including agricultural operations, resulting from the heavily populated Lake Erie watershed.

4.2.2 HOW IS BEACH HEALTH MONITORED?

The presence of *E. coli* is used as an indicator of the presence of human or animal fecal wastes in beach water. While most strains of *E. coli* are harmless, they are an indicator that other disease-causing (pathogenic) microbes may be present as well. People swimming in water contaminated with pathogens can contract diseases of the gastrointestinal tract, eyes, ears, skin and upper respiratory tract. When monitoring results reveal elevated levels of *E. coli*, the state or local government/health units issue a beach advisory or closure notice until further sampling shows that the water quality meets the applicable water quality standards. A beach advisory functions as a warning against swimming at a particular beach but is not a closure. Ontario and Michigan, Pennsylvania, New York may also issue beach closures when health and safety thresholds are exceeded.

Water quality monitoring at swimming beaches on Lake Erie is conducted by municipal Health Units in Ontario, and County/State Health Departments or other public agencies that may have jurisdiction over beaches in the United States (e.g., within state-owned parks). Water sampling and laboratory testing is typically performed weekly during the swimming season (late May to early September). Research is underway to shorten the time between when samples are taken and beach advisories are posted, and in some areas forecasting is available to predict unsafe conditions (https://ny.water.usgs.gov/maps/nowcast/).

U.S. and Canadian agencies use different bacterial standards or criteria to determine when a beach is unsafe for swimming or other recreational activities (Table 5). The Ontario standards are more stringent and, as a result, Ontario often has more beach health advisories issued.

Jurisdiction	Beach Advisory	Beach Closure
Ontario	100 cfu*	1000 cfu
Michigan	300 cfu	
Ohio	235 cfu	
Pennsylvania	235 cfu	1000 cfu
New York**	235 cfu	235 cfu

Table 5. Beach advisory and closure criteria (cfu=colony forming units/100 ml) for each Lake Erie jurisdiction.
* In 2018 the Ontario beach standard was changed to 200 cfu.
**New York State utilizes the criterion of 235 cfu for both beach advisories and closures; implementation (advisory or closure) is based upon a category/tier system that also takes into consideration other site-specific environmental conditions.

4.2.3 STATUS AND SUPPORTING DATA

Lake Erie beaches are in overall 'fair' condition with an unchanging trend (ECCC and U.S. EPA). From 2015 to 2017, monitored U.S. Lake Erie beaches were open and safe for swimming an average of 82% of the swimming season, with an unchanging trend from 2008-2017. During the 2015-2017 swimming seasons, monitored Canadian Lake Erie beaches were rated as 'fair'. Monitored beaches met Ontario bacterial standards and were open and safe to swim an average of 74% of the swimming season. The trend from 2008-2017 was 'improving' (ECCC and U.S. EPA 2019).

4.2.4 THREATS

In rural areas, failing household sewage treatment systems and agricultural runoff from lands treated with manure can be sources of *E. coli* to the lake. In urban settings, inputs from sanitary and combined (sanitary/stormwater) sewer overflows and stormwater runoff from roads, roofs, construction sites and parking lots can carry bacterial contamination to local beaches. A changing climate brings more frequent and intense rain events that can increase the impacts from sewer overflows and stormwater runoff events.

In recent years, HABs have increased along the shore of Lake Erie's western basin. In 2010, Ohio started monitoring for algal toxins at state park beaches along the lake. If the toxin levels exceed safe recreational contact levels, the beaches are posted to advise against swimming (Ohio real-time beach advisories: (publicapps.odh.ohio.gov/beachguardpublic/). Ohio has listed its western assessment units of the lake as impaired for recreation use due to HABs in report to U.S. EPA required under the U.S Clean Water Act under Section 303(d).

In the United States, beach monitoring and assessment programs implemented under the Beaches Environmental Assessment and Coastal Health Act (BEACH Act) are designed to identify pollution sources and help focus actions to address those sources.

4.2.5 IMPACTED AREAS

A description of the issues impacting beach health in the four regions of Lake Erie is presented in Table 6.

4.2.6 LINKS TO ACTIONS THAT SUPPORT THE GENERAL OBJECTIVE

Actions that address beach health and advance the achievement of this General Objective are found in Strategies to *Prevent and Reduce Nutrient and Bacterial Pollution* (5.1). Actions under *Strategies to Protect and Restore Habitat and Native Species* (5.3) and *Strategies to Promote Resilience to Climate Trend Impacts* (5.5) may also help to minimize bacterial contamination at beaches.

Lake Erie Region	Issues Impacting Beach Health
St. Clair – Detroit River System	• Urban stormwater and combined sewer overflows in the Detroit/Windsor area • Stormwater runoff entering small creeks, rivers, and drains from agricultural watersheds • Harmful algal blooms in southeastern Lake St. Clair (Ontario)
Western Basin	• Stormwater runoff entering small creeks, rivers, and drains from agricultural watersheds • Urban stormwater and combined sewer overflows • Harmful algal blooms
Central Basin	• Stormwater runoff entering small creeks, rivers, and drains from agricultural watersheds • Inputs from household sewage treatment systems
Eastern Basin	• Urban stormwater and sanitary/combined sewer overflows • Stormwater runoff entering small creeks, rivers, and drains from agricultural watersheds • Inputs from household sewage treatment systems • Nuisance filamentous alga *Cladophora* washing up on beaches

Table 6. Issues impacting beach health in the regions of Lake Erie.

4.3 ALLOW FOR HUMAN CONSUMPTION OF FISH AND WILDLIFE UNRESTRICTED BY CONCERNS DUE TO HARMFUL POLLUTANTS

Lake Erie fish and wildlife are a nutritious food source but should be consumed responsibly as chemical contaminants still trigger consumption advisories.

4.3.1 BACKGROUND

Commercial fisheries, sport fishing, and hunting are economically and socially important activities. Fish are an especially nutritious food source, being high in protein and low in saturated fat. However, fish and wildlife may bioaccumulate environmental contaminants over time. Concentrations of mercury and polychlorinated biphenyls (PCBs) are responsible for the majority of fish consumption advisories for large fish in Lake Erie (see 4.3.2).

Mercury is a naturally occurring metal found in the environment; it is also used in numerous human applications and is released into the atmosphere during the combustion of fossil fuels. PCBs are a group of chlorinated organic compounds manufactured in United States for a variety of industrial and commercial applications from the late 1920s until 1977. Dioxins and furans, which also contribute to fish consumption advisories in some areas, are unintentional by-products of several industrial processes and, in some cases, waste incineration and incomplete combustion of fuel.

These and other toxic chemicals can persist in the environment because they are resistant to environmental degradation. Over time, these chemicals may bioaccumulate (transfer from water or sediments) into living organisms and may also biomagnify (increase in concentration in living tissues) with each step of the food web.

4.3.2 HOW ARE FISH AND WILDLIFE CONTAMINANTS MONITORED?

To determine potential risk to human health through fish consumption, Canadian and U.S. agencies monitor persistent, bioaccumulative, and toxic legacy and emerging chemicals in edible portions of fish. Consumption advice is issued by the states, tribes and Province of Ontario in efforts to avoid impacts of harmful pollutants found in fish and wildlife. For fish and wildlife advisory information, visit:

Michigan: www.michigan.gov/eatsafefish
Ohio: http://epa.ohio.gov/dsw/fishadvisory/index.aspx
Pennsylvania:
http://www.dep.pa.gov/Business/Water/CleanWater/WaterQuality/FishConsumptionAdvisory/Pages/default.aspx
New York:
https://www.health.ny.gov/environmental/outdoors/fish/health_advisories/ and
https://www.health.ny.gov/environmental/outdoors/fish/health_advisories/advice_on_eating_game.htm
Ontario: www.ontario.ca/fishguide

4.3.3 STATUS AND SUPPORTING DATA

The current status for contaminants in edible fish in Lake Erie is “fair” with a “deteriorating” trend over the past 10 years (ECCC and U.S. EPA 2019). Although concentrations of PCBs and mercury in edible portions of fish have been historically lower in Lake Erie fish compared to the other Great Lakes, trends for PCBs and mercury in fish fillets have increased (ECCC and U.S. EPA 2019; Figure 5). Stressors such as warming waters and invasive species will likely continue to complicate the cycling of persistent toxic contaminants in Great Lakes fish by changing the food web and increasing fish metabolic rates, thereby possibly impacting the levels of these contaminants in fish.

4.3.4 THREATS

Regulatory actions taken by U.S. and Canadian governments during the 1970s and 80s, as well as remediation actions and on-going monitoring activities over the last several decades have significantly reduced the impacts of past, or “legacy”, chemical releases into the environment.

However, atmospheric transport of chemicals from distant sources and deposition in the Great Lakes, and historically contaminated sediments still represent sources of contaminants to fish and wildlife. Chemicals of emerging concern that bioaccumulate in fish tissue may pose risks to consumers. Introduction of invasive species, such as dreissenid mussels and Round Goby (*Neogobius melanostomus*), have altered the food web structure and potentially enhanced transfer of contaminants from the bottom sediments to large bodied fish.

4.3.5 IMPACTED AREAS

Levels of contaminants in Lake Erie fish vary not only by type of fish, but also geographic location. In general, the levels are highest in the SCDRS and decline along a Western to Eastern basins gradient. This is a result of major contaminant sources that were historically present in the SCDRS. Known areas of localized sediment contamination are found in the remaining Lake Erie Areas of Concern (AOCs) for which sediment remediation is not yet complete (Appendix C).

Not all Lake Erie tributaries where localized sediment contamination occurs have severe enough contamination to be listed as AOCs, but fish consumption advisories may still be issued for specific waterbodies.

4.3.6 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address contaminants in fish and Actions that address contaminants in fish and wildlife to achieve the General Objective are found in Chapter 5.2 *Strategies to Prevent and Reduce Chemical Contaminant Pollution*.

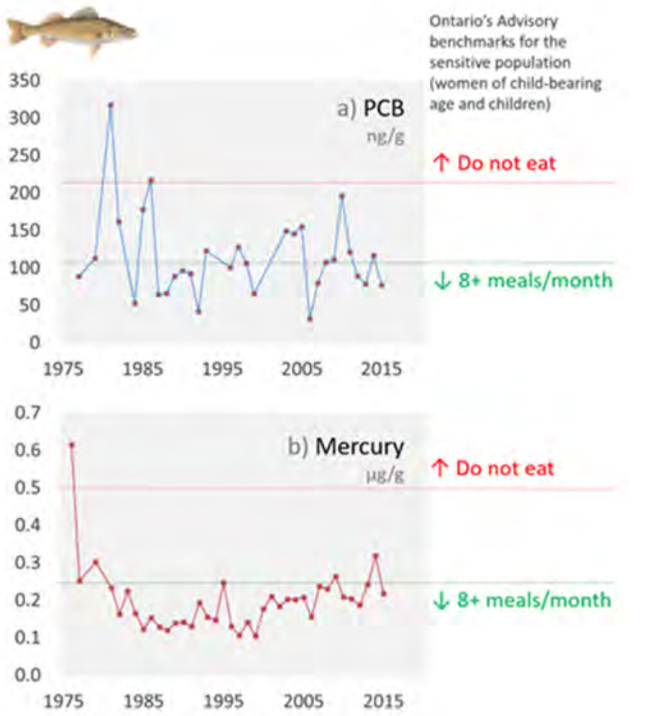


Figure 5. Concentrations of (a) PCBs and (b) mercury in walleye collected from Ontario waters of Lake Erie. Length of fish used: 45-55 cm (OMOECC 2015). The horizontal lines represent consumption advice specific to Ontario and do not reflect U.S. advisory guidelines.

4.4 BE FREE FROM POLLUTANTS IN QUANTITIES OR CONCENTRATIONS THAT COULD BE HARMFUL TO HUMAN HEALTH, WILDLIFE OR ORGANISMS THROUGH DIRECT OR INDIRECT EXPOSURE THROUGH THE FOOD CHAIN

Levels of legacy chemical contaminants in Lake Erie have declined considerably since the 1970s. Over the past two decades, the rate of decline has slowed and these chemicals continue to be found in water, sediments, fish and birds. While sites of historical contamination of sediments continue to be cleaned up, new and emerging chemical contaminants continue to be assessed to determine environmental threats.

4.4.1 BACKGROUND

Chemical pollution has long been a concern in Lake Erie due to the intensity of industrial activity, urban and suburban development, and agriculture in its surrounding watershed. The long residence times of some chemicals in the environment can make clean-up difficult. Many toxic chemicals can bioaccumulate in organisms and biomagnify up the food web, and ultimately accumulate in humans.

Long-term monitoring trends indicate concentrations of most monitored legacy chemicals are decreasing. Under the 2012 GLWQA, Canada and the United States committed to designate certain chemicals found in the Great Lakes as chemicals of Mutual Concern (CMCs) that are potentially harmful to human health and the environment. To date, eight chemicals (or categories of chemicals) have been designated. These include: mercury; PCBs; brominated flame retardants hexabromocyclododecane (HBCD) and polybrominated diphenyl ethers (PBDEs); perfluorinated chemicals perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and long-chain perfluorinated carboxylic acids (LC-PFCAs); and short-chain chlorinated paraffins. Chemicals of emerging concern are chemicals that are increasingly being detected in surface water, and there is concern that these compounds may have an impact on aquatic life. Surveillance of CECs is warranted due to their actual or potential for wide distribution, poorly understood environmental effects, and potential for high persistence in the environment.

4.4.2 HOW ARE CHEMICAL CONTAMINANTS MONITORED?

Long-term, basin-wide surveillance and monitoring programs for chemical contaminants are conducted by ECCC, U.S. EPA, and the Ontario Ministry of the Environment, Conservation and Parks (OMECP). Chemical contaminants are monitored in water, air, sediments, fish and Herring Gull (*Larus argentatus*) eggs. Programs that use fish to more generally assess the bioaccumulation of chemicals in the environment monitor concentrations in whole-body fish samples, whereas programs focused on determining safety of eating fish utilize chemical concentrations in only the edible portions of fish (i.e., fillets). The federal monitoring programs are augmented by state, provincial, and academic contaminant science and monitoring programs.

4.4.3 STATUS AND SUPPORTING DATA

The overall status of chemical contaminants in air, water, sediment, whole fish and wildlife in Lake Erie is 'fair' with an 'unchanging' to 'improving' trend over time (ECCC and U.S. EPA 2019; Table 7).

Great Lakes Indicator	Status	Trend
Atmospheric Deposition of Chemicals*	Fair	Improving
Chemical Concentrations in Open Water	Fair	Unchanging
Chemicals in Sediments	Fair	Improving
Chemicals in Whole Fish	Fair	Unchanging
Chemicals in Herring Gull Eggs	Good	Unchanging

Table 7. Status of chemical contaminants in Lake Erie (*indicates where assessment and trend apply to the entire Great Lakes Basin because the indicator was not assessed at the Lake Erie Basin scale).

Atmospheric Deposition of Chemicals

The overall Great Lakes assessment of atmospheric deposition of toxic chemicals is 'fair' with an 'improving' trend over time (ECCC and U.S. EPA 2019). Long-term air contaminant monitoring data show that concentrations of some toxic chemicals in the atmosphere, including PCBs, PAHs, and PBDEs are strongly correlated with urban population centers and are very low at rural monitoring sites.

Atmospheric PCB concentrations in the Great Lakes are decreasing overall. This trend is indicative of the success of management strategies to remediate contaminant sediments and phase-out of electrical and hydraulic equipment containing PCBs. Remaining sources of PCBs are in urban areas, and as a result, PCB concentrations are not decreasing as rapidly in urban areas, including the Cleveland, Ohio, monitoring site.

Concentrations of banned organochlorine pesticides are decreasing. Atmospheric concentrations of PAHs and mercury in the Great Lakes have also decreased over time (ECCC and U.S. EPA 2019). Concentrations of some halogenated flame retardants have decreased since the mid-2000s at urban monitoring sites but were generally unchanging at the remote monitoring sites. Atmospheric mercury concentrations and mercury wet deposition fluxes have generally declined since the 1990s. This suggests that reduced emissions from utilities over the past few decades and the phase-out of mercury in many commercial products have led to lower global anthropogenic emissions and associated deposition to ecosystems (Zhang et al 2016).

Chemicals in Open Water

The current status of chemicals in open (offshore) water is 'fair' with an 'unchanging' trend from 2004-2014 (ECCC and U.S. EPA 2019). Legacy contaminants that are persistent, bioaccumulative, and/or toxic have decreased in Lake Erie waters. The long-term trends for many legacy contaminants including mercury show declines to lower levels and little or no change in the more recent record.

Although long-term trends for many legacy chemicals show declines, Lake Erie displays relatively high concentrations of certain legacy organochlorines and industrial by-products compared to the other Great Lakes. Within Lake Erie, PCB concentrations are highest in western Lake Erie. Total PAHs are highest in Lake Erie relative to the other Great Lakes. Total mercury concentrations are highest in Lake Erie due to the historic presence of chlor-alkali and other industries in the SCDRS (Dove et al. 2011; Figures 6 and 7). Concentrations of current use pesticides are, in general, highest in the western basin of Lake Erie.

Recent monitoring for PBDEs showed higher concentrations in Lakes Erie and Ontario and spatial patterns consistent with consumer products as a primary source (Vernier et al. 2014). Concentrations of perfluorinated compounds also tend to be higher near urban areas. In Lake Erie fish, the highest PFOS concentrations were observed in Lake Trout and relatively high PFAA concentrations are found in Lake Trout. PFCAs were not detectable in Lake Erie (Gewurtz et al. 2013).

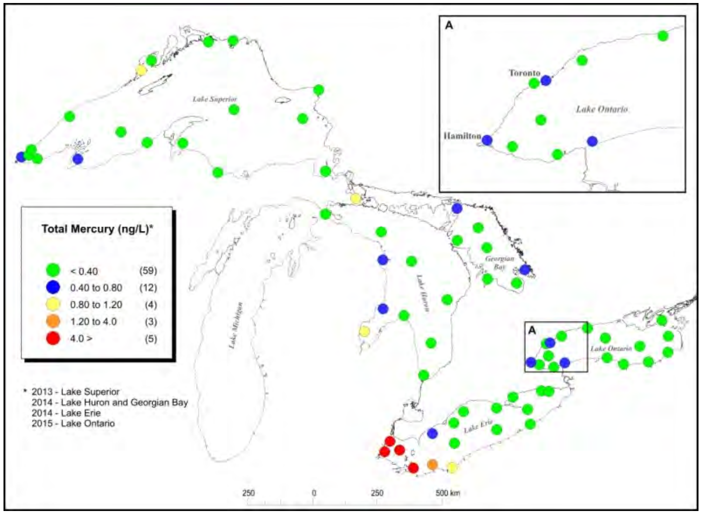


Figure 6. Total mercury in Great Lakes surface water, 2013-2015 (from ECCC and U.S. EPA 2019).

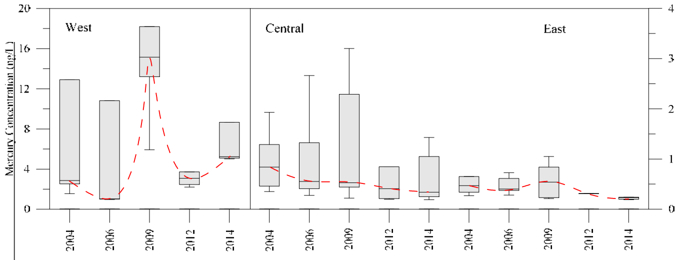


Figure 7. Temporal trends in total mercury in Lake Erie's three basins (source: Dove 2011).

Chemicals in Sediments

The current status of sediment chemical concentrations is 'fair' with an 'improving' trend over time (ECCC and U.S. EPA 2019). Legacy contaminants in sediments have declined considerably since 1970, with declines of greater than 50% for mercury, PCBs, hexachlorobenzene (HCB), DDT and lead (ECCC and U.S. EPA 2019).

Concentrations of PFAS in Lake Erie sediment have increased over the last 50 years. In general, the highest levels of perfluoroalkyl sulfonates (PFSAs) and PFOS in Great Lakes Basin sediments are found in western Lake Erie, the Detroit River, and in areas of Lake Ontario (Environment Canada 2009).

Sediments in Lake Erie generally represent a primary sink for contaminants entering the lake from land runoff and air deposition. Sediments can also act as a source of contaminants through resuspension and subsequent redistribution within the lake. Lake Erie exhibits a spatial gradient in sediment contamination, with concentrations decreasing from the western basin to the eastern basin, and from the south to the north in the central and eastern basins (Painter et al. 2001). This spatial distribution is influenced by industrial activities in the heavily populated watersheds of its major tributaries, including the Detroit River, and areas along the southern shoreline (Marvin et al. 2004). Government initiatives and remedial actions have effectively diminished point sources of chemicals across the Great Lakes Basin. Progress at restoring Areas of Concern and remediating other legacy contaminated sites continues to reduce chemical loadings to the lake.

Chemicals in Whole Fish

The current status of contaminants in whole fish (an ecological indicator designed to report on contaminant trends in the open water of the Great Lakes) is assessed as 'fair' with an 'unchanging' trend for 2007-2016 (ECCC and U.S. EPA 2019). This assessment used available data for the eight classes of Chemicals of Mutual Concern: hexabromocyclododecane (HBCD), long-chain perfluorinated carboxylic acids (LC-PFCAs), mercury, PFOA, PFOS, polybrominated diphenyl ethers (PBDEs), PCBs, and short-chain chlorinated paraffins (SCCPs). Of these chemicals, mercury, some PBDEs (TeBDE, HxBDE), and HBCD concentrations are below guidelines or targets while those of PCBs, PeBDE, and PFOS were above Canadian Federal Environmental Quality Guidelines or other published ecotoxicological thresholds (Figure 8).

Chemicals in Fish Eating Birds

The current status of Herring Gull egg chemical concentrations at monitored colonies is 'good with an 'unchanging' trend from 2002-2017 (ECCC and U.S. EPA 2019). The legacy contaminants, DDE, Total PCBs, Tetrachlorodibenzo-p-dioxin (TCDD) and mercury, have all declined significantly in Herring Gull eggs since the 1970s (1974-2017). No significant change in PBDEs were detected from 2002-2017.

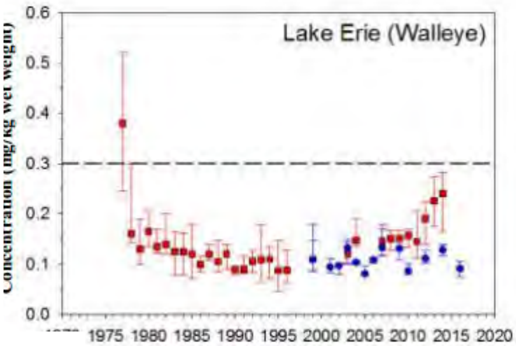


Figure 8. Total mercury concentrations for individual (ECCC, red) and composited (US EPA, blue) whole body Walleye in Lake Erie. Dashed line denotes the environmental target of 0.3 mg/kg, which is set based on the ecological risk of methylmercury to piscivorous fish in the Great Lakes (Sandheinrich et al. 2011).

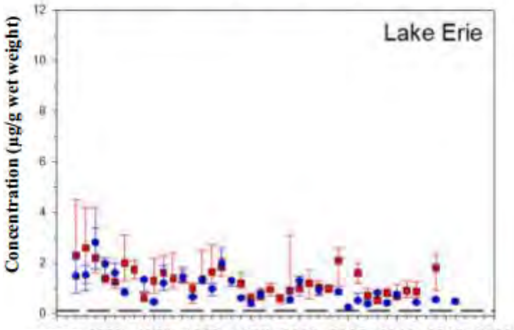


Figure 8. Total PCB concentrations for individual (ECCC, red) and composited (US EPA, blue) whole body Walleye in Lake Erie in Lake Erie. Dashed line denotes 1987 GLWQA guideline of 0.1 ug/g.

4.4.4 THREATS

Atmospheric deposition of PCBs will continue for decades due to residual sources remaining worldwide. Although mercury and dioxin deposition have declined over the past decade, elevated environmental levels are still observed. Atmospheric deposition of chemicals of emerging concern, such as non-BDE flame retardants and other compounds, could also serve as future stressors on the Great Lakes.

New chemicals of emerging concern, such as flame retardants, pharmaceuticals, personal care products and endocrine disrupting substances, are frequently being detected in the environmental media from the Great Lakes basin. These chemicals come from a variety of point and non-point sources including urban stormwater runoff, agricultural runoff, tributaries, wastewater treatment plants and combined sewer overflows, often resulting in complex chemical mixtures. Multiple studies have shown that chemicals of emerging concern can have negative effects on fish and wildlife; however, these studies are often limited to single-chemical exposures or exposures to a mixture of chemicals in a laboratory. Neither of these reflect mixtures observed in the Great Lakes environment.

U.S. and Canadian scientists have undertaken a number of studies to help understand the extent to which these chemical mixtures may pose a threat to the environment and human health. For example, the USGS, in partnership with the US Fish and Wildlife Service and St. Cloud State University, conducted a four-year study on the occurrence and distribution of chemicals of emerging concern within the U.S. Great Lakes Basin. This study shows that understanding the occurrence of mixtures of specific groups of chemicals can provide valuable information for focusing future efforts relating to risk management (Elliott et al. 2018).

Contaminated sediments represent a pollutant sink and potential source of toxic substances through resuspension, redistribution, and biomagnification through food web pathways.

4.4.5 IMPACTED AREAS

In general, atmospheric concentrations of some toxic chemicals are higher at urban monitoring sites than at rural monitoring sites. Similarly, the pattern of chemical concentrations in sediment is influenced by the intensity of industrial activities and human population in the watersheds. The influence of major tributaries with big urban centers at the mouths, including the Detroit, St. Clair and Maumee Rivers, result in a decreasing gradient of chemical concentrations in Lake Erie sediment from the western basin to the eastern basin, and from south to north in the central basin (Table 8). The ECCC Niagara River Upstream/Downstream Monitoring Program documents that Lake Erie is a source of contaminants to the Niagara River and Lake Ontario (Hill 2018). Localized sediment contamination is found at U.S. and Canadian Areas of Concern (Appendix C).

4.4.6 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address chemical contaminants and advance the achievement of this General Objective are found in Chapter 5.2 *Strategies to Prevent and Reduce Chemical Contaminant Pollution.*

Table 8. Chemical contaminant related issues in the regions of Lake Erie.

Lake Erie Regions	Chemical Contaminant Related Issues
St. Clair – Detroit River System	• Atmospheric deposition is a source of contaminants • Urban stormwater discharge and sanitary/combined sewer overflows is a source of contaminants • Food web changes due to invasive species can alter contaminant fate, exposure, bioaccumulation rate and pathways with potential negative impacts to aquatic organisms and fish consumers • Mercury contaminated sediments in St. Clair River (Canada) • PCB contaminated sediments in Trenton channel of Detroit River and Rouge River (United States)
Western Basin	• Atmospheric deposition is a source of contaminants • Urban stormwater discharge and sanitary/combined sewer overflows is a source of contaminants • Food web changes due to invasive species can alter contaminant fate, exposure, bioaccumulation rate and pathways with potential negative impacts to aquatic organisms and fish consumers
Central Basin	• Atmospheric deposition is a source of contaminants • Stormwater discharge is a source of contaminants • Food web changes due to invasive species can alter contaminant fate, exposure, bioaccumulation rate and pathways with potential negative impacts to aquatic organisms and fish consumers
Eastern Basin	• Atmospheric deposition is a source of contaminants • Stormwater discharge is a source of contaminants • Food web changes due to invasive species can alter contaminant fate, exposure, bioaccumulation rate and pathways with potential negative impacts to aquatic organisms and fish consumers

4.5 SUPPORT HEALTHY AND PRODUCTIVE WETLANDS AND OTHER HABITAT TO SUSTAIN RESILIENT POPULATIONS OF NATIVE SPECIES

Lake Erie's warm, productive waters support one of the largest freshwater fisheries in the world and the highest primary production and biological diversity of all the Great Lakes. However, deterioration of habitats, spread of invasive species, climate change effects, and pollution are of concern.

4.5.1 BACKGROUND

Lake Erie is unique among the Great Lakes. Its shallow, warm waters are the most productive of all the Great Lakes, supporting vibrant recreational and commercial fisheries. The various ecosystems of the lake, including the open lake environment, coastal wetlands, islands, sand and cobble beaches, bluffs, alvars, rocky shorelines, and the hundreds of interconnected streams and their headwaters are home to a highly diverse community of aquatic, avian and terrestrial species.

4.5.2 HOW ARE HABITAT AND NATIVE SPECIES MONITORED?

Long-term, basin-wide monitoring programs for habitats and species are conducted by federal, state, provincial agencies and their partners. The Lake Erie Biodiversity Conservation Strategy provided a health assessment of eight conservation features that represent the lake's biological health (Pearsall et al. 2012). *State of the Great Lakes* ecosystem indicator reports provide recent information on status and trends (ECCC and U.S. EPA 2019). Several indicator assessment reports from the '2019 State of the Great Lakes' indicator series are used in this assessment, as are submissions from various scientists and members of the Lake Erie Partnership Working Group and the Lake Erie Committee of the Great Lakes Fishery Commission.

4.5.3 STATUS AND SUPPORTING DATA

This section reports on the status and trends of several important Lake Erie native species and their critical habitat types. This includes assessment of:

- **Coastal wetlands** because of their essential role in maintaining the health of the aquatic ecosystem,
- **Native migratory fish** because they require access to spawning habitats in rivers, tributaries and coastal wetlands to maintain their populations and thus represent a proxy for habitat connectivity,
- **Open Water Ecosystem** described using a bottom-up approach (phytoplankton and zooplankton to prey items to top predator fish) because of the interconnection within the aquatic food web, and
- **Fish-eating colonial nesting waterbirds** because they are sentinels of aquatic ecosystem health

As summarized in Table 9, the condition of Lake Erie's habitats and species indicators is variable, ranging from "poor" to "good", with varying trends from "deteriorating" to "improving".

FEATURE	INDICATOR	STATUS	TREND
Coastal Wetlands	Plants	POOR	UNCHANGING
	Birds	FAIR	UNCHANGING
	Amphibians	POOR	UNCHANGING
Native Migratory Fish	Lake Sturgeon	POOR	IMPROVING
	Walleye	GOOD	UNCHANGING
	Aquatic Habitat Connectivity	FAIR	IMPROVING
Open Water Species	Zooplankton	GOOD	UNCHANGING
	Prey fish	POOR	DETERIORATING
	Lake Trout	FAIR	IMPROVING
Native Migratory Birds	Colonial Nesting Water Birds	FAIR	UNCHANGING

Table 9. A summary of the Lake Erie status and trends for habitat and species by the State of Great Lake indicator (ECCC and U.S. EPA 2019).

Coastal Wetlands

Lake Erie currently supports 22,000 ha (54,500 acres) of coastal wetlands (Great Lakes Coastal Wetland Inventory 2004). The St. Clair River Delta is the most prominent single wetland feature in the Great Lakes, accounting for over 13,000 ha (32,000 acres). Coastal wetlands formerly occurred throughout Lake Erie and were especially abundant in the Western Basin, Lake St. Clair, and along the shores of the Detroit River, St. Clair River, and the Upper Niagara River. In many of these areas wetland losses have been significant, sometimes in excess of 95% (e.g., Detroit River; Manny 2007, Pearsall et al. 2012, Hartig and Bennion 2017). Similarly, the Upper Niagara River was once lined by coastal wetlands but now over 75% of the shorelines are artificially hardened (GLEAM 2012).

Substantial and highly diverse coastal wetlands remain in the Lake Erie basin, with prime examples at Long Point, Rondeau Bay, the mouth of the Grand River, and Point Pelee in Ontario; Lake St. Clair, especially the St. Clair River Delta (Ontario and Michigan); Presque Isle Pennsylvania; and in several public and private wetlands in the Western Basin, many of which are diked. Restoration activities to control Phragmites and increase native plant diversity have recently improved Metzger Marsh, Ohio, one of the largest natural marshes along Lake Erie's shore. In 2018, a large farmland property in the Western Lake Erie marsh region was converted to a 1,000-acre functioning wetland named Howard Marsh near the Lake Erie shore. This marsh will filter runoff before it reaches Lake Erie and provide important spawning habitat for fish and stopover habitat for a variety of birds, as well as creating additional opportunities for visitors to enjoy the outdoors.

Based on scores of three plant community measures that incorporate information on the presence, abundance, and diversity of aquatic macrophytes in the Great Lakes from the Coastal Wetland Monitoring Program between 2011 and 2017, the status of Lake Erie **coastal wetland plants** was generally classified as "poor and unchanging" (ECCC and U.S. EPA 2019). There is widespread dominance by cattails and the non-native invasive Common Reed (*Phragmites australis australis).* In the Lake Erie basin, riverine wetlands have slightly lower average plant community quality than barrier or lacustrine wetlands. The Ohio EPA sampled 20 plots within 15 wetlands along Ohio's coast of Lake Erie from 2000-2004 measuring plant diversity and quality utilizing the Vegetative Index of Biotic Integrity (VIBI). In 2014, these 20 sites were revisited. The difference in the scores represents a 25% drop of the average VIBI score over a period of 10-14 years. Expansion of the non-native wetland plants during the past 10 years and replacement of native wetland plants by the invaders, caused a significant reduction of both native wetland plant species diversity and percentage cover. Fluctuating water levels may also have an influence on extent and composition of coastal wetlands.

The health of Lake Erie coastal wetlands as evaluated by measurements of composition and abundance of **wetland breeding birds** between 2011 and 2017 was also assessed as "poor and unchanging" (ECCC and U.S. EPA 2019). The species composition, diversity and relative abundance of **breeding frogs** in coastal wetlands measured between 2011 and 2017 in Lake Erie was assessed as "poor and unchanging" (ECCC and U.S. EPA 2019).

Native Migratory Fish

The **Lake Sturgeon** population in Lake Erie continues to be well below historical levels. Self-sustaining populations are found in only three rivers (St. Clair, Detroit, and upper Niagara Rivers) of the historic 15 tributaries in Lake Erie. For these reasons, the Lake Sturgeon population is rated as "poor"; however incidental catches since 1992, an increase in spawning locations in the SCDRS, and increased river connectivity suggest an "improving" trend in Lake Erie (ECCC and U.S. EPA 2019). Spawning has been documented in the Detroit and St. Clair Rivers, and habitat restoration efforts in this system have created an additional eight spawning locations over the last 10 years. In spring 2017, spawning was detected for the first time in Buffalo Harbor, a discovery that is the first of its kind for eastern Lake Erie lake sturgeon in recent history. Lake Sturgeon stocking began in the Maumee River the fall of 2018, which will hopefully lead to increased catch per unit effort of juvenile Lake Sturgeon in the Lake Erie basin.

The health of **Walleye** populations in Lake Erie is assessed as "good and unchanging" between 2007 and 2017 (ECCC and U.S. EPA 2019, LEC WTG 2018). Since 2011, the commercial harvest has annually exceeded the 1,814 metric tonnes (4 million pounds) management objective identified in the Walleye Management Plan (LEC 2015). Walleye recruitment has improved since 2011, with moderate to strong year classes in 2014, 2015, and 2017. In 2017 these year classes started to make strong connections into the fishery, with the estimated age-2 and older walleye abundance for

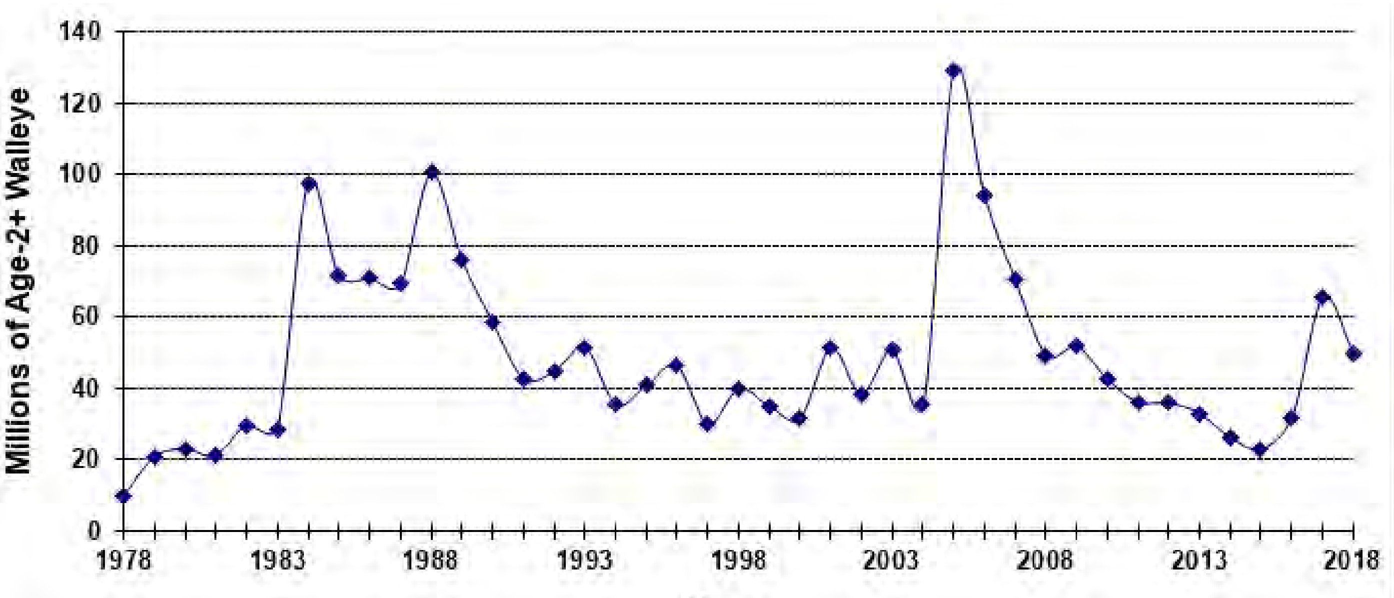


Figure 9. Population estimate of Lake Erie walleye (ages 2 and older) from 1978-2018 (modified from the 2019 Lake Erie Committee Walleye Task group executive summary (WTG 2019).

2017 being over 50 million fish (WTG 2018, Figure 9).

Aquatic habitat connectivity is defined as those connections between the Great Lakes and waterways that are used by migratory fish species. These connections provide unobstructed routes to fulfill life history requirements of migratory fish, including access to tributary spawning habitats and opportunities for genetic exchange. For Lake Erie, aquatic habitat connectivity is assessed as “fair and improving” as approximately 26% of tributary habitat in the Lake Erie basin is connected to the lake (ECCC and U.S. EPA 2019). Dams and barriers are ranked as a medium threat to migratory fishes (Pearsall et. al 2012b). Several dam removal and mitigation projects have been initiated in recent years. For example, completion of the Ballville Dam removal on the Sandusky River in 2018 opened up 35 km of river habitat for Walleye. Note that dam and barrier removal/modification is not always straightforward, since barriers often serve as flood control protections and also provide ecological benefits, such as serving as major control mechanisms used to limit the movement of Sea Lamprey (*Petromyzon marinus*) into tributaries to spawn. A fishway channel is being installed adjacent to Henry Ford Estate Dam at the University of Michigan Dearborn campus on the banks of the Rouge River, which will open up 50 main river and 108 tributary miles for fish migration from the Rouge River to Detroit River and Lake Erie for the first time in over 100 years.

Open Water Species

Phytoplankton and **zooplankton** communities are the main source of food for prey fish and are essential to sustaining a healthy food web. The high biomass of **phytoplankton** in Lake Erie supports the productive Lake Erie fisheries. Lake Erie has the highest zooplankton diversity of the Great Lakes and is rich in herbivorous cladoceran zooplankton species, which is typical for a shallow productive lake (Figure 10). The current status of Lake Erie **zooplankton** is “good” with an “unchanging” trend from 2007-2017 (US EPA and ECCC 2019).

The Lake Erie preyfish community status is classified as “poor and deteriorating” as both preyfish diversity and the proportion of native species comprising the total preyfish catch significantly declined from 2007-2017 (ECCC and U.S. EPA 2019; Figure 11). Much of that change was due to declines in Emerald Shiners (*Notropis atherinoides*), Yellow Perch (*Perca flavescens*), Spottail Shiner (*Notropis hudsonius*), and Trout-perch (*Percopsis omiscomaycus*). As the native species declined, Rainbow Smelt (*Osmerus mordax*), Gizzard Shad (*Dorosoma cepedianum*), and White Perch (*Morone americana*) made up a larger proportion of a less-diverse prey fish community.

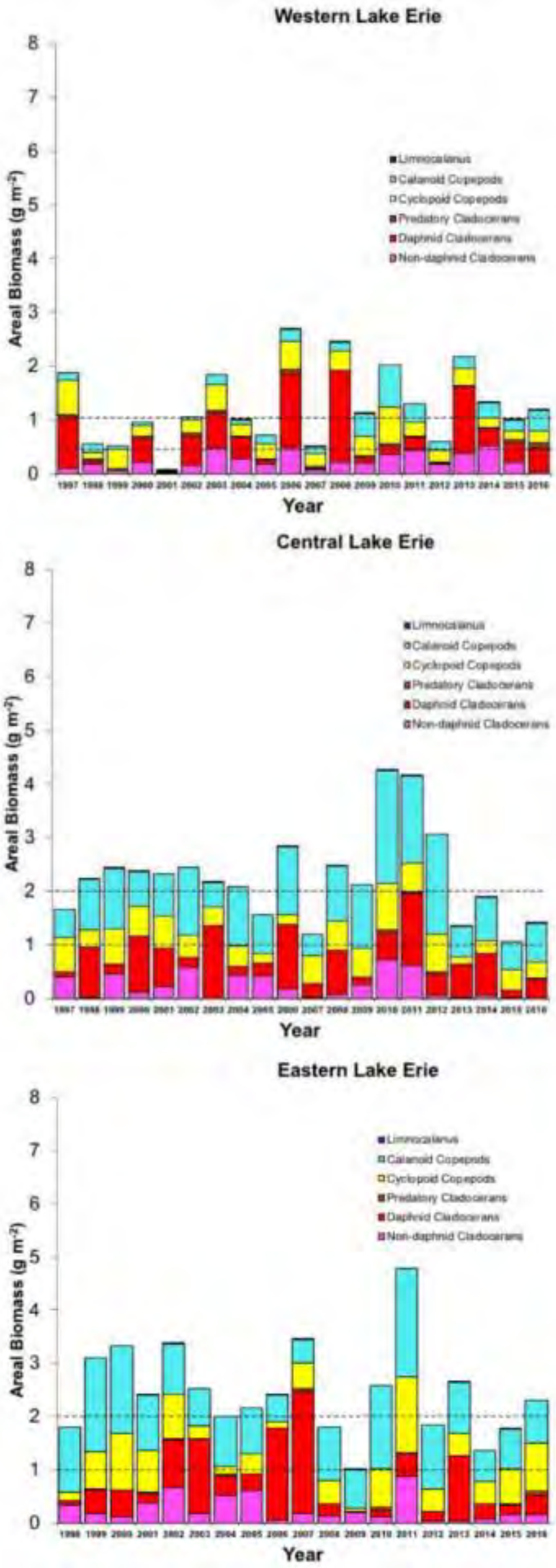


Figure 10. Areal zooplankton biomass (g/m^2) for Western, Central and Eastern Lake Erie calculated from U.S. EPA's GLNPO summer survey deep tows (collected from 2 m above bottom to the surface). "Good" and "Poor" thresholds are identified by dashed lines for each figure. Data Sources: U.S. EPA Great Lakes National Program Office and Cornell University.

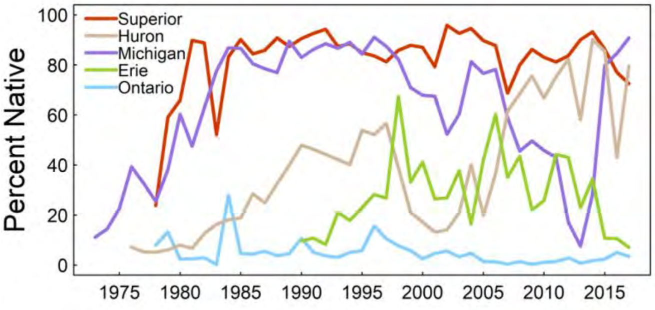


Figure 11. Percent of native preyfish biomass in the total preyfish catch in Lake Erie. Data primarily from bottom trawl surveys collected by U.S. federal and state and Canadian provincial agencies.

The status for **Lake Trout,** native to the deep waters of the eastern basin, is "fair" and the trend from 2007-2017 is "improving" (ECCC and U.S. EPA 2019). Increased stocking levels and survival of stocked fish have increased adult populations to near or above GLFC Lake Committee rehabilitation targets (Figure 12). Stocking has recently expanded to include all basins in the lake. The 2015-2017 average Sea Lamprey adult index estimate is above GLFC targets and has been holding steady over the past five years despite increased lampricide treatments. Sea Lamprey populations continue to suppress the adult Lake Trout population. Natural Lake Trout reproduction has still not been detected in Lake Erie despite more than 30 years of restoration efforts (LEC CWTG 2018).

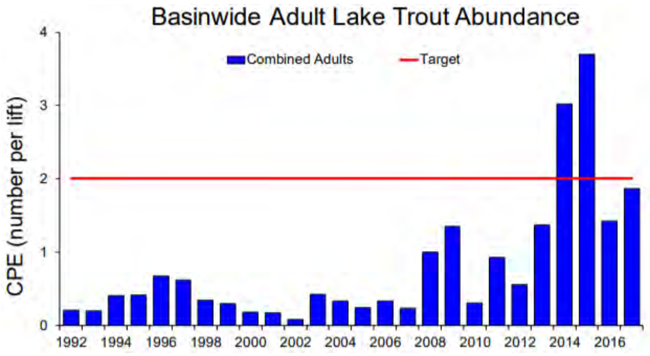


Figure 12. Lake Erie basinwide abundance of adult Lake Trout from 1992 - 2017(Lake Erie Committee Cold Water Task Group 2018).

Native Migratory Birds

The status for **colonial nesting water birds** is "fair and unchanging" (ECCC and U.S. EPA 2019). A 2009 survey by ECCC showed that since 1989-1991, Great Egrets (*Ardea alba*), Black-Crowned Night-Herons (*Nycticorax nycticorax*), Herring Gulls have exhibited a moderate decline in abundance at Lake Erie monitoring sites; Great Blue Heron (*Ardea herodias*), Ring-Billed Gull (*Larus delawarensis*), and Common Tern (*Sterna hirundo*) populations have been stable; and Double-

Crested Cormorants (*Phalacrocorax auratus*) have had a large increase in population size (ECCC and U.S. EPA 2019).

Other Species of Interest
Mayfly (*Hexagenia* spp.) nymphs have been widely used as indicators of water and substrate quality in lakes. They also have historically supplied a large amount of energy to the food chain in support of native bottom-dwelling fish species in Lake Erie, most notably Yellow Perch, Trout-perch and Silver Chub (*Macrhybopsis storeriana*). From 1999-2014, populations of mayfly nymphs in the Western Basin declined (Figure 13); a connection between this decline and increases in temperature and eutrophication in Lake Erie, which exacerbate hypoxic events, is suspected (Stapanian et al. 2017).

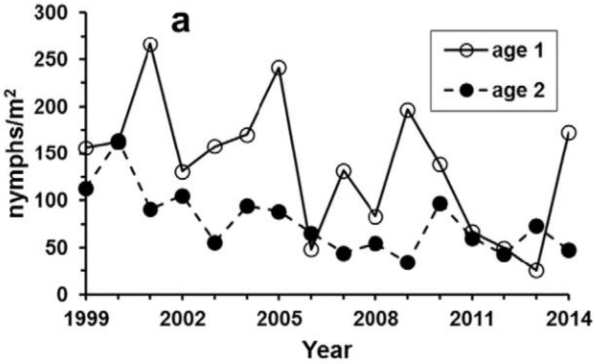


Figure 13. Population densities of age-1 (open circles) and age-2 (closed circles) mayfly (Hexagenia spp.) nymphs in western Lake Erie during April–May 1999–2014. From: Stapanian et al. 2017.

As a top-level predator, **bald eagles** (*Haliaeetus leucocephalus*) serve an important role in the Lake Erie ecosystem. Their nesting success is an indicator of the health of the species and that of other species in the ecosystem. Bald eagles generally prefer home sites that are near water and food sources. Bald eagles are now commonly seen throughout the Lake Erie basin in Ontario and the United States, especially along the shorelines and adjacent wetland areas, and successful breeding is occurring along the Lake Erie and SCDRS shoreline (ODNR 2017).

4.5.4 THREATS

The *International Biodiversity Conservation Strategy for Lake Erie* (Pearsall et al. 2012) identified chemical contaminants, excess nutrients, shoreline development (including jetties, groins, piers and shoreline armoring), dams and barriers, non-native invasive species, and climate change as critical threats to biological diversity. These threats impede the full achievement of the General Objective to "support healthy and productive wetlands and other habitats to sustain resilient populations of native species." These threats are covered in detail in other *Status and Supporting Data* sections, including *Chemical Contaminants* (4.4), *Nutrients and Algae* (4.6), and *Invasive Species* (4.7), *Other Substances, Materials or Conditions* (4.9), and *State of Nearshore Waters* (4.10). Shoreline development and the resulting physical changes to the land-water interface can disrupt the movement of sand along the shore and back and forth between the shore and the lake bed. This disruption can degrade the structure and function of coastal wetlands and nearshore habitats, thus reducing spawning and nursery habitat for native fish species (Pearsall et al. 2012).

4.5.5 IMPACTED AREAS

Degradation and loss of habitat in streams, upland and nearshore areas, and coastal wetlands are major stressors throughout Lake Erie and its watershed (Table 10). However, parts of the basin still exhibit a high level of biological and geophysical diversity that supports productive habitats and native species.

Human activities, including shoreline alteration, dredging and construction of jetties and marinas, have resulted in the destruction or degradation of Lake Erie's coastal wetlands. Shoreline hardening is a habitat-related impact all along the Lake Erie coastline, particularly along the two connecting river systems.

Non-native invasive species such as Zebra and Quagga Mussels (*Dreissena polymorpha* and *D. rostriformis bugensis*, respectively), Sea Lamprey, and Round Goby are found throughout the basin. Dense stands of the invasive Common Reed occur throughout the watershed in roadside ditches, coastal wetlands, and along shorelines. The presence of these species decreases native biodiversity by choking out native plants and other species and by changing physical and chemical habitat parameters.

The documented stressors impacting habitat and species are also influenced by invasive species-related drivers (discussed in more detail in Chapter 4.7 *Invasive Species*) and by several climate change-related drivers (discussed in more detail in Chapter 5.5 *Strategies to Promote Resilience to Climate Trend Impacts*).

4.5.6 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address loss of habitat and native species and advance achievement of this General Objective can be found in Chapter 5.3 – *Loss of Habitats and Species.* Actions that address other threats such as *Strategies to Prevent and Reduce Nutrient and Bacterial Pollution* (5.1), *Strategies to Prevent and Reduce Chemical Contaminant Pollution* (5.2), *Strategies to Prevent and Contain Invasive Species* (5.4), and *Strategies to Promote Resilience to Climate Trend Impacts* (5.5) will also help to minimize the loss of habitat and the native species.

Lake Erie Regions	Habitat and Species Related Issues
St. Clair - Detroit River System	• Shoreline development and alteration • Stream habitat fragmentation due to dams and barriers • Non-point sources of sediment and excess nutrients cause harmful algal blooms that degrade habitat • Loss of reef spawning habitat for native species due to dredging and/or sedimentation • Historic wetland loss
Western Basin	• Shoreline development and alteration • Stream habitat fragmentation due to dams and barriers • Non-point sources of sediment and excess nutrients cause algal blooms that degrade habitat • Historic wetland loss
Central Basin	• Shoreline development and alteration • Stream habitat fragmentation due to dams and barriers • Non-point sources of sediment and excess nutrients exacerbate central basin hypoxic “dead zone” • Historic wetland loss
Eastern Basin	• Shoreline development and alteration • Stream habitat fragmentation due to dams and barriers • Abundance of *Diporeia* has drastically declined in offshore waters • Historic wetland loss
Upper Niagara River	• Shoreline development and alteration; over 75% of the shoreline is hardened

Table 10. Water quality impacts on habitat and species in the regions of Lake Erie.

4.6 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

Harmful and nuisance algae in Lake Erie pose significant threats to the ecosystem and the health of the over 12.5 million people in the United States and Canada for which Lake Erie provides drinking water. Viewable from space, harmful algae (cyanobacteria) blooms can produce toxins and persist for weeks during the summer as winds and currents carry them eastward through the lake. Recent years have seen record-setting algal blooms and "dead zones" – oxygen depleted areas created when these algae die and decompose. In addition, there is extensive growth of attached nuisance algae (Cladophora) in some nearshore areas where hard substrate exists. These events have been shown to negatively impact the lake's ecological condition, multibillion-dollar tourism industry, shoreline property values, and the overall quality of life for residents of the Lake Erie Basin.

4.6.1 BACKGROUND

Nutrients such as phosphorus and nitrogen and are an essential part of aquatic ecosystems; they support the production of aquatic plants and algae which provide food and habitat for small organisms and fish. However, excess nutrients, or eutrophication, can lead to harmful algal (cyanobacteria) blooms, hypoxia, and excessive amounts of filamentous benthic algae, such as *Cladophora*. Managing excessive nutrients in aquatic ecosystems is a challenging problem because nutrients enter waterbodies from a variety of natural and man-made sources and can have acute and chronic negative impacts on ecosystems.

Phosphorus is generally considered the "limiting nutrient" for algae growth in Lake Erie. A limiting nutrient in an aquatic ecosystem is a relatively scarce element needed by algae and other primary producers to grow and multiply. When a water body receives an amount of a limiting nutrient in excess of what is considered healthy for proper ecosystem function, algae blooms can occur. Phosphorus may enter the system in a dissolved form or particulate (usually bound to sediments or other particulate matter) form. The portion of total phosphorus in the dissolved form (Dissolved Reactive Phosphorus or Soluble Reactive Phosphorus), which is readily taken up by algae, promotes rapid growth of algae, including cyanobacteria and *Cladophora*. Nutrients and algae interact in unique ways in Lake Erie's three distinct basins and connecting river systems (Table 11). The western basin receives about 61% of the whole lake annual total phosphorus load, while the central basin and eastern basin receive 28% and 11%, respectively (Nutrient Annex Subcommittee Report 2015). The types and densities of algae growing in each basin are different due to the depth, water temperature, substrate, the local influence of tributaries and overall nutrient loadings to the basin.

Lake Erie Regions	Nutrient Related Issues
St Clair - Detroit River System	• Cyanobacteria blooms and associated toxins in southeastern Lake St. Clair
Western Basin	• Cyanobacteria blooms and associated toxins • Shunting of nutrients to benthic zone by non-native invasive dreissenid mussels
Central Basin	• Cyanobacteria blooms and associated toxins • Seasonal hypoxia • Shunting of nutrients to benthic zone by non-native invasive dreissenid mussels
Eastern Basin	• Excessive growth of nuisance algae, primarily *Cladophora,* that fouls beaches and other nearshore areas • Shunting of nutrients to benthic zone by non-native invasive dreissenid mussels

Table 11. Nutrient-related issues in the regions of Lake Erie.

The western basin is very shallow with an average depth of 7.4 meters (24 feet) and a maximum depth of 19 meters (62 feet). It is warm, and it receives most of the total phosphorus load to the lake because of the size of the Detroit and Maumee Rivers. As a result, the harmful algal blooms dominated by the cyanobacteria *Microcystis* occur regularly in the summer months. This species can form blooms that contain toxins (e.g., microcystin) dangerous to humans and wildlife.

The central basin is deeper, with an average depth of 18.3 meters (60 feet) and a maximum depth of 25 meters (82 feet). Harmful algal blooms that originate in the western basin often move into the central basin. Blooms also form at the mouth of Sandusky River, which is the third highest tributary nutrient load to the Lake overall. Excess phosphorus also contributes to hypoxic conditions in the cold bottom layer of the Lake (the hypolimnion) when algae die and decompose. Hypoxia, which is defined in Lake Erie as the reduction of dissolved oxygen to less than two parts per million, can affect the growth and survival of fish species, and cause water chemistry changes that impact drinking water quality. The late summer occurrence of hypoxic conditions in the central basin of Lake Erie is believed to be a naturally occurring phenomenon resulting from the basin's shape and depth. However excessive algal growth in the second half of the 20th century, resulting from the increased phosphorus loads, is believed to have exacerbated the extent of hypoxic conditions, since oxygen is consumed when the algae decompose. The hypoxic area extent was generally lowest in the mid-1990s and highest in the late 1980s (1987, 1988) and the 2000s (Zhou et al. 2013). Since the early 2000s, size of the hypoxic area in the central basin has averaged approximately 4,500 km^2 (1,737 mi^2) (U.S. EPA 2018). The largest hypoxic extent recorded in the past decade – 8,800 km^2 (3398 mi^2) – occurred in 2012, following the record setting algal bloom of 2011 (U.S. EPA 2018).

The eastern basin is the deepest of the three basins with an average depth of 24 meters (80 feet) and a maximum depth of 64 meters (210 feet). While the phosphorus levels in the Eastern basin are generally much lower than the Western and Central basins, conditions are adequate to promote the excessive growth of benthic algae, primarily *Cladophora*, on the rocky substrate in the nearshore. Mats of *Cladophora* can cause beach fouling, undesirable odors from decomposing *Cladophora*, clogged industrial intakes, and degraded fish habitat. These conditions are experienced morefrequently on the north shore of the Eastern Basin.

To achieve Lake Ecosystem Objectives for hypoxia and HABs in the Agreement (Table 12), in 2016 new binational phosphorus loading targets were established for Lake Erie under the Nutrients Annex of the Agreement.

GLWQA Lake Ecosystem Objective	P Reduction Target
Minimize the extent of hypoxic zones in the Waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie	40 percent reduction (from 2008 levels) in total phosphorus loads entering the Central Basin of Lake Erie from the United States and from Canada to achieve 6,000 annual metric tonnes (MTA) Central Basin load
Maintain algal species consistent with healthy aquatic ecosystems in the nearshore Waters of the Great Lakes	40 percent reduction (from 2008 levels) in spring total and soluble reactive phosphorus loads from priority tributaries to minimize harmful algal blooms in the nearshore areas
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	40 percent reduction (from 2008 levels) in spring total and soluble reactive phosphorus loads from the Maumee River (U.S.) to minimize harmful algal blooms in the western basin

Table 12. Lake Erie binational phosphorus loading reduction targets.

4.6.2 HOW IS NUTRIENT POLLUTION MONITORED?

Phosphorus Loads

To improve our understanding of how and when phosphorus enters Lake Erie, several entities in the U.S. and Canada conduct year-round sampling of phosphorus and related parameters from major Lake Erie tributaries. Water quality and stream flow monitoring stations are located near river mouths so that they can capture phosphorus loads moving from the tributary into the Lake, but far enough upstream from the lake to avoid any lake effects on the data. The loads from tributaries are then combined with available data on other sources to the lake, including municipal wastewater treatment plants, loading from the atmosphere, and input from Lake Huron, to arrive at a lakewide total estimated P load to the lake. The loading calculations methodology is documented in Maccoux et al. (2016).

Nutrients, Water Quality & Phytoplankton
Data collected annually (spring and summer) by ECCC and U.S. EPA are used to assess offshore water quality, including concentrations of nutrients and phytoplankton community composition. In Canada, both ECCC and OMECP oversees long-term water monitoring and science programs that provide information on nearshore water quality condition and identification of threats (see 4.10 *State of Nearshore Waters* for more details). In the United States, U.S. EPA in partnership with States and Tribes conducts the National Coastal Condition Assessment. This assessment is designed to yield unbiased estimates of the condition of nearshore waters based on a random stratified survey and to assess changes in condition over time (see 4.10 *State of Nearshore Waters* for more details).

Harmful Algal Blooms
In the western basin of Lake Erie, several state and federal partners monitor algal biomass and toxin levels of cyanobacterial blooms. NOAA has developed an operational HAB bulletin (https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/) to provide twice-weekly forecasts for blooms of the cyanobacterium *Microcystis* in western Lake Erie. The forecasts use a combination of remotely-sensed imagery, *in-situ* water quality data, and hydrodynamic models to report on current bloom location, size, cyanobacteria density and predicted movement of the bloom over the next seven days. At the end of the season, NOAA and partners combine all this information to assess the severity of the bloom on a scale of 1 to 10. The severity index is based on the maximum 30-day average of biomass, which is captured both in terms of spatial extent and density of the bloom.

In the Ontario waters of Lake St. Clair, OMECP and ECCC are monitoring the water quality of the Canadian shoreline of Lake St. Clair to determine the extent to which harmful algal blooms occur.

Nuisance Benthic Algae (*Cladophora*)
Since 2010, OMECP and ECCC have conducted regular assessments of *Cladophora* biomass at 4-5 transects near the Grand River, Ontario. In the U.S. portion of the basin, *Cladophora* research has been more focused on Lake Michigan and Lake Ontario. U.S. EPA is coordinating with ECCC and other partners to enhance/expand *Cladophora* monitoring in Lake Erie in 2018 and 2019, in support of the binational *Cladophora* Research Plan developed under the Nutrients Annex.

Hypoxia
U.S EPA's Lake Erie Dissolved Oxygen Monitoring Program has measured dissolved oxygen and temperature in the Central Basin of Lake Erie since 1983. The rate at which oxygen declines in the hypolimnion (termed the oxygen depletion rate) is used to measure changes in the onset and duration of hypoxia (oxygen concentrations below 2 mg/L) over time. Ten stations are visited at approximately 3-week intervals during the stratified season (typically, summer to early fall). Sampling usually begins in early June, when the water column begins to stratify into a warmer upper layer (epilimnion) and a cooler bottom layer (hypolimnion) and concludes in late September or early October just before the water column mixes and returns to a uniform temperature profile.

In 2016, OMECP established a real-time water quality monitoring station on the north shore of the central basin of Lake Erie. The station was set up to learn more about the risks of periodic onshore movement of low oxygen water from the lower water depths of the offshore (hypoxic upwelling) and of harmful algal (cyanobacterial) blooms occurring within the basin and being transported from the western basin.

4.6.3 STATUS AND SUPPORTING DATA

The overall status of this general objective is 'poor' with a 'deteriorating' to 'unchanging' trend over time (ECCC and U.S. EPA 2019; Table 13).

INDICATOR	STATUS	TREND
Nutrients in Lake Erie (offshore and nearshore)	Poor	Unchanging
Phytoplankton	Fair-Poor	Deteriorating
Harmful Algal Blooms	Poor	Deteriorating
Cladophora	Poor	Unchanging

Table 13. Current status and trends of offshore nutrient concentrations, phytoplankton, occurrence of harmful algal blooms, and occurrence of *Cladophora* (ECCC and U.S. EPA 2019, Ohio Lake Erie Commission 2014). Indicators for Phosphorus Loads and for Hypoxia are currently under development.

Nutrient Concentrations, Offshore Water Quality, and Phytoplankton

Data collected by ECCC, U.S. EPA and other partners show that the overall condition of nutrients in Lake Erie is "poor" with a "unchanging" trend from 2008-2017 (ECCC and U.S. EPA 2019). Total phosphorus objectives continue to be exceeded. Although high values are most frequently elevated in the western basin, exceedances of objectives are observed offshore in all three basins of Lake Erie in some years. Elevated total phosphorus concentrations are also observed in some nearshore regions, including a portion of Lake St Clair, the western basin of Lake Erie, and the southern shore of central Lake Erie (Figure 14). Harmful algal blooms plague the western basin and parts of the central basin, and nuisance benthic algae have resurged in the eastern basin of Lake Erie (Watson et al. 2016). Lake Erie trophic status ranges from eutrophic in the western basin to mesotrophic in the central basin to oligotrophic in the eastern basin. From a water quality standpoint, the open water phytoplankton abundance and community composition is in "poor" condition with a "deteriorating" trend (ECCC and U.S. EPA 2019). This reflects the re-eutrophication of the western basin of Lake Erie, the proliferation of undesirable cyanobacteria, and spring diatom blooms that contribute substantial biomass to the central basin bottom waters that exacerbates seasonal hypoxia (Reavie et al. 2016). An Ohio EPA assessment of phytoplankton integrity for the western and central basins of Lake Erie during 2003-2013 reported a "fair" assessment of phytoplankton (Ohio Lake Erie Commission 2014).

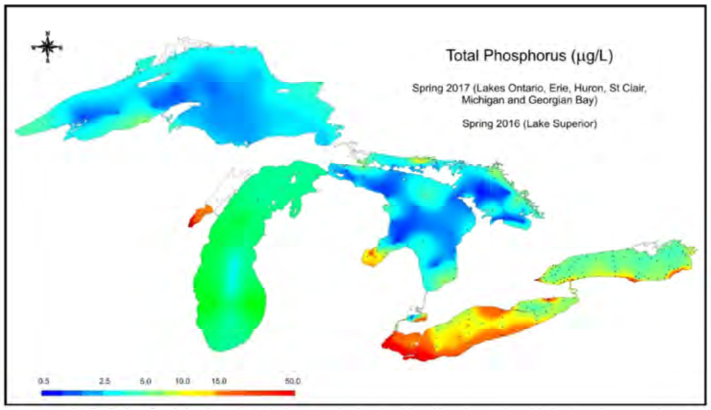


Figure 14. Spatial distributions of total phosphorus concentrations in the Great Lakes based on lakewide cruises conducted by ECCC and U.S. EPA (ECCC and U.S. EPA 2019).

Phosphorus Loads

The historic record of annual phosphorus loads since 1967 indicates that the total amount of phosphorus entering Lake Erie varies significantly each year, largely due to the variability in nonpoint source runoff. The amount of nonpoint source runoff is directly related to the amount and timing of precipitation within a year.

There was a resurgence of algal blooms in Lake Erie in the late 1990s, despite no increase in annual Total Phosphorus loadings to the lake during this time. Monitoring has shown that there has been a significant increase in the proportion of the total phosphorus loading to Lake Erie that is in the dissolved form of phosphorus, as opposed to particulate form, since the mid-1990s.

ECCC, U.S. EPA and the United States Geological Survey (USGS) are working to improve the accuracy of measuring and tracking phosphorus loads to Lake Erie. Starting in 2018, these partners will routinely report on status of loads and achievement of targets, on an annual basis.

Using loadings through 2016, the central basin target load of 6,000 MT total phosphorus was met in two of eight years since the 2008 baseline (Figure 15). Spring phosphorus targets for the Maumee River, which drives the western basin algae bloom, were not met. Visit ErieStat
(https://www.blueaccounting.org/isues/eriestat)
for current status of phosphorus loads.

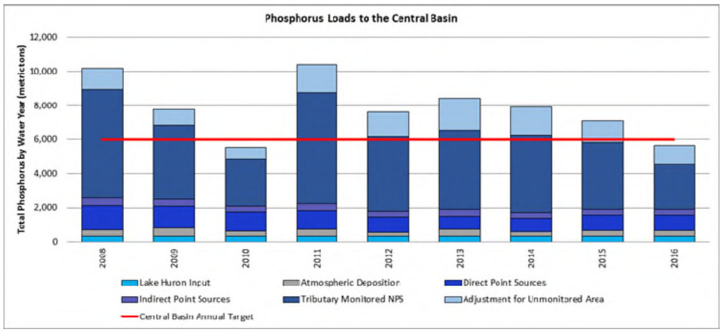


Figure 15. Total phosphorus loads (metric tons per water year) to the central basin of Lake Erie by source type (2008-2016). Red line indicates central basin total phosphorus load target.

Harmful Algal Blooms

The National Oceanic and Atmospheric Administration (NOAA) and its partners use remote sensing, multiple models and daily monitoring of the Maumee River to predict and track the formation and movement of harmful algal blooms during the summer months. The *Microcystis* cyanobacteria bloom in 2018 had a severity index of 3.6, indicating a relatively mild bloom (Figure 16). The largest blooms, 2011 and 2015, had severities of 10 and 10.5, respectively. The 2017 bloom had a severity of 8. It is important to note that the size of a bloom is not necessarily an indication of its toxicity. The toxins in a large bloom may not be as concentrated as in a smaller bloom. NOAA is developing tools to predict the toxicity of blooms.

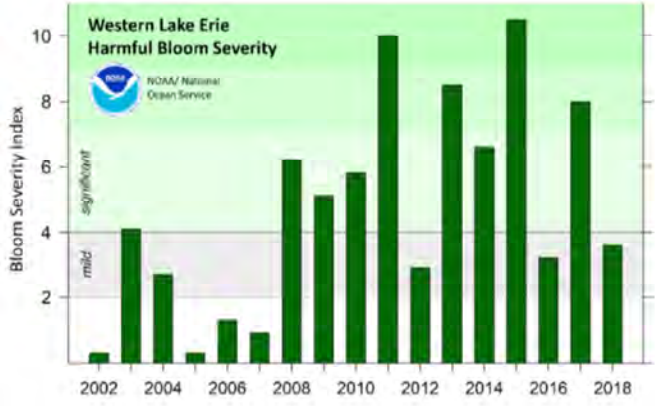


Figure 16. Lake Erie harmful algal bloom severity 2002-2018.

The concentrations of the algal toxins in the raw water supply can be extremely high; measurements of microcystin during the 2011 algal blooms 6ere 50 times higher than the World Health Organization limit for safe body contact, and 1,200 times higher than the limit for safe drinking water (U.S. EPA and ECCC 2015). In August 2014, more than 500,000 people in Toledo, Ohio were without drinking water for three days when elevated levels of algal toxins forced officials to issue a “do not drink” advisory for water from the Toledo drinking water treatment plant. In the same year, the Windsor-Essex County Health Unit in Ontario warned residents of Pelee Island not to drink, bathe or cook with water from their private wells that drew water from Lake Erie because of concerns about potentially toxic cyanobacteria in Lake Erie.

Satellite image of Lake Erie on September 23, 2017. The bright green areas show the peak of the 2017 algal bloom (NOAA derived image from Copernicus Sentinel).

Beyond the western basin of Lake Erie, harmful algal blooms are an emerging issue in the SCDRS. In 2016, OMECP and ECCC initiated a multi-year project to assess nutrients and harmful algal blooms in Lake St. Clair and the Thames River. Harmful algal blooms were observed along the Canadian shoreline of Lake St. Clair in 2017 and 2018 and in the lower Thames River in 2017.

Nuisance Benthic Algae (*Cladophora*)

Lake Erie is assessed as being in poor condition with respect to *Cladophora,* with an undetermined trend. ECCC monitoring has found thick, dense growths of *Cladophora* (up to 700 g DW/m^2) in the Eastern Basin at shallow depths of 0.5-3 m, but growth has also been observed at depths of up to 20 m. Under the Nutrients Annex of the Agreement, U.S. EPA and ECCC developed a binational Research Plan to establish more robust monitoring of *Cladophora* growth in key areas. It is expected that in 2020, new information from these studies will help the United States and Canada determine whether nuisance *Cladophora* could be managed by limiting tributary phosphorus inputs, and whether a phosphorus reduction target is required in the eastern basin of Lake Erie to control *Cladophora* growth.

Cladophora mats along the shore in Reeb’s Bay, Ontario, in the eastern basin (ECCC).

Hypoxia

In 2017, U.S. EPA GLNPO conducted six dissolved oxygen surveys from June 8 to October 3. During this time, dissolved oxygen concentrations in the hypolimnion reached ≤2.0 mg O_2/L by early August, which was the second fastest depletion rate in the ten-year period from 2008-2017. This means that in 2017, dissolved oxygen levels in the hypolimnion decreased faster than average, resulting in hypoxic conditions earlier in the season.

4.6.4 THREATS

A variety of human activities can increase nutrient pollution and promote nuisance algae and potentially toxic harmful algae growth. Sources of excess nutrients from urban areas include the effluent from wastewater treatment plants, stormwater runoff, and sewer overflows. In rural areas, the application of livestock manures or commercial fertilizers either in excessive amounts or at the wrong time or place, can contribute to excess nutrients losses from the farm fields through surface runoff and tile drains. Failing household sewage treatment, which can leak nutrients and bacterial pollution into nearshore waters, can also be important contributors in certain areas.

Compounding the problem of nutrient pollution, the Lake Erie ecosystem has changed due to the spread of invasive zebra and quagga mussels that became established in the 1990s. Invasive mussels retain and recycle nutrients in nearshore and bottom areas of the lake through their filtering and excretion activities. In addition, the increased water clarity due to their filtration results in greater light penetration and warming of the water column, allowing *Cladophora* to grow at greater depths. These alterations to water clarity and in-lake nutrient cycling are resulting in greater nuisance algal growth in the nearshore regions, closer to where humans interact with the Lake. Other factors contributing to the resurgence of algae include the loss of wetlands and riparian vegetation that once trapped nutrients.

Increasing temperatures in recent years are creating longer growing seasons for nuisance and harmful algae, and more frequent high-intensity spring storms are delivering nutrients at a critical time when they can promote the intensity and duration of summer harmful algal blooms. While many factors contribute to algal growth, controlling phosphorus loads remain the best management strategy to address these problems.

4.6.5 IMPACTED AREAS

The nutrient-related issues described in Table 11 are described in detail in section *4.6.1 Background*.

4.6.6 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions and control measures that address excessive nutrient inputs and nuisance and harmful algal blooms are presented in *Strategies to Prevent and Reduce Nutrient and Bacterial Pollution* (Chapter 5.1). Actions that address other threats such as *Strategies to Protect and Restore Habitat and Native Species* (Chapter 5.3) and *Strategies to Promote Resilience to Climate Trend Impacts* (Chapter 5.5) will also help to address excess nutrients and algal blooms.

Details on the domestic action plans for achieving the Lake Erie 40% phosphorus loading reduction targets developed for Canada (ECCC and MOECC 2018) and the United States (US EPA 2018) are provided in Chapter 5.1.

Lake Erie Regions	Nutrient Related Issues
St Clair - Detroit River System	• Cyanobacteria blooms and associated toxins in southeastern Lake St. Clair (Ontario)
Western Basin	• Cyanobacteria blooms and associated toxins • Shunting of nutrients to benthic zone by non-native invasive dreissenid mussels
Central Basin	• Cyanobacteria blooms and associated toxins • Seasonal hypoxia • Shunting of nutrients to benthic zone by non-native invasive dreissenid mussels
Eastern Basin	• Excessive growth of nuisance algae, primarily *Cladophora,* that fouls beaches and other nearshore areas • Shunting of nutrients to benthic zone by non-native invasive dreissenid mussels

Table 11. Nutrient-related issues in the regions of Lake Erie.

4.7 BE FREE FROM THE INTRODUCTION AND SPREAD OF AQUATIC INVASIVE SPECIES AND FREE FROM THE INTRODUCTION AND SPREAD OF TERRESTRIAL INVASIVE SPECIES THAT IMPACT THE QUALITY OF WATERS OF LAKE ERIE

Invasive species, both aquatic and terrestrial, have drastically altered Lake Erie's ecosystem at all trophic levels. Invasive species are one of many stressors that reduce ecosystem resilience. They have contributed to decreased abundance of native fish, zooplankton, benthic invertebrates and plant species and alteration of energy and nutrient pathways. Invasive species enter Lake Erie through various pathways, including shipping, bait and aquarium releases, and migration from other waterbodies via tributaries/connecting channels and man-made canal systems.

4.7.1 BACKGROUND

Over 140 non-native aquatic and terrestrial species have been identified in the Lake Erie basin in the past 200 years. Some of these species, such as Sea Lamprey, Zebra and Quagga mussels, Spiny Water Flea (*Bythotrephes longimanus*), Eurasian Ruffe (*Gymnocephalus cernua*), Round Goby, Common Reed and Japanese Knotweed (*Fallopia japonica*) are classified as "invasive" because their introductions have caused significant environmental and/ or economic impacts. According to the Great Lakes Aquatic Nonindigenous Species Information (GLANSIS) database, at least 32% of the non-native species found in the Great Lakes have moderate or high environmental impacts (Sturtevant et al 2014, NOAA TM-161, https://www.glerl.noaa.gov/pubs/tech_reports/glerl-161/tm-161.pdf).
These impacts may include reduction of native biodiversity and degradation of habitats via alteration of water column light regimes, bioaccumulation of toxins, and alteration of nutrient and energy flows within the food web.

4.7.2 HOW ARE INVASIVE SPECIES MONITORED?

Newly introduced, established, and potentially invasive species are monitored by a variety of organizations, including local, state, provincial, and federal agencies, First Nations and Tribes, non-governmental organizations, industries, and academic institutions. The public is also playing an increasingly important role in invasive species surveillance. Monitoring and assessing the impacts of invasive species is challenging due to the size of Lake Erie and its watershed. With the exception of a few species, resource limitations prevent comprehensive assessments of invasive species, so estimates of the status of aquatic and terrestrial invasive species are based on limited information.

Aquatic Invasive Species: Most of the monitoring of aquatic invasive species occurs as a part of routine surveillance programs by environmental protection and natural resource management agencies. Only a few aquatic invasive species have targeted monitoring programs. Adult Sea Lamprey status is assessed annually by the Sea Lamprey Program of the Great Lakes Fishery Commission; the population size of invasive Zebra and Quagga Mussels is estimated on a five-year cycle through a multi-agency sampling effort; and coordinated Asian Carps monitoring is performed cooperatively by Canada and the United States.

The binational "Early Detection and Rapid Response Initiative", established by experts working under the Aquatic Invasive Species Annex of the Agreement, is monitoring additional locations in Lake Erie that are potential points of invasion by new aquatic invasive species. This monitoring includes environmental DNA (eDNA), which is a surveillance tool used to monitor for the genetic presence of an aquatic species in the ecosystem.

New AIS reports are received and existing AIS distributions are tracked in several ways, including the regional GLANSIS database (https://www.glerl.noaa.gov/glansis/nisListGen.php), National USGS Nonindigenous Aquatic Species database (https://nas.er.usgs.gov/), and the Midwest Invasive Species Information Network (MISIN) (https://www.misin.msu.edu). Data and information are shared between these three systems.

Terrestrial Invasive Species: Due to the variety of different governmental jurisdictions and the mix of public and private land ownership, there is no single method for assessing the location and spread of terrestrial invasive species in the Lake Erie watershed. Some plants classified as terrestrial in this LAMP, such as *Phragmites* and Purple

Loosestrife *(Lythrum salicaria)*, also occur in wetland areas and are classified as aquatic plants in some databases.

Land managers and the public can voluntarily report sightings and share information on terrestrial invasive species distributions via MISIN and the Early Detection and Distribution Mapping System (EDDMapS) hotline maintained by the Ontario Federation of Anglers and Hunters and Ontario Ministry of Natural Resources and Forestry (OMNRF). Reporting can also be done online (www.eddmaps.org/ontario) or via a phone app. MISIN and EDDMapS provide spatial data that helps track the spread of terrestrial invasive species, including Emerald Ash Borer (*Agrilus planipennis*), Asian Longhorned Beetle (*Anoplophora glabripennis*), European Buckthorn (*Rhamnus cathartica*), Garlic Mustard (*Alliaria petiolate*), Common Reed, and Purple Loosestrife. iMapInvasives (https://www.imapinvasives.org) is an on-line, GIS-based data management system used to track invasive species across several states including Pennsylvania and New York.

Additionally, there are a number of species-specific efforts under way, including the United States Department of Agriculture Forest Service and Michigan State University's Emerald Ash Borer Information Network website, which includes monthly updates on the confirmed locations for this species in the U.S. and Canada: http://www.emeraldashborer.info/about-eab.php.
Zebra and Quagga Mussels is estimated on a five-year cycle through a multi-agency sampling effort.

The binational "Early Detection and Rapid Response Initiative", recently established by experts working under the Aquatic Invasive Species Annex of the Agreement, is now monitoring additional locations in Lake Erie that are potential points of invasion by new aquatic invasive species.

Terrestrial Invasive Species: Due to the variety of different governmental jurisdictions and the mix of public and private land ownership, there is no single method that assesses the location and spread of terrestrial invasive species in the Lake Erie watershed.

New internet-based technologies, including the Early Detection and Distribution Mapping System (EDDMapS) (http://www.eddmaps.org/), allow land managers and private citizens to voluntarily share information. EDDMapS provides some limited spatial data that helps track the spread of terrestrial invasive species, including Emerald Ash Borer, European Buckthorn, Garlic Mustard, *Phragmites* and Purple Loosestrife.

The USDA Forest Service and Michigan State University maintain the Emerald Ash Borer Information Network website, which includes monthly updates on the confirmed locations for this species in the U.S. and Canada: http://www.emeraldashborer.info/about-eab.php

4.7.3 STATUS AND SUPPORTING DATA

The sub-indicators report that the status of this general objective ranges from 'fair' to 'poor', and the trend ranges from 'improving' to 'deteriorating' (Table 14).

Sub-Indicator	Status	Trend
Aquatic Invasive Species Impacts	Poor	Deteriorating
Rate of Invasion of Aquatic Non-Indigenous Species	Fair	Improving
Sea Lamprey	Fair	Improving
Dreissenid mussels	Poor	Deteriorating
Terrestrial Invasive Species	Poor	Deteriorating

Table 14. Current status and trends of invasive species sub-indicators in the Lake Erie basin (ECCC and U.S. EPA 2019).

Presence, Number and Distribution of Invasive Species

The status of aquatic invasive species impacts in the Lake Erie is rated as 'poor' with a 'deteriorating' trend from 2008-2017 (ECCC and U.S. EPA 2019). GLANSIS lists 143 known and established non-native aquatic species including fish, plants, invertebrates, and diseases in Lake Erie and its surrounding watershed and 102 non-native aquatic species in Lake St. Clair and its surrounding watershed (NOAA, 2012; USGS, 2012). Most of these non-indigenous species have little impact and are not considered invasive; those considered most invasive are listed in Table 15. No species is known to have been eradicated once introduced. Four species new to the Great Lakes were established in Lake Erie in the last decade (2009-2018) – the crustacean zooplankton *Thermocyclops crassus* (2014), Diaphansoma fluvitalis (2015) and *Mesocyclops pehpeiensis* (2016), and the rotifer *Brachionus leydigii*. In addition to these four species, 35 other species have expanded their ranges within the Lake Erie basin during this period.

SPECIES	ABUNDANCE	VECTOR	IMPACT FACTOR SCORE
Sea Lamprey	Abundant	Canals	30
Zebra Mussel	Common	Ballast water	55
Quagga Mussel	Abundant	Ballast water	45
Round Goby	Abundant	Ballast water	26
Alewife	Abundant (EB)	Canals	32
Rainbow Smelt	Abundant	Stocking and subsequent spread	12
Spiny Waterflea	Abundant (CB, EB)	Ballast Water	8
European Frog-bit	Common (WB, SCDRS)	Trade	6
Eurasian Watermilfoil	Abundant	Trade	16
***Phragmites* (Common Reed)**	Abundant	Ballast/packing material for shipping	23

Table 15. Population status, initial vector of entry, and impact factor score for established populations of important invasive species in Lake Erie and Lake St. Clair (Bunnell et al. 2014; DiDonato and Lodge 1993; GLANSIS). The species impact factor score is based on an analysis of species' environmental, socio-economic, and beneficial impact, with scores >5 considered high impact (Sturtevant et al. 2014). CB= Central Bain, EB=Eastern Basin, SCDRS= St. Clair-Detroit River System.

Sea Lamprey: Sea Lamprey was first detected in Lake Erie in 1921, having arrived from Lake Ontario via the Welland Canal. Predation by sea lamprey has severely decreased lake trout and burbot population sizes in Lake Erie. Sea lamprey control programs must be effective for these highly predation-sensitive species to be self-sustaining (Pearsall et al. 2012) and to achieve fishery management goals and objectives for Lake Erie (Ryan et al. 2003).

Unlike most other aquatic invasive species, there are management tools available for controlling Sea Lamprey. Lake Erie Sea Lamprey populations have been reduced to about 30% of pre-control levels with the implementation of physical barriers, chemical lampricides, and other techniques. The adult Sea Lamprey index of abundance estimate of 14,743 in 2017 was above the target of 3,039 but has decreased since the high in 2012 (GLFC 2018; Figure 17) and thus Sea Lamprey are considered in 'fair' condition with an 'improving' trend (ECCC and U.S EPA 2019).

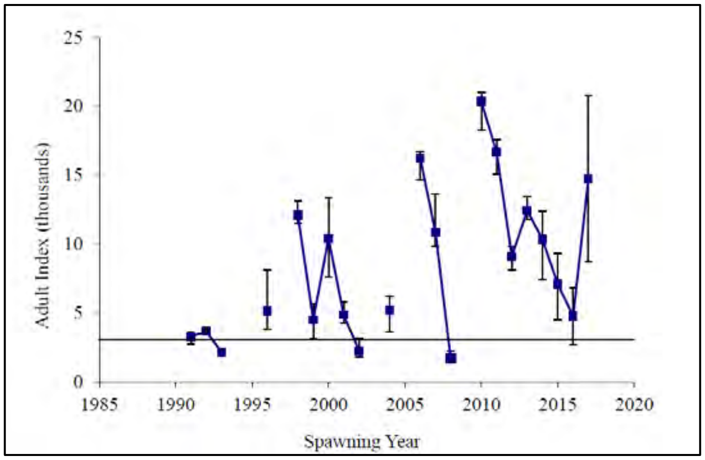


Figure 17. Index estimates with 95% confidence intervals (vertical bars) of adult Sea Lamprey in Lake Erie (GLFC 2018). Horizontal line represents the target of 3,039.

Sources of Sea Lamprey that are of concern include hard-to-treat tributaries (e.g., Cattaraugus Creek in NY), tributaries with non-target species of fish that may be negatively impacted by lampricide applications (Conneaut Creek, OH), and the SCDRS. Lampricides are selectively toxic to sea lampreys, but a few fish species, including the early life stages of lake sturgeon exhibit low tolerance to lampricide exposure. Streams where Sea Lampreys and Lake Sturgeon co-exist are being treated both with lower concentrations of lampricide and later in the field season. Lampricide control effort dramatically increased during 2008-2010 with the implementation of a large-scale treatment strategy where all known Sea Lamprey-producing tributaries to Lake Erie were treated in consecutive years. Increased control effort was also applied during 2013 with the treatment of 12 tributaries. Assessment and treatment strategies are being developed for the St. Clair River, an area recently identified as a potential source of lamprey production, with treatment planned for 2020.

Dreissenid Mussels: Zebra and Quagga Mussels were introduced to the Great Lakes in the late 1980s, likely the result of ballast water discharges. They are now the dominant species (in terms of biomass) comprising Lake Erie's benthic community. Zebra mussels were first detected in Lake St. Clair in 1986 and by 1989 had colonized most of the hard substrates in the nearshore areas of Lake Erie, reaching maximum densities by the early 1990s. Quagga mussels were first observed in Lake Erie in 1989 and quickly flourished in the depths of the central and eastern basins. However, both Quagga and Zebra mussel populations declined soon after peaking and overall lake-wide densities of dreissenids were much lower in 2014 compared to the peaks in 1993 (zebras) and 1998 (quaggas). Dreissenid mussel status is “fair” and “unchanging” for the ten-year period from 2004-2014.

Zebra and Quagga mussels can promote harmful algal blooms and attached nuisance algae via multiple mechanisms. The water filtering activity of mussels increases water transparency and therefore increases the depth of light penetration, which facilitates more algal growth (Pillsbury et al. 2002). Wastes excreted by mussels can also have a fertilizing effect on algae (Arnott and Vanni 1996). In addition, Zebra and Quagga Mussels can selectively reject phytoplankton they do not prefer (such as toxic *Microsystis*) while filtering, which can lead to a concentration of undesirable algae in the water (Vanderploeg et al. 2001, Tang et al. 2014). Dreissenid mussels are suspected of being a major link for the transfer of botulism to upper trophic levels, but they are but one of numerous benthic invertebrate pathways that can transmit type E botulism to upper trophic levels, given the right conditions (Pérez-Fuentetaja 2001).

Ecosystem changes associated with Zebra and Quagga Mussels can decrease habitat quality and availability for some native species of fish, plants and invertebrates (Nalepa and Schloesser et al. 2013). However, the establishment of mussels has increased the abundance of some bottom-dwelling invertebrates by virtue of habitat creation and increases in food supplies (Burlakova et al. 2018).

Quagga Mussels have replaced Zebra Mussels throughout the western basin, except in shallow, nearshore zones. In the central basin, summer hypoxia restricts Quagga mussels to depths < 20m and infrequent hypoxic episodes limit mussel populations in the western basin (Karatayev et al. 2018). The eastern basin supports the largest Quagga mussel population, though there are now signs of limited recruitment of small mussels in deeper areas (Karatayev et al. 2018).

Recent Introductions

There have been four new detections of nonnative aquatic invertebrate zooplankton species reported in the Lake Erie Basin (GLANSIS). In 2014, a small established population of the copepod *Thermocyclops crassus* was sampled in the Western Basin of Lake Erie (Connolly et al. 2017). In 2105, an established population of the cladoceran *Diaphanosoma fluviatile* was sampled in the Maumee River and the Western Basin of Lake Erie (Whitmore et al., in press). In 2016, one individual of the rotifer species *Brachionus leydigii* (Connolly et al. 2018) and an established population of the copepod *Mesocyclops pehpeiensis* (Connolly et al. in 2019) were collected in the Western Basin of Lake Erie. According to the U.S. Fish and Wildlife Service, the ecosystem risk from these species is uncertain (US FWS 2016, 2018a, 2018b). Populations of these species remain low.

U.S. and Canadian resource management and research agencies in the Lake Erie basin have identified the growing threat of invasive **Grass Carp** (*Ctenopharyngodon idella*) as a high priority requiring focused and aggressive response actions and monitoring. Grass Carp have historically been documented within the Great Lakes basin for decades, with records of captures of individual adult specimens going back to the 1980’s (USGS NAS Database). Captures have included both triploid (reproductively sterile) and diploid (reproductively viable) adult Grass Carp, with the greatest total numbers found in Lake Erie. More recently, in 2015 agency monitoring has documented natural reproduction by Grass Carp in the western basin of Lake Erie, primarily in the Sandusky River and, to a lesser extent, the Maumee River. In June 2018, a three-day binational multi-agency coordinated effort to collect adult and juvenile Grass Carp in the Sandusky and Maumee rivers caught 30 Grass Carp (27 from the Sandusky River and three from the Maumee River). Although present in the system, Grass Carp population sizes are considered to be low, as was confirmed by the 2018 sampling event.

Terrestrial Invasive Species

The status of terrestrial invasive species in the Lake Erie watershed is rated as ‘poor’ with a ‘deteriorating’ trend (ECCC and U.S. EPA 2019). Despite ongoing management efforts, several terrestrial invasive species that are associated with degraded water quality and habitat impacts continue to expand, although some species are effectively controlled or eradicated.

The **Common Reed** (*Phragmites australis subsp. australis*) is considered the most aggressive, invasive species of marsh ecosystems in North America (Bains et al. 2009). The Lake Erie Biodiversity Conservation Strategy identified *Phragmites* as the key terrestrial invasive species threatening Lake Erie (Pearsall et al. 2012). This invasive plant out-competes native vegetation and expands into massive mono-culture stands in wetlands and beaches. The loss of native plant diversity and habitat complexity reduces suitable habitat for wildlife, especially for aquatic birds such as ducks. Tourism, society, and local economies are also impacted by the loss of shoreline views, reduced recreational use and access, increased fire risks, declining property values, and plugged roadside and agricultural drainage ditches (Kowalski et al. 2015). Once established, there are no natural controls to regulate *Phragmites* stands at this time, and human intervened eradication and control efforts are typically time consuming and costly. More than 8,200 hectares of dense *Phragmites* stands in U.S. coastal wetlands were detected by satellite imagery in 2008-2010 (Bourgeau-Chavez et al. 2013). A study by ECCC suggests that *Phragmites* continued to spread in Canadian wetland areas around the SCDRS from 2006-2010 (ECCC CWS 2014).

Garlic mustard *(Alliaria petiolate)* continues to be widespread in the Lake Erie basin watersheds. By altering forest composition and understory growth, Garlic Mustard can control the nutrient supply in soil, making it difficult for tree seedlings to germinate (Rodgers et al. 2008).

The first North American discovery of the **Emerald Ash Borer** was in the SCDRS region in the early 2000s. It is now spread throughout the Great Lakes region. This insect feeds on Green Ash (*Fraxinus pennsylvanica*), Red Ash (*F.P. pennsylvanica*), White Ash (*F. americana*), Black Ash (*F. nigra*) and Blue Ash (*F. quadrangulata*) trees. High mortality rates are typical once an infestation occurs. Deforestation in natural areas can increase erosion, runoff, and water temperature in previously-shaded streams. In urban centers, the loss of ash and other tree species can increase the amount of stormwater runoff and exacerbate the urban heat island effect. Emerald Ash Borer effects on forests in southwestern Ontario have been particularly devastating; from 2004-2012, over 66,000 hectares of forests in the OMNRF Aylmer and Guelph Districts experienced moderate to severe defoliation and decline.

Purple Loosestrife *(Lythrum salicaria)* is a large, perennial, wetland plant that can grow up to 3 meters (9.8 feet) tall. It weaves thick mats of roots that cover vast areas, reducing the quality of habitat for birds, insects and other plants (Government of Ontario 2014). Furthermore, Purple Loosestrife threatens wetland ecosystems by altering water levels and reducing food sources for both aquatic and terrestrial native species (Thompson et al. 1987). The extent and severity of purple loosestrife infestations has been controlled using two biocontrol agents: larvae and adult Black-margined and Golden loosestrife leaf beetles (*Galerucella calmariensis* and *G. pusilla)* which, when released and established, feed on the foliage (USDA 2004).

No infestations of the **Asian Longhorned Beetle** *(Anoplophora glabripennis)* have been reported in the Lake Erie basin. In North American areas where it is established, this beetle kills a wide variety of hardwood trees, especially maples, elms, willows, and birches, and threatens to devastate forests that protect water quality and habitat for rare species.

The **Hemlock Woolly Adelgid** (*Adelges tsugae*) (HWA) is an invasive, sap-sucking aphid-like insect that kills North American Hemlock trees (*Tsuga canadensis*). HWA has been detected in counties in Lake Erie watersheds in Ohio, Pennsylvania, and New York and bordering the Niagara Gorge in Ontario (the Niagara Gorge population has since been eradicated). Hemlocks are ecologically important due to the unique environmental conditions they create under their dense canopies. These cooler, darker and sheltered environments are critical to the survival of a variety of species that rely on them for food, protection, and ideal growing conditions. Well-suited for growing on steep slopes where not many other species can grow, hemlocks stabilize shallow soils and provide erosion control. In addition, they are often found along streams, where their shade helps moderate water temperatures, maintaining a suitable environment for cold-water species such as trout. Removal of hemlocks from ecosystems can dramatically change ecosystem processes and may result in the loss of unique plants and wildlife (NYSDEC 2016).

4.7.4 THREATS

The Lake Erie Biodiversity Conservation Strategy identifies invasive species, both aquatic and terrestrial, as a High to Very High threat in the three basins of Lake Erie and the SCDRS. All biodiversity targets – Islands, Native Migratory Fish, Aerial Migrants, Offshore Zone, Nearshore Zone, Coastal Terrestrial Systems and Coastal Wetlands – are threatened by invasive species (Pearsall et al. 2012).

The spread of aquatic and terrestrial invasive species occurs as an unintended consequence of global trade, movement of people, and recreational activities like boating and fishing. Potential pathways for the introduction of invasive species include canals and waterways, boating and shipping, illegal trade, solid wood packing materials and other wood products, and the release of aquarium species and live bait. Plant species purchased through garden centers, nurseries, internet sales and the water garden trade are also vectors of spread.

Silver Carp (*Hypophthalmichthys molitrix*), Bighead Carp (*H. nobilis*), Black Carp (Mylophryngodon piceus), and Grass Carp (*Ctenopharyngodon idella*), escapees from southern U.S. fish farms, have emerged as major potential threats to the Great Lakes because of their widespread distribution in the Mississippi River drainage, potential connections to the Great Lakes, and favorable habitats in Lake Erie and Lake St. Clair (Pearsall et al. 2012). Potential consequences of establishment would include changes in plankton communities and biomass, reduced recruitment of native fish with early pelagic life stages and reduced native fish populations (Cudmore et al. 2012).

In 2016, there was one positive environmental DNA detection for Bighead Carp in Ontario assessments (Thames R., near Chatham). No Bighead or Silver Carp were observed in targeted sampling by agencies, or in commercial and recreational fisheries. Bighead Carp have not been observed in Lake Erie since 2000, when two adult Bighead Carp were caught by commercial fishermen in Point Pelee (Ontario) and Cedar Point (Ohio). Silver Carp have never been observed in the system (LEC 2016).

Hydrilla verticillata is a highly invasive submersed aquatic plant introduced from Asia to the United States and is present in several locations in the Great Lakes basin watershed. It grows rapidly compared with many native aquatic plants and is a threat due to its ability to rapidly spread and cause adverse impacts on water quality, native plant and fish communities, recreation, and irrigation and hydropower generation.

Red swamp crayfish (*Procambarus clarkii*) has recently invaded multiple locations within the Lake Erie basin. This aggressive crayfish, native to the southeastern United States, has the ability to outcompete and displace native crayfish species and other aquatic organisms. It can also dig complex burrows in the riparian area of waterbodies, which can result in shoreline instability, erosion, and decreased water quality. This species can be introduced through releases from live food sources, biological supply, pet stores, and unused bait, and via overland dispersal from locations where it is established. For the protection of Lake Erie's ecosystem, it is important to respond to and control this invasive crayfish species.

Changes in water quantity and quality, climate change impacts, land use changes, and alterations to remaining natural shorelines may make Lake Erie more prone to new invasive species and the spread of existing invasive species.

4.7.5 IMPACTED AREAS

Non-native invasive species have impacted Lake Erie water quality and ecosystem health and integrity, as explained in Table 16.

4.7.6 LINKS TO ACTONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that address invasive species and advance the achievement of this General Objective can be found in Chapter 5.4 *Preventing and Containing Invasive Species*. Actions that will help minimize the impacts of invasive species are also found in Chapter 5.3 *Protecting and Restoring Habitat and Native Species*.

Lake Erie Region	Invasive Species-Related Issues
St. Clair – Detroit River System	• Sea lamprey production in the St. Clair River • Red Swamp Crayfish population spread in Southeast Michigan • Phragmites impacts native plant diversity and habitat, recreational opportunities, real estate values, increases cost of maintaining agricultural and roadway drainage systems and is a fire hazard
Western Basin	• Zebra and quagga mussels have increased water clarity, altered nutrient pathways • Phragmites impacts native plant diversity and habitat, recreational opportunities, real estate values, increases cost of maintaining agricultural and roadway drainage systems and is a fire hazard • Grass carp spawning confirmed in the Sandusky River (OH)
Central Basin	• Quagga Mussel populations are mostly limited to sites <20m due to hypoxia, and so impacts are lessened in the Central Basin. • Several important tributaries for Sea Lamprey production, including the Grand River (OH) • Hydrilla is an aquatic plant found in the Lake Erie watershed and can clog up waterways, reduce flow, and eliminate native plants in tributaries to Lake Erie • Several important tributaries for sea lamprey production, including the Grand River (OH) • *Hydrilla* is an aquatic plant found in the Lake Erie watershed and can clog up waterways, reduce flow, and eliminate native plants in tributaries to Lake Erie
Eastern Basin	• Zebra mussels have altered conditions in the nearshore by increasing water clarity, altering nutrient pathways, and may contribute to increased density of benthic macroalgae such as *Cladophora* • Several important tributaries for sea lamprey production, including Cattarragus Creek (NY) • *Hydrilla* is an aquatic plant found in the Lake Erie watershed and can clog up waterways, reduce flow, and eliminate native plants in tributaries to Lake Erie

Table 16. Summary of invasive species issues in the regions of the Lake Erie basin.

4.8 BE FREE FROM THE HARMFUL IMPACT OF CONTAMINATED GROUNDWATER

There is no evidence of significant impacts from contaminated groundwater to Lake Erie. Known contaminated groundwater sites are localized and actively managed and monitored through environmental programs.

4.8.1 BACKGROUND

Groundwater is the water stored within and moving through the cracks and spaces of geologic formations in soil, sand, and rock, known as aquifers. Groundwater is linked with surface water and other parts of the water cycle and can be a major source of water for surface water bodies. Groundwater influences water quality and the availability, amount, and function of habitats for aquatic life within streams, inland lakes, coastal wetlands, and nearshore waters (Grannemann et al. 2000).

Lake Erie cannot be protected without protecting the groundwater resources in the Great Lakes Basin (IJC 2010). Groundwater plays an important role as a reservoir of water that, if contaminated, can become a continuous source of contamination to the Great Lakes, either as a direct source to the lake or as an indirect source via seepage in rivers and wetlands. Groundwater can become contaminated with various substances including nutrients, salts, metals, naturally-occurring and synthetic chemicals (e.g. petroleum, pesticides, solvents, halogenated hydrocarbons pesticides, pharmaceuticals), and many other contaminants.

Two naturally-occurring substances that can be found at elevated levels in groundwater are nitrate and chloride. Sources of nitrate include animal and human wastes and fertilizers. In rural areas, sources of nitrate have been reduced in the past several decades by the implementation of nutrient management planning, use of alternative wastewater treatment systems, and upgrading of municipal sewage treatment and collection systems. Chloride is mainly an urban contaminant as a result of de-icing road salt. Elevated concentrations of nitrate in water have been shown to have detrimental effects on aquatic organisms and aquatic ecosystems (e.g., direct toxicity and increasing the risk of algal blooms and eutrophication; CCME 2012), and human health (Health Canada 2013). Elevated concentrations of chloride in water have been shown to have detrimental effects on aquatic organisms and aquatic ecosystems (e.g., toxicity; CCME 2012).

4.8.2 HOW IS GROUNDWATER MONITORED?

In Ontario, groundwater quality is monitored and reported on by Conservation Authorities, in partnership with the Ontario Ministry of the Environment, Conservation and Parks as part of Ontario's provincial groundwater monitoring network (www.ontario.ca/data/provincial-groundwater-monitoring-network).

In the United States, contaminated groundwater is monitored on a site-by-site basis. Several sites within the Lake Erie watershed are being managed for contaminated groundwater plumes by states with federally-designated authority under the Clean Water Act. Contaminated site information is available at www.epa.gov/cleanups/cleanups-my-community. The USGS Online Mapper tool (https://nawqatrends.wim.usgs.gov/decadal/) provides summaries of decadal-scale changes in groundwater quality across the United States, including areas of the Great Lakes basin.

NYSDEC has the federally-designated responsibility to assess and report on the quality of groundwater as part of the Clean Water Act Amendments of 1977. This responsibility is supported by an ongoing Ambient Groundwater Monitoring Program between the NYSDEC Division of Water and the USGS (http://www.dec.ny.gov/lands/36064.html). The objectives of the program are to assess and report on the quality of the State's groundwater, identify long-term groundwater quality trends, characterize naturally occurring or background conditions, and establish an initial statewide comprehensive groundwater quality baseline for future comparison. The program is designed so that all major drainage basins in the State are monitored once every five years. 2018 will mark completion of the third full sampling rotation. Sampling and analysis of groundwater includes field and physical parameters, bacteria, nutrients, inorganic and organic contaminants, dissolved gasses and radiochemicals at approximately 60 wells per study year. Data reports are developed by the USGS for each major basin and are available online at USGS's New York 305(b) Ambient Groundwater Quality Monitoring webpage (https://ny.water.usgs.gov/projects/305b/). Monitoring data collected under this program is available from the USGS through their National Water Information System (https://waterdata.usgs.gov/nwis).

The Ohio EPA Division of Drinking and Ground Waters maintains the Ambient Ground Water Monitoring Network as part of an effort to characterize general water quality conditions in Ohio (http://epa.ohio.gov/ddagw/gwqcp.aspx). The program currently includes over 200 wells (stations). Of the total stations, roughly 85 percent are public water systems and 15 percent are industrial or commercial enterprises or residential. Raw water is analyzed for a suite of inorganic parameters every 6, 18 or 36 months depending on the total number of samples that have been collected and the stability of the geochemistry of major elements at the site. Samples are also analyzed for volatile organic compounds once every 18 or 36 months. Some ambient sites have historical semi-volatile organic compounds and pesticide data. A central goal of the Ambient Ground Water Monitoring Program is to provide reliable ground water quality data to enhance water resource planning and protection on a state-wide basis. This is consistent with the Division of Drinking and Ground Waters' mission to protect human health and the environment by characterizing and protecting ground water quality and ensuring that Ohio's public water systems provide adequate supplies of safe drinking water. An interactive map of the ambient monitoring well locations (https://oepa.maps.arcgis.com/apps/webappviewer/index.html?id=b39b9cbeb3834e9ca598d968d16333ce) allows users to zoom into an area in Ohio and click on a monitoring location to access information such as water quality summary reports and time series analyses for each monitoring location.

Despite the large volumes of surface and groundwater in Michigan – more than one quadrillion gallons by some estimates – there is growing concern about its use and about groundwater withdrawal effects on environmental function and integrity. Most of Michigan's large groundwater withdrawals are for agricultural irrigation. More than 2,500 high-capacity irrigation groundwater wells have been registered for installation in recent years. Responsible management of groundwater recharge is an issue of growing importance for ensuring sustainable groundwater resources and supporting demands for agriculture and other human uses. Michigan has developed the Michigan's Water Withdrawal Assessment Tool to help the State manage groundwater withdrawals. The Water Withdrawal Tool creates publicly accessible streamflow and groundwater elevation data, along with the total quantity of permitted withdrawals (Michigan Office of the Great Lakes 2016).

4.8.3 STATUS AND SUPPORTING DATA

Within the areas of the basin for which data are available, the overall status of the Great Lakes basin Groundwater Quality indicator that assesses nitrate and chloride contamination is 'fair' and the trend is 'undetermined' (ECCC and U.S. EPA 2019).

The extent of groundwater contamination and the overall status of the General Objective are not fully understood for Lake Erie, as the spatial distribution of data used in this assessment was uneven. Data for the assessment were primarily concentrated in Ontario, resulting in large areas, especially in Ohio's Lake Erie watershed, where groundwater data were limited. Of the 177 wells that were assessed in the Lake Erie watershed, the groundwater quality was good in 78 (44%), fair in 49 (28%), and poor in 50 (28%). Trend analysis was not part of this assessment (ECCC and U.S. EPA 2019).

4.8.4 THREATS

In the Lake Erie watershed, water takes a long time to pass through glacial deposits (clay, silt, sand, gravel, rock) before it is stored in underground aquifers. Therefore, ground water is vulnerable to contamination from human activities. Many potential sources of groundwater contamination exist (Grannemann and Van Stempvoort 2016). These include spills and legacy contamination at industrial sites, improper use or management of fertilizers, manure, and pesticides in agricultural operations, and failing household sewage treatment systems. Other urban sources include roads and leaking underground storage tanks containing home heating oil, diesel, or gasoline.

Leaking household sewage treatment systems can be a primary cause of nonpoint source groundwater pollution in vulnerable hydrogeologic settings such as karst limestone (which is present in some areas of the Lake Erie drainage basin) and shallow, permeable sand and gravels. Other potential causes of excessive nutrient leaching from household sewage treatment systems into groundwater are poor design, poor maintenance, and/or inappropriate site conditions (IJC 2010).

Development in urban areas reduces the amount of water that cycles into groundwater, and there is considerable evidence that urbanization radically alters the entire urban water cycle (Custodio 1997; Lerner 2002). Chloride contamination from salts is likely to occur wherever road density is greatest.

4.8.5 IMPACTED AREAS

Sawyer (2009) reported increasing concentrations of nitrate and chloride in groundwater throughout the Grand River (Ontario) watershed and noted that chloride levels “can be linked to urban growth and its associated land uses.” Sawyer et al. (2009) attributed increasing chloride concentrations in municipal wells in the Grand River watershed to winter de-icing of roads with sodium chloride.
In a study of nitrate concentrations in groundwater in an agricultural region (southeastern Michigan, northwestern Ohio, and northeastern Indiana) draining to the western basin of Lake Erie, Thomas (2000) found that 37% of the samples had elevated nitrate concentrations, indicating human effects (e.g., fertilizer, manure, septic systems), and that 7% of the samples had nitrate concentrations that exceeded the U.S. EPA’s Maximum Contaminant Level of 10 mg/L (U.S. EPA 2015).

Table 17 provides a summary of the main threats to groundwater quality in the watershed of the four regions of Lake Erie.

4.8.6 LINKS TO ACTIONS THAT SUPPORT THIS GENERAL OBJECTIVE

Actions that support this General Objective can be found in Section 5.1 *Strategies to Prevent and Reduce Nutrient and Bacterial Pollution* and Section 5.2 *Strategies to Prevent and Reduce Chemical Contaminant Pollution*.

Lake Erie Region	Groundwater Related Issues
St. Clair – Detroit River System	• Agricultural pesticides, fertilizers, and livestock waste (e.g., manure) are potential sources of groundwater contamination • Inputs from household sewage treatment systems
Western Basin	• Agricultural pesticides, fertilizers, and livestock waste (e.g., manure) are potential sources of groundwater contamination • Inputs from household sewage treatment systems
Central Basin	• Agricultural pesticides, fertilizers, and livestock waste (e.g., manure) are potential sources of groundwater contamination • Inputs from household sewage treatment systems
Eastern Basin	• Agricultural pesticides, fertilizers, and livestock waste (e.g., manure) are potential sources of groundwater contamination • Inputs from household sewage treatment systems

Table 17. Summary of groundwater-related issues in the regions of Lake Erie.

4.9 BE FREE FROM OTHER SUBSTANCES, MATERIALS OR CONDITIONS THAT MAY NEGATIVELY AFFECT THE GREAT LAKES

Other issues of public concern may impact the health of the Lake Erie basin ecosystem. Understanding these issues and the threats they pose will help inform the public and guide management decisions and priority actions.

4.9.1 CURRENT CONCERNS

Other issues of public concern may impact ecosystem health and impede progress to achieve this General Objective. Understanding these threats will help inform the public and guide management decisions and priority actions.

4.9.2 MICROPLASTICS

Microplastics are non-biodegradable organic polymers such as polyethylene, polypropylene, and polystyrene, that are generally less than 5 millimeters (0.2 inches) in size. They include fibers from clothing and rope, plastic particles from the breakdown of bags, packaging and containers, and plastic beads from personal care products.

A recent study of plastic pollution in 29 tributaries of the Great Lakes found that 98% of the plastics collected were microplastics; 71% of these were microfibers (Baldwin et al. 2016). A study focused on the open waters of the Great Lakes found the highest levels of microplastics in Lake Erie (Figure 18), which is attributed to the fact that the Lake Erie basin is most populated (Eriksen et al. 2013).

The impacts of microplastics on Great Lakes water quality and ecosystem health are not fully understood. Further research is required to determine the risk to fisheries and aquatic wildlife populations.

Plastic pollution has the potential to affect fish wildlife populations in three different ways: 1) complications due to ingestion; 2) leakage of plastic additives; and 3) exposure to persistent organic pollutants associated with the surface of the plastics (Anderson et al. 2016). A recent review of the effects of exposure to microplastics on fish and aquatic invertebrates by Purdue University (Foley et al. 2018) reported that feeding, growth, reproduction, and survival of freshwater biota in the presence of microplastics was highly variable across taxa. They noted that animals that serve as prey to larger predators (e.g., zooplankton) may be particularly susceptible to negative impacts of exposure to microplastic pollution, with potential for ramifications throughout the food web.

In addition to the potential for physical or toxicological effects on organisms, microplastics introduce hard substrate into aquatic ecosystems, which can subsequently alter pelagic and bacterial communities (Anderson et al. 2016).

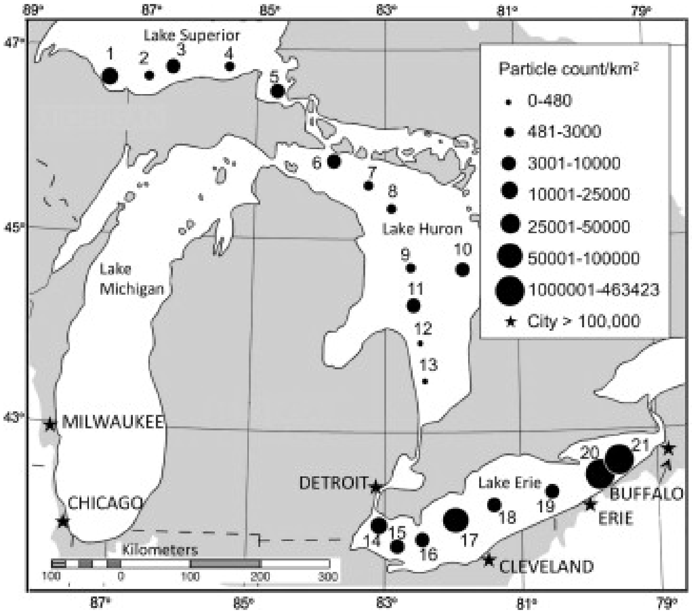


Figure 18. Distribution of plastic particles at 21 sites in Lakes Erie, Huron and Superior (from Eriksen et al. 2013).

The U.S. government signed into law the Microbeads-Free Waters Act on December 28, 2015 under the U.S. Federal Food, Drug and Cosmetic Act. Under this legislation, the manufacture of personal care products containing plastic microbeads was banned after July 1, 2017, and the sale of these products banned as of July 1, 2018. This new law also applies to both cosmetics and non-prescription drugs, such as toothpastes.

In June 2017, the Canadian government published the Microbeads in Toiletries Regulations which will help reduce the quantity of plastic microbeads entering Canadian freshwater and marine ecosystems by prohibiting the manufacture, import, and sale of toiletries used to exfoliate or cleanse that contain plastic microbeads, including non-prescription drugs and natural health products. A prohibition on the manufacture, import and sale of toiletries that contain plastic microbeads occurred in 2018.

These bans on the use of microbeads in personal care products are an important first step in reducing the flow of microplastics into the Great Lakes. However, numerous other sources of microplastics remain, including: urban runoff (containing polystyrene, plastic bags, bottles, wrappers, cigarette butts, and tire particles); fishing gear and discarded debris from boats; plastic shavings and dust from factory floors; wastewater treatment facility effluent (synthetic fibers from clothing and textiles, fragments of larger debris); combined sewer overflows; and atmospherically-deposited synthetic fibers.

NOAA's Great Lakes Marine Debris Action Plan establishes a comprehensive framework for strategic action to ensure that the Great Lakes, its coasts, people and wildlife are free from the impacts of marine debris https://marinedebris.noaa.gov/great-lakes-land-based-marine-debris-action-plan.

4.9.3 DREDGED MATERIAL

In order to maintain Great Lakes channels and harbors at safe depths for navigation, periodic dredging is required. Dredged material includes material excavated or dredged from a lake or stream. Dredged material can consist of soil, sand, silt, clay and organic matter that have settled out onto the bottom of the channel.

Each year, U.S. and Canadian harbors must be dredged to keep the shipping channels open so commodities can move in and out of the ports. There are 140 US Federal harbors within the Great Lakes Basin, with 1198 km (745 miles) of navigation channels maintained by the U.S. Army Corps of Engineers. Typically, about 2.5 million cubic meters (3.3 million cubic yards) of sediments are dredged by the U.S. Army Corps of Engineers each year from Great Lakes harbors and channels. This is equivalent to 330,000 truckloads of soil. Approximately 1.1 to 1.3 million cubic meters (1.5 to 1.7 million cubic yards) of sediment accumulates in U.S. Lake Erie harbors annually, although not all of this is removed every year.

In Canada, navigation dredging is the responsibility of Fisheries and Oceans Canada's Small Craft Harbours program, which maintains and operates 11 harbors on Lake Erie. Harbour Authorities manage the day-to-day operations of the core fishing harbors (Wheatley harbor, Erieau, Port Dover, and Port Maitland) through a lease agreement with the Small Craft Harbours program.

Historically, clean dredged material was placed in the open waters of Lake Erie. Material that is not suitable for open water placement is placed in Confined Disposal Facilities (CDFs) that are nearing full capacity. With passage of Senate Bill 1 in Ohio, open lake placement will no longer be an option for material dredged from Ohio ports after July 1, 2020. In Michigan, Lake Erie CDFs still have 10 years or more of capacity. Ideally, these facilities will be utilized for sediments that are contaminated and not suitable for beneficial uses. Within Ohio, Pennsylvania, and New York, some CDFs have less than 10 or even 5 years of capacity remaining.

Uncontaminated dredged material is becoming sought-after as a resource and is being utilized for multiple purposes. With proper characterization and handling, uncontaminated dredged material can be used for purposes including: beach/nearshore nourishment; shallow water habitat creation or restoration; landscaping; road construction; land reclamation; landfill cover; brownfield and other land reclamation; in the manufacture of marketable products such as concrete, brick, block, topsoil, and other construction materials; to restore soil on farm fields.

4.10 STATE OF NEARSHORE WATERS

The Great Lakes have more than 16,000 kilometers (10,000 miles) of coastline. The nearshore waters of the Great Lakes basin are used directly by humans in a variety of ways and are critical habitats that sustain fish and wildlife populations. Most pollutants to the lakes that result from activities within watersheds enter the Great Lakes first through a nearshore zone-of-impact.

4.10.1 BACKGROUND

As described in Chapter 3.3, the Great Lakes nearshore areas are a key priority for restoration and protection because they are the source of drinking water for most communities within the basin, are the areas of the lakes where most human recreation (e.g., swimming, boating, fishing, wildlife viewing) occurs, and are the critical ecological link between watersheds and the open waters of the Great Lakes.

The Nearshore Framework is a systematic, integrated and collective approach for assessing nearshore health and identifying and communicating cumulative impacts and stresses. It was developed by Canada and the United States in 2015 under the Lakewide Management Annex of the Agreement to inform and promote action to restore and protect the ecological health of Great Lakes nearshore areas.

4.10.2 HOW IS THE NEARSHORE ASSESSED?

Canada

Environment and Climate Change Canada's approach to report on differences in the state of health of 15 nearshore regional units in Lake Erie, allows for the identification of both high and low quality areas. The Overall Assessment of Nearshore waters is at a regional scale, builds on existing monitoring data and research programs conducted by key government and non-government partner agencies and organizations, and data collected remotely through satellite imagery. Twelve lines of evidence are incorporated into the following categories: Physical Processes, Connectivity and Habitat; Water and Sediment Quality; Nutrients; and Human Use. The process uses a geospatial framework that allows for a scaled approach to map and communicate the assessment results. The geospatial approach provides modularity, where parameters can also be assessed in isolation to understand which are of low, moderate and high quality across the Lake. This allows for discrete prioritization of areas depending on the interests of the assessment user. This also allows for the discrimination of threats affecting one particular area over another, and for change detection over time. The approach has three phases as described below:

1. Phase 1 involves delineation of the nearshore into units based on depth contours, alongshore boundaries, river mouth boundaries, consideration of gradients in wave energy density, substrate and the onshore boundary based on high water conditions. The units are then classified by ecosystem type (*e.g.,* low, moderate and high energy nearshore, sheltered embayment, wetland, large rivermouth and connecting channel).
2. Phase 2 is the assessment of condition, using four categories of evidence: physical processes and habitat, water and sediment quality, risk to human uses and nutrients, and their levels compared to thresholds.
3. Phase 3 involves the review of data on key attributes of biological assemblages, guilds and communities to confirm findings of the condition assessment of units.

United States

The United States uses a system of long-standing collaborative programs between U.S. EPA, states, and tribes under the Clean Water Act to assess the quality of watersheds and nearshore waters in the Great Lakes. Achievement of the U.S. Clean Water Act's primary goal – to restore and maintain the integrity of the nation's waters- is dependent on having good information about watershed condition, as the health of receiving waters is heavily influenced by the condition of their surrounding watersheds.

The Impaired Waters and Total Maximum Daily Load (TMDL) Program is an important component of the Clean Water Act's framework to restore and protect U.S. waters. The program is comprised primarily of a two-part process. First, states and tribes identify waters that are impaired or in danger of becoming impaired (threatened) and second, for these waters, states and tribes calculate and allocate pollutant reduction levels for these waterbodies necessary to meet approved water quality standards. These pollution reduction levels, called Total Maximum Daily Loads (TMDLs), establish the maximum amount of a pollutant allowed in a waterbody and serve as the starting point or planning tool for restoring water quality. Great Lakes assessment units for watersheds, coastal areas and nearshore waters for each state are shown in Figure 1920.

Figure 19. a) Lake Erie assessment units for each State's Integrated Water Quality Monitoring and Assessment Report. The Integrated Reports indicate

Every two years, States are required to develop Integrated Water Quality Monitoring and Assessment Reports (also called the Integrated Report) that indicate the general condition of the State's waters and identify waters that are not meeting water quality goals. The Integrated Report satisfies the Clean Water Act requirements for both Section 305(b) for biennial reports on the condition of the State's waters and Section 303(d) for a prioritized list of impaired waters. To find impaired waters in your state using the Assessment and TMDL Tracking System (ATTAINS) visit https://ofmpub.epa.gov/waters10/attains_index.home. Because of differences in state assessment methods, the information in this site should not be used to compare water quality conditions between States or to determine water quality trends.

Under the Clean Water Act, the U.S. EPA is also required to periodically report on the condition of the nation's water resources by summarizing water quality information provided by the States. However, approaches to collecting and evaluating data vary from state to state, making it difficult to compare the information across states, on a nationwide basis, or over time. To enable this reporting, the U.S. EPA uses the National Aquatic Resource Surveys (NARS), which are statistical surveys designed to assess the status of and changes in quality of the nation's coastal waters, lakes and reservoirs, rivers and streams, and wetlands. Using sample sites selected at random, these surveys provide a snapshot of the overall condition of the nation's waters. Because the surveys use standardized field and lab methods, results from different parts of the country and between years can be compared. U.S. EPA works with State, tribal and federal partners to design and implement the National Aquatic Resource Surveys. These surveys provide critical, nationally consistent water quality information. Additionally, the national surveys are helping to build stronger water quality monitoring programs across the country by fostering collaboration on new methods, new indicators and new research.

The National Coastal Condition Assessment (NCCA) is a national coastal monitoring program with rigorous quality assurance protocols and standardized sampling procedures designed and used by NARS to produce unbiased national and regional estimates of coastal condition and to assess change over time. The sample design is based on a random, stratified survey, where each site sampled represents a known portion of the nearshore system. NCCA evaluates four indices of condition—water quality, sediment quality, benthic community condition, and fish tissue contaminants – to evaluate the ecological condition and recreational potential of coastal waters. During the summer of 2015, 57 NCCA sampling stations were visited in Lake Erie for a lakewide assessment of conditions. An additional 33 enhancement sites were sampled in Lake Erie to allow for estimates of water quality condition in each basin of the lake (i.e., Western basin, Central basin and Eastern basin) (Figure 20). Additionally, the SCDRS was sampled by US EPA in 2014 and 2015 as a pilot project using the same sample design and protocols as the NCCA. A total of 19 sites in the St. Clair River, 49 sites in Lake St. Clair, and 30 sites in the Detroit River (Figure 21) were sampled and used to assess the coastal condition of the connecting river system. In addition to the four NCCA indices of condition, additional parameters collected in Lake Erie and SCDRS included phytoplankton, algal toxins, enterococci fecal indicator bacteria, underwater video footage of benthic habitat and mercury from fish tissue.

Results for each index of condition are categorized as good, fair and poor based on set thresholds (Gregor and Rast, 1979; PMSTF, 1980). The SCDRS was assessed using Central Lake Erie thresholds (Wick et al., in review). For specifics on the methods see links to reports at www.epa.gov/national-aquatic-resource-surveys/ncca. Results from the 2015 NCCA surveys are considered provisional at this time.

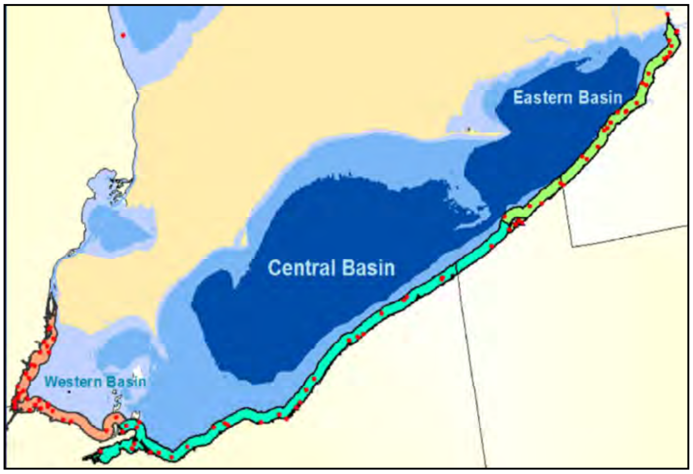


Figure 20. Map of Lake Erie sites sampled in 2015 NCCA in the western (orange), central (blue) and eastern basin (green) nearshore.

Critical coastal monitoring also occurs via implementation of the U.S. Coastal Zone Management Program. The program is a voluntary partnership between the federal government and U.S. coastal and Great Lakes states and territories, authorized by the Coastal Zone Management Act (CZMA) of 1972 to address national coastal issues. The program is administered by NOAA. The Coastal Zone Enhancement Program was established in 1990 under Section 309 of the Coastal Zone Management Act to encourage improvements to state and territory coastal management programs. The focus is on nine enhancement areas: wetlands, coastal hazards, public access, marine debris, cumulative and secondary impacts, special area management plans, ocean and Great Lakes resources, energy and government facility siting, and aquaculture.

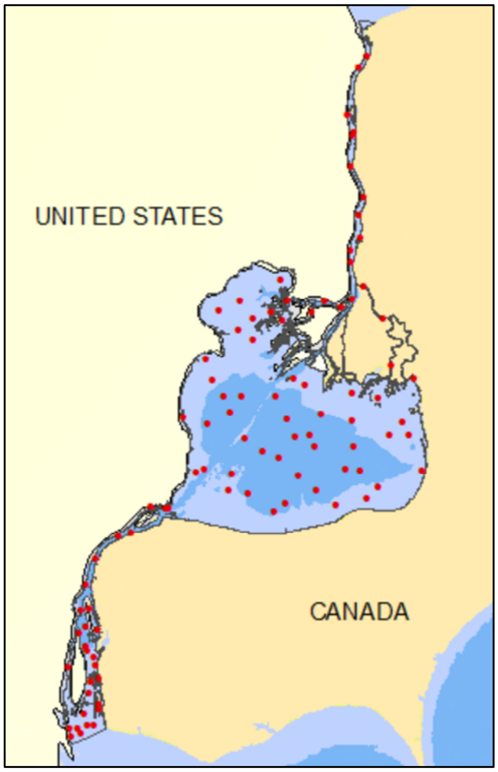


Figure 21. Map of SCDRS sites sampled in the 2014-2015 NCCA pilot.

Recent coastal monitoring initiatives by Great Lakes States' Coastal Zone Management Programs:

- ODNR has mapped Ohio's Lake Erie coast since 1988 to identify coastal erosion areas. A coastal erosion area (CEA) is a designated area of land adjacent to Lake Erie that is anticipated to be lost to erosion in 30 years unless preventive measures are taken. The current CEA designations, as depicted in the 2018 CEA Maps, are based on the amount of recession that occurred between 2004 and 2015. The Lake Erie Shore Erosion Management Plan (LESEMP) is being developed by ODNR as part of an on-going effort to assist property owners along Ohio's Lake Erie coast by providing free technical assistance to address erosion issues. The LESEMP Coastal Viewer map can be assessed at http://coastal.ohiodnr.gov/erosion.

- PADEP's Coastal Resources Management Program measures rates of shoreline erosion and bluff recession along Lake Erie's coastline.

- Michigan's Coastal Management Program partnered with a team of researchers from University of Michigan, Michigan Technological University, the Michigan Tech Research Institute, and Land Information Access Assoc. to gain essential information on the value, function, and locations of Great Lakes coastal wetlands. The team worked to research, map, and gather data on coastal wetlands influenced by the Great Lakes with a goal to help local governments improve their shoreland management efforts.

- NYSDEC is required to review the boundaries of New York State's Coastal Erosion Hazard Areas (CEHAs) every 10 years, pursuant to Article 34 of the Environmental Conservation Law. In reviewing the boundaries of the CEHAs, NYSDEC uses advanced technology such as orthoimagery and LiDAR topographic data to identify and map coastal areas and landforms (such as beaches, bluffs, and dunes that protect coastal lands) subject to adverse impacts of erosion, high water and development. Properties located within a CEHA are subject to regulation, which limit coastal development in order to protect these sensitive areas.

4.10.3 NEARSHORE STATUS & SUPPORTING DATA

Canada

The key findings from the nearshore condition assessment conducted in 2018 for the north shore of Lake Erie and the Canadian portion of the St. Clair-Detroit River Corridor are presented in Figure 22 and summarized below. Further details are available in the Lake Erie and the Huron Erie Corridor Nearshore Framework Baseline Assessment Report (ECCC 2018).

The Canadian portion of the Lake Erie nearshore and the St. Clair – Detroit River Corridor was subdivided into 15 regional units for the assessment. An east-west gradient exists across the north shore of Lake Erie, with the regional units of highest quality in the east and lowest quality in the west. Cyanobacteria blooms (assessed by Cyanobacteria Index using satellite data, Wynne et al. 2010) exert a strong influence on the overall health of the western basin and the western half of the central basin. Highest quality areas include Long Point Bay where large, ecologically significant coastal wetlands remain intact, and the Port Dover to Port Maitland area. Of the total wetlands in Lake Erie, 92% are found in Point Pelee, Rondeau Bay and Long Point; however, they are under significant threat due to recent storm events that have eroded and in some cases, breached their protective barrier beaches. Storm events continue to impact shoreline features, infrastructure and properties due to excessive erosion.

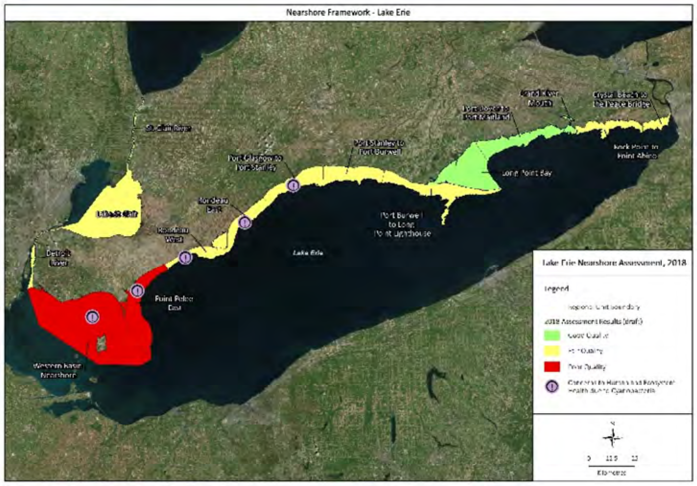


Figure 22. Map of Lake Erie sites sampled in 2015 NCCA in the western (orange), central (blue) and eastern basin (green) nearshore.

See below for summaries of each regional unit assessed and the scores for each evidence category according the following legend:

Good Quality, met or exceeded the highest threshold of health	✓
Fair Quality, within threshold range of moderate health	⊖
Poor Quality, within the threshold range of low health	⊗
Concerns to Human and Ecosystem health due to Cyanobacteria blooms or Drinking Water Treatment Plant Closures	!

St. Clair River: Fair Quality

Physical Processes, Connectivity, & Habitat	⊖	Contaminants in Water & Sediment	✓	Nuisance and Harmful Algae	✓	Human Use	⊖

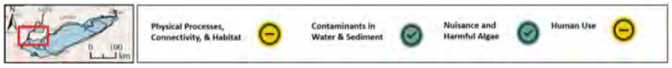
The Canadian portion of the St. Clair River is an Area of Concern due to contaminated sediment and loss of fish and wildlife habitat. However, the nearshore assessment for the St. Clair River is fair, using the weight of evidence approach. The shoreline is heavily developed and armored and has less than

1% wetlands. The majority of the tributaries are connected directly to the lake (86%). Water quality is good and there have been no recent issues with drinking water or beach postings. Fish consumption restrictions are in place for mercury and PCBs.

Lake St. Clair: Fair Quality

The Canadian portion of Lake St. Clair is classified as low energy nearshore. Aong the southern shore of Lake St. Clair, the Thames River strongly influences water chemistry (high turbidity and nutrient-enriched), while further offshore, the waters are influenced by the St. Clair River and the inflow from Lake Huron. Forty-four percent of the area is coastal wetlands, providing significant habitat, however littoral barriers are present that restrict sediment movement along the shore. In 2015 and 2016, all three monitored beaches have had swimming advisories more than 30% of the July-August swimming season.

Detroit River: Fair Quality

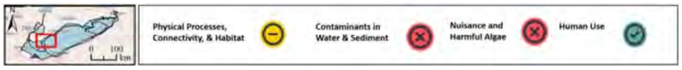


The Detroit River is a high energy environment with a shoreline that has been heavily modified by industry, flow control structures and the shipping channel. The Windsor-Little River watershed in Canada has a relatively high concentration of urban activity, with more rural conditions in the south. Many of the historical wetlands have been removed. Mercury was detected in water, whereas sediment quality was high. PCBs are responsible for fish consumption advisories.

Lake Erie Western Basin: Poor Quality including impacts from Cyanobacteria

The Canadian portion of the Western Basin of Lake Erie is a large, low energy nearshore area approximately 151,000 hectares in size. It is influenced by the Detroit River inflow and nutrient loads from the Maumee River in the United States. Cyanobacteria blooms are a serious water quality, human health and ecological issue affecting the western basin, and in 2014, Pelee Island residents were warned to only drink bottled water, as private well water systems may be compromised. Another stressor in the regional unit is hardening of the shoreline with engineering structures, which negatively affect sediment supply to the nearshore. Further, several large harbors (Kingsville and Leamington) disrupt the alongshore transport of sediment which historically supplied Point Pelee National Park. Consequently, the southwestern shoreline of the park is eroding rapidly due to this sediment deficit (Baird 2008).

Point Pelee East: Poor Quality and impacted by Cyanobacteria

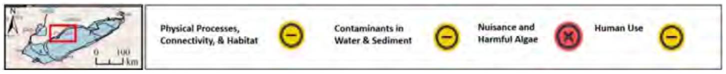


Point Pelee East is a moderate energy coast extending between the Rondeau and Point Pelee peninsulas. The watershed is used intensely for agriculture, including greenhouses. Portions of the shoreline are subject to high erosion rates, especially along Point Pelee. The coastal wetlands cover 5% of the Lake Erie shoreline, of which less than 5% is populated by the growth of *Phragmites*. The overall assessment for this area is very low quality due to the occurrence of cyanobacteria blooms.

Rondeau West: Fair Quality and impacted by Cyanobacteria

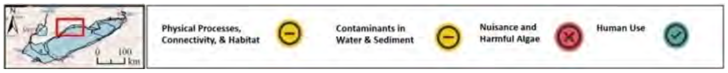
Rondeau West is a moderate energy nearshore zone in the central basin of Lake Erie. The majority of the nearshore is backed by eroding bluffs that contribute new sediment to the coast. Much of this sediment is now trapped by a large jetty in the Town of Erieau. Since the shoreline consists predominantly of high bluffs, it does not feature any coastal wetlands. Beach quality varies where some advisories were posted for over 30% of the July-August swimming season in the years 2015-2016. The most significant finding for this area, recorded in the years 2014-2016, is the cyanobacteria algae blooms that travelled into the area from the Western Basin.

Rondeau East: Fair Quality and impacted by Cyanobacteria



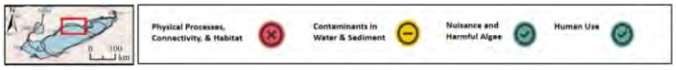
Rondeau East is a nearshore unit with moderate wave exposure. While the eastern and central portions feature high bluffs with minimal shoreline hardening, the west has a large embayment that features a coastal wetland. The adjacent watersheds are primarily agricultural and lack significant natural heritage cover. Cyanobacteria blooms were detected in this area over three years (2013, 2014, 2015).

Port Glasgow to Port Stanley: Fair Quality and impacted by Cyanobacteria



This regional unit features eroding bluffs which generate sediment for the Long Point littoral cell extending east more than 130 km to the tip of the Long Point sand spit. The adjacent watersheds feature a mixture of crop and livestock agriculture. Given the high bluff environment, there are no coastal wetlands present, however the nearshore does provide habitat for a productive Lake Erie fishery. The overriding issue for this area is cyanobacteria as in the units further west. Beach health is moderate, as is sediment quality and benthic communities. Ninety-nine percent of the tributaries offer unimpeded water flow and fish movement.

Port Stanley to Port Burwell: Fair Quality

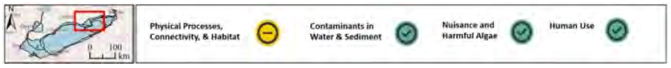


These regional unit boundaries are defined by two large jettied river mouths, which have trapped significant volumes of sand and locally modified the nearshore substrate from consolidated glacial sediment to sand. The adjacent watersheds feature mixed agriculture, including crops and livestock. There are no coastal wetlands in the area; however, the nearshore environment is an important part of the Central Basin's commercial and recreational fishery. The beach in Port Stanley is a popular recreational destination with occasional postings (6-30% of the July-August swimming season in the years 2015-2016. The benthic community is rated poor in this regional unit, as is water quality due to the presence of mercury.

Port Burwell to Long Point Lighthouse: Fair Quality

Half of this area features an eroding high bluff environment while the remaining section includes the Long Point sand spit. Agriculture land use in the connected watersheds includes high levels of corn and soybean production, relative to the remainder of the Lake Erie watershed. The deposition and growth of the sand spit over thousands of years created the sheltered condition in Long Point Bay and is responsible for the presence of the coastal wetlands in the lee of the spit and at Turkey Point. The sandy beaches along the south shore of the sand spit are popular high-quality swimming and camping areas during the summer. The assessment found some moderate impediment to littoral transport, and a benthic community that is lower than average quality.

Long Point Bay: Good Quality



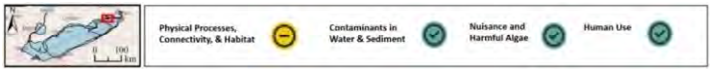
Long Point Bay is a 48,900 hectare sheltered embayment located in the lee of the 40 km sand spit. This low energy environment features 74% of the total remaining coastal wetlands along the north shore of Lake Erie. The adjacent watersheds feature low to moderate urban development relative to the rest of the Lake Erie basin and mixed agriculture. The wide range of beach and nearshore habitats in this regional unit are also home to more than 60 fish species and rare plants, reptiles and amphibians https://www.canada.ca/en/environment-climate-change.html). Only tributary connectivity (37% connected) and littoral barriers (2) failed to achieve a high-quality rating in the assessment. Although the coastal wetlands are a high-quality feature of the area, 10% have *Phragmites* coverage and are the subject of trials for spraying and removal.

Port Dover to Port Maitland: Good Quality

The shoreline and lake bottom in this area are dominated by bedrock headlands, shoals, and sand pocket beaches. Coastal wetlands are small and limited primarily to river mouths. Locally, the accumulation of *Cladophora* can foul beaches and the nearshore. Water and sediment quality are high, as are measures of nutrient status and human uses.

More than 25% of the shoreline is hardened while three littoral barriers restrict sediment movement along the shore.

Grand River Mouth: Good Quality



The lower reaches of the Grand River, below the Dunnville Dam, are characterized as a large river mouth that extends into the nearshore to capture the influence of the watershed. There are extensive riverine wetlands, however 11% of the wetlands are covered in *Phragmites*. The moderate quality rating is primarily due to the lack of tributary connectivity because of the Dunnville Dam (only 1% of the river's 6000 km of stream length is connected to the lake).

Rock Point to Point Abino: Fair Quality

This shoreline has a rocky substrate, headlands and embayments, with sand close to shore on the beaches. It is dissected by the entrance to the Welland Canal and associated shipping infrastructure. Its watershed is very small. Due to the moderate wave energy exposure and bedrock substrate, there are no coastal wetlands. The nearshore is used extensively for swimming, and the 10 beaches in this area were posted an average of 30% of the July-August swimming season in 2015 and 2016. Cladophora significantly impacts this portion of the coast. Very low dissolved oxygen levels were detected, potentially impacting aquatic species.

Crystal Beach to the Peace Bridge: Fair Quality

This area, characterized as low energy nearshore, is partly sheltered from the large westerly waves by the Point Abino headland that extends into the lake. Bedrock dominates the headlands, but sandy beaches are present in the embayments, the largest being Crystal Beach. The watershed is very small and without major tributaries. *Cladophora* washes up on the local beaches and is an aesthetic and public health concern. Several of the local beaches are regularly posted for swimming advisories due to bacterial pollution.

With four littoral barriers, transport of sediment along the coast is impaired.

United States

Lake Erie Condition: Based on the information collected by the NCCA in 2015, 63±10% of the U.S. nearshore area of Lake Erie was categorized in poor condition for water quality, 21±9% of the nearshore area was in good condition and 16±10% of the nearshore area was in fair condition (Figure 23). Conditions were good in greater than 90% of the U.S. nearshore areas of Lake Erie for microcystin algal toxins, *enterococci* bacteria, and fish plug mercury indices. Conditions were mostly good and fair according to the cyanobacteria and sediment quality indices. Fish tissue contaminant conditions were mostly fair and poor while benthic conditions were poor in more than half of the area (Figure 23).

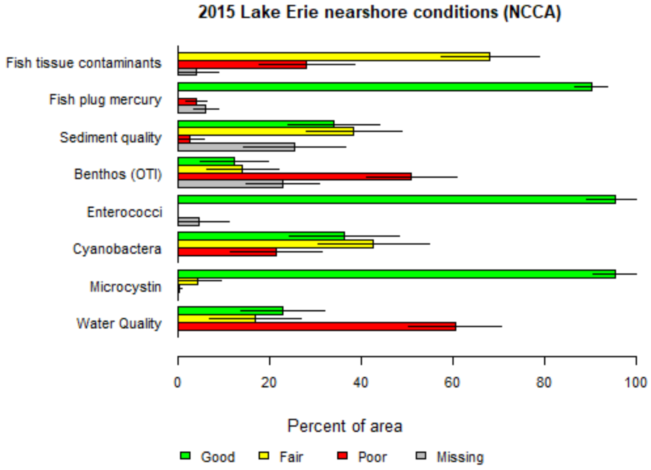


Figure 23. Condition results for the primary NCCA indicators at the base nearshore sites of Lake Erie (n = 57) in 2015. Error bars indicate the 95% confidence region. A description of each indicator can be found in the 2010 Great Lakes Technical memo.

Water quality condition was also assessed separately for each basin of Lake Erie. The percent area in poor condition in the Western basin was greater than 80% for the total phosphorus, chlorophyll-a, water clarity, and overall water quality index (Figure 24). Dissolved oxygen conditions were good in the majority of area in each of the basins. Excluding dissolved oxygen, all the water quality parameters had somewhat lower percent area in poor condition in the Central and Eastern basins of Lake Erie compared to the Western Basin. NCCA 2015 results demonstrated a west-to-east reduction in trophic conditions in the nearshore waters of the Lake (Figure 24).

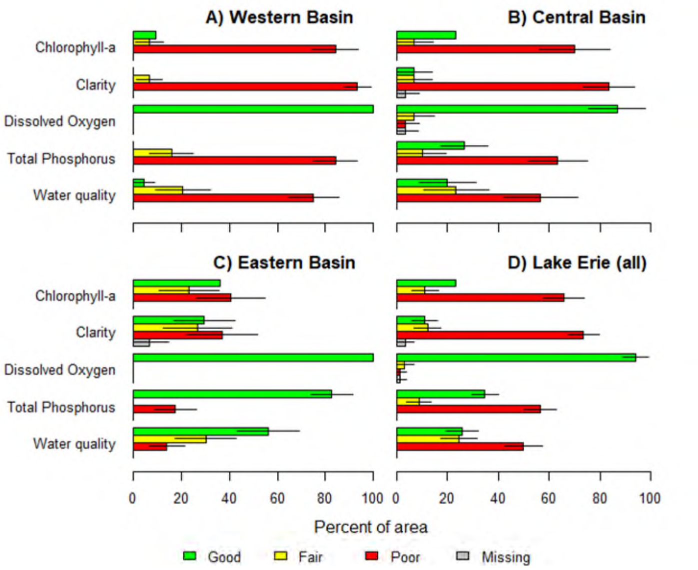


Figure 24. Condition results for the water quality parameters and the water quality index from the Lake Erie enhancement (33 sites added to the base assessment) of the 2015 NCCA. Error bars indicate the 95% confidence region. A description of each water quality parameter and the water quality index can be found in the 2010 Great Lakes Technical memo.

St. Clair-Detroit River System Condition: In 2014 to 2015, water quality condition in the SCDRS was assessed as mostly good and fair, with 46± 10% of the area in good condition and 39± 9% in fair conditions across the entire system (Figure 25). The sampling design also allowed for the categorization of condition status in the three components of the SCDRS (St. Clair River, Lake St. Clair, and Detroit River). Water quality conditions in the St. Clair River were fair in 70± 17% of the area in the system and were good in the remaining 30 ± 17% of the area (Figure 25). Water quality in Lake St. Clair was primarily in good to fair condition (Figure 25). The Detroit River had the largest proportion of its area (55± 14%) in fair condition for water quality, and water quality conditions in the remaining area of the Detroit River were 34± 13% poor and 11± 10% good (Figure 25).

Lake St. Clair had 90±10% of area with good condition for sediment quality (Figure 25). The St. Clair River had 44±20% of area with good condition and the Detroit River had 30± 16% of area in good sediment quality condition. The Detroit River had approximately 12± 11% area with poor sediment quality conditions, which was consistent with locations of sediment impairment identified in the Detroit River AOC.

Overall, benthic conditions in the SCDRS were mostly poor with 74± 10% area in poor condition (Figure 25). The St. Clair River had the most area with good benthic condition, with 60 ± 17% good conditions and 34 ± 16% poor conditions. Downstream, Lake St. Clair had 75 ± 11% of area with poor benthic condition and the Detroit River had 75± 13% of area with poor conditions.

Fish for the fish tissue contaminants index were sampled primarily in U.S. waters of the SCDRS and condition estimates in Figure 25 reflect only areas where sampling was attempted. No portion of the SCDRS was assessed as in good condition. The St. Clair River had 91 ± 17% of area in poor condition, and 70 ± 26% of Lake St. Clair was in poor condition. Poor conditions were found in 56 ± 17% of area in the Detroit River, with 44 ± 17% in fair condition. Poor conditions in each part of the SCDRS were primarily driven by fish tissue concentrations of selenium and mercury exceeding the lowest-observed-adverse-effect level (the lowest concentration at which there was an observed toxic or adverse effect in controlled laboratory experiments) for predators, especially bird and mammal species, that would potentially eat these fish.

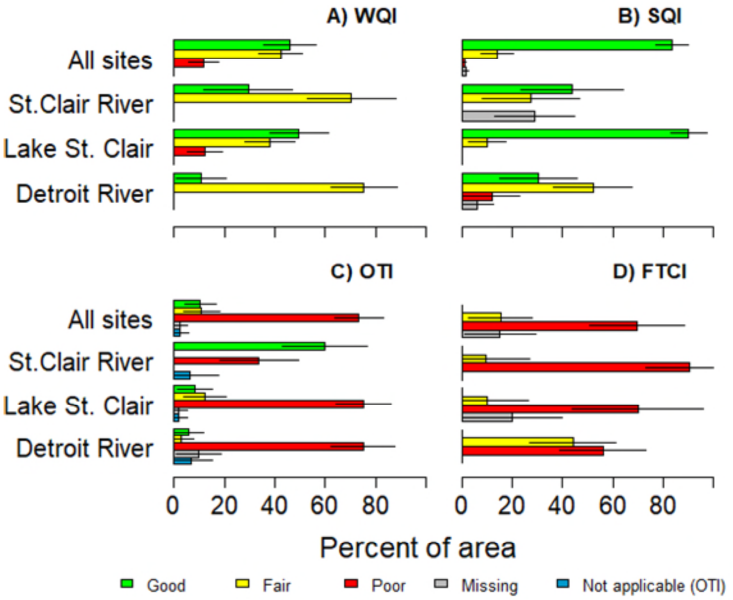


Figure 25. Condition estimate results for SCDRS, based on the water quality index (a), sediment quality index (b), the oligochaete trophic index (c) and the fish tissue contaminant index (d). Green indicates good condition, yellow indicates fair condition, red indicates poor condition. Gray indicates unassessed or missing area due to no sample collected, and blue indicates unassessed area due to no oligochaetes (or no oligochaetes assigned to categories) in the sample.

4.10.4 THREATS

Threats to Lake Erie's nearshore areas include impacts to habitats and/or water quality due to shoreline hardening; loss of tributary connectivity and coastal wetlands; invasive species; nuisance algae; eutrophication-driven harmful algal blooms;

and contaminants and bacteria. These threats are discussed in more detail in the relevant *Threats* sections of Chapters 4.1- 4.9.

4.10.5 IMPACTED AREAS

For the Canadian Lake Erie shoreline, refer to Section 4.10.3 for a description of threats presented by regional unit.

For the U.S. shoreline, State Integrated Reports can be accesed at:

Michigan: www.mi.gov/waterquality;

Michigan's Integrated report includes assessment units for Michigan waters Lake Erie, the SCDRS, and Lake St. Clair. The EGLE designated all the waters of Lake Erie under its jurisdiction as impaired for phosphorus pollution, because of its effect on "Other Indigenous Aquatic Life" (any aquatic animals that are not fish). Because of the complexity of the cyanobacteria bloom problem, Michigan believes the best approach for solving the issues in western Lake Erie is through the collaborative process established under Nutrients Annex of the Great Lakes Water Quality Agreement and the Western Basin of Lake Erie Collaborative Agreement as they afford a holistic, multi-jurisdictional perspective that does not exist in a traditional TMDL process. Michigan's Lake Erie jurisdiction is also listed as impaired for not supporting the fish consumption designated use based on extensive fish tissue data from multiple species for bioaccumulative chemicals.

Ohio:
https://epa.ohio.gov/dsw/tmdl/OhioIntegratedReport;

Ohio's Integrated Report includes Lake Erie nearshore and open water assessment zones. In the 2018 Integrated Report, Ohio EPA designated the open waters of Lake Erie's Western Basin (from the Michigan/Ohio state line to the Marblehead Lighthouse) as impaired for recreation due to harmful algae and drinking water due to occurrences of microcystin. Previously, only the shoreline area of the Western Basin and drinking water intakes had been designated as impaired. The water quality designation doesn't mean that Lake Erie isn't safe for drinking water, or for recreational boating and swimming. It means that the open waters of Lake Erie do not meet federal or state water quality goals. The designation does help pave the way for more action to combat pollution that leads to harmful algal blooms.

Pennsylvania:
https://www.dep.pa.gov/Business/Water/CleanWater/WaterQuality/Pages/Assessment-Methodology.aspx;

Pennsylvania's Integrated report includes a Lake Erie assessment unit

New York:
https://www.dec.ny.gov/chemical/110222.html;

New York's Integrated report includes a Lake Erie shoreline assessment unit

4.10.6 LINKS TO ACTIONS THAT SUPPORT NEARSHORE HEALTH

Actions that address nearshore health and advance the achievement of the General Objectives are found in *Strategies to Prevent and Reduce Nutrient and Bacterial Pollution* (5.1), *Strategies to Prevent and Reduce Chemical Contaminant Pollution* (5.2), *Strategies to Protect and Restore Habitat and Native Species* (5.3), *Strategies to Prevent and Contain Invasive Species* (5.4), and *Strategies to Promote Resilience to Climate Trend Impacts* (5.5).

5.0 LAKEWIDE ACTIONS

The member agencies of the Lake Erie Partnership have developed an ecosystem-based strategy to improve the water quality of Lake Erie. Government agencies, stakeholders, and the public all have an important role in implementing priority actions over the next five years.

5.0.1 ACTIONS THAT ADVANCE ACHIEVEMENT OF THE GENERAL OBJECTIVES

As reported in Chapter 4, several of the Agreement's General Objectives are not being fully achieved in Lake Erie and the St. Clair – Detroit River System (Table 18). Fish consumption advisories are in place due to legacy contaminants and other chemicals of concern. Excessive nutrients fuel harmful and nuisance algal blooms in the western and eastern basins and exacerbate hypoxia in the central basin. Bacterial pollution makes beaches unsafe for recreation. Aquatic habitat continues to be impacted by shoreline development and dams and barriers continue to impact access to important tributary habitat. Invasive species such as Sea Lamprey, dreissenid mussels, and *Phragmites* continue to impact fisheries, alter physical habitats and nutrient cycling in the lake, and habitat quality throughout the lake. These threats interact with a changing climate to produce complex management challenges.

	GENERAL OBJECTIVE	STATUS
1	Be a source of safe, high quality drinking water.	Good
2	Allow for unrestricted swimming and other recreational use.	Fair
3	Allow for unrestricted human consumption of fish and wildlife.	Fair
4	Be free from pollutants that could harm people, wildlife or organisms.	Fair
5	Support health and productive habitats to sustain our native species.	Poor-Good
6	Be free from nutrients that promote unsightly algae or toxic blooms.	Poor
7	Be free from aquatic and terrestrial invasive species.	Poor-Fair
8	Be free from the harmful impacts of contaminated groundwater.	Fair
9	Be free from other substances, materials or conditions that may negatively affect the Great Lakes.	NA

Table 18. The status of Lake Erie by GLWQA General Objective. NA = not assigned (no Great Lakes indicators to allow for status assessment).

This chapter describes strategies and actions that address the key environmental threats identified in Chapter 4. These strategies and actions are based on an assessment of the scope and severity of impacts to water quality. The chapter is organized into five sub-sections, each of which is linked with various General Objectives.

Since the beginning of the Agreement in 1972, Canada and the United States have enacted national and regional programs that address major sources of pollution and threats to Lake Erie. These now long-established programs provide much of the environmental protection and natural resource management needed to address water quality. These national and regional programs, which have their own inherent tracking and accountability processes, are identified in this Chapter, along with other Great Lakes-specific activities implemented under the Agreement that also advance progress on these issues, including the work of other Annexes and Partnership agencies. Among these ongoing programs, is a subset of actions which are of major significance for implementation and tracking by the Lake Partnership and these are summarized in the Action Tables within each section of Chapter 5. The sections conclude by describing how effectiveness of actions will be assessed over the next 5 years and proposing recommended actions that the public can take to help improve and maintain Lake Erie's water quality.

The Lake Erie Partnership will work with many others, including watershed management agencies, local public agencies, non-profit environmental groups, and the public, to address key environmental threats through the implementation of 40 management actions between the years of 2019 to 2023. Management actions will build on the many achievements already observed from ongoing science, monitoring and binational and domestic initiatives. Actions will focus on cooperative, collaborative implementation efforts and reporting under the Lake Erie LAMP, and will be implemented to the extent feasible, given available resources and domestic policy considerations by the agencies with corresponding mandates.

5.1 STRATEGIES TO PREVENT AND REDUCE NUTRIENTS AND BACTERIAL POLLUTION

5.1.1 CONNECTIONS TO THE AGREEMENT GENERAL OBJECTIVES

Lake Erie is impacted by excessive nutrients (phosphorus and nitrogen) that fuel harmful and nuisance algal blooms and by bacterial pollution that makes beaches unsafe for recreation. This nutrient and bacterial pollution is an ongoing issue that is limiting the full achievement of the following General Objectives:

- General Objective 5: Support healthy and productive wetlands and other habitats to sustain resilient populations of native species; and
- General Objective 6: 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.

Actions that control excess nutrient and bacterial pollution will also help to improve nearshore water quality and make progress toward full achievement of the General Objective:

- General Objective 2: Allow for swimming and other recreational use, unrestricted by environmental quality concerns

5.1.2 MANAGEMENT OF MAJOR NUTRIENT AND BACTERIAL POLLUTION SOURCES

Existing domestic legislation, initiatives, and programs that address the major types of nutrient and bacterial pollution sources are identified in Table 19. This sub-section highlights the point source pollution and non-point source pollution programs in place in the Lake Erie basin.

Excessive nutrients and bacteria can enter Lake Erie through point sources and nonpoint sources. Point sources of pollution can be attributed to a specific physical location -- an identifiable, end-of-pipe "point", such as wastewater treatment facilities. Nonpoint source pollution comes from many diffuse sources and occurs when rainfall or snowmelt moves over and through the ground, picking up natural and human-made pollutants and depositing them into lakes, rivers, wetlands, coastal waters and ground waters. Atmospheric deposition may also be considered a type of nonpoint source pollution.

Examples of Nutrient Pollution Reduction Legislation	
Agricultural Act of 2014 (U.S. Farm Bill)	Provides authorization for services and programs by the U.S. Department of Agriculture, which include several agricultural environmental conservation programs that benefit water quality.
Canadian Environmental Protection Act, 1999	An *Act* respecting pollution prevention and the *protection* of the *environment* and human health in order to contribute to sustainable development.
Nutrient Management Act, 2002 (Ontario)	A nutrient management framework for Ontario's agricultural industry, municipalities, and other generators of materials containing nutrient; includes environmental protection guidelines.
Environmental Protection Act/Water Resources Act, 1990 (Ontario)	Environmental approval is required by every business or facility in Ontario that creates a discharge to the natural environment.
Fisheries Act, 1985 (Canada)	Section 36 prohibits the deposit of deleterious substances into waters frequented by fish, unless authorized. Also under the Fisheries Act, the 2015 Wastewater Systems Effluent Regulations established Canada's first national standards for wastewater treatment.
Clean Water Act, 1972 (U.S.)	Regulates discharges of pollutants into the waters of the United States and establishes quality standards for surface waters.
Coastal Zone Management Act, 1972 (U.S).	Provides for the management of the nation's coastal resources, including the Great Lakes. The Act outlines three national programs, the National Coastal Zone Management Program, the National Estuarine Research Reserve System, and the Coastal and Estuarine Land Conservation Program.

Table 19. Pollution reduction legislation by Federal and Provincial agencies

Point Source Pollution

Efforts to protect water quality by regulating "end of pipe" point source discharges from outfalls have been generally successful. Industrial and municipal wastewater facilities must have an environmental compliance approval to establish, use, and operate facilities, and there are site-specific effluent limits and monitoring and reporting requirements for operation.

Opportunities exist to optimize the performance of wastewater treatment plants and to reduce the volume and frequency of bypasses and overflows. During heavy rain events or snowmelt, the volume of runoff, domestic sewage, and industrial wastewater can exceed the capacity of combined sewer systems resulting in discharges ("overflows") of untreated or undertreated stormwater and wastewater directly into nearby streams, rivers, and lakes. Federal and State initiatives to address point source pollution include:

- The U.S. EPA has a combined sewer overflow control policy and a national framework for controlling combined sewer overflows through the National Pollutant Discharge Elimination System (NPDES) permitting program implemented in partnership with State Pollutant Discharge Elimination System (SPDES) permitting programs.
- The National Pollutant Release Inventory (NPRI) is Canada's legislated inventory of pollutant releases and a resource for encouraging actions to reduce the release of pollutants. The inventory tracks the wastewater treatment sector and reports on the release of phosphorus into water.
- The Total Maximum Daily Load (TMDL) program, established under Section 303(d) of the U.S. Clean Water Act (CWA), focuses on identifying and restoring polluted rivers, streams, lakes and other surface water bodies. A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. Each state must develop TMDLs for all the waters identified on their Section 303(d) list of impaired waters.

Nonpoint Source Pollution

The diffuse nature of nonpoint source pollution makes this more difficult to regulate and control, as compared to point source pollution. However, there are regulatory and voluntary mechanisms by which nonpoint sources are managed in order to reduce their impacts to water quality.

Agricultural operations are a predominant part of the landscape and important to the economy of Lake Erie, especially in the Western Lake Erie Basin watersheds. Consequently, the management of private agricultural lands has a significant influence on the quality of the region's natural resources, including the water that flows to Lake Erie (USDA 2016). Commercial fertilizers and animal manure can be a threat to water quality if they are over-applied, applied too close to a watercourse, or applied on frozen ground, or applied just before a heavy rain. Threats to water quality from row-cropped fields can decrease with the implementation of best management practices (BMPs) such as diverse crop rotation, conservation tillage, drainage management, riparian buffers or cover crops. Federal, state, provincial and multi-jurisdictional initiatives to address agricultural nonpoint source pollution programs include:

- Under the U.S. CWA, or individual State regulatory programs, nutrient management plans are required for concentrated animal feeding operations (CAFOs). These include BMPs and other measures to ensure proper management of nutrients while increasing water quality protection.
- Voluntary farm assistance programs support farms of all sizes to engage in agricultural pollution prevention practices that comply with Federal, State, Provincial environmental regulations. Programs are implemented in Michigan by the Michigan Agricultural Environmental Awareness Assurance Program http://www.michigan.gov/mdard, in New York by the Agricultural Environmental Management Framework and the Agricultural Nonpoint Source Abatement & Control Grant Program https://www.nys-soilandwater.org/aem/, by the USDA Natural Resources Conservation Service (NRCS) https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/, and in Ontario through the Canada-Ontario Environmental Farm Plan http://www.omafra.gov.on.ca

and the Canadian Agricultural Partnership Program

- New York's Agricultural Nonpoint Source Abatement and Control Program (ANPSACP) provides technical and financial support to Soil & Water Conservation Districts and NY farms in support of a Program goal to reduce and or prevent the nonpoint source contribution from agricultural activities in watersheds across the state. The Program utilizes the Agricultural Environmental Management (AEM) framework and provides cost-share funds to develop farm conservation plans and to implement Best Management Practices (BMPs) Systems.
- Michigan's Nonpoint Source (NPS) Program provides technical and financial support to stakeholders in developing and implementing watershed management plans (WMPs) to restore and protect water quality. The NPS Program supports implementation of BMPs to reduce or eliminate pollutant loads from livestock and cropping operations in watersheds dominated by agricultural land uses. In urban watersheds, the priority actions often include Low Impact Development and Green Infrastructure BMPs intended to address storm water impacts. Failing onsite septic systems are linked to water quality impairments in some watersheds. The NPS Program supports efforts to find and fix failing systems as well as provide information to homeowners regarding proper septic system maintenance. The NPS Program also supports efforts to protect high quality waters through the implementation of conservation easements or ordinance development.
- USACE is working in collaboration with other Great Lakes stakeholders interested in exploring construction of wetlands for phosphorus reduction (called P-optimal wetlands), including The Nature Conservancy, Ducks Unlimited, academic institutions and other federal agencies, to conduct research and engineering evaluation to inform decision-making about the potential or treatment wetlands to be a significant part of controlling phosphorus from agricultural runoff in the Great Lakes. Research is underway to optimize phosphorus removal through placement and design of a series of wetlands in the Western Lake Erie Basin. USACE and partners anticipate construction of new full-scale
- wetland sites to test and demonstrate the potential of P-optimal wetlands starting in 2019.

Soil erosion from forestry and logging practices, road building, and burning can also be potential sources of water contamination. Practices have improved to such an extent that impacts on Lake Erie are generally localized.

Residential, urban and shoreline development can disrupt natural water flows, generate nutrients from lawn fertilizers, cause sediment pollution from land clearing and road development, and create high volumes of stormwater runoff from impervious surfaces. Improper disposal of pet feces can result in increased nutrient and microbiological loadings to surface water. Improperly maintained or sited household sewage treatment systems can contribute bacteria, organic matter and nutrients to waterways. Federal, State, Provincial and multi-jurisdictional initiatives to address nonpoint source pollution from these sources/activities include:

- Under the U.S. CWA, stormwater discharges from certain construction activities are unlawful unless they are authorized by a NPDES/SPDES permit.
- Under the U.S. CWA, operators of small municipal separate storm sewer systems (MS4s), located in urbanized areas and those additionally designated by States are unlawful unless they are authorized by a NPDES/SPDES permit for stormwater discharges.
- Under the U.S. Coastal Zone Management Act, the Coastal Zone Act Reauthorization Amendments of 1990 require States with federally approved Coastal Zone Management Programs to develop coastal nonpoint pollution control programs to address specific management measures focusing on a wide variety of nonpoint source pollution.
- New York State Nutrient Runoff Law (https://www.dec.ny.gov/chemical/67239.html)
- Nine element watershed plans under the U.S. Clean Water Act are used to identify in-stream and edge of field improvements, which are important for nutrient loading reductions and assimilative capacity improvements.
- In Michigan, the goal of Michigan's Storm Water Program is to protect and preserve Michigan's water resources through pollution prevention measures. The EGLE works to accomplish this goal through a two-step process. First, EGLE has been authorized by the U.S. EPA to manage a stormwater

- discharge permit program. Second, EGLE is implementing a compliance assistance approach to the permit program www.mi.gov/deqstormwater
- Michigan's Nonpoint Source (NPS) Program provides technical and financial support to stakeholders in developing and implementing watershed management plans (WMPs) to restore and protect water quality. In urban watersheds, the priority actions often include Low Impact Development and Green Infrastructure BMPs intended to address storm water impacts. Failing onsite septic systems are linked to water quality impairments in some watersheds. The NPS Program supports efforts to find and fix failing systems as well as provide information to homeowners regarding proper septic system maintenance. The NPS Program also supports efforts to protect high quality waters through the implementation of conservation easements or ordinance development.
- In Ohio, since 2007, new or altered discharging sewage treatment systems must obtain coverage under the Ohio EPA General Household NPDES permit and install systems that meet Ohio Dept. of Health standards. Both the Ohio EPA NPDES permit and ODH rules require regular system maintenance and annual effluent sampling for these systems.
- The Ontario Water Resources Act (1990) contains a number of important mechanisms that protect water resources including prohibiting the discharge of polluting material in or near water and prohibiting or regulating the discharge of sewage.
- The Ontario Cosmetic Pesticides Ban Act (2008) prohibits the use and sale of pesticides that may be used for cosmetic purposes.
- The US Forest Service awards grants through the Great Lakes Restoration Initiative to install green infrastructure to reduce runoff from degraded sites. https://www.fs.usda.gov/naspf/working-with-us/grants/great-lakes-restoration-initiative.

5.1.3 OTHER ACTIVITIES UNDER THE AGREEMENT THAT ADVANCE PROGRESS ON NUTRIENT AND BACTERIAL POLLUTION

Article 4 and the Nutrients Annex of the 2012 Agreement commits the Parties to implement and assess programs for pollution abatement and enforcement for municipal sources (including urban drainage), industrial sources, agriculture, and forestry.

The Nutrients Annex highlights Lake Erie as the top priority to address and includes two important milestones:

- By 2016, review and if necessary, establish new nutrient targets for Lake Erie
- By 2018, develop action plans to meet the new targets.

Both of these milestones have been met. The Nutrients Annex is co-led by ECCC and U.S. EPA. Initial efforts under this Annex have been focused on assessing the adequacy of existing nutrient management programs and policies to prevent algal blooms in Lake Erie, and developing the scientific information required to evaluate progress towards achievement of nutrient objectives. Binational phosphorus load reduction targets were established for the western and central basins of Lake Erie in 2016 and Domestic Action Plans were released by both countries and each contributing state in 2018.

Nutrient and bacterial pollution often effect nearshore areas. In fulfillment of a U.S. and Canadian commitment under the Lakewide Management Annex of the Agreement, 'The Great Lakes Nearshore Framework' was developed to provide an approach for assessing nearshore waters, sharing information, identifying stressors and areas requiring protection, restoration, or prevention activities. See *State of Nearshore Waters* (4.10).

5.1.4 LAKE ERIE PARTNERSHIP ACTIONS THAT ADDRESS NUTRIENT AND BACTERIAL POLLUTION

In consideration of the current trends, main sources of nutrients, geographic scope of the issues, localized impacts (as explained in Chapter 4.6 and above), the member agencies of the Lake Erie Partnership have identified nutrient monitoring and management actions to implement over the next five years.

The nutrient reduction efforts identified in the Domestic Action Plans (DAPs) released in 2018 by Canada and the United States pursuant to the 2012 Agreement and in the 2019 Binational Phosphorus Reduction Strategy outline strategies for reducing phosphorus loads to the western and central basins of Lake Erie by 40% from 2008 levels. The plans describe the specific measures each jurisdiction and its partners will implement to achieve binational phosphorus reduction targets for Lake Erie to ultimately curb the growth of excess algae that threatens the ecosystem and human health.

The DAPs are available at:

- Canada-Ontario: https://www.canada.ca/en/environment-climate-change/services/great-lakes-protection/action-plan-reduce-phosphorus-lake-erie.html
- United States: https://www.epa.gov/glwqa/us-action-plan-lake-erie
- Ohio: http://lakeerie.ohio.gov/LakeEriePlanning/OhioDomesticActionPlan2018.aspx
- Michigan: https://www.michigan.gov/ogl/0,9077,7-362-85257_64889_86336---,00.html
- Indiana: http://www.in.gov/isda/3432.htm
- Pennsylvania: http://www.dep.pa.gov/Business/Water/Compacts%20and%20Commissions/Great%20Lakes%20Program/Pages/default.aspx

While there are currently no nutrient reduction targets for the eastern basin of Lake Erie, New York State is participating in the U.S. DAP and is committed to the development of a Lake Erie watershed plan and implementation of a tributary monitoring program that supports the broader goals of the DAP and lakewide nutrient loading assessments and modeling efforts under the Nutrients Annex of the GLWQA. Canada and Ontario are taking precautionary actions via the Canada-Ontario DAP to reduce phosphorus loads to the Grand River watershed and the Eastern Basin.

Bacterial and nutrient pollution often have the same sources, and the DAP-related nutrient efforts are also expected to contribute to the mitigation of bacterial-related water quality impacts that exist in some nearshore areas of the lake.

Each Domestic Action Plan is unique and the priority strategies (in bold) and examples of categories of action (bullets) outlined below are a synthesis of what can be found in the Domestic Action Plans referenced above.

Strategies to Reduce Phosphorus Loadings from Agricultural Sources

- Continue to encourage and incentivize farmers to adopt on-farm best management practices, emphasizing a "systems approach" (combinations of management practices) to comprehensively address concerns at the farm scale
- Adopt 4R's Nutrient Stewardship Certification or similar programs
- Avoid nutrient applications on frozen or snow-covered ground
- Implement and enforce fertilizer and manure application requirements where they apply
- Prevent agricultural runoff by improving soil health and managing drainage systems to hold back or delay delivery of runoff to receiving waterbodies
- Reduce the impact of effluent releases from greenhouses on Lake Erie

The 4R Nutrient Stewardship Certification program encourages agricultural retailers, service providers and other certified professionals to implement proven 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.

Strategies to Reduce Phosphorus Loadings from Municipal Sources

- Optimize wastewater infrastructure
- Encourage investments in green infrastructure
- Identify and correct failing home sewage treatment systems
- Enable water quality trading as a potential future tool for managing phosphorus

Watershed Based Planning and Restoration Efforts

- Develop or refine local watershed plans to meet the phosphorus reduction goals for the lake
- Target watershed restoration efforts to areas most prone to phosphorus losses
- Establish ecological buffers for rivers, streams, and wetlands to intercept and infiltrate runoff and prevent streambank erosion

Science, Surveillance and Monitoring

- Enhance in-lake monitoring of algae and hypoxic conditions
- Improve monitoring of nutrient loads in tributaries and watersheds

- Invest in research and demonstration initiatives to improve knowledge and understanding of the effectiveness of BMPs

Outreach and Education

Undertake outreach and education on local and regional scales to increase the understanding of water quality condition and management challenges, nearshore and beach health, and best management practices and policies.

5.1.5 ASSESSING EFFECTIVENESS OF NUTRIENT AND BACTERIAL CONTROL EFFORTS

The programs highlighted in this sub-section will allow us to assess the effectiveness of the LAMP Actions over the next five years.

Open lake

Monitoring of offshore nutrient concentrations and the productivity of the lower food web is performed annually by ECCC and U.S. EPA as a part of Great Lakes surveillance programs, and by the interagency GLFC Lake Erie Committee Forage Task Group. Monitoring of nearshore nutrient concentrations in the Canadian waters of Lake Erie is conducted on a three-year basis by the Ontario Ministry of Environment, Conservation, Parks (OMECP).

Lake Erie water quality and algal bloom conditions are monitored every summer by the NOAA. NOAA bulletins provide analysis of the location of cyanobacteria blooms, as well as 3-day forecasts of transport, mixing, scum formation, and bloom decline. During the Lake Erie HAB season, which typically begins in July, bulletins are emailed to subscribers twice weekly during a bloom. Visit https://tidesandcurrents.noaa.gov/hab/lakeerie.html to subscribe.

U.S. EPA samples vertical profiles of dissolved oxygen and temperature in the Central Basin of Lake Erie each summer, over approximately 3-week intervals, to calculate the bottom water oxygen depletion rate as a measure of hypoxia. Ohio EPA and Pennsylvania DEP also conduct hypoxia monitoring in the Central Basin along six fixed transects each summer. The National Oceanic and Atmospheric Administration (NOAA) is developing an operational dissolved oxygen forecast model for Lake Erie, coupled to an existing real-time, fine-scale hydrodynamic model. The forecast will give public water systems advance warning of lake circulation events that are likely to cause changes in raw water quality. This coupled system will allow drinking water managers to prepare when conditions that promote hypoxic water movement into the vicinity of water intakes occur.

Watersheds, tributaries and beaches

Routine stream and coastal monitoring is conducted by Federal, State, and Provincial agencies to report on water quality trends, including nutrients and bacteria. Additional monitoring is conducted on an as-needed basis in support of State and Provincial water quality program priorities, including for example supplementary monitoring of nutrient loadings in the rivers and streams tributary to the western basin of Lake Erie by Ohio, Michigan, and Indiana and their research partners for the purpose of tracking progress towards the Western Lake Erie Basin Collaborative and the Nutrients Annex Phosphorus targets.

ECCC and U.S. EPA have updated the time series of annual phosphorus loading calculations for Lake Erie from 1967-2016 (Fig 16) and will continue to update the load annually to track DAP progress in reducing loads.

In addition to State and Provincial jurisdictions providing information on DAP implementation progress, the Great Lakes Commission's online tool ErieStat (https://www.blueaccounting.org/issue/eriestat) will compile information from all the jurisdictions on the status of phosphorus reduction strategies, investments and resulting outcomes in Lake Erie. Edge-of-field monitoring is being used to quantify the effectiveness of agricultural best management practices, and to inform future BMP decisions and support the development of models that can predict nutrient loss reductions from fields based on BMPs being implemented.

Municipal Health Units in Ontario, and County/State Health Departments or other public agencies that may have jurisdiction over beaches in the United States (e.g., within state-owned parks) monitor select public bathing beaches for *E. coli* levels to determine whether conditions are sufficiently protective of human health and to inform beach posting or closure decisions. In New York, beaches located within state parks are monitored by the Office of Parks, Recreation and Historical Preservation. Beach monitoring results are made available to the public through various mechanisms, including web-based reporting portals (for NYS: http://ny.healthinspections.us/ny_beaches/; https://parks.ny.gov/recreation/swimming/beach-results/).

In addition, USGS, in partnership with State and local health departments, have developed NowCast, a system that uses easily measured environmental and water-quality "variables," such as turbidity and rainfall, to estimate levels of fecal indicator bacteria. Information from NowCast is used along with other location-specific beach water quality and environmental conditions to inform beach posting/closing decisions.

In Michigan, the EGLE awards grants to local health departments to voluntarily monitor and report levels of *E. coli* in the swimming areas of public beaches through Beach Guard http://www.deq.state.mi.us/beach/.

Michigan is the first Great Lakes state to monitor beaches statewide using a new, rapid testing method for water quality to quickly address potential public health concerns. The new quantitative polymerase chain reaction (qPCR) method quickly identifies and measures *E. coli* DNA in a beach water sample. The method provides results on the same day that a sample is collected.

5.1.6 ACTIONS THAT EVERYONE CAN TAKE

Landowners and the public are encouraged to do their part to prevent nutrient and bacterial pollutants from entering groundwater, streams, lakes, wetlands, and Lake Erie by undertaking the following actions:

- Choose phosphate-free detergents, soaps, and cleaners;
- Avoid using lawn fertilizers containing phosphorus, unless establishing a new lawn or a soil test shows that your lawn does not have enough phosphorus. Follow recommendations for application provided by manufacturer and apply in accordance with any guidelines or regulations that exist within your jurisdiction;
- Always pick up pet waste;
- Install a rain barrel and reuse the water for beneficial purposes, such as watering a lawn or garden. Plant a rain garden with native trees, shrubs, and herbaceous plants to direct rainwater to this area so that the water can soak into the ground and be used by the vegetation;
- Inspect and pump out your septic system regularly;
- Implement improved septic technologies, including conversion of septic systems to municipal or communal sewage systems, where available; and
- Incorporate agricultural best management practices, such as grassed swales, filter and/or buffer strips, and cover crops to control and reduce stormwater runoff; keep cattle and other animals out of streams; and plant a shelter belt.

5.2 STRATEGIES TO PREVENT AND REDUCE CHEMICAL CONTAMINANT POLLUTION

5.2.1 CONNECTIONS TO THE AGREEMENT GENERAL OBJECTIVES

While most areas of Lake Erie are not significantly impacted by chemical contaminants, environmental concentrations of some contaminants continue to be ongoing problems that may limit the full achievement of the following General Objectives in the waters of Lake Erie:

- General Objective 3: Allow for human consumption of fish and wildlife unrestricted by concerns due to harmful pollutants;
- General 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; and
- General Objective 8: Be free from harmful impact of contaminated groundwater.

Numerous environmental programs have been established to control the release of chemicals via municipal and industrial discharges, to remediate contaminated waste sites, and to remove contaminated sediments from Lake Erie. As a result, environmental concentrations of most chemicals in air, water, sediment, fish and wildlife samples are at low levels and declining. Further reductions in chemical contaminants will be achieved by a combination of in-basin and out-of-basin programs. This section describes actions that will be taken to further reduce chemical contaminants in Lake Erie and how reductions in the environment will be monitored.

5.2.2 MANAGEMENT OF MAJOR CHEMICAL CONTAMINANT POLLUTION SOURCES

Chemical pollutants enter Lake Erie in a number of different ways, including atmospheric deposition, point-sources (municipal/industrial wastewater discharges), nonpoint sources (stormwater/surface runoff), and release from existing contaminated bottom sediments. Existing domestic legislation, initiatives and programs that address these contaminant pollution sources are identified in Table 20. This sub-section highlights the programs in place to address atmospheric pollution, point and non-point source pollution, and contaminated bottom sediments.

Atmospheric Deposition

Atmospheric deposition has been recognized as a significant source of certain persistent toxic pollutants, such as PCBs, pesticides, PAHs, mercury, flame-retardants, and trace metals, to the Great Lakes since the 1970s. Canada and the United States acted on a Great Lakes regional scale by establishing the Integrated Atmospheric Deposition Network (IADN) in 1989 as a joint effort in support of the Agreement. Today, the United States IADN, Canada's Great Lakes Basin Monitoring and Surveillance, and the Mercury Deposition Network air monitoring stations measure atmospheric and precipitation concentrations of toxic chemicals in the Great Lakes region to determine temporal and spatial trends and the effectiveness of national and international control measures. In general, atmospheric concentrations of PCBs, organochlorine pesticides, and PAHs continue to decrease at most monitoring stations over time. The picture is less clear, however, for certain chemicals like halogenated flame retardants which, while generally highest around urban centers like Cleveland and Chicago, are sometimes elevated at even remote monitoring sites.

Atmospheric deposition of pollutants is also evaluated and regulated on an out-of-basin regional or international scale. Examples of actions include the Stockholm Convention on Persistent Organic Pollutants and the United Nations' Economic Commission for Europe's Convention on Long Range Transboundary Air Pollution. Reducing atmospheric deposition requires continued permitting and enforcement of air emissions in North America and participation with international efforts to reduce chemical contaminants worldwide.

Point Source Pollution

Sewers collect sewage and wastewater from homes, businesses, and industries and deliver it to wastewater treatment facilities before it is discharged to water bodies. One ongoing problem is combined sewer overflows that result from stormwater being routed into municipal wastewater systems; high water volumes during severe weather can overwhelm treatment systems resulting in untreated discharge. Programs to separate stormwater and wastewater systems are

REGULATORY CONTAMINANT PROGRAMS AND REDUCTION LEGISLATION	
Canada Shipping Act, 2001	Prevention of pollution from ships.
Canada Environmental Protection Act, 1999	Pollution prevention and the protection of the environment and human health to contribute to sustainable development.
Canada Fisheries Act, 2016	Section 36 prohibits the deposit of deleterious substances into waters frequented by fish, unless authorized. The 2015 Wastewater Systems Effluent Regulations is Canada's first national standards for wastewater treatment.
Canada Pipeline Safety Act, 2016	Sets technical standards for the design, construction, operation, maintenance, and decommissioning of Canada's oil and gas pipelines.
U.S. Protecting our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act, 2016	Requires annual federal reviews of all pipelines' age and integrity.
U.S. Clean Air Act, 1990	Federal law regulates air emissions from stationary and mobile sources and establishes National Ambient Air Quality Standards to protect public health. Implementation and enforcement may be delegated to States and incorporated into their regulatory programs.
U.S. Clean Water Act, 1972	Regulates discharges of pollutants into the waters of the U.S. and establishes water quality standards for surface waters. Implementation and enforcement may be delegated to the States and incorporated into their regulatory programs.
U.S. Toxic Substances Control Act (TSCA)	Addresses human health and environmental impacts of chemicals in industrial use through a combination of voluntary and regulatory risk management activities.
Ontario Water Resources Act, 1990 and Environmental Protection Act, 1990	Provincial regulation of industrial discharges of contaminants from prescribed industrial sectors into surface waters.
Michigan Natural Resources and Protection Act, 1994	Establishes permitting and regulatory programs for water quality.
U.S. Great Lakes Legacy Act, 2002	Provides federal funding to accelerate contaminated sediment remediation in Areas of Concern.

Table 20. Regulatory chemical contaminant reduction legislation by different government agencies. State also implement programs that regulate chemical discharges to the environment (soil, air, water) and clean up contaminated waste sites that pose environmental or health risks.

well underway, but combined systems remain and can result in point source pollution. Several Acts and pieces of legislation support compliance (permitting) and enforcement programs that prevent the creation of contaminants at the source, control the direct discharge of contaminants, and reduce public and environment risks posed by chemicals (Table 20).

Non-Point Source Pollution

Diffuse chemical pollution from agricultural and urban activities occurs throughout the Lake Erie watershed. Non-point source pollution programs, described in Chapter 5.1 *Strategies to Reduce Nutrient and Bacterial Pollution* will also help reduce chemical loadings to Lake Erie.

Contaminated Bottom Sediments

Prior to pollution laws coming into effect beginning in the 1970s, pollutants were released directly to surface waters and settled into the sediment at the bottom of rivers and harbors. Polluted bottom sediments in Lake Erie are most often contaminated with toxic chemicals such as PCBs, PAHs, dioxins, heavy metals like mercury, as well as oil, grease or other petroleum by-products.

In Lake Erie, remediating contaminated bottom sediments has been a focus in the Detroit River, St. Clair River, Rouge River, Clinton River, Maumee River, Black River, Cuyahoga River, Ashtabula River and Buffalo River Areas of Concern (AOCs). Appendix C provides more information on the AOCs in Lake Erie and the St. Clair-Detroit River System (SCDRS). Ongoing work within these AOCs will remediate contaminated sediments and other site-specific remediation efforts will remove contaminant sources. Considerable progress being made at AOCs via Federal, State, Provincial, municipal and industry funding partnerships, including:

- A Canadian multi-agency technical team has been working toward developing a sediment management plan to clean up mercury-contaminated bottom sediments along the Ontario shoreline of the St. Clair River.
- Remediation design has been completed to remove about 215,000 cubic yards (164,400 cubic meters) of sediment contaminated with PCBs, PAHs, PCNs, mercury, and non-aqueous phase liquids (NAPLs) from the Trenton Channel in the Detroit River.
- Remediation design is expected for cleanup of Monquagon Creek, a Detroit River tributary. The project will involve 50,000 cubic yards (38,200 cubic meters) of sediment contaminated with of PAHs, PCBs, mercury, 2,4-Di-tert-pentylphenol, and total petroleum hydrocarbons.
- Work has been initiated to remove about 53,500 cubic meters (70,000 cubic yards) of PAH and metal contaminated bottom sediment from the Rouge River-Old Channel.
- More than 1 million cubic yards of PCB, PAH, lead and mercury contaminated bottom sediments were removed from the Buffalo River AOC from 2011 to 2014. Partners included U.S. EPA, USACE, NYSDEC, Buffalo Niagara Riverkeeper, and Honeywell.
- Following the completion of two dredging projects and a large habitat restoration project in 2013, all management actions at the Ashtabula River AOC have been completed. The two remaining BUIs are Restriction on Dredging Activities and Fish Tumors or Other Deformities.

Remediation of contaminated sediments at AOCs has been a decades-long process that remains underway. However, some AOCs have been de-listed, and management actions are complete or nearly complete for most others. Remediation has set the stage for habitat restoration that, ultimately, could provide the basis for coastal community revitalization via economic benefits from restored ecosystem services.

5.2.3 OTHER ACTIVITIES UNDER THE AGREEMENT THAT ADVANCE PROGRESS ON CHEMICAL POLLUTION

Article 4 of the 2012 Agreement commits the Parties to implement programs for pollution abatement, control, and prevention for industrial sources, contaminated sediments, and radioactive materials. Article 6 commits the Parties to notification and response protocols under the Canada-United States Joint Inland Pollution Contingency Plan to advise each other of threats of a pollution incident, or planned activities that could lead to a pollution incident.

Binational efforts to address contaminants are also being taken through the Agreement's Chemicals of Mutual Concern (CMC) Annex, such as:

- Preparing binational strategies for CMCs;
- Coordinating the development and application of water quality standards, objectives, criteria, and guidelines for CMCs;
- Reducing releases and products containing CMCs throughout entire life cycles; and
- Promoting the use of safer chemicals.

Canada and the United States have designated a list of eight chemicals as the first suite of CMCs identified by the CMC Annex under the 2012 Agreement:

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

Binational strategies for PCBs and HBCD have been issued and draft strategies for mercury, PBDEs, and SCCPs have been released for public review (available at https://binational.net/annexes/a3/); draft strategies for the remaining CMCs will soon be available for public review. These strategies can be used by the Canadian and U.S. Governments, and their partners, as guidance to identify, prioritize and implement actions to reduce CMCs.

The Agreement's Areas of Concern Annex reaffirms the commitment to restore water quality and ecosystem health in these Great Lakes areas. Federal, provincial, and state agencies, continue to work with local stakeholders to implement Remedial Action Plans for the St. Clair River, Clinton River, Detroit River, Rouge River, River Raisin, Maumee River, Black River, Cuyahoga River, Ashtabula River and Buffalo River AOCs. Canada's Chemicals Management Plan allows the

Government of Canada to assess and manage, where appropriate, the potential health and ecological risks associated with chemical substances. Since the launch of CMP in 2006, the Government of Canada has assessed over 3,500 substances, and 457 existing chemicals have been found to be harmful to the environment and/or human health. For these substances, 90 risk management actions have been implemented, and additional risk management tools are in development.

The U.S. Toxics Release Inventory developed under Section 313 of the Emergency Planning and Community Right-to-Know Act is a resource for learning about toxic chemical releases and pollution prevention activities reported by industrial and federal facilities. TRI data support informed decision-making by communities, government agencies, companies, and others.

5.2.4 LAKE ERIE PARTNERSHIP ACTIONS THAT ADDRESS CHEMICAL POLLUTION

In consideration of the trends in chemical contaminant concentrations, the main contaminant sources, and impacts explained above and in Chapters 4.3 and 4.4, the member agencies of the Lake Erie Partnership have developed chemical management actions and identified the agencies who will lead project implementation (Table 21).

Over the next five years, member agencies of the Lake Erie Partnership will encourage and support chemical contaminant reduction efforts and work with scientists to understand and reduce the impacts of chemicals in the waters of Lake Erie and the SCDRS. This will be achieved by a combination of binational and domestic programs and other measures.

The Lake Erie Partnership will track and report out on the status of chemical contaminant monitoring and site remediation. However, not all of the member agencies of the Lake Erie Partnership are responsible for contaminant monitoring, surveillance, and implementation. Rather, actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

5.2.5 ASSESSING THE EFFECTIVENESS OF CHEMICAL CONTAMINANT CONTROL EFFORTS

Chemical contaminant monitoring and surveillance programs assess the status and trends of chemical contaminants and reveal the presence or absence of newer compounds that may not have been monitored or detected in the past. The programs highlighted in this sub-section will allow us to assess the effectiveness of the LAMP Actions over the next five years. Examples of existing domestic and binational surveillance and monitoring programs in the Great Lakes include:

- ***Open Water Chemical Monitoring Programs*:** ECCC and the U.S. EPA conduct ship-based open water monitoring of chemicals in water, fish and bottom sediment as part of Great Lakes surveillance.
- ***Nearshore Chemical Monitoring Programs:*** State and U.S. federal partners sample contaminants in Lake Erie nearshore sediments and fish as part of the National Coastal Condition Assessment Survey. OMECP maintains a Great Lakes nearshore monitoring program for contaminants in water, sediments and benthic invertebrates.
- ***Wildlife Contaminants***: ECCC annually monitors concentrations of persistent organic pollutants and metals in Herring Gull eggs from three colonies in Lake Erie. Gull colonies are also monitored by EGLE in Michigan.
- ***Fish Contaminants:*** OMECP, supported by OMNRF, and State natural resource agencies/health departments collect fish and monitor contaminants on an as-needed basis in support of state and provincial fish consumption advisory efforts. The Great Lakes Consortium for Fish Consumption Advisories, a collaboration of fish advisory program managers from government health, water quality, and fisheries agencies bordering the Great Lakes, also use the data to develop fish consumption advice. Top predator fish are also sampled by the U.S. EPA's Great Lakes National Program Office and ECCC's Fish Contaminants Monitoring and Surveillance Program. NYSDEC and OMECP have monitored young-of-the-year fish to assess persistent organic contaminants in the Great Lakes Basin dating back to the 1970s. Young-of-the-year are excellent bio-monitors because they are ubiquitous, relatively abundant, are localized nearshore in calm waters and have a limited exposure period during which they can bioaccumulate organic compounds of concern such as PCB and organochlorine pesticides. In

#	LAKE ERIE PARTNERSHIP ACTIONS 2019-2023	AGENCIES INVOLVED
ADDRESSING POINT SOURCE CHEMICAL CONTAMINANTS		
6	Federal, provincial, state and regulatory partners monitor and ensure compliance with clean water laws and regulations (see Table 20 above).	USEPA, OEPA, NYSDEC, EGLE, OMECP
7	Provide support and funding assistance for municipal wastewater infrastructure programs/improvements.	OEPA, NYSDEC, EGLE
ADDRESSING SEDIMENT CHEMICAL CONTAMINANT REMEDIATION		
8	Superfund and AOC specific actions, including sediment remediation activities in the Canadian St. Clair River AOC and in the U.S. Detroit River AOC and Rouge River AOC.	USEPA, ECCC, OMECP, EGLE
9	Proper management of sediment dredged from federal navigation channels in Lake Erie, as well as non-federal/recreational harbor areas.	USACE, OEPA, NYSDEC, EGLE
ADDRESSING NON-POINT SOURCE CHEMICAL CONTAMINANTS		
10	Efforts to ensure NPS pollution from brownfields/remedial sites (via groundwater migration), stormwater (e.g., GI projects) are also covered.	EGLE, States
ADDRESSING CHEMICAL CONTAMINANT SCIENCE, SURVEILLANCE AND MONITORING		
11	Continue monitoring and periodic reporting on atmospheric pollutant deposition at Great Lakes stations.	ECCC, USEPA, OMECP
12	Continue long-term monitoring of Lake Erie and SCDRS water and sediment contaminants to examine legacy organics, PAHs, trace metals, mercury, and selected new and emerging compounds.	ECCC, USEPA, OEPA, EGLE, OMECP, NOAA
13	Conduct fish contaminant monitoring between 2019 and 2023.	MDHHS, EGLE, PA DEP, OEPA, ODNR, USEPA, OMECP, OMNRF NYSDEC
14	Conduct annual Herring Gull monitoring in each year between 2019 and 2023 at sampling locations within the Lake Erie basin.	ECCC, EGLE
15	Support the development and implementation of the Chemicals of Mutual Concern binational strategies	ECCC, USEPA

Table 21. Lake Erie Partnership actions that address chemical contaminants over the next five years

Michigan, EGLE's Surface Water Assessment Section (SWAS) contributes to the annual fish advisory by coordinating fish collections and contaminant analyses. The data collected by SWAS is used by the Michigan Department of Health and Human Services to develop Eat Safe Fish Guides that are updated annually.

- ***Surface Water Quality Monitoring Programs:*** The U.S. States maintain surface water quality monitoring programs in order to meet the reporting requirements under the U.S. Federal Clean Water Act (CWA) Section 305(b) and Section 303(d), which are used to communicate information to the public about the health of the nation's waters. States are required to report every two years on the quality of all water resources in the state and to identify the subset of state waterbodies where water quality standards are not met and where uses are not supported. In Ontario, the OMECP maintains a provincial surface water quality monitoring network which measures water quality in rivers and streams across Ontario. A standard set of water quality indicators is monitored at each station, including chloride, nutrients, suspended solids, trace metals and other general chemistry parameters.
- ***Sediment Contaminant Monitoring:*** U.S. Federal and State agencies and Canadian federal and Provincial agencies monitor contaminant levels in sediment on an as-needed basis in support of navigational/recreational dredging, site-specific investigative and remedial projects (including AOCs), and other agency monitoring and assessment program efforts.

5.2.6 ACTIONS THAT EVERYONE CAN TAKE

The public is encouraged to do its part to prevent chemical contaminants from entering Lake Erie, Lake St Clair, its connecting channels, watershed streams, lakes, wetlands and groundwater by undertaking the following actions:

- Take household hazardous materials to hazardous waste collection depots;
- Don't burn garbage in barrels, open pits, or outdoor fireplaces, to prevent the release of toxic compounds like dioxins, mercury, lead, etc.;
- Properly dispose of unwanted or expired medication through pharmaceutical take-back programs;
- Choose environmentally-friendly household cleaning and personal care products;
- If you seal your driveway or parking lot, consider use of sealant products that have lower PAH levels.
- Use natural non-toxic pest-control methods.

To reduce risks to human health from Great Lakes fish consumption while maximizing the health benefits of making fish a part of your diet, always follow the recommendations found in Provincial and State guides/advisories to eating sport fish, especially children and pregnant women.

5.3 STRATEGIES TO PROTECT AND RESTORE HABITAT AND NATIVE SPECIES

5.3.1 CONNECTIONS TO THE AGREEMENT GENERAL OBJECTIVES

The main factors contributing to the loss of biological diversity within the Lake Erie basin are chemical contaminants, urban and agricultural nonpoint source pollution, and the loss and alteration of natural habitats due to unsustainable development, dams and barriers, invasive species and climate change. These issues threaten achievement of the following General Objective:

- General Objective 5: Support healthy and productive wetlands and other habitats to sustain resilient populations of native species.

Actions to restore and protect habitat and species will also help support achievement of:

- General Objective 6: 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.

5.3.2 MANAGEMENT OF HABITAT AND SPECIES

Numerous binational, regional, and place-based plans and ecological assessments have been developed to identify threats, recommend conservation action, and implement restoration projects. Some examples include:

- The *International Biodiversity Conservation Strategy for Lake Erie* (Pearsall et al. 2012) identifies the key threats to the biodiversity of Lake Erie and articulates long-term actions to conserve them. www.conservationgateway.org/ConservationByGeography/NorthAmerica/wholesystems/greatlakes/Pages/lakeerie.aspx.
- The binational Western Lake Erie Coastal Conservation Vision project (https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/wholesystems/greatlakes/coasts/wle/Pages/default.aspx) engaged stakeholders to target local actions needed to achieve the biodiversity conservation targets and goals established by the Lake Erie Biodiversity Conservation Strategy. The Lake Erie Committee of the Great Lakes Fishery Commission has developed Fish Community Goals and Objectives for Lake Erie (Ryan et al. 2003) and the SCDRS (McLennan et al. 2003) and supporting Environmental Objectives (Davies et al. 2005), and is currently working towards implementing the Council of Lake Committees' Environmental Principles for Sustainable Fisheries in the Great Lakes Basin http://www.glfc.org/pubs/clc/Environmental%20Principles%20for%20Sustainable%20Fisheries%20in%20the%20Great%20Lakes%20Basin_Mar_2016_CLC%20appproved%20version.pdf. As of December 2018, the Lake Erie Committee is in the process of revising the Fish Community Goals and Objectives.
- Michigan Department of Natural Resources Watershed Assessment Reports and the Michigan Wildlife Action Plan https://www.michigan.gov/dnr/0,4570,7-350-79136_79608_83053---,00.html.
- New York State has a Comprehensive Wildlife Conservation Strategy/State Wildlife Action Plan (SWAP), a Great Lakes Action Agenda, and Habitat Management Plans for Wildlife Management Areas within the Lake Erie watershed.
- The SCDRS Initiative has identified a suite of habitat connectivity-related priority objectives and projects to improve habitat connectivity in the corridor by 2023. Priorities include: increasing riparian complexity/connectivity through increased softened shorelines and native riparian vegetation; increasing continuous area of functional wetlands and their connectivity to the SCDRS; increasing river spawning habitat; and identifying and protecting critical habitat areas for rare species, including river mouth habitats and connectivity within tributaries.
- The Niagara River Habitat Conservation Strategy and Niagara River AOC (NY) Habitat Project Master List includes implementation of coastal and aquatic habitat projects.
- Ontario has a provincial Wetland Conservation Strategy, which provides a framework to guide wetland conservation across the province (OMNRF 2017).
- Ohio's Lake Erie Protection and Restoration Plan includes a Habitat and Species Priority Area and OEPA maintains a comprehensive nearshore monitoring program.

- U.S. and Canadian DAPs outline the State, Provincial and Federal strategies for reducing phosphorus loadings to Lake Erie. Further details are provided in Chapter 5.1.
- The Great Lakes Coastal Wetland Restoration Assessment (https://glcwra.wim.usgs.gov/) supports an online mapper (https://glcwra.wim.usgs.gov/wlera) that helps users identify areas along the U.S. coast that have the most potential to restore coastal wetland habitat.
- The USACE's Great Lakes Coastal Wetland Assembly Engineering with Nature (EWN) Initiative encourages more sustainable delivery of economic, social, and environmental benefits associated with water resources infrastructure through innovation. EWN is a partnering opportunity for the alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits.
- The USACE's Nationwide Permit (NWP) 54, Living Shorelines and NWP 27 Aquatic Habitat Restoration, Establishment, and Enhancement Activities provide opportunities to streamline the permitting process by utilizing natural features and restoration or enhancement of aquatic habitat on aquatic projects.
- The USFWS's Great Lakes Coastal Program provides funding and technical assistance to partners for conservation and restoration of priority coastal habitats, including wetlands, shorelines, uplands, rivers and streams. The regional Program is guided by the Midwest Region Strategic Work Plan (2017-2021), which identifies priority species and focus areas for targeting habitat protection and restoration efforts on the Great Lakes (http://www.fws.gov/midwest/es/coastal/index.html).
- The Great Lakes Coastal Assembly (Assembly), in partnership with Blue Accounting, is working to address the problem of lost and degraded wetlands by developing ecological and socioeconomic metrics, compiling data, and building visualizations to enable tracking progress towards shared goals. By collaboratively setting shared basin-wide goals, identifying strategies to achieve those goals, cataloging investments in coastal wetlands, and reporting on relevant metrics to show progress, the Assembly strives to deliver the data and the context needed to make informed decisions around coastal wetland management.

Lake Erie Partnership agencies are working together to achieve healthy and productive wetlands and other habitats to sustain resilient populations of native species. Many funding programs facilitate habitat and native species conservation (Table 22).

Threats to Lake Erie's biodiversity were determined through a binational, collaborative process and are detailed in the *International Biodiversity Conservation Strategy for Lake Erie* (Pearsall et al. 2012). As well, the Great Lakes Environmental Assessment Mapping project mapped 34 stressors and their cumulative impacts to Lake Erie; key stressors included aquatic habitat alterations, climate change, coastal development, invasive species, non-point source pollution, and toxic chemicals (Allan et al. 2013). Many of these threats and the actions to address them are covered in other sections of Chapter 5, including: *Reducing Nutrient Loss and Bacterial Loading* (5.1), *Preventing and Containing Invasive Species* (5.4), and *Promoting Resilience to Climate Change Impacts* (5.5). This sub-section covers the threats that directly impact Lake Erie habitat and native species.

Shoreline Development and Alterations
Shoreline development and the resulting physical alteration to the land-water interface can disrupt physical processes such as littoral flow and sediment transport and the movement of sand along the shore and back and forth between the shore and the lake bed. This disruption can degrade the structure and function of coastal wetlands and nearshore habitats, reducing spawning and nursery habitat for native fish species (Kowalski and Wilcox 1999, Pearsall et al. 2012). Lake bed modifications due to jetties, groins, piers and shoreline armoring may also make it easier for nearshore aquatic invasive species to supplant more desirable native species (Pearsall et al. 2012).

Regional, multi-jurisdictional initiatives that address and monitor shoreline development and alterations include:

UNITED STATES	CANADA
• U.S. Great Lakes Restoration Initiative https://www.glri.us/ • USFWS Great Lakes Coastal Program https://www.fws.gov/midwest/es/coastal/index.html • USDA, NRCS Conservation Programs https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/ • USEPA Environmental Justice Grants https://www.epa.gov/environmentaljustice • USFWS Partners for Fish and Wildlife https://www.fws.gov/partners/ • USFWS National Fish Passage Program https://www.fws.gov/fisheries/whatwedo/nfpp/nfpp.html • Great Lakes Fish Habitat Partnership http://www.fishhabitat.org/the-partnerships/great-lakes-basin-fish-habitat-partnership • USFWS National Wildlife Refuge System https://www.fws.gov/refuges/ • USFWS National Coastal Wetlands Conservation Grant Program https://www.fws.gov/coastal/coastalgrants/ • Sustain Our Great Lakes http://www.sustainourgreatlakes.org/ • NOAA Great Lakes Habitat Restoration Regional Partnership Grants https://www.fisheries.noaa.gov/grant/2019-noaa-great-lakes-habitat-restoration-regional-partnership-grants • USFS Forest Insect and Disease Mitigation. Reduce Runoff and Enhance Coastal Wetland Filtration GLRI grants https://www.fs.usda.gov/naspf/index.php?q=working-with-us/grants/great-lakes-restoration-initiative	• ECCC Eco-Action Community Funding Program • ECCC National Wetland Conservation Fund; Habitat Stewardship Program • ECCC Environmental Damages Fund • ECCC Aboriginal Fund for Species at Risk • ECCC Great Lakes Protection Initiative - Link to all ECCC programs: http://www.ec.gc.ca/financement-funding/default.asp?lang=En&n=923047A0-1 • Recreational Fisheries Conservation Partnerships Program http://www.dfo-mpo.gc.ca/pnw-ppe/rfcpp-ppcpr/index- eng.html • Ontario's Great Lakes Guardian Fund https://www.ontario.ca/page/great-lakes-guardian-community-fund • Provincial COA and Great Lakes Strategy Funding

Table 22. Examples of Canadian and U.S. funding programs that support rehabilitation of aquatic habitat and native species.

- State Coastal Zone Management Programs promote wise management of the cultural and natural resources of the Lake Erie coast in Michigan, Ohio, Pennsylvania, and New York;

- Under Ontario's *Biodiversity Strategy* and *Great Lakes Strategy*, OMNRF supports biodiversity conservation to reduce ongoing shoreline erosion, and improve the ability of coastal and inland wetlands to control water flow and reduce sediment phosphorus loads; and

- The Great Lakes Coastal Wetland Monitoring Program monitors Great Lakes coastal wetland biota, habitat, and water quality.

Habitat Connectivity

Dams, barriers and other anthropogenic structures (i.e., culverts, water control structures, impoundments, and dikes) that block or disrupt connectivity among water bodies are considered significant threats to migratory fish, coastal wetlands and the nearshore zone of Lake Erie (Pearsall et al. 2012). This is because anthropogenic structures can hinder natural movements of aquatic organisms (Kowalski et al 2014) or disrupt ecologically functional processes including the transportation of nutrient, suspended sediments, and other materials.

Many native Lake Erie fish species, such as walleye and lake sturgeon, have (or historically had) populations that migrate into tributaries to spawn (Trautman 1981). However, only 36% of Lake Erie tributary habitats are currently accessible to Lake Erie fishes due to blockage from dams (Pearsall et al. 2012). Other aquatic organisms also require access to these tributary habitats, including imperiled freshwater Unionid mussels, such as the federally endangered Snuffbox Mussel (*Epioblasma triquetra*), that are dependent on species of tributary fish to complete their juvenile stage and for dispersal (Nichols and Wilcox 2001, Sietman et al. 2001). However, dams may help prevent the spread of Sea Lamprey and other aquatic invasive species, and management decisions must consider their benefit for Sea Lamprey control before dam replacement, removal, or modification.

Tributaries are critically important for nearshore habitats, supplying materials and nutrients to the lake. Barriers can disrupt the downstream delivery of nutrients, sediment, and woody debris from tributaries (Roberts et al. 2007, Csiki and Rhoads 2010, Morang et al. 2011) and can contribute to the loss of these sediments in downstream areas, including the nearshore (O'Brien et al. 1999, Shabica et al. 2004, Garza and Whitman 2004, Meadows et al. 2005). Barriers may also modify the downstream temperature regime of the tributary (Lessard and Hayes 2003). These disruptions can fundamentally change the character of the tributary and the nearshore areas of the lake (Fuller 2002, Postel and Richter 2003, Morang et al. 2011).

Loss of habitat connectivity is not limited to tributaries. Only 10% of the original coastal marshes in western Lake Erie are estimated to be remaining today (Herdendorf 1987) and of those about 85% are diked (Johnson et al. 1997) and are therefore not accessible to nearshore aquatic communities that rely on the marshes for spawning, feeding, protection from predation and other activities at various times throughout their life cycles (Kowalski et al 2014). Dikes also impede other nearshore processes such as longshore transport of currents and sediment.

Federal, regional, and multi-jurisdictional initiatives that examine opportunities for dam decommissioning and dam and barrier removal include:

- Fishwerks is a web-based GIS platform that allows users to access tools that identify barriers which, if removed, would maximize habitat improvements for migratory fish. www.greatlakesconnectivity.org.
- Multiple federal, provincial and municipal partners, including ECCC and the OMNRF, are using a Decision Analysis approach to assess options for remediating the impacts of the Dunnvillle Dam, located just 7 km upstream of the Lake Erie on the Grand River in Ontario.
- Ballville Dam Removal in Ohio, completed in 2018, is restoring and expanding upon self-sustaining fishery resources within the lower Sandusky River and Lake Erie by providing fish passage at the Ballville Dam impoundment site in both upstream and downstream directions, resulting in a net gain in the amount of free-flowing riverine habitat for fish and wildlife and additional spawning habitat for anadromous lake fish.
- Multiple dam removals and fish passage projects are being implemented in the SCDRS to achieve priority objectives related to increasing riparian complexity and connectivity to improve habitat for fish and other wildlife in the SCDRS and associated tributaries.
- The North Atlantic Aquatic Connectivity Collaborative, consisting of individuals from universities, conservation organizations, and state (including NY and PA) and federal natural resource and transportation departments, is focused on improving aquatic connectivity. It has developed common protocols for assessing road-stream crossings (culverts and bridges) for update and replacement and has developed a regional database for these field data. (https://streamcontinuity.org/index.htm).
- The USFWS Midwest Region Coastal Program Strategic Plan identifies Lake Sturgeon and Snuffbox Mussel as priority species for its Western Lake Erie/Lake St. Clair Focus Area and targets dam and barrier removal as a key conservation strategy for both species.

Loss of Critical Habitat in Connecting Waterways

Millions of tons of limestone bedrock, cobble, and gravel were removed from the St. Clair and Detroit Rivers to create over 100 km of shipping channels beginning in the early 1900s (Manny et al. 2014). Those substrates were spawning and nursery habitat for Lake Sturgeon, Walleye, Lake Whitefish and numerous other native fish species (Goodyear et al. 1982). Increasing the amount of spawning habitat in the SCDRS is a priority objective of the binational SCDRS Initiative.

Emergent coastal wetlands in connecting waterways form important habitat for aquatic insects, shellfish and small fish, nursery and spawning habitat for fish species including Walleye and Lake Sturgeon, and foraging habitat for Northern Pike (*Esox lucius*), Grass Pickerel (*Esox americanus vermiculatus*) and Muskellunge (*Esox masquinongy*), and nesting habitat for waterfowl and colonial water birds such as Black Tern (*Chlidonias niger*), Common Tern, and Blue-winged Teal (*Anas discors*). The upper Niagara River, which was once lined by coastal wetlands, now contains 77% artificially hardened shoreline (Pearsall et al. 2012). Furthermore, the loss of a graduated shoreline caused by infilling of former lowlands, shoreline armoring, and removal of large woody debris, means that the minimal patches of existing coastal wetlands occur at the base of vertical banks, or several meters from the shoreline. In their current state, coastal wetlands in the upper Niagara River are significantly degraded lacking important connectivity with upland vegetation and seasonal inundation of vegetated lands. Restoration of emergent coastal wetlands is a focus of agencies working to address habitat concerns in the Upper Niagara River as part of the U.S. and Canadian Niagara River Remedial Action Plans.

Degraded River Mouth Deltas

Rivermouths are the mixing zones that occur at the confluence between riverine and lake ecosystems. The convergence of these two ecosystem types creates a unique environment that is biologically productive and provides critical habitats for the life-cycles of many species. There is a nascent effort to replace lost river deltas. Deltas are difficult to restore due to presence of shipping infrastructure, but their wetland habitats can be recreated via engineered structures that trap sediment such that river mouth areas with protected, shallow substrates can once again exist. This has the added benefit of beneficial re-use of dredged sediment from navigation channels.

Food Web Changes

The Lake Erie food web has seen significant changes resulting from the invasion of dreissenid mussels and round gobies, details of which are covered in the invasive species sections 4.7 *State of Aquatic and Terrestrial Invasive Species* and 5.4 *Preventing and Containing Invasive Species.*

5.3.3 OTHER ACTIVITIES UNDER THE AGREEMENT THAT ADVANCE PROGRESS TOWARD PROTECTING AND RESTORING HABITAT AND SPECIES

Article 4 (2.c) of the Agreement commits the U.S. and Canada to implement conservation programs to restore and protect habitat and recover and protect species. The Habitat and Species Annex of the Agreement calls for a baseline survey of existing habitat against which to establish an ecosystem target of net habitat gain to measure progress.

5.3.4 LAKE ERIE PARTNERSHIP ACTIONS THAT ADDRESS HABITAT AND SPECIES

In consideration of the current condition of aquatic habitat and native species, and an understanding of the geographic scope of threats and extent of localized impacts, as explained in Chapter 4.5 and above, member agencies of the Lake Erie Partnership have developed habitat and species monitoring and management actions (Table 23).

Over the next five years, the Lake Erie Partnership, in collaboration with partners leading domestic programs and other initiatives, will work to better understand and address loss of habitat and the impacts to native species. This will be achieved by a combination of binational and domestic initiatives and other measures.

5.3.5 ASSESSING HABITAT AND SPECIES PROGRAM EFFECTIVENESS

Federal, state, provincial, tribal and First Nation governments, academic institutions, and not-for-profit organizations work to assess aquatic habitat and native species populations and trends, including:

- GLFC Lake Erie Committee, Habitat Task Group Technical Reports and Publications;
- USGS Bottom Trawl and Acoustics Surveys;
- Area of Concern (AOC) programs;
- St. Clair – Detroit River System Initiative (SCDRS);
- Great Lakes Coastal Wetland Monitoring Program assessment and inventories; and
- Provincial, state, First Nation and tribal habitat and fish community monitoring programs;
- USEPA, NOAA, OMECP, OMNRF, and State Lake Erie monitoring programs

The findings from these programs will allow us to assess the effectiveness of the LAMP actions over the next five years.

5.3.6 ACTIONS THAT EVERYONE CAN TAKE

Protecting and restoring habitats and species involves the coordination of many different government and non-governmental organizations, and the pursuit implementation of actions by various partners and the public. Here are some ways that you can do your part:

- Maintain natural vegetation along the coast, streams, and wetlands; resist the urge to "tidy up" the beach. Natural vegetation and woody debris serve as habitat;
- Plant native trees and shrubs on your property;
- Get involved with shoreline clean up events, such as the Alliance for the Great Lakes Adopt-a-Beach Program (http://greatlakesadopt.org/);
- Consider working with neighbors, not-for profit organizations and municipalities, to restore beach dune health by installing sand fencing and planting dune grasses;
- Stay on constructed beach and dune paths and avoid trampling the sparse and fragile vegetation in these areas;
- Support and/or volunteer with local conservation authorities, stewardship councils and non-governmental environmental organizations;
- Access shoreline stewardship guides for advice(e.g., https://bertmillernatureclub.org/wp-content/uploads/sites/15/2017/11/Dune-Restoration-Brochure.pdf, Ohio Coastal Design Manual, Lake Erie Shore Erosion Management Plan), including the Michigan Natural Shoreline Partnership http://www.mishorelinepartnership.org/about-mnspcontacts.html;
- Share your knowledge with your friends, neighbors, cottage renters or even strangers, about the rarity and ecological importance of each of the special shoreline types.

#	LAKE ERIE PARTNERSHIP ACTIONS, 2019-2023	AGENCIES INVOLVED
16	***Spawning Reefs:*** Increase functional river spawning habitat for native species in the main channel and tributaries of the Detroit and St. Clair Rivers.	OMNRF, MDNR, USGS, USFWS
17	***Aquatic Habitat Protection and Restoration:*** • GLFC Habitat Task Group is developing a Priority Management Area exercise to help identify priority areas. • Implementation of the Niagara River AOC (U.S.) Habitat and Species Restoration Plan • Implement SCDRS Initiative projects identified to achieve the habitat connectivity-related priority objectives by 2023 • Continued monitoring of terrestrial and aquatic invasive species and implementation of boat launch stewards. • Promote on-farm habitat restoration around streams, wetlands and woodlots through development and implementation of environmental farm plans	OMNRF, ODNR, MDNR, PADNR NYSDEC, USACE, USEPA, USFS SCDRS agencies (NOAA, USFWS, USGS, MDNR, EGLE, USEPA) OMAFRA
18	***Stream Connectivity:*** • Lowering and modification of the Springville (Scoby) Dam on Cattaraugus Creek (New York) • Assess options for remediating impacts of Dunnville Dam on Grand River (Ontario) • Ballville Dam Removal (Ohio) • SCDRS Initiative projects identified to achieve connectivity-related priority objectives of the Initiative • Promote North Atlantic Aquatic Connectivity Collaborative road-stream crossing assessments. • Install 2 aquatic organism passage structures within the Western Lake Erie/Lake St. Clair Focus Area (Great Lakes Coastal Program 5-year Target)	USACE, NYSDEC, Erie County (NY) OMNRF, ECCC ODNR USFWS, MDNR, EGLE, NOAA, USGS, USEPA USFWS, NYSDEC USFWS
19	***Species Recovery:*** • Implementation of the Great Lakes Fishery Commission *Strategic Plan for the Rehabilitation of Lake Trout in Lake Erie, 2008-2020* • Maumee River Lake Sturgeon restoration (Ohio) • SCDRS Initiative projects identified to achieve the rare species-related priority objectives of the Initiative	NYSDEC, OMNRF, MDNR, ODNR, USFS USFWS, ODNR USFWS, USGS, NOAA, DFO, MDNR
20	***Coastal Wetlands:*** • Sandusky Bay Initiative • Woodlawn Beach (NYS) Wetland Enhancement • Continued shoreline softening and coastal wetland restoration projects in connecting channels and embayments • Restoration of hydrologic connectivity between coastal wetlands and Lake Erie • SCDRS Initiative projects identified to achieve the coastal wetland-related priority objectives of the Initiative • Assess coastal wetland health and vulnerability to climate change • Restore/Enhance 110 acres of coastal wetland within the Western Lake Erie/Lake St. Clair Focus Area (Great Lakes Coastal Program 5-year Target)	ODNR, OEPA NYSDEC USEPA, OMNRF, USGS, USFWS, USFS USACE, USFWS USFWS, NOAA, USACE, USGS, MDNR, ODNR, EGLE ECCC, OMNRF USFWS
21	***Dunes and Bluffs:*** • Development of a decision-support tool/technical guidance for natural and nature-based features shoreline management along NY's Great Lakes. • Implementation of State Coastal Management Programs and efforts to promote the use of natural and nature-based features shoreline protection and stabilization techniques.	NYSDEC, USFS NYSDEC, ODNR, NOAA
22	***Islands:*** Support protection and restoration of Lake Erie and SCDRS islands, particularly unique habitats and globally rare or endemic species	USFWS, ECCC, EGLE, Province

Table 23. Lake Erie Partnership actions that address aquatic habitat and native species issues from 2019-2023

5.4 STRATEGIES TO PREVENT AND CONTAIN INVASIVE SPECIES

5.4.1 CONNECTIONS TO THE AGREEMENT GENERAL OBJECTIVES

The introduction, establishment, and spread of invasive species are significant threats to Lake Erie water quality and biodiversity. An aquatic invasive species (AIS) is one that is not native and whose introduction causes harm, or is likely to cause harm, to the economy, environment, or human health. The history of Great Lakes non-native species introductions can be accessed through Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS). Over the years, 187 aquatic non-native species have become established in the Great Lakes basin but only a subset of these species are considered invasive. Some of the most harmful and well-known invaders include Sea Lamprey, which continue to impact valuable commercial and recreational fisheries, Dreissenid mussels, which have altered physical habitats and nutrient cycling in the lake, promoting harmful algal blooms and botulinum toxin (Hecky et al. 2004, Perez-Fuentetaja et al. 2011), and nonnative *Phragmites australis australis*, an invasive clonal grass that has been aggressively colonizing wetlands throughout the Great Lakes basin freshwater coastal marshes and displacing resident plant species with dense, nearly monotypic stands that provide little benefit to native wildlife (Trebitz and Taylor 2007, Whyte et al. 2008, Tulbure and Johnston 2010, Bourgeau-Chavez et al 2012, Great Lakes *Phragmites* Collaborative 2018).

Aquatic invasive species are undermining efforts to restore and protect ecosystem health, water quality, and the full achievement of the following General Objectives:

- General Objective 4: Be free from pollutants (i.e., botulinum toxin) 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;
- General Objective 5: Support healthy and productive wetlands and other habitats to sustain resilient populations of native species;
- General Objective 6: 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; and
- General 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 the quality of the Waters of the Great Lakes.

5.4.2 MANAGEMENT OF INVASIVE SPECIES

Existing domestic legislation, initiatives, and programs that serve to limit the introduction and spread of invasive species are identified in Table 24. The most effective approach to prevent the introduction and spread of new invasive species is to manage the pathways through which they enter and spread within the Great Lakes Basin. The key invasion pathways are described in this sub-section along with examples of existing management approaches.

The government of Ontario published an Invasive Species Strategic Plan (2012) that coordinates actions by provincial and federal organizations. It builds on Canada's Invasive Alien Species Strategy (2004) and is focused on preventing new invaders from arriving and surviving in the province, slowing or reversing the spread of existing invasive species and reducing the harmful impacts of existing invasive species.

In the United States, the National Invasive Species Council published a National Invasive Species Management Plan (2016-2018) that directs the actions of thirteen federal agencies and their partners on invasive species issues by establishing policy and planning needed to prevent, eradicate, and/or control invasive species (https://www.doi.gov/sites/doi.gov/files/uploads/2016-2018-nisc-management-plan.pdf).

The 2013 U.S. Forest Service National Strategic Framework for Invasive Species Management defines an Invasive Species Systems Approach (ISSA) that identifies four key elements: (1) prevention, (2) detection, (3) control and management, and (4) restoration and rehabilitation. The framework prioritizes these elements for

invasive insects, pathogens, plants, wildlife, and fish that threaten terrestrial and aquatic ecosystems.

Examples of Invasive Species Reduction Measures	
Ontario Invasive Species Act, 2015	Rules to prevent and control the spread of invasive species in Ontario.
National Invasive Species Act, 1996	U.S. Federal law intended to prevent invasive species from entering inland waters through ballast water carried by ships.
Michigan's Natural Resources and Environmental Protection Act, 1994 (NREPA)	Part 413 of NREPA defines prohibited and restricted species in Michigan and limits the possession, import or sale of such species.
Ohio SB 192 of 2014	Senate Bill 192 grants regulatory authority over invasive plants to the Ohio Department of Agriculture (ODA). This authority includes the identification of invasive plant species and the establishment of prohibited activities regarding invasive plants.
New York Environmental Conservation Law	New York Codes, Rules and Regulations (NYCRR) Title 6, Chapter V, Subchapter C: Part 575 establishes procedures to identify and classify invasive species and to establish a permit system to restrict the sale, purchase, possession, propagation, introduction, importation, and transport of invasive species in New York, as part of the Department of Environmental Conservation's statewide invasive species management program; Part 576 establishes reasonable precautions that must be taken by persons launching watercraft or floating docks into public waterbodies to prevent the spread of aquatic invasive species.
Canada Fisheries Act, 1985	Aquatic Invasive Species Regulations (2015) made under this act on import, possession, transport, release.
Lacey Act, 1900	U.S. Federal act that prevents transport of species designated as 'Injurious to Wildlife'.

Table 24. Examples of invasive species reduction initiatives by Federal, State, and Provincial agencies

The states of Michigan, Ohio, Pennsylvania, and New York also have published Aquatic Invasive Species Management Plans (available at https://www.anstaskforce.gov/stateplans.php).
The Michigan Aquatic Invasive Species Management Plan identifies strategic actions to prevent the introduction and dispersal of aquatic invasive species, detect and respond to new invaders, and minimize the harmful effects of aquatic invasive species in Michigan waters.

The Ohio State Management Plan for Aquatic Invasive Species and the Asian Carp Tactical Plan (2014-2020) (http://ohiodnr.gov/portals/0/pdfs/invasives/asian-carp-tactical-plan-2014.pdf) focuses on relative risks and meaningful strategies related to preventing Bighead and Silver Carp introduction/pathways into Lake Erie. The Ohio State Management Plan also includes a Rapid Response component that addresses the potential eradication of newly discovered AIS with limited distribution.
The Pennsylvania Aquatic Invasive Species Management Plan was published in 2006.

The New York Aquatic Species Invasive Management Plan and the Rapid Response Framework for Invasive Species (NYDEC) provide resource managers with a response system and list of procedures that can be initiated upon discovery of a new invasive species infestation. The draft New York Invasive Species Comprehensive Management Plan (ISCMP) was issued to minimize the introduction, establishment and spread of invasive species throughout NYS.

Additionally, a binational study, The Ecological Risk Assessment of Grass Carp for the Great Lakes Basin, identified the potential susceptibility of Lake Erie to Grass Carp introduction and establishment, further underscoring the need for management action. Based on available physical habitat, temperature profile, high biological productivity and other factors, Lake Erie was identified as potentially highly susceptible to Grass Carp establishment relative to other Great Lakes. To address the threat, in 2016, Michigan DNR and collaborating agencies initiated the development of an Adaptive Management Framework for Grass Carp Control in Lake Erie to inform the identification, prioritization, selection, and implementation of key strategic actions. Lake Erie management and research agencies are now utilizing this structured decision making model to serve as a baseline process to inform and evaluate the implementation of new actions including: gathering key data on Grass Carp population status and life history; develop new, state-of the-art detection tools; quantify and map potential habitat available for Grass Carp within the basin; and develop effective control options for potential use within a comprehensive Lake Erie control strategy.

Ballast Water

Eggs, larvae, and juveniles of larger species (fish, mollusks, crustaceans) and the adults of smaller species can be transported by ship ballast water. In the 1990s, an average of one non-native species was found to be established in the Great Lakes about every 8 months, or roughly 1.5 new species per year. The peak rate (based on a running decadal average) was 2.4 per year in 1996. However, recent practices, including ballast water exchange or treatment (started in 1993) and sediment management (started in 2006), have significantly reduced the rate of introduction.

- Ballast water regulatory regimes are being implemented at the international, national and state levels. The Coast Guard and the EPA currently regulate ballast water management and discharges with States regulating the quality of their waters. Vessel incidental discharges are currently regulated by the EPA's 2013 Vessel General Permit (VGP) program. The Vessel Incidental Discharge Act (VIDA), enacted in December 2018, amends the Clean Water Act to establish "Uniform National Standards for Discharges Incidental to Normal Operation of Vessels," and authorizes the EPA to promulgate new regulations to establish federal standards of performance for marine pollution control devices for each type of discharge incidental to the normal operation of covered vessels, including ballast water and graywater. Regulations to be developed under VIDA will replace the 2013 VGP program and the current Coast Guard ballast water management rules. The EPA has two years to promulgate the new regulations, and the United States Coast Guard will administer and enforce the new regulations.
- In 2009, the U.S. Saint Lawrence Seaway Development Corporation, in conjunction with the International Joint Commission, initiated the formation of the Great Lakes Ballast Water Collaborative to share information and facilitate communication and collaboration among key stakeholders.
- Significant efforts are underway to improve design and performance testing of ballast water management systems and to develop eDNA tools to detect the presence of aquatic invasive species in ballast water.

Illegal Trade of Non-native Species

Invasive, non-native plants and animals which could potentially cause significant harm to the Great Lakes region may be entering through illegal trade.

- A risk analysis of illegal trade and transport into Great Lakes jurisdictions was completed by USFWS and TNC and a report of these findings was delivered to the Great Lakes Fishery Commission's binational Law Enforcement Committee (add date). The report recommends risk management efforts to address the unacceptable risks documented for invasive species regulated by state, provincial, and federal agencies and sold via the internet as live bait, live food, aquaculture, private pond/lake stocking, water garden, aquarium/pet, and cultural release pathways. The aquatic invasive species Subcommittee will continue to work with the Law Enforcement Committee to address risk management needs described in the risk analysis report.
- The Ontario Invasive Species Act (2015) prohibits the import, possession, deposit, release, transport, purchase or sale of selected invasive species to prevent their arrival and control their spread. For more information, go to https://news.ontario.ca/mnr/en/2016/11/prohibited-and-restricted-invasive-ecies.html.

- In 2014, New York adopted regulation that prohibits or regulates the possession, transport, importation, sale, purchase, and introduction of select invasive species. The purpose of this regulation is to help control invasive species by reducing the introduction of new and spread of existing populations. This regulation became effective in 2015. (http://www.dec.ny.gov/animals/99141.html).

- ODA prohibited the sale and distribution of 38 invasive plant species in January of 2018. The Ohio Department of Natural Resources also bans the possession of 35 high risk injurious AIS (http://ohiodnr.gov/invasive-species/aquatic-invasives/injurious-aquatic-invasive-species).

Recreational Activities

Float planes, sailboats, personal watercraft, kayaks, diving equipment, ropes, and fishing gear may transport fragments, larvae, and eggs of invasive species to new bodies of water. In addition to regulations directed at recreational and commercial boating to prevent the spread of aquatic invasive species, education and voluntary compliance are key activities, and governments and non-government organizations offer public awareness programs. For example, boat inspection programs can serve the dual purpose of heightening public awareness of aquatic invasive species and providing inspection of trailered watercraft for AIS.

- In the U.S., a government-industry partnership is working toward development of new recreational boat design standards for building new “AIS-Safe Boats,” and development of United States standards for aquatic invasive species removal from existing recreational boats.
- Michigan’s Natural Resources and Environmental Protection Act of 1994 (NREPA Part 413) makes it illegal to place a boat, boating equipment or a trailer in the water if any of these has an aquatic plant attached.
- Michigan’s Fisheries Order 245.16 makes it unlawful to transport a vessel overland without first draining all water from the live well(s) and bilge, to release live bait into public waters and to transfer live fish from one waterway to another.
- In New York, regulations adopted in 2014 prohibit boats from launching from or leaving NYSDEC launch sites without first draining the boat and cleaning the boat, trailer and equipment of visible plant and animal material. In 2016, statewide regulations known as the Aquatic Invasive Species (AIS) Spread Prevention regulation, require that "reasonable precautions", such as cleaning, draining and treating, are taken to prevent the spread of aquatic invasive species prior to placing watercraft, float planes, and floating docks into public waterbodies. Many New York counties, towns and villages also have laws in place that prohibit the transport of aquatic invasive species on boats, trailers and equipment.
- New York has more than 7,000 lakes, ponds, and rivers that could potentially be exposed to dozens of harmful aquatic invasive species (AIS) that have already been introduced and many more species that pose a threat. In 2015, New York released its updated Aquatic Invasive Species Management Plan to help prevent the introduction and spread of aquatic invasive species into and within New York State's waters. One of the main pathways for transfer of aquatic invasive species between waterbodies is recreational water vehicles (boats, canoes, kayaks, and jet skis). For this reason, the top priority of the statewide AIS management plan is to expand the coverage of boat stewardship programs across the state, particularly in popular, high-use areas.
- In Canada, a National Recreational Boating Risk Assessment, with focus on the potential movement of aquatic invasive species within Canadian and United States waters of the Great Lakes, was carried out during 2015. The products of this assessment will assist in identifying focal areas for minimizing risk of recreational boaters spreading aquatic invasive species.

Canals and Waterways

Connecting rivers and canals allow free movement of aquatic invasive species across watersheds and lakes.

- The Great Lakes and Mississippi River Inter-basin Study (GLMRIS) Report developed by the U.S. Army Corps of Engineers (USACE) presents results of a multi-year study regarding the range of options and technologies available to reduce the risk of future aquatic nuisance species movements between the Great Lakes and Mississippi River basins through aquatic pathways. For more information, go to http://glmris.anl.gov/glmris-report/.

- The Asian Carp Regional Coordinating Committee (ACRCC), formed in 2009, works to prevent the introduction, establishment, and spread of Bighead, Black, Grass, and Silver Carp populations in the Great Lakes. The ACRCC developed a comprehensive approach focused on prevention and control opportunities in the Illinois Waterway and Chicago Area Waterway System as the primary potential pathway; binational surveillance and early detection of Asian Carp, and assessment and closure of secondary pathways of potential introduction in Indiana and Ohio, are explained in the Asian Carp Action Plan. For more information, go to http://www.asiancarp.us/Documents/2019ActionPlan.pdf.
- Ohio is working to end the risk of transfer of bighead, silver, and black carp, as well as other high risk AIS, through medium risk connections between Lake Erie and Mississippi River basin by working on separation at key points identified in GLMRIS II by the U.S. Army Corps of Engineers. The Ohio Erie Canal connection in Akron, Ohio will be closed to the movement of AIS through raising the tow-path elevation and screening at the Long-lake flood gate and feeder canal and the design for the Little Killbuck Creek connection outside Lodi, Ohio continues.

Additional Efforts Underway

Domestic efforts in Canada and the United States are underway to address invasive species.
The Great Lakes and St. Lawrence Governors and Premiers have signed several agreements aimed at better coordination and cooperation in addressing non-native species issues:

- In 2014, the Governors and Premiers signed a Mutual Aid Agreement that empowered the States and Provinces to work together by sharing staff, expertise, and resources, to address serious regional threats from aquatic invasive species. The agreement itself establishes mutual aid request action protocols and responsibilities, information sharing guidance, and resource sharing, reporting, liability, compensation, and confidentiality guidelines for requesting and assisting parties.
- In 2015, the Governors of Ohio and Michigan and the Premier of Ontario committed to development of a pilot project to harmonize approaches to address aquatic invasive species and further cooperation among the three jurisdictions. The agencies, through the GLFC Law Committee, are documenting current regulatory approaches, and existing fines and penalties for possessing, transporting selling, purchasing and introducing AIS in each jurisdiction.
- In 2013, the Governors and Premiers released the first list of 16 “least wanted” aquatic invasive species that present a serious threat to the Great Lakes - St. Lawrence Basin. Since then, the region’s eight states and two provinces have taken more than 40 actions to prohibit or restrict these high-risk species. In 2018, five additions to the list were announced (http://www.gsgp.org/projects/aquatic-invasive-species/).

New York State Department of Environmental Conservation partners with resource managers, non-governmental organizations, industry, resource users, citizens and other state agencies and stakeholders to combat invasive species. Eight Partnerships for Regional Invasive Species Management (PRISMs; http://nyis.info/prisms-and-partners/) exist across NYS, coordinating partner efforts, recruiting and training citizen volunteers, identifying and delivering education and outreach, establishing early detection and monitoring networks and implementing direct eradication and control efforts. The Western New York PRISM (http://www.wnyprism.org/) covers the Lake Erie watershed within NYS. PRISM, NYSDEC and OPRHP manage boat stewardship programs to check for plant material transport and raise awareness. Starting in 2019, the Western New York PRISM will provide boat steward coverage to more than 20 locations in the Lake Erie and Ontario watersheds.

Sea Lamprey management and control have been ongoing since the late-1950s by the Great Lakes Fishery Commission in collaboration with all levels of government. Adult sea lamprey abundance (approximately 15,000 fish) continues to be above target levels (approximately 3,000) and has remained steady over the previous five years. Sea Lamprey wounding rates (17 marks/100 Lake Trout) also continues to be above the target of 5 marks/100 Lake Trout but has remained steady over the previous five years. Additionally, wounding rates of burbot and steelhead have been increasing over the past several years. Increased control efforts have been implemented since 1999, with a large-scale treatment occurring in 2008-2010, and three to seven tributaries treated annually with lampricide in the past four years. Untreated sources of Sea Lamprey (particularly the Detroit and St. Clair rivers) continue to remain a concern, with more intense survey plans being proposed, to further define larval Sea Lamprey distribution in the SCDRS and to identify previously undiscovered sea lamprey producing tributaries Lampricide control effort dramatically increased during 2008-2010 with the implementation of a large-scale treatment strategy where all known Sea Lamprey-producing tributaries to Lake Erie were treated in consecutive years. Increased control effort was also applied during 2013 with the treatment of twelve tributaries. Assessment and treatment strategies are being developed for the St. Clair River, an area recently identified as a potential source of lamprey production.

Invasive *Phragmites* is mapped using satellite imagery (U.S.) and aerial photographs to monitor its spread. Efforts to manage this species using the best science and approaches are underway in the U.S. by the Great Lakes Commission's Great Lakes *Phragmites* Collaborative (www.greatlakesphragmites.net), the *Phragmites* Adaptive Management Framework (http://www.greatlakesphragmites.net/pamf/), and in Ontario by the Ontario *Phragmites* Working Group (www.opwg.ca). These partnerships were established to improve communication and collaboration and implement a more coordinated, efficient, and strategic approach to managing this invasive plant species. Non-governmental, place-based programs are also active in the control of highly invasive *Phragmites*. Control measures have been implemented in key areas around eth lakes including, Long Point Bay, Rondeau Bay and in Point Pelee (Ontario) and Times Beach (New York).

The **Invasive Mussel Collaborative (IMC)** was established to advance scientifically sound technology for invasive mussel control to produce measurable ecological and economic benefits. The IMC provides a framework for communication and coordination, identifies needs and objectives of resource managers, prioritizes the supporting science, recommends communication strategies, and aligns science and management goals into a common agenda for invasive mussel control. Strong connections with other regions outside of the Great Lakes basin are being developed and provide a framework for application elsewhere.

Grass carp in Lake Erie have received specific attention by federal and state agencies through research to understand fish behavior, habitat use, and levels of reproduction in the watershed, which has informed several interagency response efforts to remove fish from the lake. Grass Carp response efforts are ongoing by state and federal agencies with the goal to eradicate the species from Lake Erie. Grass carp have been detected in the lake since the mid-1980s, but recently the increased captures of fertile adults by commercial fishers and the presence of spawning in the Sandusky and Maumee Rivers have elevated concerns for population expansion. Multi-jurisdictional coordinated and science-based response efforts have been informed by a formal Structured Decision-Making process. There have also been numerous projects implemented to determine risk of the species in the Great Lakes and to help guide the timing and location of response actions to enhance the effectiveness of efforts. The GLFC Lake Erie Committee has led the coordinated binational response efforts and funding has been provided through the Great Lakes Restoration Initiative.

Outreach and Engagement efforts are implemented domestically in Michigan, Ohio, Pennsylvania, New York and Ontario to increase public awareness and involvement in the control of aquatic invasive species. Experts are also working across jurisdictions to support the work of the Great Lakes Panel on Aquatic Nuisance Species, a binational body comprised of representatives from government (State, Provincial, Federal, and Tribal), business and industry, universities, citizen environmental groups, and the public. Examples include:

- The Ontario invading species awareness program is a partnership between the Ontario Federation of Anglers and Hunters and OMNRF. It generates public awareness of aquatic and terrestrial invading species, addresses key pathways contributing to introductions and spread, and facilitates monitoring and tracking initiatives for the spread of new invaders found in Ontario.

- Michigan supports boater outreach through an annual AIS Awareness Week, support of two mobile boat washes, signage at boating access sites, regional outreach programs through Cooperative Invasive Species Management Areas and the statewide Reduce Invasive Pet and Plant Escapes (RIPPLE) campaign.
- Each year New York posts educational signs at boat launches to raise awareness of aquatic invasive species transport, and the Department of Motor vehicles includes an educational brochure in its mailings to those who registered boats. In 2019, AIS information is being made available at all NYS Thruway rest areas. NYSDEC's NYCRR Part 575 mandates that potentially invasive species sold at stores, nurseries or pet shops must include a tag that alerts buyers to the potential invasive nature of that species and recommends alternatives.
- NYSDEC maintains a web page for invasive species K-12 educator resources (https://www.dec.ny.gov/animals/114620.html) including a recently released invasive species curriculum for middle school students (grades 6-8) that is aligned to the New York State P-12 Learning Standards.
- The Great Lakes Sea Grant Network works to curtail the spread of AIS and manage existing invaders more effectively through research and public education.
- The ODNR Division of Wildlife, Ohio Sea Grant, and The Ohio State University produced the Ohio Field Guide to Aquatic Invasive Species. This guide was developed as an education and early detection tool to combat AIS. The guide covers invasive plants, invertebrates, and fish and provides information on identification, habitat, spread, and distribution. An important component of the guide is the notification icon that directs people to report specific AIS that have limited distribution or are yet to be found in Ohio. This will allow for potential eradication of a newly discovered AIS.
- The ODNR Division of Wildlife continues an AIS outreach campaign through Wildlife Forever to target anglers moving bait. This outreach program includes billboards, print media, and items for distribution at events with the slogan "Trash Unused Bait".

5.4.3 OTHER ACTIVITIES UNDER THE AGREEMENT THAT ADVANCE PREVENTION AND CONTAINMENT OF INVASIVE SPECIES

Article 4 of the 2012 Agreement commits the Parties to implement aquatic invasive species programs and other measures to prevent the introduction of new species; control and reduce the spread of existing species; and when feasible, eradicate existing aquatic invasive species.

The Discharges from Vessels Annex is co-led by Transport Canada (TC) and United States Coast Guard (USCG). Efforts under this Annex will establish and implement programs and measures that protect the Great Lakes basin ecosystem from the discharge of aquatic invasive species in ballast water.

The Aquatic Invasive Species Annex is co-led by Fisheries and Oceans Canada (DFO) and the United States Fish and Wildlife Service (USFWS). Coordinated and strategic binational responses to invasive species management are ongoing. Efforts under this annex will identify and minimize the risk of Asian Carp and other species invading the Great Lakes using a risk assessment approach to better understand the risks posed by species and pathways and by implementing actions to manage those risks. Through efforts of federal, state, and provincial agencies, Canada and the United States have developed and implemented an Early Detection and Rapid Response Initiative with the goal of finding new invaders and preventing them from establishing self-sustaining populations. Key components include:

- A "species watch list" of those species of the highest priority and likelihood of risk of invading the Great Lakes;
- A list of priority locations to undertake surveillance on the "species watch list";
- Protocols for systematically conducting monitoring and surveillance methodologies and sampling;
- The sharing of relevant information amongst the responsible departments and agencies to ensure prompt detection of invaders and prompt coordinated actions; and
- The coordination of plans and preparations for any response actions necessary to prevent the establishment of newly detected aquatic invasive species.

5.4.4 LAKE ERIE PARTNERSHIP ACTIONS THAT ADDRESS INVASIVE SPECIES

In consideration of the pathways, distribution, and ecosystem impacts of aquatic invasive species, as explained in Chapter 4.7 and above, member agencies of the Lake Erie Partnership have developed actions and projects that address this threat and the responsible implementing agencies (Table 25).

Over the next five years, the member agencies of Lake Erie Partnership will encourage and support invasive species management efforts and work with scientists and Great Lakes experts to understand and reduce ecosystem impacts in the waters of Lake Erie.

#	LAKE ERIE PARTNERSHIP ACTIONS 2019-2023 AQUATIC AND TERRESTRIAL INVASIVE SPECIES	AGENCIES INVOLVED
23	*Ballast Water:* Establish and implement programs and measures that protect the Great Lakes basin ecosystem from the discharge of AIS in ballast water, consistent with state and federal authorities and commitments made by the Parties through Discharges from Vessels Annex of the Agreement.	Transport Canada, USCG, USEPA, States
24	*Organisms in Trade*: Prevent the introduction of invasive species through management and trade (e.g. bait, aquaculture, internet, pet shops) by improving and implementing laws and rules, using science-based risk assessment to inform prohibited species lists, and coordinating efforts across jurisdictions	USFWS, USDA, DFO, ODNR, States and province
25	*Early Detection and Rapid Response:* • Implement an 'early detection and rapid response initiative' with the goal of finding new invaders and preventing them from establishing self-sustaining populations. • Conduct Lakewide benthic assessments of dreisennid mussels through the Agreement's Science Annex Cooperative Science and Monitoring Initiative. • Improve detection and assessment by developing surveillance monitoring for non-native species in the SCDRS.	DFO, USFS, USFWS, SCDRS, States and Province NOAA, USEPA, USGS **MDNR, EGLE, USGS, USFWS, USEPA**
26	*Canals and Waterways:* Through the Asian Carp Regional Coordinating Committee, prevent the establishment and spread of Bighead, Silver and Black Carp in the Great Lakes.	USEPA, USFWS, USACE, ODNR, MDNR
27	*Grass Carp:* Use an adaptive management framework to guide response actions in western Lake Erie based on current knowledge. Response efforts include but are not limited to partnering with commercial fishers to remove fish and gain biological data from those captures, conducting targeted removal efforts with traditional fishing gears, determining the seasonal habitat use and movements to inform response actions, and evaluating novel removal approaches. Specific actions include: • Conduct targeted inter-jurisdictional response actions • Evaluate the feasibility of seasonal barriers in identified spawning tributaries • Inform seasonal habitat use and movement patterns via acoustic telemetry • Provide bounty to commercial fishers for grass removals • Develop, implement, and evaluate novel control methods	USFWS, USGS, DFO, MDNR, States and Province
28	*Sea Lamprey:* • Control the larval Sea Lamprey population in 11 regular producing tributaries in Lake Erie (Grand River (OH), Big Otter Creek (ON), Big Creek (ON), Youngs Creek (ON), Conneaut Creek (PA), Crooked Creek (PA), Raccoon Creek (PA), Canadaway Creek (NY), Buffalo Creek (NY), Cattaraugus Creek (NY), and Big Sister Creek (NY)) with selective lampricides. Continue operation and maintenance of existing barriers and the design of new barriers where appropriate. • Implement a spot treatment of the St. Clair River in 2020 • Advance sea lamprey management through development and implementation of new control	GLFC Sea Lamprey Control Program (DFO, USFWS as control agents, USACE)

#	LAKE ERIE PARTNERSHIP ACTIONS 2019-2023 AQUATIC AND TERRESTRIAL INVASIVE SPECIES	AGENCIES INVOLVED
29	*Control of Terrestrial and Aquatic Invasive Species:* • Maintain terrestrial, coastal and nearshore aquatic habitat diversity and function through appropriate control of *Phragmites* and other detrimental invasive species including monitoring, mapping, and control efforts guided by science-based BMPs. • Actively respond to Red Swamp Crayfish invasion in Southeast Michigan. Use collaborative measures to implement and evaluate response/control actions at infested locations using novel approaches. Conduct inspections at known sources of introduction (e.g., live food markets, biological supply, etc.) in states within the basin where the species is prohibited. • Coordinate *Phragmites* control efforts and share BMPs through the Ontario *Phragmites* Working Group, Great Lakes *Phragmites* Collaborative and the *Phragmites* Adaptive Management Framework. • Implement coordinated prioritized invasive species control efforts using an adaptive management framework to ensure support of multiple uses (e.g. recreational boating, hunting, water intake, non-motorized vehicles), limit the spread of invasive species to new areas, and mitigate impacts of AIS to aquatic ecosystems. Better understand and assess vulnerability of high-quality areas to the introduction of invasive species.	Parks Canada, USDA-NRCS, USEPA, USFS, USFWS, USACE, CAs, states and provinces EGLE
30	*Regional efforts:* Implement strategic actions identified in Terrestrial Invasive Species State Management Plans and Aquatic Invasive Species State Management Plans approved by the ANS Task Force including regional and local priorities.	States
SCIENCE, SURVEILLANCE, AND MONITORING		
31	Develop implementable control strategies for Dreissenid Mussels	Invasive Mussel Collaborative (led by GLC, GLFC, USGS, NOAA, USACE)
32	*Pathway monitoring* Conduct surveillance, compliance inspections, and enforcement actions to identify and minimize risk of transporting and introducing invasive species associated with key industries and pathways (e.g. bait, fish market, aquarium, recreational boating).	USFWS, USDA, States
33	*Improve understanding of invasive species impacts to inform management efforts:* • *Role of mussels in HABs toxicity and the invasion curve*: More data needed to inform ecosystem models and understand where Lake Erie mussels are on the invasion curve. • *Impacts of Round Goby on the food web:* Enhance assessment methods and technology to better understand Round Goby population density/distribution. • *Causes of botulism outbreaks:* Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl.	States, Province, USGS, NOAA
33	Continue to use invasive species databases and mapping tools to support invasive species management, survey, and outreach efforts.	States and Province
34	Conduct aquatic plant (e.g. *Hydrilla*) surveys as needed in NY's portion of the Lake Erie basin	USACE, NYSDEC
35	*Improve understanding of invasive species impacts to inform management efforts:* • *Role of mussels in HABs toxicity and the invasion curve*: More data needed to inform ecosystem models and understand where Lake Erie mussels are on the invasion curve. • *Impacts of Round Goby on the food web:* Enhance assessment methods and technology to better understand Round Goby population density/distribution. • *Causes of botulism outbreaks:* Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl.	States, Province, USGS, NOAA

#	LAKE ERIE PARTNERSHIP ACTIONS 2019-2023 AQUATIC AND TERRESTRIAL INVASIVE SPECIES	AGENCIES INVOLVED
OUTREACH AND EDUCATION		
36	**Communication:** Undertake aquatic invasive species prevention outreach and education, including discussions with key industries (e.g. water garden, aquarium, shipping) and natural resource user groups (e.g. recreational boaters and lake access site signage), and to local law enforcement to support State efforts.	DFO, CAs, SCDRS agencies, States and Province
37	Support and participate in Invasive Species Awareness Week.	States

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Table 25. Lake Erie Partnership actions to prevent and contain aquatic and terrestrial invasive species.

5.5 STRATEGIES TO PROMOTE RESILIENCE TO CLIMATE TREND IMPACTS

5.5.1 CONNECTIONS TO THE AGREEMENT GENERAL OBJECTIVES

Climate trends include: warming air and water temperatures, changing precipitation patterns, decreased ice coverage, and changing patterns of water level fluctuations. These climate trend-related effects interact with one another; alter the physical, chemical, and biological processes in the lake and surrounding watershed; and pose challenges to management agencies as they work to achieve many of the Agreement's General Objectives (Figure 26).

5.5.2 CLIMATE TREND OBSERVATIONS AND PROJECTIONS

The following observed and projected Great Lakes climate trends are taken from State of Climate Change Science in the Great Lakes Basin (McDermid et al. 2015) and other cited sources.

Temperature

- Projected 1.5-7°C (2.7-12.6°F) increase in air temperature by the 2080s in the Great Lakes basin;
- Projected increase in the number of frost-free days (Davidson-Arnott 2016).

Precipitation

- Total annual precipitation in the Great Lakes region increased by 10.7 cm (4.2 in) (approximately 13%) between 1955 and 2004, with the majority of change occurring during the summer and winter (Andresen et al. 2012; Hodgkins et al. 2007);
- Projected 20% increase in annual precipitation across the Great Lakes basin by 2080s, with greater variability in winter precipitation;
- Projected decrease in snowfall, with accompanying decrease in duration and depth of snow cover; and
- Changes in frequency and magnitude of extreme weather events with increased flooding and intensity of storms while at the same time increased risk of drought and drier periods in between (Winkler et al. 2012).

Ice Cover

- Average ice coverage for the Great Lakes basin has decreased by more than 50% over the last two decades (Wang et al. 2012); can we update?
- Projected annual average ice cover, thickness, and duration (across all Great Lakes) could fall to near zero by 2050s (Hayhoe et al. 2010; Music et al. 2015);
- Reduction of lake ice cover resulting in an early onset of stratification and longer surface water temperature warming period (Austin and Colman 2008; Franks Taylor et al. 2010).

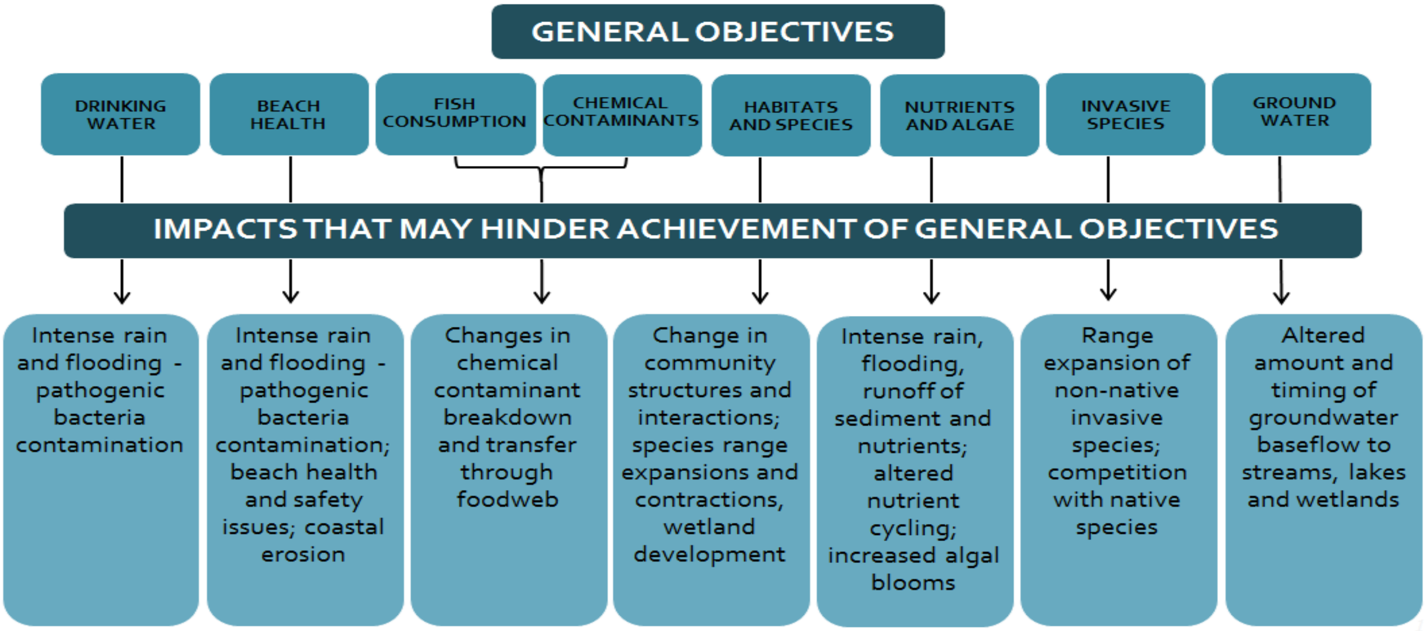


Figure 26. Potential climate change impacts, and challenges to achieving the General Objectives of the 2012 *GLWQA*.

Projected Seasonal Changes

- Models that forecast climate-related effects on the Great Lakes suggest a downward shift in water level range with less inter-annual fluctuation (Abdel-Fattah and Krantzberg 2014; Bartolai et al. 2015);
- Changes in precipitation and ice cover lead to a change in the seasonal lake level cycle with somewhat lower levels at the end of the summer and higher levels in the winter (MacKay and Seglenicks 2013);
- Shorter, warmer winters and longer and hotter summers;
- Future projections show that Midwest surface soil moisture likely will transition from excessive levels in spring due to increased precipitation to insufficient levels in summer driven by higher temperatures, causing more moisture to be lost through evaporation
- Fluctuations around lower mean water levels; and
- Increases in the direction and strength of wind and water currents.

Biological Impacts

Water temperature is a key driver of biological, chemical, and physical processes in lakes. Likely biological responses to increasing water temperatures in Lake Erie include changes in the distribution, relative abundances, and spawning patterns of fishes; increased rates of biological production and respiration; increased phytoplankton dominance by cyanobacteria; and changes in the distribution and abundances of aquatic vegetation and algae. In short, warmer waters are changing the ecology of the Lake Erie and many of these changes are in direct opposition to LAMP goals. Of particular concern are likely increases in the frequency, duration, and areal extent of harmful algal blooms and an exacerbation of hypoxia in the central basin “dead zone.”

Recent climatic warming in the Great Lakes has altered the open water diatom community over the past 30–50 years to a present community characterized by high abundances of several diatom species in the *Cyclotella* genus and closely related genera. The high relative abundance of such diatoms coincides with rising atmospheric and water temperatures (Reavie et al. 2016). and altered physical regimes in the lakes such as changing stratification depths and longer ice-free periods and may have important implications to Great Lakes food web.

Climate change is likely to have both short and long-term effects on individual organisms, populations, species and wildlife communities in the forests of Lake Erie. These effects may range from direct habitat loss to complex indirect impacts on wildlife populations and their habitat. In general, species with limited distributions are believed to be disproportionately vulnerable to the negative impacts of climate change because suitable habitat may not be available or because they have no way of migrating to suitable habitat (Schwartz et.al 2006b).

Climate trends have the potential to negatively affect fish and fisheries in the Great Lakes through its influence on habitat (as reviewed in Collingsworth et al. 2017). Climate-driven alteration of fish spawning times can lead to mismatches between newly hatched fish larvae and their zooplankton prey (Durant et al. 2007; Thackeray et al. 2010, 2013). This mechanism was posed as a possible reason for consistent low yellow perch year-classes in Lake Erie following short, warm winters, in addition to the negative effects of a short winter duration on egg size and hatching success (Farmer et al. 2015). Warming lake waters will negatively influence growth of coldwater species living in ecosystems at the extremes of their distributions in the basin (e.g., Lake Erie Lake Trout, Burbot, and Whitefish; Collingsworth et al. 2017). It must be acknowledged that there is much uncertainty around what drives fish recruitment patterns in a complex system as large as Lake Erie. Changes in environmental conditions, coupled with interactions associated with prey densities and invasive species like Zebra and Quagga mussels, pose challenges when attempting to relate temperature trends to recruitment success.

Recent evidence from Lake Erie suggests that increased precipitation-driven river discharge could benefit yellow perch recruitment by influencing the formation of bigger, more prominent river plumes during the spring (Collingsworth et al. 2017). As reviewed in Collingsworth et al. (2017), larval yellow perch use turbid river plumes as a refuge from predators without compromising the ability of larvae to feed (Reichert et al. 2010; Pangle et al. 2012; Carreon-Martinez et al. 2015). However, the benefits of turbidity for fish recruitment are not universally experienced for fish across the Great Lakes (Collingsworth et al. 2017), and increased discharges/turbidity may have other negative impacts on nearshore water quality and recreational opportunities.

5.5.3 MANAGEMENT TO RESPOND TO CHANGING CLIMATE TRENDS

There are two main approaches for responding to the effects of climate trends: 1) those that are ongoing by Federal, State, and Provincial governments focused on reducing greenhouse gas emissions (see Table 26) and, 2) those aimed at reducing ***vulnerability*** and improving environmental and societal ***resilience*** to increased climate variability and long-term climatic changes (***adaptation***). Adaptation actions are accordance with the Agreement's commitment to address climate change effects by using available domestic programs to achieve the General Objectives. This sub-section highlights the challenges that changing climate trends pose to Lake Erie and the adaptive measures in place by Federal, State and Provincial agencies and partners.

Protecting Against Loss of Habitat and Species and Enhancing Resiliency

Lake Erie's shorelines and wetlands are already subject to a range of social and environmental stressors, and climate trends can exacerbate habitat loss and degradation. Lake Erie's long-term mean water level is 174.2 m (571.5 ft) above mean sea level. The highest monthly mean was 176 m (577.4 ft), recorded in 1986.

Adaptive Measures: Climate change adaptation strategies to protect vulnerable coastal wetland habitat and fisheries are underway, including:

- The U.S. Resilient Lands and Waters Initiative supports the National Fish, Wildlife, and Plants Climate Adaptation Strategy. The goal of the initiative is to build and maintain an ecologically connected network of terrestrial, coastal, and marine conservation areas likely to be resilient to climate change; https://www.wildlifeadaptationstrategy.gov/partnerships.php
- Development of new coastal wetland decision support tools that support the identification and prioritization of restoration actions for existing and historical coastal wetlands between Saginaw Bay and Western Lake Erie basin; https://greatlakeslcc.org/issue/landscapeconservation-planning-and-design
- Central Appalachians and Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis Framework reports. These reports evaluate key vulnerabilities for forest ecosystems in the highly forested areas of the Lake Erie (https://forestadaptation.org)

GOVERNMENT	POLICY OR PLAN
International	• 2015 – United Nations 21st Conference of Parties (COP21) Paris Agreement • 2015 – Climate Summit of the Americas • 2012 – Climate and Clean Air Coalition to reduce Short Lived Climate Pollutants • 1987 – Montreal Protocol
Canada	• 2016 – Pan-Canadian Framework on Clean Growth and Climate Change • 2016 – Vancouver Declaration on Clean Growth and Climate Change • 2011 – Federal Adaptation Policy Framework
United States	• 2014 - Federal Agency Climate Adaption Plans
Ontario	• 2016 – Ontario's Five Year Climate Change Action Plan 2016-2020 • 2016 – Climate Change Mitigation and Low-Carbon Economy Act
Michigan	• 2012 – Climate Change Adaptation Plan for Coastal and Inland Wetlands 2009 – MDEQ Climate Action Plan
New York	• 2009 – Regional Greenhouse Gas Initiative (RGGI; with other States) • 2010 – Transportation and Climate Initiative (with other States) • 2015 – NYS Energy Plan • 2017 – Methane Reduction Plan

Table 26. Examples of strategies or actions that manage the amount of greenhouse gases in the atmosphere

Protecting Against Excessive Nutrient, Sediment, and Impaired Water Quality

As the climate has changed, severe storm events, flooding, and overland runoff have increased in frequency and magnitude. These storms increasingly wash nutrients, sediments, and pathogenic bacteria into waterways, setting the stage for algal blooms and unsafe beaches.

Adaptive Measures: Strategies to protect water quality by reducing sediment and nutrient runoff are underway, including:

- Enhancing farm soil health, planting cover crops, and using no-till soil management increase carbon storage and reduce energy use. Such Agricultural BMPs improve water quality by reducing the loss of sediments and nutrients from farm fields. The DAPs provide additional details on adaptive measures relevant to the various jurisdictions.
- NYS Trees for Tributaries Program is designed to support riparian tree planting projects for communities across the state. Streamside plantings improve wildlife habitat, protect water quality and increase resiliency.
- NYS Climate Resilient Farming Program was developed with the goal to reduce the impact of agriculture on climate change and to increase the resiliency of New York State farms in the face of a changing climate. This is accomplished by completing agricultural waste storage cover and flare systems, water management projects and management systems that enhance soil health.

Protecting Critical Community Infrastructure

Flooding due to more frequent and intense storms throughout the Great Lakes has the potential to threaten urban waste, stormwater facilities, and water withdrawal systems and operations. More frequent and intense storms could result in sewer system overflows and reduced wastewater treatment capacity, which in turn could increase the cost of treating source water.

LOW IMPACT DEVELOPMENT

A green infrastructure approach to stormwater management that uses landscaped features and other techniques to reduce flood risks and clean, store, and conserve

Adaptive Measures: Climate change adaptation measures to reduce the vulnerability of urban stormwater management systems and wastewater infrastructure from future extreme storm events are underway. All levels of government are investigating and promoting Low Impact Development (LID) and its important role in climate adaptation planning for municipalities. Through the use of LID practices, watershed resiliency can be enhanced to help mitigate the impacts of excess stormwater and flooding on social and environmental health.

- The Ontario Centre for Climate Impacts and Adaptation Resources is a university-based resource hub for information on climate change impacts and adaptation;
- National Climate Assessment: Water Resources: http://nca2014globalchange.gov/reports/sectors/water
- An Implementation Framework for Climate Change Adaptation Planning at a Watershed Scale (2015) was developed by the Water Monitoring and Climate Change Project Team of the Canadian Council of Ministers of the Environment; and http://www.climateontario.ca/tools.php
- The state of Michigan, the province of Ontario, and several conservation authorities and municipalities are developing LID manuals or are incorporating LID principles into their stormwater programs/manuals.
- Ohio Balanced Growth Program https://balancedgrowth.ohio.gov/Best-Local-Land-Use-Practices/Best-Local-Land-Use-Practice-Chapters

5.5.4 OTHER ACTIVITIES UNDER THE AGREEMENT THAT ADVANCE THE PROGRESS ON ADAPTING TO CLIMATE TREND IMPACTS

Under the Climate Change Impacts Annex of the Agreement, the governments are tasked with coordinating efforts to identify, quantify, understand, and predict effects of climate trends on the quality of the waters of the Great Lakes. Provisions for science include coordinating binational climate change science activities (including monitoring, modeling, and analysis) to quantify, understand, and share information that Great Lakes resource managers need to address climate trend challenges to the general objectives on the quality of the waters of the Great Lakes and to achieve the General Objectives of this Agreement.

5.5.5 Lake Erie Partnership Actions that Address Climate Trend Impacts

In consideration of the current and future potential challenges to water quality, fishes and other species vulnerable to climate change impacts, as explained in Chapter 4 and above, member agencies of the Lake Erie Partnership have developed actions and identified the management agencies involved in implementing them (Table 27). Over the next five years, the Lake Erie Partnership will encourage and support efforts that address the impact of climate trends and work with scientists and Great Lakes experts to understand and reduce the impacts of climate trends in the waters of Lake Erie. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

5.5.6 Actions that Everyone Can Take

Many solutions exist for reducing one's personal contribution to climate change, and for contributing to adaptation strategies that benefit Lake Erie:

- Be energy efficient by greening your home. Change your lightbulbs to LED bulbs; turn off the lights and unplug electronics and appliances when not in use; look for ENERGY STAR labels when buying new electronics or appliances; heat and cool smartly; and seal and insulate your home. You will also save money on your electricity bill!
- Choose green power. Switch your energy source to renewable energy such as wind or solar.
- Plant trees. Trees should be native or adapted to the local climate. Trees sequester carbon, helping to remove carbon dioxide and other greenhouse gases from the air. Tree leaves and roots intercept stormwater runoff, increase infiltration of rainwater, and reduce soil erosion.
- Consider disconnecting downspouts from direct conduits (subsurface drains) to municipal sewer systems and redirecting the water onto vegetated areas of your property.
- Lake Erie and other waterfront shoreline property owners should consider nature-based shorelines and maintaining native vegetation and trees along the shore.
- Choose sustainable transportation. Transportation produces about 14% of global greenhouse gas emissions (IPCC, 2014). Walk, cycle, carpool, or take public transit when you can. Fly less or consider taking buses or trains. Purchase a smaller, fuel-efficient vehicle. Drive efficiently.
- Conserve water. Take shorter showers; install low-flow shower heads and toilets. Use the dishwasher and washing machine only when you have full loads. Wash clothes in cold water. Use rain barrels to capture roof-top runoff and water your garden with the captured run-off.
- Incorporate green infrastructure into your landscape. Use rain-gardens to capture stormwater, create habitat and enable infiltration of water back into the soil.
- Eat locally. Buy locally grown food, as it does not have to travel as far.

- Reduce your waste. Garbage buried in landfills produces methane, a potent greenhouse gas. Compost when you can. Recycle paper, plastic, metal, and glass. Buy products with minimal packaging.
- Follow the 6 Rs of Sustainability: Rethink, refuse, reduce, reuse, repair, and recycle.
- Get involved and informed! Follow the latest news on climate change, voice your concerns via social media, and spread the word to your family and friends.

Climate Trend Adaptation Planning at the Community Level

Climate resiliency and adaptation planning develops and applies plans to reduce the impacts and consequences of climate change and climate variability. There are a variety of approaches to climate resiliency and adaption planning. Some communities create dedicated climate resiliency and adaptation plans that describe strategies for how to address impacts of climate change — while others focus on existing goals, adding the lens of climate variability to assess implications for stated goals, objectives, and strategies. If such large-scale efforts are not possible, you can focus on a specific project to ensure that environmental variability is addressed in a proactive way. Even without a dedicated resiliency and adaptation planning process, a community can do a broad assessment of what fluctuating environmental conditions will mean for existing goals, objectives, and strategies.

- If you are looking for information on climate resiliency and adaptation, visit:
- Great Lakes Climate: A collection of Great Lakes climate change resources to help educators, government officials, community planners, and the publics(http://climategreatlakes.com/)
- Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR): A university-based resource hub for researchers and stakeholders http://www.climateontario.ca/);

- Develop new or revise existing conservation, restoration, and management plans, guidelines and regulations as required in response to projected climate change impacts;
- Create coastal development setbacks to allow vegetation communities (e.g., coastal wetlands) to migrate in response to water level fluctuations;
- Incorporation more climate change information into the communications, management, technical assistance, science, research, and development programs of parks, forests, and protected areas;
- Undertake climate change education and outreach activities, with a focus on disseminating materials and information available from climate change programs; and
- Use parks, natural areas or sentinel sites as long-term integrated monitoring sites for climate change impacts (e.g., monitoring of species, especially those at-risk or extinction-prone).

Table 27. Lake Erie Partnership actions that address climate trend impacts.

#	LAKE ERIE PARTNERSHIP ACTIONS (2019-2023)	AGENCIES INVOLVED
	CLIMATE TREND ACTIONS Actions identified for nutrients and bacterial pollution (5.1) and loss of habitat and native species (5.3) will help to maintain ecosystem function and enhance resilience to the effects of climate change.	
38	***Watershed Resilience***: Continue efforts that engage landowners and the public to protect and enhance the function and resilience of watershed headwater features, streams, forests, and wetlands to maintain and enhance resilience to climate change impacts, including Conservation Authority Climate Change Strategies and Action.	CAs, MDNR, OMECP, USDA NRCS, USFS, EGLE, OMAFRA
	Reduce inland vulnerability to extreme weather events by promoting wetland protections in flood-prone areas and expanding green infrastructure and urban forests to slow storm runoff.	States, EGLE, OMAFRA
	Adapt to threats caused by climate change by restoring ecosystem biodiversity, increasing habitat connectivity, and supporting resiliency initiatives for natural and built environments, including flood mitigation studies for priority flood-prone Lake Erie tributaries.	NYSDEC, EGLE
	Implement New York State Climate Resilient Farming (CRF) Program (https://www.nys-soilandwater.org/programs/crf.html)	NRCS, NYSDAM
	Improve in-field infiltration practices to reduce runoff from agricultural fields.	NRCS, OMAFRA, MDARD, EGLE
39	***Critical Community Infrastructure:*** Plan and implement LID initiatives that are suited to future extreme weather events via watershed work that increases green space and green infrastructure.	CAs, OMECP, USFS, EGLE
	• Michigan Low Impact Development manual (section 319 funding supporting Michigan non-point source grant programs)	EGLE
	• Ontario Low Impact Development manual, in development	
	• Ohio Balanced growth program	OLEC
	• Protect critical infrastructure in coastal communities by using natural and engineered measures to improve resiliency where possible.	NYSDEC, ODNR
	• Strengthen drinking and wastewater infrastructure to reduce vulnerability to flooding, drought, and other extreme weather events.	NYSDEC
40	***Coastal Resilience:*** Develop Great Lakes coastal restoration and resilience strategies to alleviate flood and erosion impacts to build and natural shorelines and improve overall coastal ecology, and promote improved shoreline stewardship through technical assistance.	NYSDEC, ODNR, EGLE
	OUTREACH AND EDUCATION	
41	***Communications:***	
	• Publish Great Lakes *Quarterly Climate Summary* that addresses trends and forecasts	NOAA
	• Host state by state Climate Services Workshops	NOAA
	• Undertake and support outreach and education to stakeholders and the public on the impacts of climate change to the Great Lakes and Lake Erie through fact sheets, newsletters and other means.	CAs, ECCC, USFS, OMECP
	• Encourage municipalities and landowners to implement flood mitigation actions (e.g., soil health practices, natural infrastructure, wetland restoration/protection, etc.) to reduce peak flows in high-risk streams.	States (NYSDEC, ODNR), OMAFRA
	• Undertake community-based stewardship and education activities (e.g., coastal debris prevention, habitat restoration, etc).	ODNR
	• Promote living shorelines and coastal/riparian stewardship on public and private lands to improve aquatic habitat and enhance coastal resiliency.	EGLE
	• Develop and implement nature-based shoreline certification programs	EGLE

6.0 SCIENCE AND MONITORING

This section provides information on how researchers are supporting management actions through an improved understanding of the Lake Erie ecosystem.

6.1 GREAT LAKES COOPERATIVE SCIENCE AND MONITORING INITIATIVE (CSMI)

The Cooperative Science and Monitoring Initiative (CSMI) is a joint United States and Canadian effort implemented under Science Annex of the Agreement. CSMI provides managers with the science and monitoring information necessary to make management decisions on each Great Lake.

CSMI follows a five-year rotating cycle (Figure 27) in which one lake undergoes intensive investigation, coordinated by the GLWQA Science Annex, each year. The emphasis on a single lake per year allows for coordination of science and monitoring activities focused on the information needs of lakewide management for the particular lake. Previous Lake Erie intensive field years took place in 2004, 2009, and 2014.

Figure 27. Lake Erie CSMI 2019-2023 timeline

As part of the reporting phase of the 2014 CSMI cycle, the Lake Erie Millennium Network hosted a *State of Lake Erie* conference in Windsor, Ontario in February 2017, at which key science findings were shared and discussions of the prevailing needs for the 2019 CSMI field year began. The conference was planned in conjunction with the Lake Erie Partnership and included reporting out on the 2014 Lake Erie CSMI field year efforts. In the fall of 2017, the Lake Erie Partnership convened over 70 representatives from Canadian and U.S. resource management agencies, environmental non-governmental organizations, and academic scientists to share information and establish joint science and monitoring priorities for the 2019 CSMI field year for the Lake Erie Partnership to consider.

Results from research and monitoring studies confirm that the Lake Erie's ecosystem and water quality have seen significant system-wide changes in nutrient inputs and invasive species in recent decades, resulting in undesirable changes in lake productivity and food web structure. Phosphorus concentrations in the western and central basins consistently exceed the desired levels for a healthy ecosystem. Annual estimates of loading from tributaries and other sources indicate that the total amount of phosphorus entering the Lake varies significantly each year due to the corresponding variability in nonpoint runoff. Coinciding with the resurgence of algal blooms in Lake Erie during the mid to late 1990s and shifts in bloom dominance to potentially toxin producing *Microcystis* sp., there has been a significant increase in the proportion of the phosphorus load to Lake Erie that is in dissolved form. Dissolved phosphorus is more easily taken up by algae and the corresponding change in nutrient ratios contributes to increased growth of this kind of algae.

Compounding this problem, the ecosystem has changed due to the spread of invasive zebra and quagga mussels that became established in the 1990s. Invasive mussels retain and recycle nutrients in nearshore areas through their filtering and excretion activities. In addition, the increased water clarity results in greater penetration of solar energy for chlorophyll production and warming of the water column, allowing algae to grow at greater depths. These alterations to water clarity and in-lake nutrient cycling are resulting in greater nuisance algal growth in the nearshore regions, closer to where humans interact with the Lake.

The Lake Erie Partnership has identified the need for scientific research to: 1) better understand loading of nutrients to Lake Erie and cycling of nutrients within the lake; 2) understand and track changes in the Lake Erie food web; and 3) track contaminant loading and cycling in Lake Erie.

6.2 LAKE ERIE SCIENCE AND MONITORING PRIORITIES

The science and monitoring priorities described below are the focus of the 2019 CSMI intensive field year for Lake Erie. The findings from the 2019 CSMI year of study will be shared with resource managers to better inform management programs, future CSMI activities, and the next Lake Erie LAMP.

Nutrient Fate, Loading and Transport
Recommended watershed and in-lake science activities to help explain nearshore and offshore nutrient dynamics consist of improving the understanding of:

- How the benefits of best management practices implementation scale from edge-of-field to stream sub-basin to watershed;
- The significance of legacy phosphorus on agricultural land as a source of phosphorus to Lake Erie;
- How phosphorus bioavailability and transport at the field scale impact the Lake Erie phosphorus mass budget;
- Biotic and abiotic drivers of: phytoplankton community composition and succession; toxin production, concentration, distribution and fate; and nutrient retention in Lake Erie;
- The spatiotemporal availability of phosphorus and nitrogen in Lake Erie and its influence on the onset and scale of harmful algal blooms;
- The drivers of summer Cladophora production; and
- The spatio-temporal extent of hypoxia in the Sandusky sub-basin, northwestern basin, and Lake Erie central basin.

Changing Lake Erie Food Web
Understanding the distribution of critical habitats for species, as well as how lower food web health, harmful algal blooms and hypoxia impact fish production is critical within the context of the changing Lake Erie food web. Information on the abundance of key aquatic invasive species is also critical to understanding current and potential impacts of these species on the Lake Erie ecosystem.

The following studies are recommended to aid in better identification of habitat/stock restoration opportunities, to characterize the status of invasive species, and to inform the implementation of both environmental protection and natural resource management programs:

- Identification of habitat components that are limiting production for important species and stocks of fish identified by Lake Erie fisheries managers;
- Quantification of the production of various habitats and stocks to the overall fisheries in the St. Clair Detroit River System (SCDRS), Lake Erie and Upper Niagara River; and
- Determination of population levels of invasive species such as Grass Carp and dreissenid mussels.

Contaminant Loading and Cycling
Long-term monitoring of environmental media (air, water, sediment, fish, and wildlife) generally indicates decreasing levels of contaminants in Lake Erie. However, fish and wildlife consumption advisories are still required to protect human health. Chemicals of emerging concern continue to warrant investigation due to their distribution and persistence in the environment.

The following studies are recommended by water quality managers to track the effectiveness of restoration and protection programs:

- Continued long-term monitoring of environmental media (air, water, sediment, plants, fish, and wildlife) to track progress and inform environmental protection, natural resource management, and human health programs;
- Continued monitoring of sentinel species like colonial water birds and walleye to support long-term chemical contaminant assessments for the Lake Erie basin; and
- Continued Great Lakes-wide efforts to assess fate, distribution, and effects of chemicals of emerging concern.

6.3 OTHER BINATIONAL SCIENCE AND MONITORING COORDINATION INITIATIVES

Lake Erie Millennium Network
The binational Lake Erie Millennium Network (LEMN; http://www.lemn.org/) was initiated to foster and coordinate research that will identify and solve basic ecological questions relevant to the Lake Erie Ecosystem through a binational, collaborative network. The objectives of the LEMN are to: (1) summarize the current status of Lake Erie from process and ecosystem function perspectives; (2) collectively document the research and management needs of users and agencies; and 3) develop a framework for a binational research network to ensure coordinated collection and dissemination of

data that addresses the research and management needs.

The 8th LEMN meeting was recently held in February 2017 and focused on assessing and understanding the key role of the nearshore as an integrator of land and lake-based processes. The meeting program, including presentation abstracts, is available on the meeting website: http://www.lemn.org/LEMN2017.htm.

St. Clair-Detroit River System Initiative
The SCDRS Initiative is a binational collaborative partnership with more than 30 organizations, including U.S. and Canadian natural resource-related agencies, First Nations, units of local government, industry and university partners, non-profits, and interested citizens. The SCDRS Initiative Partners share a common vision: the restoration of 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.

Using a “Collective Impact” approach, a Partnership Agreement and Strategic Vision were adopted to formally recognize how signatories will interact to fulfill the Priority Objectives of the SCDRS Initiative for the next decade (i.e., 2014-2023). The Partnership Agreement was ultimately formalized with the purpose of coordinating research and management efforts to collectively achieve measurable progress toward the shared vision of a thriving ecosystem managed with science-based principles and broad social support for the region as well as the Great Lakes basin. To learn more, visit https://scdrs.org/.

7.0 OUTREACH AND ENGAGEMENT

Everyone has a role to play in protecting, restoring, and conserving Lake Erie. Member agencies of the Partnership will pursue binational and domestic outreach and engagement activities to consult on challenges, priorities, and strategies and to encourage and support active community-based environmental action.

Engagement, collaboration and active participation of all levels of government, watershed management agencies, and the public are essential for the successful implementation of the Lake Erie Lakewide Action and Management Plan, and for the achievement of the General Objectives of the Agreement.

Member agencies of the Partnership will pursue binational and domestic outreach and engagement activities to consult on challenges, priorities, and strategies and to encourage and support active community-based environmental action. Local communities, groups, and individuals are among the most effective champions to achieve environmental sustainability in their own backyards and communities. In Chapter 5 of this LAMP, the ***Actions Everyone Can Take*** sections identify actions the public can take to reduce threats to the Lake Erie ecosystem.

Public engagement and public participation are inherent components in the implementation of agency environmental management programs. As such, member agencies of the Partnership will pursue binational and domestic outreach and engagement activities to consult on challenges, priorities, and strategies and to encourage and support active community-based environmental action as part of their mandate. Outreach may include, but is not limited to, web resources, public meetings, news outlets, and public comment periods. These actions can be binational, coordinated by the Lake Erie Partnership, or jurisdiction or agency driven.

The public can stay abreast of Lake Erie Partnership and LAMP-related activities by:

- Visiting Binational.net, where GLWQA *State of the Lake* Reports and annual LAMP update reports are posted, and where opportunities to review and provide input on the development of the next 5-year LAMP are announced
- Participating in webinars hosted by the Lake Erie Partnership Outreach and Engagement Sub-Committee
- Visiting the Great Lakes Commission's *Great Lakes Calendar* (https://www.glc.org/greatlakescalendar) to learn about Lake Erie meetings and events in your region
- Attending a triennial Agreement Great Lakes Public Forum event, where Canada and the United States review the state of the Great Lakes, highlight ongoing work, discuss binational priorities for science and action, and receive public input.
- Learning about Great Lakes issues and events via *Great Lakes Daily News* (https://www.glc.org/dailynews)

8.0 CONCLUSION

Achieving the General Objectives of the Agreement is a challenging task and one that will require the collective action by many partners throughout the Lake Erie basin.

The health of Lake Erie and the condition of its watershed are interconnected. A host of factors – chemical contaminants, urbanization, shoreline development, nutrient and sediment loading, invasive species, and degraded or fragmented habitat – interact with a changing climate to produce complex changes.

To help achieve the Agreement's General Objectives, 40 management actions are put forth in this LAMP. These actions will address key environmental threats using an integrated management approach that recognizes the interactions across Lake Erie, including humans, and the need to maintain and enhance ecosystem resilience in view of climate change.

Implementation and Accountability

As demonstrated in Chapter 5, Lake Erie Partnership agencies are committed to incorporating LAMP actions in their decisions on programs, funding, and staffing. These agencies will be guided by a set of principles and approaches (Table 28) and a shared commitment to ensure that the chemical, physical, and biological integrity of the waters of Lake Erie is maintained or restored for current and future generations.

Implementation of LAMP actions is guided by a governance system (Figure 28) wherein coordination and implementation of the Agreement occurs on a basin-wide scale with oversight provided by the Great Lakes Executive Committee. At the lake scale, a *Management Committee* provides direction and coordination of LAMP development and implementation efforts, and a *Working Group* performs the support operations necessary for the development and implementation of the LAMP, including regular communication, reporting and tracking of progress. The committees are co-chaired by the U.S. Environmental Protection Agency and Environment and Climate Change Canada.

PRINCIPLES & APPROACHES	IMPLEMENTATION DESCRIPTION
Accountability	Evaluating actions by individual partner agencies, tracked and reported through LAMP annual and five-year reports.
Adaptive Management	Assessing actions that will be adjusted to achieve General Objectives when outcomes, ecosystem processes, and new threats are better understood.
Coordination	Managing, planning, and coordinating actions across agencies.
Prevention	Anticipating and preventing pollution and other threats to water quality to reduce risks to environment and human health.
Public Engagement	Integrating public input and advice when appropriate; providing information and opportunities for participation to help achieve General Objectives.

Table 28. Principles and approaches to achieving the General Objectives of the Agreement.

Figure 28. Lake Erie lakewide management under the Agreement.

APPENDIX A: HISTORY OF LAKEWIDE MANAGEMENT ON LAKE ERIE

Great Lakes Water Quality Agreement

In 1972, the United States and Canada came together to sign the historic Great Lakes Water Quality Agreement (GLWQA), a commitment between the two countries to address water quality issues of the Great lakes in a coordinated and joint fashion. A formal international agreement overseen by the International Joint Commission (IJC), the GLWQA has since been updated three times in 1978, 1987, and 2012.

A major milestone of the 1987 amendment by Protocol was the commitment to develop Lakewide Management Plans (LaMPs) for each of the five Great Lakes. It was determined that the LaMPs should, "embody a systematic and comprehensive ecosystem approach to resorting and protecting beneficial uses in Areas of Concern or in open lake waters" (GLWQA 1987). The 14 beneficial use impairments (BUIs) listed in Annex 2 of the GLWQA were to be the main focus. Originally, LaMPs centred on critical pollutants and were submitted to the IJC for review and comment at four different stages: problem definition, load reduction targets, during the selection of remedial measures, and when monitoring indicated that critical pollutant impairments had been improved upon (GLWQA 1987).

Lakewide Management

By 1993, a temporary Lake Erie binational Implementation Committee was established, consisting of members of all the state, federal, and provincial agencies with jurisdiction over the basin. In 1995, the Committee produced the first Lake Erie LaMP concept paper (U.S. EPA 1995) that provided a framework for future LaMPs. The Implementation Committee felt that, in addition to addressing critical pollutants, the Lake Erie LAMP needed to be broadened to include a greater ecosystem approach that would examine habitat loss, nutrient and sediment loading, and non-native invasive species.

In order to explain clearly the geographic scope of the Lake Erie LaMP, three aspects needed to be defined. First, it was determined that BUIs were assessed within the waters of Lake Erie, including: the open waters, nearshore areas, and river mouth/lake effect areas. Second, the search for the sources or causes of impairments to beneficial uses was to be conducted in the lake itself, the Lake Erie watershed, and even beyond the Great Lakes basin. Third, management actions needed to restore and protect Lake Erie could be extended and implemented outside of the Lake Erie basin.

The Lake Erie Vision

A Lake Erie basin ecosystem...

-Where all people, recognizing the fundamental links among the health of the ecosystem, their individual actions, and their economic and physical well-being, work to minimize the human impact in the Lake Erie basin and beyond;

-Where natural resources are protected from known, preventable threats;

Where native biodiversity and the health and function of natural communities are protected and restored to the greatest extent that is feasible;

-Where natural resources are managed to ensure that the integrity of existing communities is maintained or improved;

-Where human-modified landscapes provide functions that approximate natural ecosystem processes;

-Where land and water are managed such that water flow regimes and the associated amount of materials transported mimic natural cycles; and

-Where environmental health continually improves due to virtual elimination of toxic contaminants and remedial actions at formerly degraded and/or contaminated sites".

Binational committees were established in 1995 to begin actively working on the development of the Lake Erie LaMP. Senior managers from each jurisdiction were invited to participate on the Lake Erie LaMP Management Committee, the group charged with overseeing the development of the Lake Erie LaMP. The Lake Erie LaMP Work Group was set up to carry out the directives of the Management Committee and to organize and oversee various subcommittees. The Lake Erie binational Public Forum was created to provide front line coordination and communication with the public.

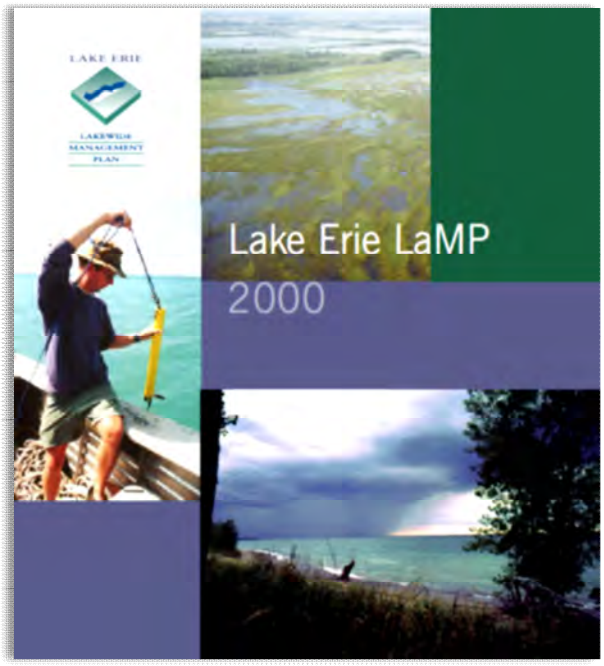
The Lake Erie LaMP Ecosystem Objectives Subcommittee (EOSC) was established with the task of developing ecosystem management objectives for Lake Erie. The EOSC adopted a fuzzy cognitive map (FCM) approach to model ecosystem alternatives for Lake Erie (Table X?). A FCM model is one way to analyze a complex system by representing the most important components of the system as nodes of a network. A change at one node will affect all connected nodes, and then all the nodes connected to those nodes, generating a ripple effect.

From the modelling exercise, four distinct ecosystem management alternatives emerged. The selected alternative represented the importance and urgency of improving land use activities, continued diligence in nutrient management, and the vulnerability of fish and wildlife species to human activities, and became the Lake Erie Vision. The vision was consistent with the themes of sustainability and multiple benefits to society of a healthy Lake Erie ecosystem.

In order for the vision to be achieved, ecosystem management goals were established in relation to the main management categories influencing the status of the lake: land use, nutrients, natural resource use and disturbance, chemical and biological contaminants, and non-native invasive species. The LaMP's vision and the ecosystem management objectives were set-up in relation to the restoration of BUIs observed in Lake Erie. Indicators for the different habitat zones were established as a way to track the progress towards achieving the vision and ecosystem management objectives of the LaMP.

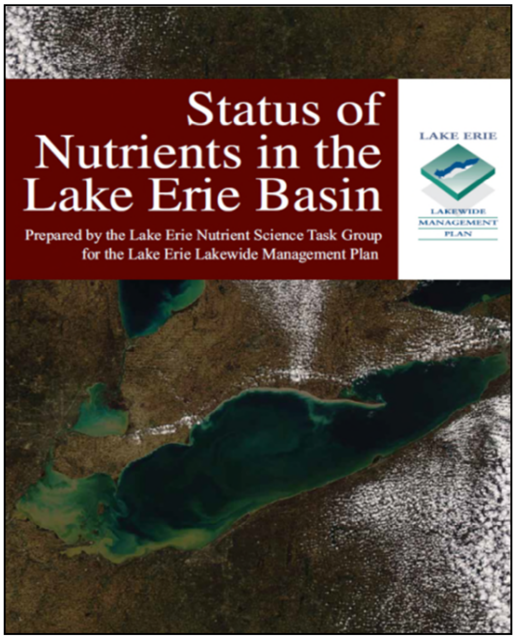
By 1999, the Binational Executive Committee (BEC) of the GLWQA passed a resolution adopting a streamlined approach to the document review process in an effort to accelerate the development of LaMPs. Under this approach the Lake Erie LaMP would no longer be developed through the four-stage process outlined in the GLWQA. Instead, the LAMP treated problem identification, selection of remedial and regulatory measures, and implementation as a concurrent and integrated process, rather than a sequential one. The BEC also recommended that the LAMPs be prepared every two years based on the current body of knowledge and the state of remedial actions that could be implemented.

In 2000, the first Lake Erie LaMP was released; one of its major accomplishments was determining the status of the BUIs. At that point only three of the 14 BUIs were concluded not to be found in Lake Erie: tainting of fish and wildlife flavor, restrictions on drinking water, and added costs to agriculture and industry. The second LaMP was released in 2002, representing the first update on the status of Lake Erie. Although 11 of the 14 BUIs still remained, the report highlighted the significant progress that had been made in various areas, such as determining viable ecosystem alternatives, proposing ecosystem management objectives, and initiating a source track down program for critical pollutants and pollutants of concern to Lake Erie.



The next Lake Erie LaMP updates were released in 2004, 2006, and 2008. Unlike the 2002 LaMP (a stand-alone document), these three subsequent LaMPs combined and updated sections from each other in order to maintain the BEC concept of one working draft. Although the last LaMP was produced in 2008, many other significant reports and milestones were achieved throughout the past decade.

In 2007 the Lake Erie Nutrients Task Group was formed to assess the status of nutrients in Lake Erie in response to the growing concern over the re-emergence of cyanobacteria. The group produced the 2009 report, *Status of Nutrients in the Lake Erie Basin*, which highlighted the complexity of the nutrient problem as numerous causal factors were linked to the worsening conditions. The report also provided the scientific foundation for the *Lake Erie Binational Nutrient Management Strategy*, released by the Lake Erie LaMP Work Group in 2012. The strategy outlined goals, objectives, quantitative targets, and actions needed to improve current conditions and prevent further eutrophication. A major action this report recommended was to bring down total phosphorus concentrations and continuously monitor nutrient loading.



Status of Nutrients in the Lake Erie Basin

Prepared by the Lake Erie Nutrient Science Task Group for the Lake Erie Lakewide Management Plan

LAKE ERIE LAKEWIDE MANAGEMENT PLAN

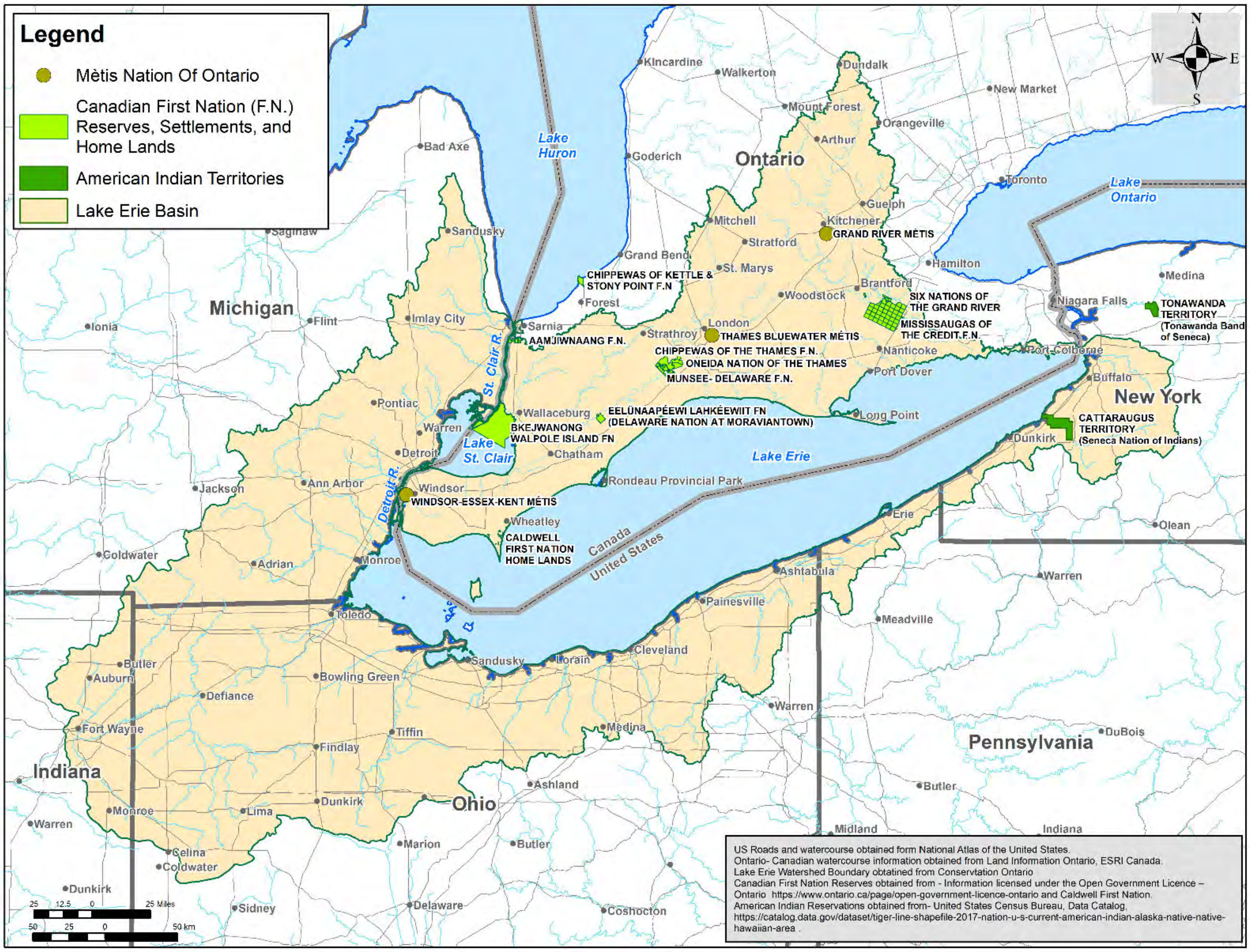
The Lake Erie Biodiversity Conservation Strategy (LEBCS) was an additional binational initiative that began in 2012. It was designed to support the efforts of the Lake Erie LaMP by identifying specific strategies and actions to protect and conserve the native biodiversity of the lake. It was the end product of a two-year planning process involving over 87 agencies and organizations around the basin.

In 2012, Canada and the United States signed a new GLWQA and the Lakewide Management Annex specifically set out goals for the binational lakewide management process and structure. Major changes included: changing the LaMP title to Lakeide Action and Management Plan (LAMP), updating the LAMP reporting period from every two years to every five years, placing greater emphasis on monitoring the nearshore waters of the Great Lakes, and officially adding the St. Clair River, Lake St. Clair, and the Detroit River into the Lake Erie LAMP (GLWQA 2012). The Lakewide Management subcommittee decided that the five- year LAMPs would be released sequentially, beginning with Lake Superior in 2015, and that each Lake would provide additional annual updates.

Lake Erie Binational Public Forum

Since the beginning of the Lake Erie LAMP process, U.S. and Canadian agencies have viewed public participation as crucial to the success of binational lakewide management under the GLWQA. In 1995, the government agencies that were responsible for the LAMP created the Lake Erie Binational Public Forum. From 1995 to 2014, the Forum provided front line coordination and communication with the interested public. Consisting of interested stakeholders from Canada and the U.S., the Forum developed and implemented outreach projects and initiatives, educated the general public about Lake Erie issues, and provided advice to the LAMP Working Group.

APPENDIX B: MAP OF U.S. FEDERALLY RECOGNIZED TRIBAL LANDS, FIRST NATIONS COMMUNITIES AND RESERVE LANDS, AND METIS NATION COUNCILS IN THE SCDRS, LAKE ERIE, UPPER NIAGARA RIVER BASINS



US Roads and watercourse obtained form National Atlas of the United States.
Ontario- Canadian watercourse information obtained from Land Information Ontario, ESRI Canada.
Lake Erie Watershed Boundary obtatined from Conservtation Ontario
Canadian First Nation Reserves obtained from - Information licensed under the Open Government Licence – Ontario https://www.ontario.ca/page/open-government-licence-ontario and Caldwell First Nation.
American Indian Reservations obtained from- United States Census Bureau, Data Catalog, https://catalog.data.gov/dataset/tiger-line-shapefile-2017-nation-u-s-current-american-indian-alaska-native-native-hawaiian-area .

APPENDIX C: AREAS OF CONCERN (AOC)

The 2012 Agreement defines an Area of Concern (AOC) as a geographic area designated by the United States and Canada, where significant impairment of beneficial uses has occurred as a result of human activities at the local level. An impaired beneficial use is a reduction in the chemical, physical, or biological integrity of the waters of the Great Lakes sufficient to cause environmental issues. Delisting of an AOC occurs when locally derived delisting targets for the Beneficial Use Impairments (BUIs) have been met.

Following management actions, the Canadian government delisted Wheatley Harbour in 2010 and the U.S. government delisted Presque Isle Bay AOC in 2013. The status of the remaining eleven Lake Erie AOCs and Beneficial Use Impairments are shown in Table 29. The table includes two Lake Ontario AOCs located in the Upper Niagara River (Eighteen Mile Creek and Rochester Embayment), as this LAMP identifies habitat and species actions needed in these AOCs.

Remedial Action Plans for the remaining U.S. AOCs are being implemented to restore the beneficial uses within each AOC. In Lake Erie, the Ashtabula River, River Raisin, and St. Clair River (U.S) AOCs have been designated as having all Management Actions Complete, meaning all projects necessary to remove the remaining impairments have been identified and implemented. All management actions necessary to remove the remaining two BUIs at the Black River AOC have been identified.

Remedial Action Plans for the remaining Canadian AOCs are also being implemented. For the Canadian side of the Detroit, St. Clair and Niagara River AOCs, the successful cleanup of contaminated sediment, creation of fish and wildlife habitat, and reduction of chemicals and nutrients entering the rivers have resulted in close to half of the beneficial use impairments being restored and redesignated as not impaired.

Information is available online for each AOC at https://www.epa.gov/great-lakes-aocs/list-great-lakes-aocs and https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/restoring-great-lakes-areas-concern.html.

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AOC	BENEFICIAL USE IMPAIRMENT (BUI) STATUS													
🟩 BUI RESTORED 🟨 BUI IMPAIRED ⬜ NOT APPLICABLE	Restrictions on fish and wildlife consumption	Tainting of fish and wildlife flavor	Degradation of fish and wildlife populations	Fish tumors and other deformities	Bird or animal deformities or reproductive problems	Degradation of benthos	Restriction on dredging activities	Eutrophication or undesirable algae	Restrictions on drinking water consumption or taste/odor	Beach closings	Degradation of aesthetics	Added costs to agriculture or industry	Degradation of phytoplankton/zooplankton populations	Loss of fish and wildlife habitat
Ashtabula River*	🟩	⬜	🟩	🟨	⬜	🟩	🟨	⬜	⬜	⬜	⬜	⬜	⬜	🟩
Black River	🟩	⬜	🟨	🟨	⬜	🟨	🟨	🟩	⬜	🟨	🟨	⬜	⬜	🟨
Buffalo River	🟨	🟨	🟨	🟨	🟨	🟨	🟨	⬜	⬜	⬜	🟩	⬜	⬜	🟨
Clinton River	🟨	⬜	🟨	⬜	⬜	🟨	🟨	🟨	⬜	🟨	🟨	⬜	⬜	🟨
Cuyahoga River	🟩	⬜	🟨	🟨	⬜	🟨	🟨	🟨	⬜	🟨	🟩	⬜	⬜	🟨
Detroit River (US)	🟨	🟩	🟨	🟨	🟨	🟨	🟨	⬜	🟩	🟨	🟨	⬜	⬜	🟨
Detroit River (CA)	🟨	🟩	🟨	🟨	🟨	🟨	🟩	⬜	🟩	🟩	🟩	🟩	RFA	🟨
Eighteen Mile Creek	🟨	⬜	🟨	⬜	🟨	🟨	🟨	⬜	⬜	⬜	⬜	⬜	⬜	⬜
Maumee River	🟨	⬜	🟨	🟨	⬜	🟨	🟨	🟨	⬜	🟨	🟨	🟩	⬜	🟨
Niagara River (US)	🟨	⬜	🟨	🟩	🟨	🟨	🟨	⬜	⬜	⬜	⬜	⬜	⬜	🟨
Niagara River (CA)	🟨	⬜	🟨	🟩	🟩	🟨	🟩	🟩	⬜	🟨	⬜	⬜	🟩	🟨
River Raisin*	🟨	⬜	🟩	⬜	🟨	🟨	🟨	🟩	⬜	🟩	🟩	⬜	⬜	🟨
Rochester Embayment	🟨	🟩	🟨	🟩	🟨	🟩	🟨	🟨	🟩	🟨	🟨	🟩	🟩	🟨
Rouge River	🟨	⬜	🟨	🟨	⬜	🟨	🟨	🟨	⬜	🟨	🟨	⬜	⬜	🟨
St. Clair River (US)*	🟨	🟩	⬜	⬜	🟩	🟩	🟩	⬜	🟨	🟩	🟩	🟩	⬜	🟨
St. Clair River (CA)	🟨	🟩	RFA	RFA	🟩	🟨	🟩	⬜	🟨	🟩	🟩	🟩	⬜	🟨

Table 29. Beneficial Use Impairment (BUIs) status for Lake Erie AOCs and connecting river system AOCs *indicates AOCs having all Management Actions Complete. RFA indicates BUIs that require further assessment before designation can be assigned.

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5.1 Strategies to Prevent and Reduce Nutrients and Bacterial Pollution

USDA 2016

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