5.2 NUTRIENTS AND BACTERIAL POLLUTION

5.2.1 BACKGROUND

While most areas of Lake Huron are not impacted by excessive nutrients (phosphorus and nitrogen) that lead to nuisance or harmful algal blooms and bacterial pollution that make beaches unsafe, localized nutrient and bacterial pollution is an ongoing issue that is limiting the full achievement of the following General Objectives:

- #5: support healthy and productive wetlands and other habitats to sustain resilient populations of native species; and
- #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 maintain nearshore water quality and maintain the status of the General Objective:

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

Many domestic initiatives and programs are in place (Table 20) to address nutrient and bacterial pollution, including: priority watershed identification; monitoring; incentive programs for local landowners to undertake best management practices (BMPs); regulatory measures; and upgrades to municipal wastewater treatment plants.

NUTRIENT AND BACTERIAL POLLUTION: ACTIONS AT A GLANCE

- Maintain, and where possible, optimize wastewater treatment plants and stormwater management facilities
- Use green infrastructure and low impact development
- Continue/enhance integrated, systematic, and targeted nutrient reduction efforts in priority watersheds
- Develop, renew, and revise integrated watershed management plans
- Conduct research and monitoring to better understand nutrient dynamics in Lake Huron and its watershed
- Assemble, synthesize, and report on nutrient and bacterial pollution and beach health
- Improve engagement, communication and coordination to build awareness and improve understanding

5.2.2 MAJOR POLLUTANT SOURCES

Excessive nutrients and bacteria can enter Lake Huron through "point sources" and "non-point sources." Point sources originate from single locations that are relatively easy to identify, such as a wastewater treatment facility. Non-point sources originate from less easily identified sources, such as runoff from agricultural fields, forestry, golf courses, and subdivisions.

Point Sources of Pollution

Efforts to protect water quality by regulating "end-of-pipe" point 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.

Table 20. National pollution reduction initiatives.

EXAMPLES OF NUTRIENT POLLUTION REDUCTION MEASURES	
Farm Bill Act, 2014	Provides authorization for services and programs by the U.S. Department of Agriculture.
Nutrient Management Act, 2002	A nutrient management framework for Ontario's agricultural industry, municipalities, and other generators of materials containing nutrients, including environmental protection guidelines.
Environmental Protection Act / Water Resources Act, 1994	Environmental approval is required by every business or facility in Ontario that creates a discharge to the natural environment.
The Fisheries Act, 1985	Section 36: prohibits the deposit of deleterious substances into waters frequented by fish, unless authorized. The 2015 Wastewater Systems Effluent Regulations: Canada's first national standards for wastewater treatment.
Clean Water Act, 1972	Regulates discharges of pollutants into the waters of the United States and establishes quality standards for surface waters.

Opportunities exist to optimize the performance of treatment plants, and to reduce the volume and frequency of bypasses and overflows. During heavy storm events or snowmelt, the volume of runoff, domestic sewage, and industrial wastewater can exceed the capacity of combined sewer systems resulting in combined sewer overflows. When this occurs, untreated stormwater and wastewater discharge directly to nearby streams, rivers, and lakes with potential negative impacts to water quality.

- The USEPA has a combined sewer overflow control policy and a national framework for controlling combined sewer overflows through the National Pollutant Discharge Elimination System permitting program.
- 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.

Non-Point Source Pollution

Diffuse pollution occurs when excess nutrients and bacteria leach into surface waters and groundwater as a result of rainfall or snowmelt moving over and through the ground.

Agricultural operations are most dense in Ontario's southeast shores of Lake Huron and in Michigan's Saginaw Bay watershed. High-density confined animal feeding operations can generate large amounts of animal waste and excess nutrients and bacteria if not properly managed. Commercial fertilizers and animal manure can be a threat to water quality if they are over-applied, applied too close to a watercourse, applied on frozen ground, or just before a heavy rain. Row-cropping has generally moved toward larger fields without fence rows or riparian vegetation, and without seasonal vegetative cover. Extensive tiling and draining can compound non-point source pollution problems.

- The 2012-2017 Lake Simcoe/South-eastern Georgian Bay Clean-Up Fund supported community-based projects that reduced phosphorous inputs from urban and rural sources to address algal blooms. https://www.ec.gc.ca/eau-water/default.asp
- Since 2010, the Healthy Lake Huron: Clean Water, Clean Beaches Initiative has been implementing actions in priority watersheds with landowners to ensure safe and healthy beaches between Sarnia and Tobermory, Ontario. http://www.healthylakehuron.ca/
- Voluntary farm assistance programs support farms of all sizes to engage in agricultural pollution prevention practices that comply with state, provincial, and federal environmental regulations. The programs are implemented by the Michigan Agricultural Environmental Awareness Assurance Program http://www.michigan.gov/mdard and the Canada-Ontario Environmental Farm Plan. http://www.omafra.gov.on.ca

Before and after photos of sediment trap and municipal drain project (Maitland Valley Conservation Authority).

Soil erosion from poor ***forestry and logging*** practices, road building, fertilizer application, and burning can also be potential sources of water contamination. Practices have improved to such an extent that impacts on Lake Huron 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 runoff from impervious surfaces. Failing ***septic systems*** can contribute bacteria and phosphorus to waterways.

5.2.3 MANAGEMENT LINKAGES WITH THE *AGREEMENT*

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

Annex 4 "Nutrients" is co-led by ECCC and USEPA. Efforts under this Annex are developing the scientific information and modeling techniques required to develop nutrient targets for the Great Lakes. Annex 4 is currently focused on Lake Erie, but includes approaches for monitoring and modeling algal blooms and *Cladophora* growth for Lake Huron, including how to balance nutrients to optimize the productivity of the fishery while minimizing nuisance algae growth and beach fouling.

In fulfillment of a U.S. and Canadian commitment under the Lakewide Management Annex of the Agreement, '*The Great Lakes Nearshore Framework'* was completed to provide an approach for assessing nearshore waters, sharing information, identifying stressors and areas requiring protection, and restoring or prevention activities.

Nearshore areas are a source of drinking water and link the watersheds with the open waters (ABCA).

Agencies can then factor findings from such an approach into priority setting, engage and empower communities, and create collaborative approaches to address water quality issues. The Nearshore Framework will be implemented through the lakewide management process. See www.binational.net for details.

5.2.4 ASSESSING NUTRIENT CONTROL PROJECT EFFECTIVENESS

Ship-based monitoring of offshore nutrient concentrations and the productivity of the lower food web is performed by ECCC and USEPA as a part of Great Lakes surveillance.

Edge-of-field monitoring is now used to test the effectiveness of agricultural best management practices. County Health Units and Departments monitor select beaches for *E. coli* levels and publish annual results. Routine stream and open water monitoring is conducted by federal, provincial, and state agencies to report on nutrient trends.

Saginaw Bay water quality and algal bloom conditions are monitored every second week by the National Oceanic and Atmospheric Administration. Results are posted online at https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/.

5.2.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS NUTRIENT POLLUTION

In consideration of the current trends, main sources of nutrients and bacterial pollution, geographic scope of the issue, and localized impacts (as explained in Chapter 4.6 and above), member agencies of the Lake Huron Partnership have developed nutrient monitoring and management actions and identified the agencies who will lead project implementation (Table 21).

Over the next five years, the Lake Huron Partnership will encourage and support nutrient and bacterial pollution reduction efforts and work with scientists and Great Lakes experts to understand and reduce the impacts of nutrients in the waters of Lake Huron and to reduce harmful and nuisance algal blooms. This will be achieved through binational and domestic initiatives.

Project tracking and reporting on the status and achievements of nutrient monitoring and management actions will be undertaken by member agencies of the Lake Huron Partnership. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 21. Lake Huron Partnership actions that address nutrients and bacterial pollution over the next five years.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
OUTREACH AND EDUCATION		
1	***Communication*:** 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.	OMOECC, ECCC, Bay Mills Indian Community (BMIC), SCIT
POINT SOURCE POLLUTION		
1	***Wastewater Treatment Plants and Stormwater Management Systems:*** • Enforce permitted discharges to ensure Water Quality Standards in receiving waters; and • Enhance the use of green infrastructure and low impact urban development.	USEPA, MDEQ, OMOECC, SCIT, Conservation Authorities
NON-POINT SOURCE POLLUTION IN AGRICULTURAL AREAS		
1	***Nutrient and Bacteria Control:*** Build on existing integrated and systematic efforts within targeted watersheds to improve soil health, reduce overland runoff of nutrients, sediments, and bacteria, and maintain and restore natural heritage features: • Implement agricultural BMPs under the Saginaw Bay Watershed Regional Conservation Partnership Program within high-priority watersheds (Shiawassee, Pigeon/Pinnebog, Cass, Pine/Chippewa, Sebewaing, and Kawkawlin Rivers); • Address nuisance and harmful algae and promote safe and clean beaches in priority watersheds in Ontario's southeast shore (Pine River, Garvey Glenn, North Bayfield, Main Bayfield, Lambton Shores) through the following actions: - Targeted agricultural BMP and edge-of-field monitoring; - Continuous flow and event-based water quality monitoring and reporting; - Identification of additional priority watersheds in the Lake Huron watershed; and - Outreach and engagement with landowners and the public.	USDA-NRCS, MDEQ, SCIT OMOECC, OMAFRA, OMNRF, Parks Canada, Conservation Authorities
2	***Watershed Management Planning*:** Revise, renew, and/or develop integrated watershed management plans and link to coastal and nearshore management and other nutrient reduction actions at a community level: • Build local capacity for monitoring and best management practice implementation, and encourage and promote community involvement; and • Continue to implement management plans under Section 319 Nonpoint Source Management Program of the U.S. Clean Water Act.	USEPA, MDEQ, OMOECC, OMAFRA, OMNRF, BMIC, SCIT, Conservation Authorities
SCIENCE, SURVEILLANCE, AND MONITORING		
1	***Open Water:*** Conduct spring and fall open water nutrient surveys (2017, 2018, 2019, 2020, and 2021).	ECCC, USEPA
2	***Agricultural Areas*:** Continue edge-of-field water quality monitoring in targeted Ontario and Michigan watersheds to assess effectiveness of best management practices.	OMOECC, USGS, Conservation Authorities
3	***Streams*:** Continue surface water quality monitoring and synthesis of information from various stream and river locations: • Joint program between the province of Ontario and conservation authorities via the Provincial Water Quality Monitoring Network (PWQMN); and • Continue to assess stream water quality under Section 305(b) of the U.S. Clean Water Act.	OMOECC, Conservation Authorities, USEPA, MDEQ
4	***Watershed*:** Continue a multi-watershed nutrient study, to assess the interaction between agricultural land use and nutrient loadings in southeast shore streams.	OMOECC, Conservation Authorities

[continued on next page]

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021 (continued)	AGENCIES INVOLVED
5	***Saginaw Bay Water Quality and Harmful Algal Bloom (HAB) Monitoring and Reporting:*** • Explore expanding real-time water quality and nutrient buoy system to several sites in inner Saginaw Bay; • Enhance monitoring and reporting of algal blooms on NOAA-GLERL's HAB and Hypoxia webpage to provide weekly updates from June through October; • Conduct experiments to understand the environmental factors that influence changes in algal bloom community composition, toxicity, and ecosystem services; • Develop a Saginaw Bay Harmful Algal Bloom Bulletin; and • Develop a Saginaw Bay 3D- HAB Tracker product similar to the current 3D-HAB Tracker developed for western Lake Erie.	NOAA-GLERL, Cooperative Institute for Limnology and Ecosystems Research (CILER)
6	***Science Synthesis:*** Assemble, synthesize, and report on nutrient and bacterial contamination science and monitoring results from projects funded by the Lake Simcoe/South-eastern Georgian Bay Clean Up Fund (2012-2017).	ECCC
7	***Research and Monitoring:*** Improve understanding of invasive mussels and their influence on phosphorus cycling in the aquatic system and *Cladophora* growth.	Annex 4 Subcommittee

5.3.6 ACTIVITIES 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 Huron by undertaking the following actions:

- Choose phosphate-free detergents, soaps, and cleaners - use appropriate amounts;
- Avoid using lawn fertilizers;
- Always pick up pet waste;
- Use natural processes to manage stormwater runoff and reduce the amount of impervious surfaces;
- Install a rain barrel and plant a rain garden with native plants, shrubs, and trees so that water soaks into the ground;
- Inspect and pump out your septic system regularly;
- Implement improved septic technologies, including conversion of septic systems to municipal or communal sewage systems;
- Incorporate agricultural best management practices, such as grassed swales, filter and/or buffer strips to control and reduce store stormwater runoff; and
- Keep cattle out of streams; leave a buffer strip to trap nutrient and sediment runoff; and plant a shelter belt.

Agricultural BMP showing extensive grassed waterways (ABCA).

One of the many alternate watering devices and fencing projects that restrict cattle from streams to improve local water quality and aquatic habitat (Bruce Peninsula Biosphere Association).

5.3 LOSS OF HABITAT AND NATIVE SPECIES

5.3.1 BACKGROUND

The main factors contributing to the loss of biological diversity are habitat alteration, destruction and fragmentation-on land, in streams, in rivers, and along the shores of Lake Huron. Other threats include: non-point source pollution, non-native invasive species, climate change, unsustainable shoreline development and alterations, and dams and barriers. These factors may prevent the achievement of the following General Objective:

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

Actions that restore and protect habitat and species will also indirectly benefit other General Objectives:

- #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.

In 2010, the former Lake Huron Binational Partnership built on numerous strategies to complete *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron* (Franks Taylor et al., 2010). This involved a two-year consultation period with more than 300 individuals representing approximately 100 agencies, Tribal, First Nations and Métis governments, conservation authorities, non-government organizations and universities. The Strategy discusses ecological condition, identifies key threats to biodiversity, prioritizes conservation action sites, and recommends 21 conservation strategies for Lake Huron. For more information, go to: https://www.conservationgateway.org.

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

Lake Huron's biodiversity conservation strategy developed in partnership with the Lake Huron conservation community.

- The Great Lakes Fishery Commission's Lake Huron Technical Committee works across borders to implement fisheries management plans, report on the fishery, and develop *Fish Community Goals* and *Environmental Objectives* (Liskauskas et al., 2007);
- The State of the Lakes Ecosystem Conference 1998 Biodiversity Investment Areas for Aquatic Ecosystems (Koonce et al., 1999); and
- Michigan Department of Natural Resources Watershed Assessment Reports.

HABITAT AND NATIVE SPECIES: ACTIONS AT A GLANCE

- Nearshore reef and shoal spawning habitat rehabilitation
- Aquatic habitat assessments and rehabilitation
- Stream connectivity restoration and enhancement
- Shoreline management planning and actions that address regional stressors and threats
- Watershed restoration and protection
- Walleye, Lake Trout, Cisco and other native species restoration planning efforts
- Monitor, map and report on coastal wetland condition
- Science to inform management and assess effectiveness of actions through monitoring

5.3.2 THREATS TO LAKE HURON'S HABITATS AND SPECIES

Environmental issues and threats to Lake Huron's biodiversity were determined through a binational, collaborative process and are detailed in *The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron* (Franks Taylor et al., 2010). Many of these threats and the actions to address them are covered in other sections of the chapter,

including: *Nutrient and Bacterial Pollution* which covers non-point source pollution (Chapter 5.2); *Invasive Species* (5.4); and *Climate Change Impacts* (5.5). Other issues that directly and negatively impact Lake Huron habitat and native species are covered in this section.

Shoreline Development and Alterations

While directly degrading and destroying nearshore and coastal wetland habitat, shoreline development and alteration also disrupt natural circulatory patterns, nutrient cycles, sediment transport, and other coastal processes and pathways. Lake bed modifications due to jetties, groins, and shoreline armoring also provide hard surfaces that may facilitate the spread of invasive *Dreissenid* mussels.

Extensive dredging in the nearshore at Collingwood, Ontario (OMNRF).

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

- The Michigan State Coastal Zone Management Program promotes wise management of the cultural and natural resources of Michigan's Great Lakes coast;
- Under the Ontario government plan to conserve biodiversity, and *Ontario's Great Lakes Strategy*, the Ontario Ministry of Natural Resources and Forestry 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;
- Great Lakes Coastal Wetland Monitoring Program and McMaster University monitor coastal wetland biota, habitat, and water quality and developed a GIS-based inventory;
- The Southern Georgian Bay Shoreline Initiative coordinates efforts for monitoring shoreline alterations and water quality, and promotes community-based stewardship and information sharing.

Dams and Barriers

The installation and management of hydropower dams, low head dams, culverts, and water-control structures threaten the diversity of native fishes by restricting or eliminating connectivity between the lake and critical spawning, nursery, and overwintering habitat.

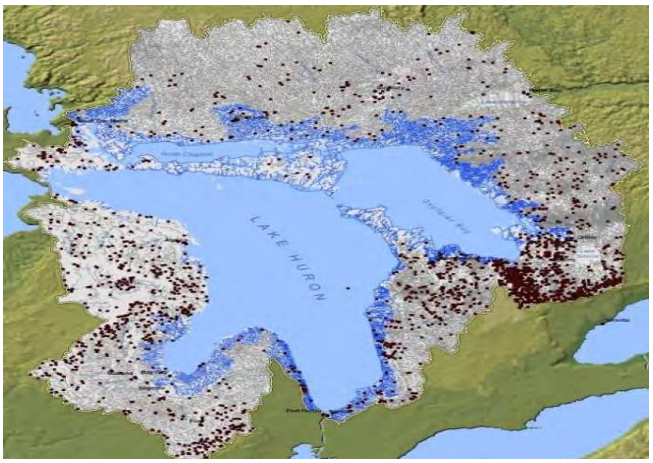

Figure 27. Map of Lake Huron dams and barriers (SOGL).

Dams, impoundments, and barriers also interrupt the natural flow of water, nutrients, and sediment to Lake Huron, alter temperature regimes (e.g., thermal heating), and increase the transformation and exposure of toxic pollutants (e.g. mercury) (St. Louis et al., 2004; Calder et al., 2016). Dams, however, help prevent the spread of Sea Lamprey and other aquatic invasive species, and management decisions must consider their benefit as tools of Lamprey control before decommisioning and replacement (Figure 27).

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

- Fishworks 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. https://greatlakeslcc.org/resource/fishworks-habitat-connectivity-decision-support-tool.

- The Great Lakes Restoration Initiative funded partners to remove the Cass River Dam at Frankenmuth, Michigan to allow passage of fish species, such as Walleye and Lake Sturgeon. Fourteen separate weirs and adjacent "resting pools" have been constructed over a span of approximately 350 feet for non-jumping species.
- The Canadian Government, through the Recreational Fisheries Conservation Partnership Program, supported the Saugeen Valley Conservation Authority to remove the Lockerby Dam on the Saugeen River.

Other Issues and Opportunities

With the variability in open water nutrients and abundance of prey fish, researchers have been examining additional means to increase the productivity of Lake Huron. Artificial reefs and strategic rock placements are ongoing efforts that have produced positive responses by fishes.

The reintroduction of Cisco (formerly known as Lake Herring), one of nine related coregonid species that originally occurred in Lake Huron, has been a focus for Lake Huron fisheries managers. The introduction of invasive species (e.g., Alewife), overfishing, and eutrophication were responsible for its collapse. Cisco rehabilitation would help to maintain a diverse prey fish community, reestablish the linkage between the inner and outer Saginaw Bay, and enhance foraging options for Walleye. It could also reduce predation to Yellow Perch.

National, provincial, and state parks dot the shores of Lake Huron. Still, almost 82% of the shoreline is unprotected (Parker, pers. comm., 2016), highlighting the importance of existing parks and the need for new protected areas.

Artificial shoals and rock clusters improved Walleye spawning habitat at the Moon River Basin (OMNRF).

Recognizing the role of non-government organizations and the public, many funding programs exist to facilitate habitat and native species conservation (Table 22).

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

UNITED STATES	CANADA
• U.S. Great Lakes Restoration Initiative https://www.glri.us//	• ECCC Eco-Action Community Funding Program
• USDA, NRCS National Conservation Innovation Grants https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/	• ECCC National Wetland Conservation Fund; Habitat Stewardship Program
• USEPA Environmental Justice Grants https://www.epa.gov/environmentaljustice	• ECCC Environmental Damages Fund
• USFWS Partners for Fish and Wildlife https://www.fws.gov/partners/	• ECCC Aboriginal Fund for Species at Risk
• USFWS National Fish Passage Program https://www.fws.gov/fisheries/whatwedo/nfpp/nfpp.html	• ECCC Great Lakes Sustainability Fund - Link to all ECCC programs: http://www.ec.gc.ca/financement-funding/default.asp?lang=En&n=923047A0-1
• Great Lakes Fish Habitat Partnership http://www.fishhabitat.org/the-partnerships/great-lakes-basin-fish-habitat-partnership	• Recreational Fisheries Conservation Partnerships Program http://www.dfo-mpo.gc.ca/pnw-ppe/rfcpp-ppcpr/index-eng.html
• USFWS National Wildlife Refuge System https://www.fws.gov/refuges/	• Ontario's Great Lakes Guardian Fund https://www.ontario.ca/page/great-lakes-guardian-community-fund
• USFWS National Coastal Wetlands Conservation Grant Program https://www.fws.gov/coastal/coastalgrants/	• Canada Ontario Agreement on Great Lakes Water Quality and Ecosystem Health
• Sustain Our Great Lakes http://www.sustainourgreatlakes.org/	

5.3.3 MANAGEMENT LINKAGES WITH THE *AGREEMENT*

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. Annex 7 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 ASSESSING PROGRAM EFFECTIVENESS

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

- Lake Huron Technical Committee – Technical Report Series and Publications;
- Bottom Trawl and Acoustics Surveys (USGS);
- St. Marys River and Saginaw Bay Area of Concern Programs;
- Great Lakes Coastal Wetland Consortium, the Great Lakes Coastal Wetland Monitoring Program, and McMaster University Coastal Wetland monitoring, assessment and Inventories; and
- Provincial, state and tribal fish community monitoring programs.

5.3.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS HABITATS 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 Huron Partnership have developed habitat and species monitoring and management actions and the agencies who will lead project implementation (Table 23).

Over the next five years, the Lake Huron 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.

Project tracking and reporting on the status and achievements of habitat and species monitoring and management actions will be undertaken by the Lake Huron Partnership. Not all of the member agencies of the Lake Huron Partnership are responsible for monitoring and project implementation. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 23. Lake Huron Partnership actions that address loss of aquatic habitat and native species.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
1	***Spawning Reefs and Shoals:*** Continue to develop strategies and implementation plans that rehabilitate and/or create nearshore reefs to support overall lake productivity.	MDEQ, MDNR, USFWS, USGS, SCIT
2	***Aquatic Habitat:*** Assess streams and estuaries to determine aquatic habitat significance, stressors, and limitations to fish spawning and migration, and consult with local partners, stakeholders, and governments to identify rehabilitation priorities, including: • Assessment of Eastern Georgian Bay estuaries with project implementation.	OMNRF, MDNR, SCIT, Eastern Georgian Bay Stewardship Council (EGBSC)
3	***Stream Connectivity:*** Restore stream connectivity and function through dam removal, the construction of fish passage alternatives (e.g., ladders), and stream culvert improvements to compensate for loss of riverine habitat.	USFWS, MDNR,OMNRF, MDEQ, Conservation Authorities
4	***Habitat and Native Species Conservation***: Build on *"The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron"* through integrated conservation planning to identify areas of ecological significance and areas facing environmental threats and stressors: • Update and share Canadian geospatial information on ecosystem classification (Lead - OMNRF); • Engage stakeholders and the public; • Facilitate information sharing; • Develop regional conservation and stewardship plans (Ontario); and • Promote community-based conservation and stewardship.	Conservation Authorities, OMNRF, DFO, PC, OMOECC, ECCC, USEPA, USFWS, MDEQ, MDNR

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#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021 (continued)	AGENCIES INVOLVED
SPECIES RECOVERY AND MONITORING		
1	***Walleye Restoration***: Develop a Walleye Management Plan for the Ontario waters of Lake Huron and track the effectiveness of harvest regulations throughout Lake Huron.	OMNRF
2	***Cisco Restoration:*** Examine the benefits of reintroducing Cisco to targeted areas of the lake.	MDNR, USFWS, OMNRF, USGS, Tribes
3	***Coastal Wetlands:*** Monitor coastal wetlands to assess coastal wetland water quality, species diversity, and the impacts of human activities; and promote restoration and enhancement efforts.	USEPA, OMNRF, USFWS, BMIC, SCIT, PC, Conservation Authorities

5.3.6 ACTIVITIES THAT EVERYONE CAN TAKE

Protecting and restoring habitats and species involves the coordination of many different agencies, non-governmental organizations, professions and the pursuit of management actions by various partners and the public. Here are some suggestions on how to do your part:

- Maintain natural vegetation along the coast and streams;
- Resist the urge to "tidy up" the beach. Natural vegetation and debris serve as habitat;
- Plant native trees and shrubs on your property;
- Get involved with shoreline clean up events;
- Consider working with neighbours, 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, see https://www.lakehuron.ca/stewardship-plans-and-guides; and
- Share your knowledge with your friends, neighbours, cottage renters or even strangers, about the rarity and ecological importance of each of the special shoreline types.

High school students erecting fence designed to keep reptiles off highway as part of a Lake Huron Youth Summit (ECCC).

River restoration and tree planting at the Kagawong River (Manitoulin Island Stream Improvement Association).

5.4 INVASIVE SPECIES

5.4.1 BACKGROUND

The introduction, establishment, and spread of invasive species are significant threats to Lake Huron 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. Sea Lamprey continue to impact valuable commercial and sport fisheries. *Dreissenid* mussels have altered the food web in the open waters and are thought to increase nutrient levels, water clarity, and algal biomass in nearshore waters. The ecological link between mussels, nuisance rotting algae, and Round Goby is also speculated to enhance the transfer of botulinum toxin through the food web, resulting in Type E botulism-related deaths of loons, waterfowl, shorebirds, and fish; some of which are species at risk. Aquatic non-native invasive species are undermining efforts to restore and protect ecosystem health, water quality, and the full achievement of the following General Objectives:

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

INVASIVE SPECIES: ACTIONS AT A GLANCE

Undertake a basin-wide approach to:

- Prevent introductions from ballast water;
- Detect and respond to new introductions; and
- Stop the establishment of Bighead and Silver Asian Carp in the Great Lakes.

Work within Lake Huron to:

- Reduce the impacts of invasive species, including *Phragmites;* and
- Minimize the spread of invasive species by recreational boating, fishing equipment, and other recreational activities.

The government of Ontario released the Ontario Invasive Species Act (2015) and 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).

Table 24. Examples of invasive species reduction initiatives by the various government departments.

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.
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'.

In the United States, the National Invasive Species Council published a four-year National Invasive Species Management Plan (2008) to direct the actions of federal agencies. The U.S. Forest Service also published a National Strategic Framework for Invasive Species Management (2013). The state of Michigan published the Aquatic Invasive Species Management Plan (2013) with actions for implementation as well as maintaining and enhancing existing efforts 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.

Ontario's Invasive Species Strategic Plan (2012) prevents new invaders from arriving and surviving in the province, slows or reverses the spread of existing invasive species and reduces the harmful impacts of existing invasive species.

5.4.2 KEY PATHWAYS FOR INTRODUCTION AND SPREAD

The most effective approach to prevent the introduction and spread of new invasive species is to manage the pathways through which invasive species enter and spread. Below are the key pathways and examples of existing management approaches.

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. Historically, an average of one non-native species was found to be established in the Great Lakes about every 8 months. Recent practices, including ballast water exchange or treatment and sediment management, have significantly reduced the rate of introduction. Because of compatible ballast water exchange regulations between Canada and the United States and stringent binational enforcement, no new aquatic invasive species attributable to the ballast water of ships have been reported in the Great Lakes since 2006.

- 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 work is underway on the design and performance testing of ballast water management systems.

Illegal Trade of Banned Species

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

- A risk analysis of illegal trade and transport into Great Lakes jurisdictions was completed and a report of these findings was delivered to the Great Lakes Fishery Commission's binational Law Enforcement Committee. The report recommends risk management efforts to address the unacceptable risks documented for species regulated by state, provincial, and federal agencies in the internet, 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-species.html.

Recreational Activities

Float planes, sailboats, personal watercraft, kayaks, diving equipment, ropes, and fishing gear (e.g., bait bucket dumping) may transport the attached fish, fragments, larvae, and eggs of invasive species to new bodies of water. Currently there are few specific regulations directed at recreational and commercial boating related to preventing 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.

- In the United States, 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.
- 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, and the products of this assessment will assist in identifying areas to focus on 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:

- Conducted by the U.S. Army Corps of Engineers (USACE), the Great Lakes and Mississippi River Interbasin Study (GLMRIS) Report 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/2016AsianCarpActionPlan.pdf.

Additional Efforts Underway

Domestic efforts in Canada and the United States are underway to address non-native species.

Sea Lamprey management and control have been ongoing since 1960 by the Great Lakes Fishery Commission in collaboration with all levels of government. Lampricide was applied to 28 streams and five lake areas as well as the St. Marys River in 2015. In addition, 17 barriers and dams that were specifically constructed or modified to block Sea Lamprey spawning migrations in Lake Huron streams were operated and maintained. Research continued into other alternatives to lampricide, such as attractants (e.g. pheromones), repellents (e.g. alarm cues), juvenile trapping, nest destruction, and new adult trapping designs. Sea Lamprey abundance has recently declined, and in 2015, the Lake Huron suppression target was achieved for the first time in 30 years.

Invasive Phragmites is mapped using satellite imagery (U.S.) and aerial photographs to monitor its spread. Efforts are underway in the U.S. by the *'Great Lakes Phragmites Collaborative'* and in Ontario by the *'Ontario Phragmites Working Group'*. 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*.

Outreach and Engagement efforts are implemented domestically in Michigan 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.

5.4.3 MANAGEMENT LINKAGES WITH THE *AGREEMENT*

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.

Annex 5 "Discharges from Vessels" 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.

Annex 6 "Aquatic Invasive Species" 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 of the Early Detection and Rapid Response Initiative 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 ASSESSING AQUATIC NON-NATIVE AND INVASIVE SPECIES PROGRAM EFFECTIVENESS

The effectiveness of invasive species programs is tracked through several basin wide initiatives. The overall success in preventing new introductions will be tracked as part of Annex 6's Early Detection and Rapid Response Initiative and NOAA's Great Lakes Aquatic Non-Indigenous Species Information Systems. https://www.glerl.noaa.gov/res/Programs/glansis/

The Great Lakes Fishery Commission will continue to control Sea Lamprey populations in Lake Huron. Annual reports that evaluate the Sea Lamprey Control Program are produced by DFO and USFWS. The Asian Carp Regional Coordinating Committee provides a forum for coordination of new research about how to detect, control, or contain Asian Carp.

5.4.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS INVASIVE SPECIES 2017-2021

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 Huron 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 Huron 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 Huron.

Project tracking and reporting on the status and achievements of monitoring and management actions will be undertaken by the Lake Huron Partnership. Not all of the member agencies of the Lake Huron Partnership are responsible for contaminant monitoring, surveillance, and implementation. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 25. Lake Huron Partnership actions that address aquatic and terrestrial invasive species over the next five years.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
1	***Ballast Water:*** Through the Annex 5 subcommittee, establish and implement programs and measures that protect the Great Lakes Basin ecosystem from the discharge of AIS in ballast water.	Transport Canada, USCG, USEPA
2	***Early Detection and Rapid Response:*** Through the Annex 6 subcommittee, implement an 'early detection and rapid response initiative' with the goal of finding new invaders and preventing them from establishing self-sustaining populations.	DFO, USFWS
3	***Canals and Waterways:*** Through the Asian Carp Regional Coordinating Committee, prevent the establishment and spread of Bighead and Silver Carp in the Great Lakes.	ACRCC member agencies

[continued on next page]

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021 (continued)	AGENCIES INVOLVED
4	***Sea Lamprey:*** Control the larval Sea Lamprey population in the St. Marys River with selective lampricides. Continue operation and maintenance of existing barriers and the design of new barriers where appropriate.	DFO, USFWS, GLFC
5	***Improve understanding of invasive species impacts to inform management efforts:*** • *Impacts of Round Goby on the Foodweb:* Enhance assessment methods and technology to better understand Round Goby population density and distribution. • *Causes of Botulism Outbreaks:* Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl. • *Cladophora growth*: Work through the Annex 4 subcommittee to support the creation of Lake Huron sentinel *Cladophora* monitoring sites to determine the role of mussels in nearshore algae growth and possible mitigation efforts.	USGS, MDNR, OMNRF
6	***Control of Terrestrial and Wetland Invasive Species:*** Maintain coastal and nearshore aquatic habitat diversity and function through appropriate control of *Phragmites* and other detrimental invasive species (e.g. Glossy Buckthorn, European Frog-bit, Purple Loosestrife, Japanese Knotweed) including monitoring, mapping, and control efforts guided by BMPs. • Coordinate *Phragmites* control efforts and share BMPs through the *Ontario Phragmites Working Group* and *Great Lakes Phragmites Collaborative.*	USFWS, USEPA, BMIC, SCIT, MDNR, Parks Canada, SCRCA, NVCA, OMNRF
SCIENCE, SURVEILLANCE, AND MONITORING		
1	***Surveillance***: Maintain and enhance early detection and monitoring of non-native species (e.g. Asian Carp) through the Annex 6 *Early Detection and Rapid Response Initiative.*	DFO, OMNRF, USFWS, MDNR
2	***Monitoring***: Maintain an index time series that shows the impact of Sea Lamprey control on Lake Trout population status.	MDNR
OUTREACH AND EDUCATION		
1	***Communication***: Undertake additional aquatic invasive species prevention outreach and education, including discussions with recreational boaters and lake access site signage.	DFO, BMIC, SCIT, MDEQ, OMNRF, SCRCA

5.4.6 ACTIVITIES THAT EVERYONE CAN TAKE

Learn about how Canada and the U.S. are contributing to aquatic invasive species science through the work of federal scientists, collaboration with national and international interest groups, and funding of partnership projects.

- Learn how to identify, report, and stop the spread of *Phragmites*;
- Use non-invasive plants for your yard or garden;
- Clean your boots before you hike in a new area to prevent the spread of weeds, seeds and pathogens;
- Drain and clean your boat before using it on a different body of water;
- Do not move firewood that can harbor forest pests;
- Do not release aquarium fish and plants, live bait or other exotic animals into the wild;
- Volunteer at a local park to help remove invasive species. Help educate others about the threat.

If you think you have discovered an aquatic invasive species, please contact the following references:

- Ontario Invading Species http://www.invasivespeciescentre.ca/
- Michigan Invasive Species - http://www.michigan.gov/invasives

Signs in Ontario (left) and Michigan (right) informing and encouraging best practices to prevent invasive species.

5.5 CLIMATE CHANGE IMPACTS

5.5.1 BACKGROUND

Impacts from a changing climate include: warming air and water temperatures, changing precipitation patterns, decreased ice coverage, and water level fluctuations. These climate-related impacts 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 28).

5.5.2 CLIMATE CHANGE OBSERVATIONS AND PROJECTIONS

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

Temperature

- Summer surface water temperatures in Lake Huron increased 2.9°C between 1968 and 2002 (Dobiez and Lester, 2009);
- Projected 1.5-7°C increase in air temperature by 2080s in the Great Lakes Basin;
- Projected 0.9-6.7°C increase in surface water temperature in the Great Lakes (2080s); and
- 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 (~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);
- 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);
- Annual lake ice coverage for Lake Huron decreased on average about 2% per year between 1973-2010, (Austin and Colman, 2007; Wang et al., 2010); and

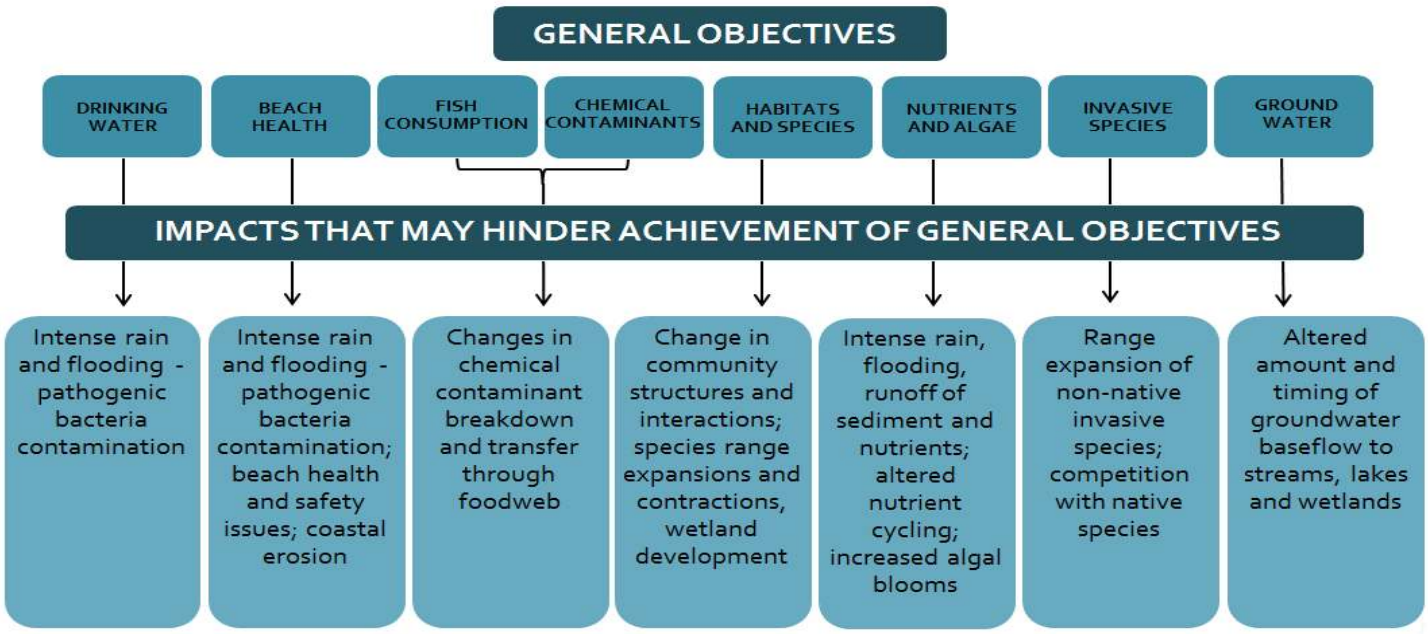

Figure 28. Potential climate change impacts, and challenges to achieving the General Objectives of the 2012 *GLWQA*.

- 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).

Projected Seasonal Changes

- Models that forecast climate-related impacts 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;
- Fluctuations around lower mean water levels; and
- Increases in the direction and strength of wind and water currents.

Biological Impacts

The first evidence of biological change in the Great Lakes shows that the diatom (phytoplankton) taxa in the group *Cyclotella sensu lato* are increasing in abundance in correlation with recent and rapid atmospheric warming (Reavie et al., 2016).

5.5.3 LAKE HURON CLIMATE-RELATED CHALLENGES AND INTERVENTIONS

Responses to climate change are organized around two main interventions: 1) those that are ongoing by Federal, State, and Provincial governments focused on reducing greenhouse gas emissions (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)***. The latter is considered essential and is in accordance with the Agreement's commitment to address climate change impacts by using available domestic programs to achieve the General Objectives.

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

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 • 2015 – ON and QC Cap and Trade • 2009 – Green Energy and Green Economy Act
Michigan	• 2012 – Climate Change Adaptation Plan for Coastal and Inland Wetlands 2009 – MDEQ Climate Action Plan

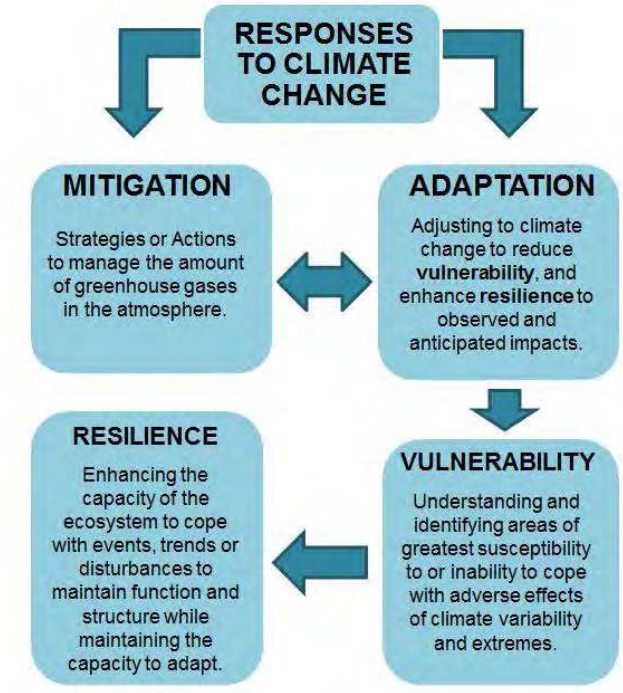

Figure 29. Climate change definitions used in this LAMP.

Protecting Against Loss of Habitat and Species and Enhancing Resiliency

Lake Huron's shorelines and wetlands are already subject to a range of social and environmental stressors, and climate change can exacerbate habitat loss and degradation. Previous sustained low water levels resulted in extensive dredging in areas with shallow sloping shorelines; by contrast, landowners harden shorelines to prevent erosion under high water levels. Each has negative ecological and water quality implications. Lake Huron water levels are currently above the long-term mean (176.45 m) following a 15-year sustained low water level and an all-time low set in December of 2013 (Figure 30).

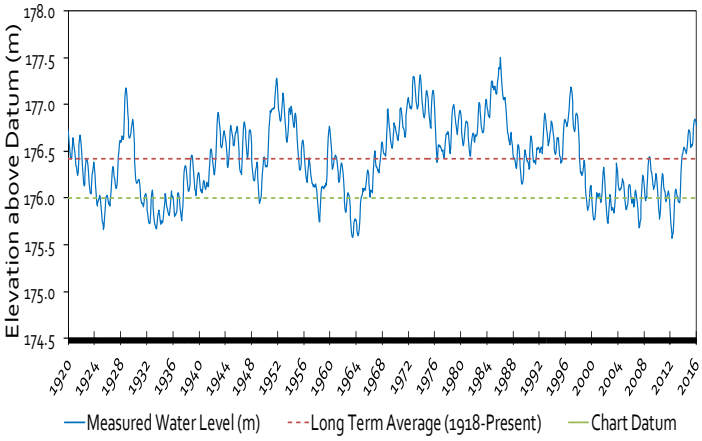

Figure 30. Lake Huron monthly average water levels in metres (1920-2016).

Impacts observed throughout the basin during long-term low levels include:

- Temporary disconnection and loss of wetland function with negative impacts to spawning fish such as Muskellunge and Northern Pike (Weller, Leblanc, Liskauskas & Chow-Fraser, 2016), migrating birds and aquatic plants;
- Reduced structural complexity and increased homogeneity of wetland plant communities (Midwood and Chow-Fraser, 2012); and
- Conditions for the highly invasive plant, *Phragmites*, to spread throughout the basin and outcompete native plant species (Tulbure and Johnston, 2010).

Coldwater fishes are critical to the economy of Lake Huron and are important ecological indicators of climate change. Potential climate-related impacts to lake ecology include: range contraction (e.g., Brook Trout, Lake Trout); competition due to range expansions and contractions of other species; and loss of hydrological connectivity between streams/rivers and Lake Huron may impede movement of migratory species.

Adaptive Measures: Climate change adaptation strategies to protect vulnerable coastal wetland habitat and fragile coldwater fish 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 central Lake Erie; https://greatlakeslcc.org/issue/landscape-conservation-planning-and-design
- Stream rehabilitation and enhancement projects that include modifications that provide fish refuge from thermal heating and low flow conditions (e.g., Manitoulin Streams Improvement Association); and
- Evaluation of migratory fish aquatic habitat significance, limitations under water level fluctuations, and stream habitat rehabilitation and enhancement projects in Eastern Georgian Bay.

The Lake Huron shoreline at Tawas Point, Michigan; part of the Great Lakes Coastal Wetlands Resilient Lands and Water Partnership (NOAA).

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: 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.

Before and after ditch and sediment trap as part of municipal drain project (Maitland Valley Conservation Authority).

Protecting Critical Community Infrastructure:

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

LOW IMPACT DEVELOPMENT

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

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;
- 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
- Michigan state, the province of Ontario, and several conservation authorities and municipalities are developing LID manuals.

5.5.4 MANAGEMENT LINKS WITH THE *AGREEMENT*

Under Annex 9 of the Agreement, the governments are tasked with coordinating efforts to identify, quantify, understand, and predict climate change impacts 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 change impacts on the quality of the waters of the Great Lakes and to achieve the General Objectives of this Agreement.

5.5.5 LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS CLIMATE CHANGE (2016-2021)

In consideration of the current and future potential challenges to water quality, coldwater fishes and other species vulnerable to climate change impacts, as explained in Chapter 4. and above, member agencies of the Lake Huron Partnership have developed actions and identified the management agencies involved in implementing them (Table 27).

Over the next five years, the Lake Huron Partnership will encourage and support efforts that address the impact of climate change and

work with scientists and Great Lakes experts to understand and reduce the impacts of climate change in the waters of Lake Huron.

Project tracking and reporting on the status and achievements of nutrient monitoring and management actions will be undertaken by the Lake Huron Partnership. Not all of the member agencies of the Lake Huron Partnership are responsible for monitoring, surveillance, and implementation. Actions will be undertaken to the extent feasible, by agencies with the relevant mandates.

Table 27. Lake Huron Partnership actions that address climate change impacts over the next five years.

#	LAKE HURON PARTNERSHIP ACTIONS (2017-2021)	AGENCIES INVOLVED
	CLIMATE CHANGE ACTIONS Actions identified for nutrients and bacterial pollution and loss of habitat and native species will help to maintain ecosystem function and enhance resilience to the impacts of climate change.	
1	***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 Actions; and • Great Lakes Restoration Initiative.	Conservation Authorities, MDNR, OMOECC
2	***Coldwater Streams:*** Support the protection and enhancement of coldwater fishes: • Develop Lake Trout monitoring and rehabilitation plans; • Identify potential restrictions preventing passage of migratory fish; and • Create and enhance coldwater refuges where appropriate to maintain appropriate habitat conditions for aquatic organisms.	Conservation Authorities, MDNR, OMNR
3	***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; and • Lake Simcoe Low Impact Development Guidance Documents.	BCIT, Conservation Authorities, OMOECC, SCIT
	OUTREACH AND EDUCATION	
1	***Communications:*** Undertake and support outreach and education to stakeholders and the public on the impacts of climate change to the Great Lakes and Lake Huron through fact sheets, newsletters and other means.	Conservation Authorities, ECCC

5.5.6 ACTIVITIES THAT EVERYONE CAN TAKE

Personal Climate Change Mitigation Actions

Here are some solutions that you can use to reduce your personal contribution to greenhouse gas emissions:

- **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 sequester carbon, helping to remove carbon dioxide and other greenhouse gases from the air.
- **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, low-greenhouse gas 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.
- **Eat locally**. Buy organic and locally grown food, as it does not have to travel as far. Avoid buying processed foods.
- **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. Buy less stuff.
- **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 s**pread the word to your family and friends**!

Climate Change Adaptation Planning at the Community Level

Climate adaptation planning is used to develop and apply plans to reduce the impacts and consequences of climate change and climate variability. There are a variety of approaches to climate adaption planning. Some communities create a dedicated climate adaptation plan — a document describing 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 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 adaptation, visit Great Lakes Climate: A collection of Great Lakes climate change resources to help educators, government officials, community planners, and the public (http://climategreatlakes.com/) and 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 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 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).

Protected Areas as a "Natural Solution" to Climate Change

Increasing the amount of protected areas not only conserves species and habitat, it also provides essential ecosystem goods and services and offers a cost-effective "natural solution" to climate change through the following ways:

- Mitigates climate change through the sequestration and storage of vast amounts of carbon in forests, wetlands and other natural ecosystems;
- Serves as a safe haven for species and as climatic conditions shift, networks of protected areas can facilitate species movement and connectivity, increasing ecosystem resilience and adaptive capacity;
- Natural ecosystems, such as wetlands and forested riparian areas, can help to clean water, mitigate floods and prevent erosion;
- Prevents biodiversity loss; and
- Serves as a benchmark for research and monitoring and demonstrate evidence-based planning and management.

6.0 SCIENCE AND MONITORING

This section provides information on science and monitoring priorities to be considered by all management agencies and scientists in an effort to enhance the understanding of Lake Huron.

6.1 GREAT LAKES COOPERATIVE SCIENCE AND MONITORING INITIATIVE (CSMI)

The Cooperative Science and Monitoring Initiative (CSMI) was created as the result of a need to coordinate science in support of management of the Great Lakes. The process includes enhanced monitoring and research activities which are conducted in one lake per year and are tied to the needs of lakewide management. Lake Huron assessments took place in 2002, 2007 and 2012.

In the fall of 2015, the Lake Huron Partnership agencies convened over 40 Canadian and U.S. resource management agencies, environmental non-governmental organizations, academic scientists, and the public to share information and establish joint science and monitoring priorities for the 2017 CSMI field year.

As explained in more detail below, the results from science and monitoring studies confirmed that Lake Huron has undergone significant system-wide changes in nutrient concentrations, lake productivity, and the abundance and distribution of native species.

The specific processes causing changes to lake productivity (i.e., the diversity and abundance of living organisms in the system) are not well understood; however, it is clear that filter-feeding invasive *Dreissenid* mussels (Zebra and Quagga Mussels) are intercepting nutrients arriving from streams and rivers and creating a series of cascading changes in the food web. The non-native Round Goby further complicates the food web by eating mussels and being a prey item for larger fish.

The Lake Huron Partnership has identified the need to better understand the relationship between nutrient loadings and lake productivity. Additional information is needed on the status and trends of the lower and upper food web components and the health of the fishery. The findings from the 2017 CSMI year of study will be shared with resource managers to better inform management programs, future CSMI activities, and the next Lake Huron LAMP.

6.2 LAKE HURON SCIENCE AND MONITORING PRIORITIES

Nutrient Loading, Fate, and Transport

Historically, productivity in the offshore waters of Lake Huron was directly linked to nutrient inputs from streams and rivers. This simple relationship is now complicated by *Dreissenid* mussel densities in the nearshore and offshore waters. Relatively stationary, these filter-feeding mussels remove nutrients and suspended algae, phytoplankton, and zooplankton from the water column, redistributing it in the form of feces and bio deposits (loose pellets of mucous mixed with particulate matter), nourishing nearshore algae and aquatic plants. Algal fouling is now found in areas not typically associated with elevated ambient nutrient levels, presumably caused by increased transparency and the "fertilizing" effect of mussel beds.

Recommended science activities to help explain nearshore and offshore nutrient dynamics consist of the following:

- Continue to characterize land use and nutrient loading linkages;
- Quantify nutrient loadings to the lake; and
- Improve the understanding of physical and biological processes that move nutrients/energy from the nearshore to offshore, with consideration of the influence of invasive species (e.g., mussels, gobies) and nearshore algal growth (e.g., *Cladophora, Chara,* and periphyton).

Lower and Upper Food Web Linkages

Lake productivity and the lower and upper food web responses to the change and variability in nutrient cycling are not well understood.

In the deep offshore waters, Quagga Mussels continue to increase. Their filter-feeding activities in the constant cold depths of Lake Huron are believed to remove nutrients and plankton, that historically drove the spring diatom bloom, from the water column.

For reasons still unknown, important native invertebrates are not thriving. The small, shrimp-like crustacean *Diporeia,* for example, is one of the most important organisms in the Great Lakes food web. It provides a rich source of food to many fish species, including Whitefish, as well as smaller fish which are eaten by Lake Trout and Walleye. *Diporeia* populations, however, have disappeared at an alarming rate, and only remnant populations exist. Preyfish abundance and diversity have decreased over the years, Yellow Perch populations have declined in Saginaw Bay, and Walleye production has remained low in Georgian Bay and the North Chanel.

Whitefish populations are in decline, with fewer adult fish and low recruitment of young fish to the adult stock. This could be due to factors such as inadequate nearshore plankton food, loss of *Diporeia*, a shift to less nutrient-rich food (e.g., Dreissenids) and the rising predation on juvenile fish following the decline of the Alewife.

The following studies are recommended to better characterize the linkages between the lower and upper food web and to inform the implementation of both environmental protection and natural resource management programs:

- Assessment of spring diatom bloom conditions and possible larval fish bottlenecks;
- Measurement and understanding of lower food web productivity, with a better characterization of the spatial differences across Lake Huron, including under-sampled species and aquatic habitat types (e.g., rocky substrates and depositional areas);
- Improve the understanding of lower to upper food web linkages, including the use of diet studies and stable isotope analyses; and
- Better estimate predatory fish growth, production, and recruitment into the population, including age structure of fish populations.

Contaminant Loading and Cycling

Long-term monitoring of environmental media (air, water, sediment, fish, and wildlife) generally shows decreasing levels of contaminants. However, fish and wildlife consumption advisories are still required to protect human health. Contaminants 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:

- 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 Lake Trout to support long-term chemical contaminant assessments for the Lake Huron basin; and
- Continued Great Lakes-wide efforts to assess fate, distribution, and effects of chemicals of emerging concern.

Open water research on Lake Huron with help from the Limnos (ECCC).

Figure 31 demonstrates the spatial extent of Lake Huron science and monitoring efforts in support of various initiatives discussed in this chapter.

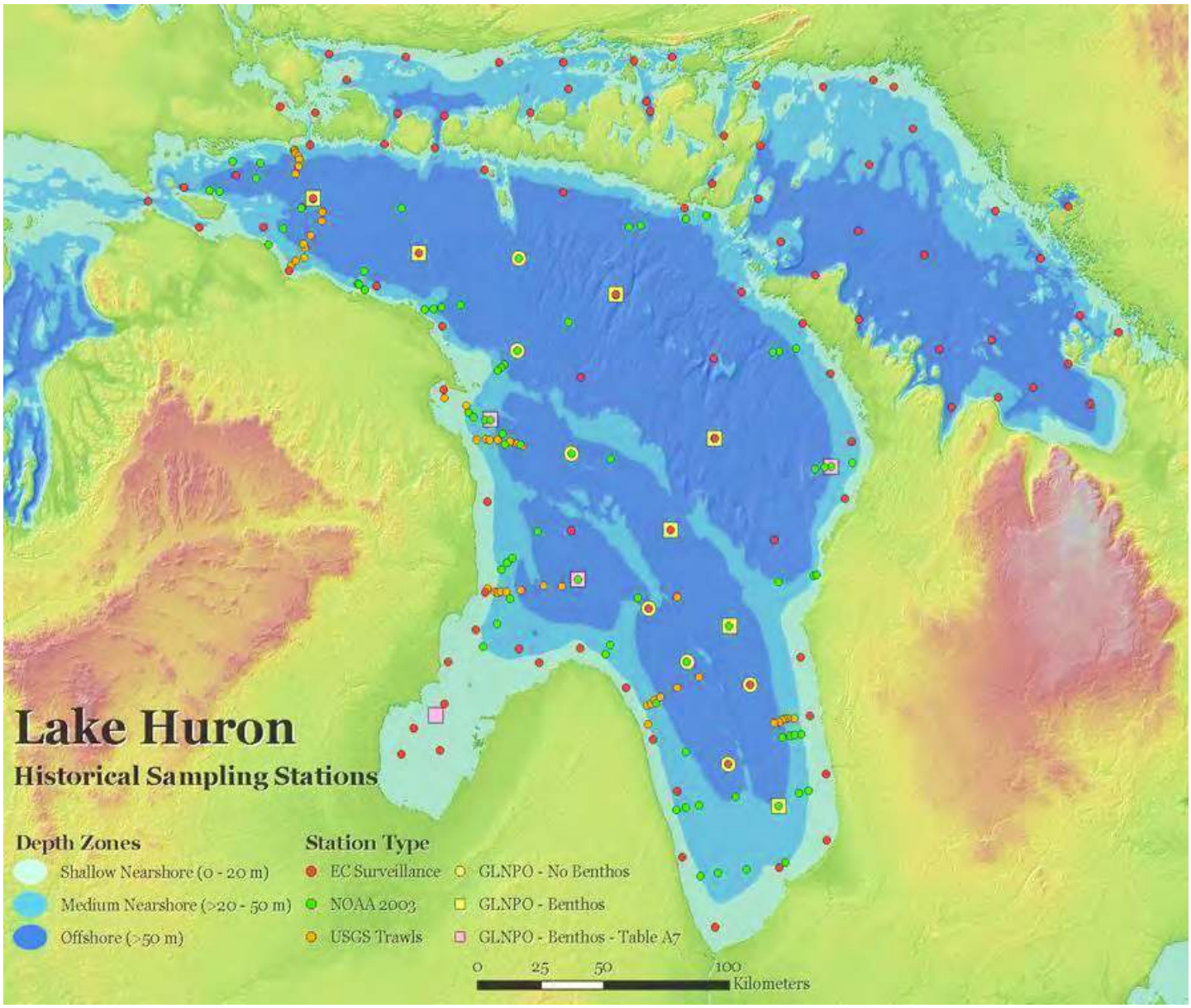

Figure 31. Lake Huron open water sampling stations and transects used by Environment and Climate Change Canada, the United States Geologic Survey, National Oceanic and Atmospheric Administration, and the United States Environmental Protection Agency – Great Lakes National Program Office.

7.0 OUTREACH, ENGAGEMENT AND EDUCATION

Everyone has a role to play in protecting, restoring, and conserving Lake Huron. Engagement, education, and involvement will support and move the public from the role of observer to active participant.

Engagement, collaboration and active participation of all levels of government, watershed management agencies, and the public are the cornerstone of current and future actions and essential for the successful implementation of this LAMP, and to achieving the General Objectives of the Agreement. The challenges and threats to Lake Huron need to be more widely recognized, as do opportunities for everyone to play a role in finding solutions that ensure a healthy watershed and lake ecosystem now and into the future. While member agencies and organizations operate independently, they are formally linked under the Lake Huron Partnership to represent a force stronger than the individual parts.

Local communities, groups, and individuals are among the most effective champions to achieve environmental sustainability in their own backyards and communities. 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.

7.1 ENGAGEMENT IN THE DEVELOPMENT OF THIS LAMP DOCUMENT

As identified earlier, the development of this LAMP was informed by research, monitoring, and consultation with partnering agencies, academia scientists, non-governmental environmental organizations, and the public at a State of Lake Huron Meeting in Alpena, Michigan in 2015. The Lake Huron Partnership also informed the general public that the Lake Huron LAMP was under development and invited public comment in the spring of 2016 via the Great Lakes Information Network (http://www.great-lakes.net/) and during the triennial Great Lakes Public Forum in Toronto, Ontario in the fall of 2016. Lake partners, stakeholders, and the general public were also consulted on a Draft Lake Huron LAMP in the winter/spring of 2017 via https://binational.net/.

7.2 LAKE HURON OUTREACH AND ENGAGEMENT EFFORTS

PURPOSE OF OUTREACH AND ENGAGEMENT

- Improve appreciation and understanding of Lake Huron
- Share information on issues, threats, management needs, and achievements
- Broaden involvement in the restoration and protection of Lake Huron

Because the public plays such a critical role as partners, advocates, and implementers, the Lake Huron Partnership established an Outreach and Engagement Subcommittee to enhance opportunities for the public to engage in lakewide management and to foster actions that sustain the health of Lake Huron. The Subcommittee will work with the Lake Huron Partnership agencies to:

- Report annually on Lake Huron management successes, challenges, and next steps;
- Advertise opportunities for public input and participation in Lake Huron activities on binational.net, the Great Lakes Information Network, and other online venues;
- Promote and encourage restoration and protection initiatives that can be adopted and implemented by individuals, groups, and communities to support the stewardship of Lake Huron; and
- Develop and implement new outreach and engagement activities.

How can the public become more involved?

The public can get involved through the following ways, including:

- Keep informed by accessing Annual LAMP Reports from https://binational.net/;
- Review and provide input on the development of Lakewide Action and Management Plans;

- Attend one of the State of the Lake Huron meetings and learn about new initiatives, monitoring results, and recent science;
- Attend one of the meetings or summits hosted by the multi-agency domestic initiatives; and
- Learn about all the Great Lakes issues and events on http://www.great-lakes.net/.

7.3 COMPLIMENTARY BINATIONAL AND DOMESTIC OUTREACH AND ENGAGEMENT INITIATIVES

Several opportunities exist for the Lake Huron community to get involved. The Great Lakes Public Forum (GLPF) takes place every three years during which Canada and the U.S. review the state of the Great Lakes, highlight ongoing work, discuss binational priorities for science and action, and receive public input.

There are many domestic initiatives that engage all levels of government, watershed management agencies, environmental organizations, community groups, and the public.

Lake Huron-Georgian Bay Watershed: A Canadian Framework for Community Action

The Framework promotes community-based actions that address environmental threats to Lake Huron. It is based on the belief that individuals, communities and organizations in the watershed operate independently, yet are united by a common cause of maintaining, restoring, and protecting the health of Lake Huron. The Framework connects the actions of government, non-government organizations, and the public, and raises awareness, builds capacity, and supports community involvement.

The Framework sets out to do the following:

- Encourage active public participation;
- Promote environmentally responsible decisions and activities;
- Establish a shared network of contacts and environmental information; and
- Promote local restoration and protection initiatives that can be adopted and implemented.

Member agencies and community groups are involved through collaboration on domestic projects, attending think tanks and information sharing sessions, and sharing information at: http://www.lakehuroncommunityaction.ca/

Healthy Lake Huron: Clean Water, Clean Beaches Initiative – Communication Efforts

The Healthy Lake Huron Initiative engages landowners, increases awareness, and promotes science, monitoring, and restoration activities to manage nutrient and sediment pollution for safe and clean beaches and shorelines from Sarnia to Tobermory. As a result of this initiative, community-based groups and landowners are informed through newsletters, beach education and outreach tours, and a website that invites dialogue and questions from the public about:

- The problems related to beach closures and nuisance algae on Lake Huron's Southeast Shore;
- The actions needed to improve water quality to reduce beach closures and nuisance algae;
- Project implementation, achievements, and findings from science and monitoring; and
- How they can participate in or support the actions being taken. http://www.healthylakehuron.ca/index.php

Lake Huron's Student Stewards and Citizen Science: Northeast Michigan Great Lakes Stewardship Initiative

Place-based education is a proven method of bringing students closer to their communities and developing knowledgeable and active stewards of the environment. Citizen science enlists members of the public in the collection of valuable scientific data. Combining the two, the Northeast Michigan Great Lakes Stewardship Initiative (NEMIGLSI) sponsors a suite of programs that promotes place-based stewardship education experiences for K-12 students that live along the shores of Lake Huron. Alongside Great Lakes scientists and natural resource professionals, youth help to conserve Lake Huron's biodiversity, map threatened and endangered species habitat, restore native fisheries, investigate marine debris, monitor vernal pool wetlands, and preserve our Great Lakes maritime heritage. These research projects are sponsored by the partnership and facilitated by Michigan Sea Grant, Michigan State University Extension, the National Oceanic and Atmospheric Administration Thunder Bay National Marine Sanctuary, and other partners. During the 2015-2016 school year, support was provided to 94 educators in 32 schools across eight northern Lake Huron counties, involving more than 4,100 youth (approximately 20% of the region's total student population) in stewardship projects. For more information, see www.nemiglsi.org

Students explore their watershed and monitor water quality (Northeast Michigan Great Lakes Stewardship Initiative).

Rain garden planting (ABCA).

Community tree planting (Manitoulin Streams Improvement Association).

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 Huron basin.

The health of Lake Huron (including the St. Marys River, North Channel, Georgian Bay and Saginaw Bay), and the condition of its watershed are interconnected. A host of factors – chemical contaminants, urbanization, shoreline development, sediment-bound nutrient loading, non-native 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 Huron, 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 Huron Partnership agencies commit to incorporating, to the extent feasible, 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 Huron is maintained or restored for current and future generations.

Implementation of LAMP actions is guided by a governance system (Figure 32) wherein coordination and implementation of the Agreement occurs on a basin-wide scale with oversight provided by the Great Lakes Executive Committee. A Management Committee evaluates progress and provides direction and coordination of implementation efforts, and a Working Group performs the day-to-day operations necessary to implement the LAMP, including regular communication and reporting. The committees are co-chaired by the U.S. Environmental Protection Agency (USEPA) and Environment and Climate Change Canada (ECCC).

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

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 all agencies and stakeholders.
Prevention	Anticipating and preventing pollution and other threats to quality of waters to reduce risks to environment and human health.
Public Engagement	Integrating public opinion and advice when appropriate; providing information and opportunities for participation to achieve GOs.
Science-based Management	Implementing management decisions, policies, and programs based on best available science, research, and knowledge, as well as traditional ecological knowledge.
Sustainability	Considering social, economic, and environmental factors in a multi-generational standard to meet current and future needs.

Figure 32. Lake Huron lakewide management governance.

APPENDIX A: MAP OF LAKE HURON BASIN INDIGENOUS COMMUNITIES

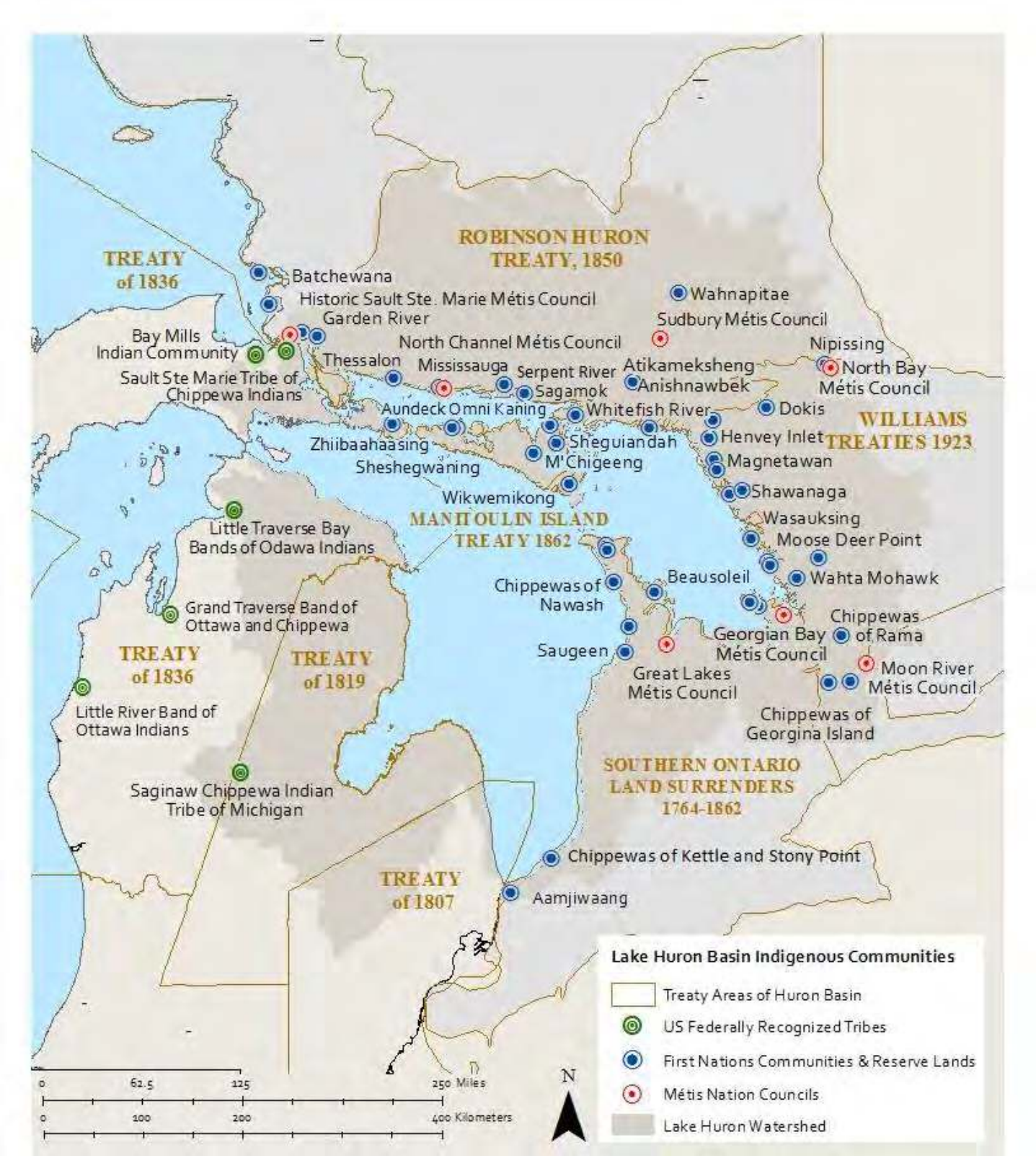

Figure 33: Lake Huron Basin Indigenous Communities. Map Data Sources: Bay Mills Indian Community, Great Lakes Indian Fish and Wildlife Commission, Saginaw Chippewa Tribe, ECCC, and http://sidait-atris.aadnc-aandc.gc.ca/atris_online/home-accueil-eng.aspx

APPENDIX B: TABLE OF 40 TOTAL LAKE HURON PARTNERSHIP ACTIONS THAT ADDRESS KEY ENVIRONMENTAL THREATS

Table 29: Forty total Lake Huron Partnership actions that address key environmental threats.

#	LAKE HURON PARTNERSHIP ACTIONS 2017-2021	AGENCIES INVOLVED
	CHAPTER 5.1: CHEMICAL CONTAMINANTS	
	ADDRESSING POINT SOURCE CHEMICAL CONTAMINANTS	
1	Federal, provincial, state and regulatory partners monitor and ensure compliance with clean water laws and regulations.	
	ADDRESSING SEDIMENT CHEMICAL CONTAMINANT REMEDIATION	
2	Continue the multi-year sediment remediation on the Tittabawassee River Floodplain – Dow Chemical Superfund site. The dioxin-contaminated floodplain includes approximately 4500 acres (1821 ha) and extends 21 miles (34 km) from Midland, Michigan, through several counties to Saginaw Bay.	USEPA, MDEQ, Saginaw Chippewa Indian Tribe of Michigan (SCIT)
3	Continue efforts to develop a sediment management plan appropriate for the Canadian portion of the St. Marys River.	OMOECC, ECCC
	ADDRESSING NON-POINT SOURCE CHEMICAL CONTAMINANTS	
	Refer to *Chapter 5.2: Nutrients and Bacterial Pollution* section of the table for non-point source pollution actions.	
	ADDRESSING CONTAMINATED GROUNDWATER	
4	Continue investigation and mitigation of perfluorinated chemicals in groundwater at the former Wurtsmith Air Force Base in Oscoda, Michigan.	United States Air Force (USAF), MDEQ
	ADDRESSING CHEMICAL CONTAMINANT MONITORING	
5	Continue long-term monitoring and periodic reporting on atmospheric pollutant deposition at Great Lakes stations.	USEPA
6	Conduct long-term sediment contaminant monitoring in the Spanish Harbour Area of Concern in Recovery to track recovery.	ECCC, OMOECC
7	Conduct a Lake Huron basin-wide sediment contaminant survey to examine legacy organics, PAHs, trace metals, Hg, and selected new and emerging compounds.	ECCC
8	Conduct fish contaminant monitoring in each year between 2017 and 2021.	USEPA, MDNR, SCIT, CORA, GLIFWC, MDHHS
9	Conduct annual Herring Gull monitoring in each year between 2017 and 2021 at sampling locations within the Lake Huron basin.	ECCC, MDEQ
	CHAPTER 5.2: NUTRIENTS AND BACTERIAL POLLUTION	
	OUTREACH AND EDUCATION	
10	***Communication*:** 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.	OMOECC, ECCC, Bay Mills Indian Community (BMIC), SCIT
	POINT SOURCE POLLUTION	
11	***Wastewater Treatment Plants and Stormwater Management Systems:*** • Enforce permitted discharges to ensure Water Quality Standards in receiving waters; and • Enhance the use of green infrastructure and low impact urban development.	USEPA, MDEQ, OMOECC, SCIT, Conservation Authorities
	NON-POINT SOURCE POLLUTION IN AGRICULTURAL AREAS	

12	***Nutrient and Bacteria Control:*** Build on existing integrated and systematic efforts within targeted watersheds to improve soil health, reduce overland runoff of nutrients, sediments, and bacteria, and maintain and restore natural heritage features: • Implement agricultural BMPs under the Saginaw Bay Watershed Regional Conservation Partnership Program within high-priority watersheds (Shiawassee, Pigeon/Pinnebog, Cass, Pine/Chippewa, Sebewaing, and Kawkawlin Rivers); • Address nuisance and harmful algae and promote safe and clean beaches in priority watersheds in Ontario's southeast shore (Pine River, Garvey Glenn, North Bayfield, Main Bayfield, Lambton Shores) through the following actions: - Targeted agricultural BMP and edge-of-field monitoring; - Continuous flow and event-based water quality monitoring and reporting; - Identification of additional priority watersheds in the Lake Huron watershed; and - Outreach and engagement with landowners and the public.	USDA-NRCS, MDEQ, SCIT OMOECC, OMAFRA, OMNRF, Parks Canada, Conservation Authorities
13	***Watershed Management Planning:*** Revise, renew, and/or develop integrated watershed management plans and link to coastal and nearshore management and other nutrient reduction actions at a community level: • Build local capacity for monitoring and best management practice implementation, and encourage and promote community involvement; and • Continue to implement management plans under Section 319 Nonpoint Source Management Program of the U.S. Clean Water Act.	USEPA, MDEQ, OMOECC, OMAFRA, OMNRF, BMIC, SCIT, Conservation Authorities
SCIENCE, SURVEILLANCE, AND MONITORING		
14	***Open Water:*** Conduct spring and fall open water nutrient surveys (2017, 2018, 2019, 2020, and 2021).	ECCC, USEPA
15	***Agricultural Areas*:** Continue edge-of-field water quality monitoring in targeted Ontario and Michigan watersheds to assess effectiveness of best management practices.	OMOECC, USGS, Conservation Authorities
16	***Streams*:** Continue surface water quality monitoring and synthesis of information from various stream and river locations: • Joint program between the province of Ontario and conservation authorities via the Provincial Water Quality Monitoring Network (PWQMN); and • Continue to assess stream water quality under Section 305(b) of the U.S. Clean Water Act.	OMOECC, Conservation Authorities, USEPA, MDEQ
17	***Watershed***: Continue a multi-watershed nutrient study, to assess the interaction between agricultural land use and nutrient loadings in southeast shore streams.	OMOECC, Conservation Authorities
18	***Saginaw Bay Water Quality and Harmful Algal Bloom (HAB) Monitoring and Reporting:*** • Explore expanding real-time water quality and nutrient buoy system to several sites in inner Saginaw Bay; • Enhance monitoring and reporting of algal blooms on NOAA-GLERL's HAB and Hypoxia webpage to provide weekly updates from June through October; • Conduct experiments to understand the environmental factors that influence changes in algal bloom community composition, toxicity, and ecosystem services; • Develop a Saginaw Bay Harmful Algal Bloom Bulletin; and • Develop a Saginaw Bay 3D- HAB Tracker product similar to the current 3D-HAB Tracker developed for western Lake Erie.	NOAA-GLERL, Cooperative Institute for Limnology and Ecosystems Research (CILER)
19	***Science Synthesis:*** Assemble, synthesize, and report on nutrient and bacterial contamination science and monitoring results from projects funded by the Lake Simcoe/South-eastern Georgian Bay Clean Up Fund (2012-2017).	ECCC
20	***Research and Monitoring:*** Improve understanding of invasive mussels and their influence on phosphorus cycling in the aquatic system and *Cladophora* growth.	Annex 4 Subcommittee

CHAPTER 5.3: LOSS OF HABITAT AND SPECIES		
21	***Spawning Reefs and Shoals:*** Continue to develop strategies and implementation plans that rehabilitate and/or create nearshore reefs to support overall lake productivity.	MDEQ, MDNR, USFWS, USGS, SCIT
22	***Aquatic Habitat:*** Assess streams and estuaries to determine aquatic habitat significance, stressors, and limitations to fish spawning and migration, and consult with local partners, stakeholders, and governments to identify rehabilitation priorities, including: • Assessment of Eastern Georgian Bay estuaries with project implementation.	OMNRF, MDNR, SCIT, Eastern Georgian Bay Stewardship Council (EGBSC)
23	***Stream Connectivity:*** Restore stream connectivity and function through dam removal, the construction of fish passage alternatives (e.g., ladders), and stream culvert improvements to compensate for loss of riverine habitat.	USFWS, MDNR,OMNRF, MDEQ, Conservation Authorities
24	***Habitat and Native Species Conservation***: Build on *"The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron"* through integrated conservation planning to identify areas of ecological significance and areas facing environmental threats and stressors: • Update and share Canadian geospatial information on ecosystem classification (Lead - OMNRF); • Engage stakeholders and the public; • Facilitate information sharing; • Develop regional conservation and stewardship plans (Ontario); and • Promote community-based conservation and stewardship.	Conservation Authorities, OMNRF, DFO, PC, OMOECC, ECCC, USEPA, USFWS, MDEQ, MDNR
SPECIES RECOVERY AND MONITORING		
25	***Walleye Restoration***: Develop a Walleye Management Plan for the Ontario waters of Lake Huron and track the effectiveness of harvest regulations throughout Lake Huron.	OMNRF
26	***Cisco Restoration:*** Examine the benefits of reintroducing Cisco to targeted areas of the lake.	MDNR, USFWS, OMNRF, USGS, Tribes
27	***Coastal Wetlands:*** Monitor coastal wetlands to assess coastal wetland water quality, species diversity, and the impacts of human activities; and promote restoration and enhancement efforts.	USEPA, OMNRF, USFWS, BMIC, SCIT, PC, Conservation Authorities
CHAPTER 5.4: INVASIVE SPECIES		
28	***Ballast Water:*** Through the Annex 5 subcommittee, establish and implement programs and measures that protect the Great Lakes Basin ecosystem from the discharge of AIS in ballast water.	Transport Canada, USCG, USEPA
29	***Early Detection and Rapid Response:*** Through the Annex 6 subcommittee, implement an 'early detection and rapid response initiative' with the goal of finding new invaders and preventing them from establishing self-sustaining populations.	DFO, USFWS
30	***Canals and Waterways:*** Through the Asian Carp Regional Coordinating Committee, prevent the establishment and spread of Bighead and Silver Carp in the Great Lakes.	ACRCC member agencies
31	***Sea Lamprey:*** Control the larval Sea Lamprey population in the St. Marys River with selective lampricides. Continue operation and maintenance of existing barriers and the design of new barriers where appropriate.	DFO, USFWS, GLFC
32	***Improve understanding of invasive species impacts to inform management efforts:*** • *Impacts of Round Goby on the Foodweb:* Enhance assessment methods and technology to better understand Round Goby population density and distribution. • *Causes of Botulism Outbreaks:* Improve understanding of links between mussels, Round Goby, and Botulism outbreaks in waterfowl. • *Cladophora growth*: Work through the Annex 4 subcommittee to support the creation of Lake Huron sentinel *Cladophora* monitoring sites to determine the role of mussels in nearshore algae growth and possible mitigation efforts.	USGS, MDNR, OMNRF

33	***Control of Terrestrial and Wetland Invasive Species:*** Maintain coastal and nearshore aquatic habitat diversity and function through appropriate control of *Phragmites* and other detrimental invasive species (e.g. Glossy Buckthorn, European Frog-bit, Purple Loosestrife, Japanese Knotweed) including monitoring, mapping, and control efforts guided by BMPs. • Coordinate *Phragmites* control efforts and share BMPs through the *Ontario Phragmites Working Group* and *Great Lakes Phragmites Collaborative.*	USFWS, USEPA, BMIC, SCIT, MDNR, Parks Canada, SCRCA, NVCA, OMNRF
SCIENVE, SURVEILLANCE, AND MONITORING		
34	***Surveillance*:** Maintain and enhance early detection and monitoring of non-native species (e.g. Asian Carp) through the Annex 6 *Early Detection and Rapid Response Initiative.*	DFO, OMNRF, USFWS, MDNR
35	***Monitoring*:** Maintain an index time series that shows the impact of Sea Lamprey control on Lake Trout population status.	MDNR
OUTREACH AND ENGAGEMENT		
36	***Communication*:** Undertake additional aquatic invasive species prevention outreach and education, including discussions with recreational boaters and lake access site signage.	DFO, BMIC, SCIT, MDEQ, OMNRF, SCRCA
CHAPTER 5.5: CLIMATE CHANGE IMPACTS		
CLIMATE CHANGE ACTIONS Actions identified for nutrients and bacterial pollution and loss of habitat and native species will help to maintain ecosystem function and enhance resilience to the impacts of climate change.		
37	***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 Actions; and • Great Lakes Restoration Initiative.	Conservation Authorities, MDNR, OMOECC
38	***Coldwater Streams:*** Support the protection and enhancement of coldwater fishes: • Develop Lake Trout monitoring and rehabilitation plans; • Identify potential restrictions preventing passage of migratory fish; and • Create and enhance coldwater refuges where appropriate to maintain appropriate habitat conditions for aquatic organisms.	Conservation Authorities, MDNR, OMNR
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; and • Lake Simcoe Low Impact Development Guidance Documents.	BCIT, Conservation Authorities, OMOECC, SCIT
OUTREACH AND EDUCATION		
40	***Communications:*** Undertake and support outreach and education to stakeholders and the public on the impacts of climate change to the Great Lakes and Lake Huron through fact sheets, newsletters and other means.	Conservation Authorities, ECCC

APPENDIX C: AREAS OF CONCERN (AOC)

The 2012 Agreement defines an Area of Concern (AOC) as a geographic area designated by the U.S. 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.

Following management actions, the Canadian government delisted the Collingwood Harbour AOC (1994) and Severn Sound AOC (2003). The status of the remaining three Lake Huron AOCs and Beneficial Use Impairments is shown in Table 30.

In 1999, the **Spanish Harbour AOC** was redesignated as an *AOC in Recovery* (AOCiR); indicating that all management actions to restore water quality and ecosystem health have been completed. The historical sediment contamination (including dioxin and furans), while much improved since the 1980s, will take more time to fully recover. Monitoring is ongoing.

The **St. Marys River** was designated as a binational AOC due to impairments of water quality, sediment, and biota that resulted in beneficial use impairments on both sides of the river.

The **Saginaw River and Bay** was designated as an AOC due to contaminated sediments, fish consumption advisories, degraded fisheries, and a loss of significant recreational values.

Remedial Action Plans for the St. Marys River and Saginaw River and Bay AOCs are being implemented to restore the remaining beneficial use impairments within each AOC. Information is available online for the St. Marys River RAP (Michigan); St. Marys River RAP (Canadian); Saginaw River and Bay RAP and progress reports.

Table 30. Beneficial Use Impairments of the AOCs of Lake Huron.

BENEFICIAL USE IMPAIRMENT (BUI)			AREA OF CONCERN			
BUI Restored	BUI Impaired	Not Applicable	SAGINAW BAY	ST. MARY'S RIVER		SPANISH HARBOUR
				U.S.	CANADA	
Loss of fish and wildlife habitat			☑	☐	☐	☑
Beach closings			☐	☑	☐	☑
Degradation of fish and wildlife populations			☐	☐	☐	☑
Degradation of aesthetics			☐	☑	☐	
Bird or animal deformities or reproductive problems			☐	☑	☑	☑
Fish tumors and other deformities				☐	☐	
Restrictions on drinking water consumption or taste/odor			☑			
Tainting of fish and wildlife flavor			☑			
Added costs to agriculture or industry						☑
Degradation of phytoplankton/zooplankton populations			☐			☑
Degradation of benthos			☐	☐	☐	☐
Restrictions on fish and wildlife consumption			☐	☐	☐	☐
Eutrophication or undesirable algae			☐	☑	☐	
Restriction on dredging activities			☐	☐	☐	☐

APPENDIX D: MAP OF LAKE HURON

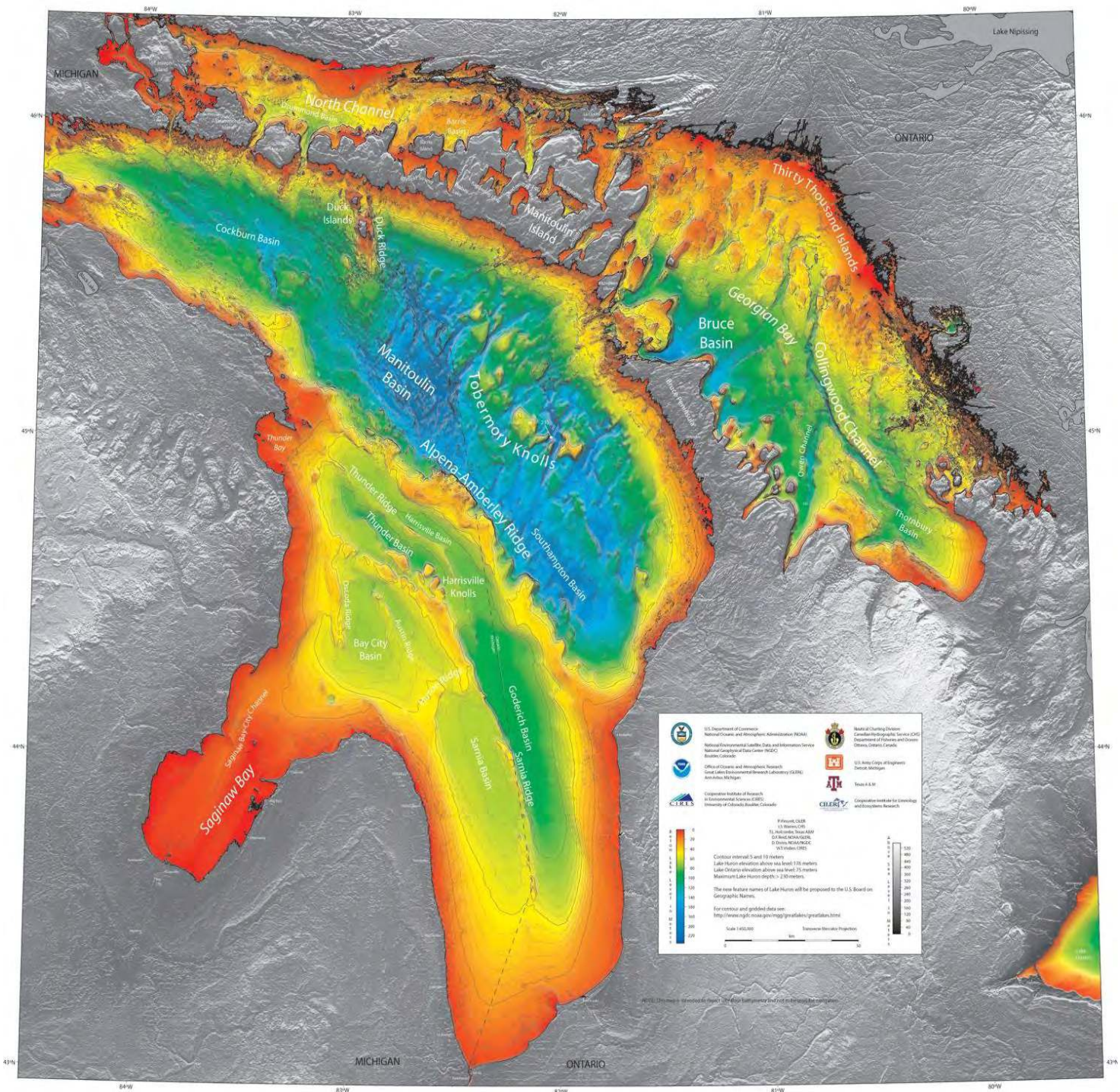

Figure 34. Map showing the complexity of Lake Huron bathymetry with multiple basins, ridges, knolls, channels, and large islands. The St. Marys River is a management priority for the Lake Huron LAMP but is missing in this map (NOAA).

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9.0 Appendix D

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