LAKE ONTARIO CANADIAN NEARSHORE Assessment

2019 RESULTS REPORT

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This document supports Canadian commitments in the Lakewide Management Annex of the Great Lakes Water Quality Agreement of 2012 to provide an overall assessment of nearshore waters.

For information on Great Lakes Areas of Concern or the State of the Great Lakes, refer to https://www.canada.ca/en/environment-climate-change/services/great-lakes-protection.html

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Introduction

The Great Lakes, with their 16,000 kilometres of coastline, connecting river systems and watersheds is the world's largest freshwater ecosystem and socially, economically and environmentally significant to the region, the nation and the planet. While efforts to restore and protect the Great Lakes have been largely successful over the last 50 years, water quality and ecosystem health in many nearshore areas continues to be degraded. At numerous places along the Great Lakes nearshore, conditions are degraded due to a variety of human-induced, climate-induced and invasive species-induced stressors. Human activities in the landscape have a more direct influence on nearshore water quality than on offshore water quality[1]. Nearshore water quality may serve as a sentinel for the longer-term trajectory of offshore water quality and lake-wide condition[2]. Management of the nearshore is challenging because it is a complex, highly variable environment in which tributary inflows and open water processes vary spatially and across daily, seasonal and annual temporal scales. In addition, Great Lakes nearshore areas are especially vulnerable to the effects of climate change and impacts can result in loss of biodiversity of aquatic species and fundamental changes to ecosystem character, distribution, structure and function. Human-induced stressors on ecosystems further limit their ability to adapt and recover.

Although significant investment has been made in localized monitoring, assessment and restoration, the lack of a comprehensive assessment of the overall state of nearshore waters has meant that there was not a robust mechanism for identifying cumulative stress on nearshore ecosystems nor a way to identify and prioritize areas in need or remediation or protection. Action is needed to address stresses and threats in nearshore areas, as they are the critical ecological link between watersheds and the open waters of the Great Lakes.

Nearshore Framework

As envisioned by the updated Great Lakes Water Quality Agreement (GLWQA) of 2012, Canada is implementing a "Nearshore Framework" that provides an overall assessment of the state of the nearshore waters of the Great Lakes. The Nearshore Framework is a systematic, integrated and collective approach for assessing nearshore health and identifying and communicating cumulative impacts and stress. It is intended to inform and promote action at all levels in order to restore and protect the ecological health of Great Lakes nearshore areas.

The purpose of the Nearshore Framework is to address ongoing and emerging challenges to the nearshore waters of the Great Lakes, where restoration, protection and prevention activities are critical to improving and sustaining the ecological health of Great Lakes coastal areas and supporting attendant social, cultural, recreational and economic benefits. Nearshore assessments and communication of results provide the basis for determining factors and cumulative effects that are causing stress or threatening areas of high ecological value. Continued and strengthened coordination and collaboration are needed to manage and protect our nearshore waters and to prevent and minimize water quality and ecosystem impacts which may result from chemical, physical, or biological stresses within the Great Lakes Basin. The Nearshore Framework will support action for nearshore areas under stress and protection for nearshore areas of high ecological value by communicating results, establishing priorities and

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[1] Yurista, P.M., Kelly, J.R., Cotter, A.M., Miller, S.E., and Van Alstine, J.D. 2015. Lake Michigan: Nearshore variability and a nearshore-offshore distinction in water quality. Journal of Great Lakes Research. 41:111-122.

[2] Yurista, P.M., Kelly, J.R. and Scharold, J.V. 2016 Great Lakes nearshore-offshore: distinct water quality regions. Journal of Great Lakes Research. 42: 375-385.

engaging organizations and entities that are developing and implementing prevention, restoration and protection strategies.

The scope of the Nearshore Framework includes the nearshore waters and embayments along the coast of the Canadian Great Lakes, the lakes' connecting river systems and the St. Lawrence River. The GLWQA recognizes the interconnectedness of the Great Lakes basin watersheds where material and water flow from problem areas into the lakes and connecting channels. The Nearshore Framework aims to consider this relationship between the zone of influence and zone of impact and the nearshore is generally defined as the area of the Great Lakes and connecting rivers near the coast where waters are subject to direct influences from watersheds, while recognizing that there are also off-shore influences.

This report provides a synthesis of the results for the 2019 Lake Ontario, Niagara River and St. Lawrence River Nearshore Assessment; for a detailed methodology of the Overall Assessment of Nearshore Waters, including descriptions of assessment categories and measures and data sources, refer to the *Canadian Great Lakes Nearshore Assessment Detailed Methodology*.

Regional Unit Delineation

The first step in the Nearshore Assessment is the classification of the nearshore into Regional Units based on ecosystem type. Slow changing variables such as depth, substrate, river mouth boundaries, wave energy density and high water conditions were used for delineating the offshore, onshore and lateral boundaries of ecologically relevant units.

Offshore boundary

Lake Ontario is the smallest Great Lake, and has an average depth of approximately 86 m. Based on this profile, a depth of 30 m was selected as the offshore boundary. The Great Lakes Aquatic Habitat Framework (GLAHF) lakewide bathymetry raster dataset[3] was converted into 5 m contour lines, and the 30 m line was used to create a seamless offshore boundary (Figure 1).

Onshore boundary

Since the assessment is focused on the nearshore of Lake Ontario and its connecting river system, the onshore boundary was defined by a high water mark. Historical monthly mean lake levels from Environment and Climate Change Canada's coordinated network of gauges for Lake Ontario[4] were reviewed and the maximum monthly mean from 1918 to 2013 was found to be 1.6 m above Chart Datum.

On Lake Ontario, Chart Datum is 74.2 m, making the maximum monthly mean 75.8 m (74.2 [Chart Datum] + 1.6 [Maximum Monthly Mean]). Lake Ontario is the lowest of the Great Lakes. Although the lake surface can exceed this elevation due to wave effects and storm surge, the focus here is the static 'non-storm' lake surface. To extract the 75.8 m contour, two bathymetric data sources were consulted. Light Detection and Ranging (LiDAR) data was collected by the

[3] Great Lakes Aquatic Habitat Framework (GLAHF) – Geomorphology – Lake Bottom: https://www.glahf.org/data/
[4] Environment and Climate Change Canada. *Historical Monthly and Yearly Mean Water Level 1918-2013* *http://www.tides.gc.ca/C&A/network_means-eng.html*

Canadian Hydrographic Service in partnership with Environment and Climate Change Canada in 2017 for much of the nearshore of Lake Ontario. This was used to create bathymetric elevation surfaces and the 75.8 m contour was extracted from the elevation surface where data existed.

To supplement the nearshore areas where there were data gaps in the LiDAR, the 2015 South Western Ontario Ortho-Photography (SWOOP) Digital Elevation Model (DEM)[5] was acquired from the Ontario Ministry of Natural Resources and Forestry (OMNRF). The provincial DEM is referenced to the Canadian Geodetic Vertical Datum of 1928 (CGVD28) and the LiDAR is referenced to the International Great Lakes Datum of 1985 (IGLD85). These two vertical datums use different reference systems and conversion was necessary to ensure the elevations extracted were consistent. Elevations for a series of random points within the DEM (data gap areas) were extracted and the average difference between CGVD28 and IGLD85 was calculated. The average difference was found to be approximately 0.07 m (IGLD85 lower then CGVD28). Therefore, the 75.9 m contour (75.8 m + 0.07 m [difference] = 75.87 m; rounded to 75.9) was extracted from the DEM. This contour was used to define the offshore boundary of all Regional Units in Lake Ontario.

For the St. Lawrence River, delineation required additional information as the river drops from Lake Ontario as it flows towards the Atlantic Ocean. The river drops approximately 1.7 m to Lake St. Lawrence and again about 26 m at the Eisenhower and Snell Locks before flowing into Lake St. Francis which has a chart datum of about 46 m. To represent these 'steps' as accurately as possible, water levels were obtained from six gauges along the St. Lawrence River (Brockville, Upper Iroquois, Lower Iroquois, Morrisburg, Cornwall and Summerstown) from Fisheries and Oceans Canada Tidal Observations.[6] For each gauge, the maximum water level was identified in order to get the onshore elevation limit at the gauge. For example, at Brockville, the Chart Datum is 73.950 m above IGLD85, and the maximum water level was 75.573 m; subtracting the maximum from the low-water datum (Chart Datum) results in a difference of 1.6 m (75.573 m – 73.95 m = 1.62 m). This is then added to the low-water datum to get the onshore elevation limit (in this case, 1.62 + 73.95 = 75.57 m). The onshore elevation limit for Regional Units along the St. Lawrence River range from 75.6 m at Brockville to 47.1 m at Summerstown.

To extract the contours, the Digital Raster Acquisition Project Eastern Ontario (DRAPE)[7] 2014 elevation tiles were obtained from the OMNRF. The resolution of these rasters is 2 m which is too detailed a resolution for purposes of Regional Unit delineation; the rasters were resampled to a 10 m cell size using the Aggregate Tool in ArcMap. The contours were then extracted from these 10 m grids, using the calculated onshore elevation limit.

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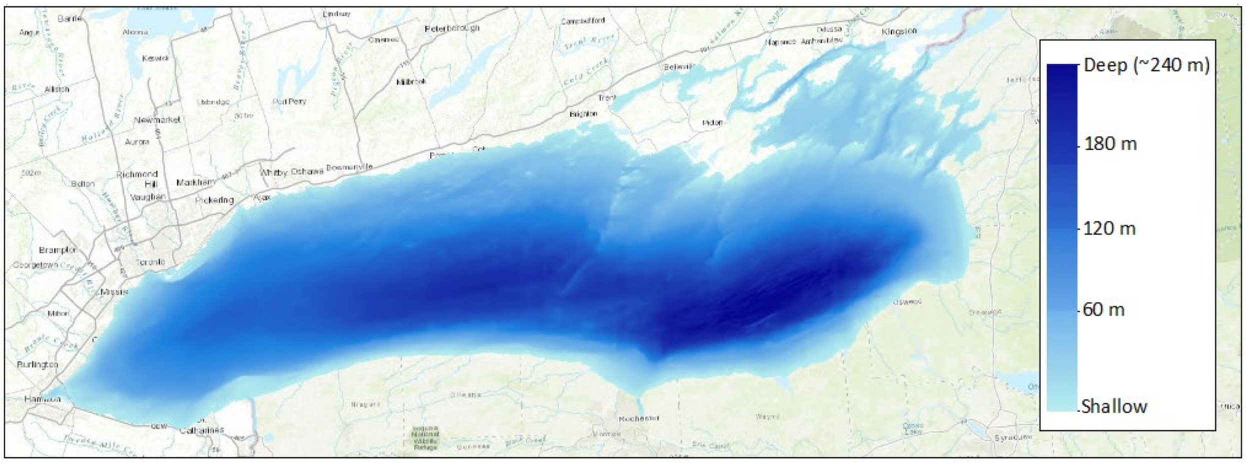
[5] Ontario Ministry of Natural Resources and Forestry. *Ontario Digital Elevation Model (Imagery-Derived)*. https://geohub.lio.gov.on.ca/datasets/mnrf::ontario-digital-elevation-model-imagery-derived

[6] Department of Fisheries and Oceans Canada. *Tides, Currents and Water Levels, Tidal Observations (various stations)* http://www.waterlevels.gc.ca/eng/station/Month?sid=14400&tz=EST&pres=2&type=1

[7] Ontario Ministry of Natural Resources and Forestry. *Digital Raster Acquisition Project Eastern Ontario* https://hub.arcgis.com/datasets/3f744636a8134155b0eeb037e4ee4367

Figure 1. Lake Ontario Bathymetry (from the Great Lakes Aquatic Habitat Framework); 30 m depth was used to delineate the offshore boundary for Regional Units



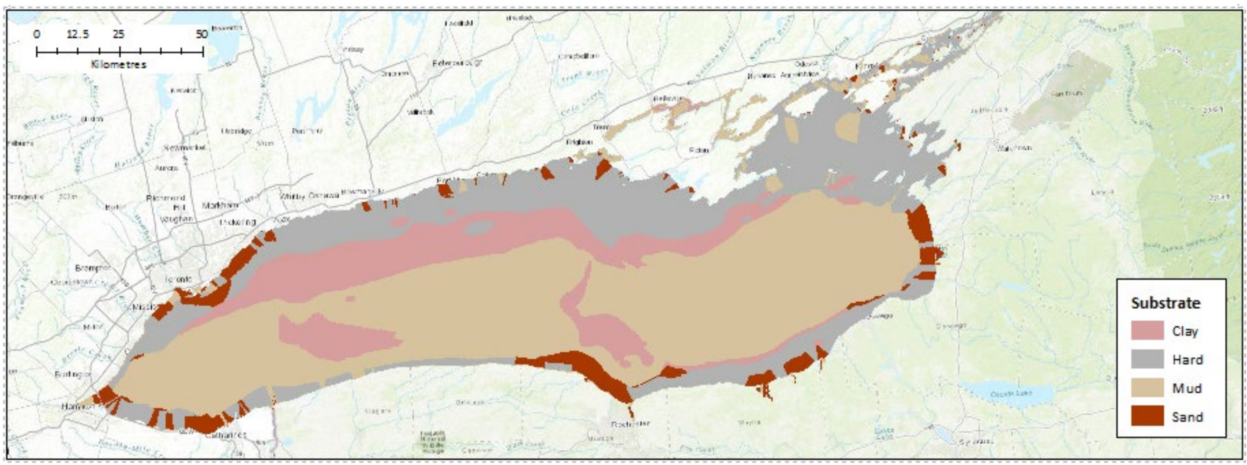
In areas with coastal wetlands, a visual inspection of the SWOOP imagery and Google Earth was undertaken to determine whether the wetland was hydrologically connected to Lake Ontario or the St. Lawrence River. The coastal wetland polygon used for this assessment was the OMNRF Great Lakes Shoreline Ecosystem Land Classification[8] dataset, which is an inventory of Lake Ontario shoreline (2 km inland) ecosystems that incorporate standard delineation processes at the ecosite scale (1:10,000). If a wetland was assessed as being hydrologically connected, the wetland boundary became the onshore extent of the Regional Unit instead of the high water mark contour. Professional judgement was exercised to create a representative, continuous onshore boundary.

Lateral boundary

The lateral boundaries were generated by assessing substrate data, shoreline morphology and wave energy. The nearshore areas of Lake Ontario and the St. Lawrence River are not homogeneous; variations in substrate (Figure 2) and wave energy result in spatially explicit characteristics that were used to delineate regional units. The orientation and morphology of the shoreline can impact presence of coastal features.

[8] Ontario Ministry of Natural Resources and Forestry. *Great Lakes Shoreline Ecosystem Inventory V 1.0 – Lake Erie.* https://geohub.lio.gov.on.ca/datasets/great-lakes-shoreline-ecosystem-inventory-v-1-0-lake-erie

Figure 2. Substrate types in Lake Ontario (from the Great Lakes Aquatic Habitat Framework[9])

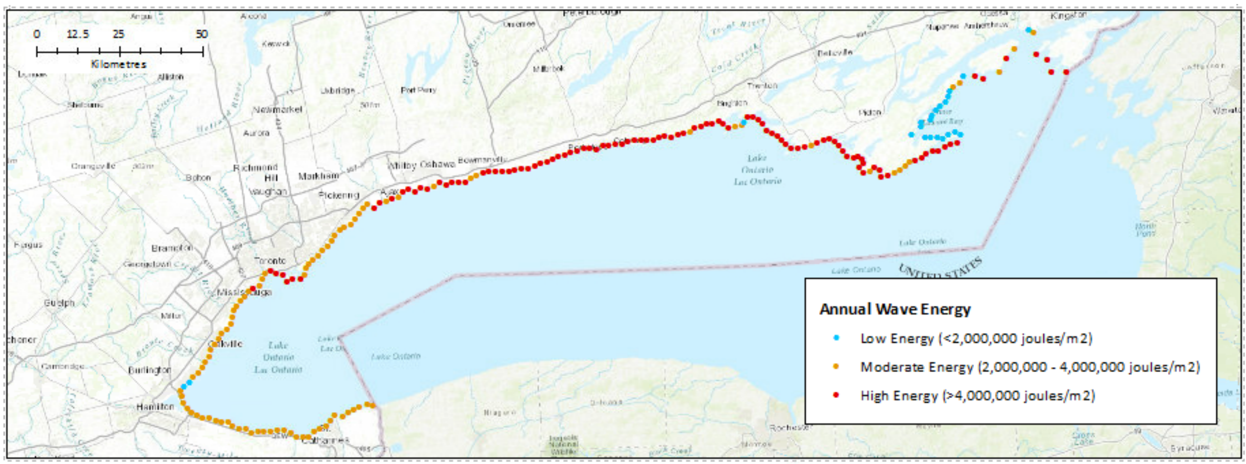


Wave energy also has a significant influence on the coastline; on a lakewide scale, gradients in wave energy influence the magnitude and directionality of longshore sediment transport, erosion and deposition patterns that shape the nearshore. In addition, exposure to wave energy is a major factor in the presence or absence of submerged/emerged aquatic vegetation. High wave exposure may result in an absence of aquatic vegetation. Wave energy also influences sediment characteristics along the coast, with sheltered environments featuring fine grained sediment and open coast areas featuring sand sized substrate and/or coarser materials.

Due to its influence on nearshore processes, wave energy was included as a physical variable in the alongshore boundary delineation. Average annual wave energy density was calculated at the 5 m depth contour around Lake Ontario, at 1 km increments (Figure 3). The input wave conditions were generated by a historical wind-wave hind cast on Lake Ontario, and then transformed to the 5 m depth accounting for lake bottom contours and linear wave theory. The results of the wave energy reveal additional patterns with other physical variables. A significant portion of the north shore is classified as high energy, corresponding to harder substrate types. The shoreline orientation relative to wind direction at Prince Edward County somewhat shelters Prince Edward Bay and results in lower wave energy. The highest proportion of coastal wetlands in Lake Ontario are found within the Bay of Quinte, which is sheltered from wind and wave action on the main lake.

[9] Great Lakes Aquatic Habitat Framework (GLAHF) – Geomorphology – Substrate: https://www.glahf.org/data/

Figure 3. Results of the w ave energy density analysis on Lake Ontario



Overlaying these slow-changing variables revealed several unique patterns from which 17 Regional Units with five ecological classifications were identified (Table 1/ Figure 4).

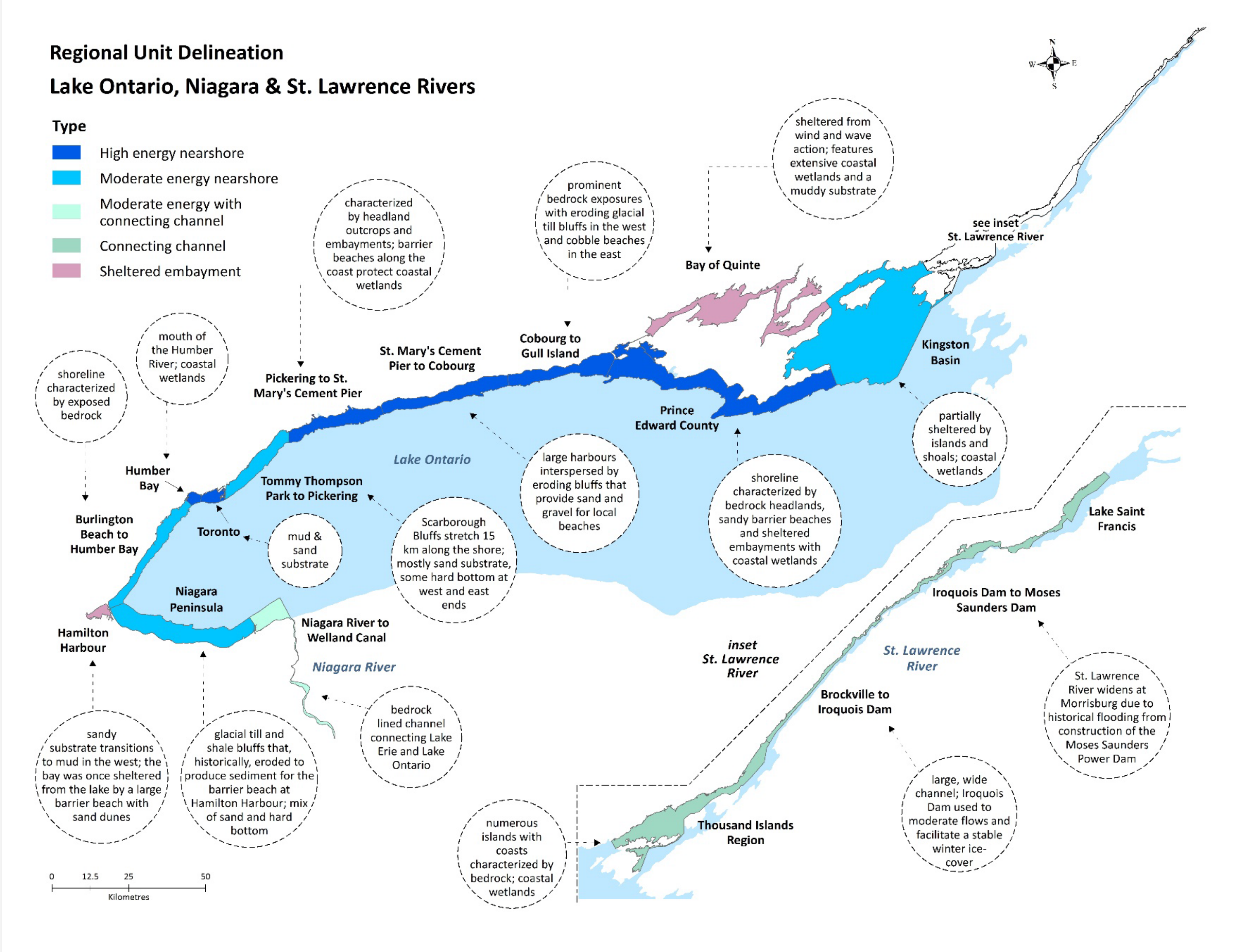
Table 1. Seventeen Regional Units w ere delineated in the first phase of the Nearshore Framew ork

Regional Unit Name and Ecosystem Type	Size	Substrate (GLAHF)	Wave Energy (Zuzek Inc.)	Description
MODERATE ENERGY NEARSHORE WITH CONNECTING CHANNEL				
NIAGARA RIVER TO WELLAND CANAL (LO01)	9,400 ha	Bedrock	Moderate energy	Bedrock lined channel that connects Lake Erie to Lake Ontario; includes the upper and lower river (connecting channel) and shoreline west to the mouth of the Welland Canal (moderate energy along the shoreline); Niagara River approximately 58 km long
CONNECTING CHANNEL				
THOUSAND ISLANDS REGION (LO14)	28,500 ha	Mud/hard	NA	Numerous islands with coasts characterized by bedrock; features extensive coastal wetlands
BROCKVILLE TO IROQUOIS DAM (LO15)	5,000 ha	Hard	NA	Large channel that is approximately 1 km wide; Iroquois Dam used to moderate flows and facilitate a stable winter ice-cover
IROQUOIS DAM TO MOSES SAUNDERS DAM (LO16)	7,600 ha	No Data	NA	St. Lawrence River widens at Morrisburg due to historical flooding following the construction of the Moses Saunders Power Dam, with portions 5 km in width

LAKE SAINT FRANCIS (LO17)	27,400 ha	No Data	NA	Shallow and warm; shipping channel deeper
SHELTERED EMBAYMENT				
HAMILTON HARBOUR (LO03)	2,100 ha	Sandy/mud		Characterized by sandy substrate that transitions to mud in the west. Bay was once sheltered from the lake by large barrier beach with sand dunes; today, it features a highway and federal navigation channel.
BAY OF QUINTE (LO12)	32,100 ha	Mud and clay	NA	Sheltered from Lake Ontario wind and wave action; features extensive coastal wetlands. Muddy substrate with clay interspersed
MODERATE ENERGY NEARSHORE				
NIAGARA PENINSULA (LO02)	26,800 ha	Sand/hard	Moderate energy	Characterized by glacial till and shale bluffs that, historically, eroded to produce sediment for the barrier beach at Hamilton Harbour. Mix of sand and hard substrate
BURLINGTON BEACH TO HUMBER BAY (LO04)	12,600 ha		Moderate energy	Historically, shoreline featured extensive cobble beaches and nearshore shoals but now characterized by exposed bedrock
TOMMY THOMPSON PARK TO PICKERING (LO07)	11,100 ha	Sand	Moderate energy	Scarborough Bluffs stretch 15 km along shore and are significant geological feature resulting from natural processes of wind and water erosion; predominantly sand substrate, some hard substrate interspersed at west and east extents of Regional Unit
KINGSTON BASIN (LO13)	106,900 ha	Hard/sand	Moderate energy	Partially sheltered from the main basin of Lake Ontario by islands and shoals; extensive cover of coastal wetlands; transition from Lake Ontario to St. Lawrence River
HIGH ENERGY NEARSHORE				
HUMBER BAY (LO05)	1,500 ha	Mud/sand	High energy	Smallest Regional Unit; high energy coast with an embayment that supports coastal wetlands
TORONTO (LO06)	2,700 ha	Mud/sand	High energy	Substrate characterized by mud and sand; natural shoreline significantly altered with construction of the Leslie Street Spit which acts as a barrier restricting natural sediment supply to the Toronto Islands. While the predominant characteristic is high energy this Regional Unit includes the sheltered of area of Toronto Harbour.

PICKERING TO ST. MARY'S CEMENT PIER (LO08)	12,400 ha	Hard	High energy	Characterized by a series of headland outcrops and embayments featuring drowned river valleys; barrier beaches along coast protect coastal wetlands; hard substrate
ST. MARY'S CEMENT PIER TO COBOURG (LO09)	16,100 ha	Hard	High energy	Coast features large harbours interspersed by eroding bluffs that provide sand and gravel for local beaches; shore has been infilled and the pier is a barrier to sediment moving east at St. Mary's Cement
COBOURG TO GULL ISLAND (LO10)	15,000 ha	Hard	High energy	Prominent bedrock exposures with eroding glacial till bluffs in the west, and cobble beaches in the east; prior to shoreline development in the west, the sand beach at Presqu'ile Provincial Park was a depositional zone for a littoral cell extending west to Pickering
PRINCE EDWARD COUNTY (LO11)	50,400 ha	Hard	High energy	Shoreline characterized by bedrock headlands, sandy barrier beaches and sheltered embayments with large coastal wetlands

Figure 4. Seventeen Regional Units were delineated in the nearshore of Lake Ontario, Niagara River and St. Lawrence River



2019 Lake Ontario Canadian Nearshore Assessment

In 2019, Environment and Climate Change Canada (ECCC) undertook the overall assessment of the state of nearshore waters in Lake Ontario and the Niagara and St. Lawrence Rivers. This report summarizes the findings of cumulative stress across 17 Regional Units.

The assessment consists of 11 measures grouped into four evidence categories that were developed with consideration of the GLWQA General Objectives and specific requirements of the Nearshore Framework. Each of the measures in a category is assigned as "low," "moderate" or "high" stress on the nearshore of each Regional Unit, and then rolled up into an overall level of stress for each category using a Weight of Evidence approach. The four category scores are subsequently combined into an overall cumulative stress for each Regional Unit.

Key findings from the assessment are summarized below and in Figure 5. The Canadian portion of Lake Ontario and the St. Lawrence River was delineated into 17 Regional Units with five classifications based on slow-changing physical parameters (e.g. bathymetry, substrate, wave energy density and physical features). Overall, nearshore areas are under moderate stress. The western portion of Lake Ontario – from the Niagara Peninsula to Pickering – is significantly more developed than the eastern portion and the St. Lawrence River. Many of the Regional Units are under high stress for coastal processes from extensive shoreline hardening and numerous littoral barriers that impede erosion and longshore sediment transport. Nuisance *Cladophora* washes up and fouls beaches and shorelines in the Burlington Beach to Humber Bay Regional Unit as well as much of the north shore from Pickering to the Kingston Basin. Additionally, harmful cyanobacteria was detected in the Hamilton Harbour, Bay of Quinte and Kingston Basin Regional Units in at least one ten-day period from 2016 to 2018, creating a concern to human and ecosystem health as well as high stress on nearshore waters.

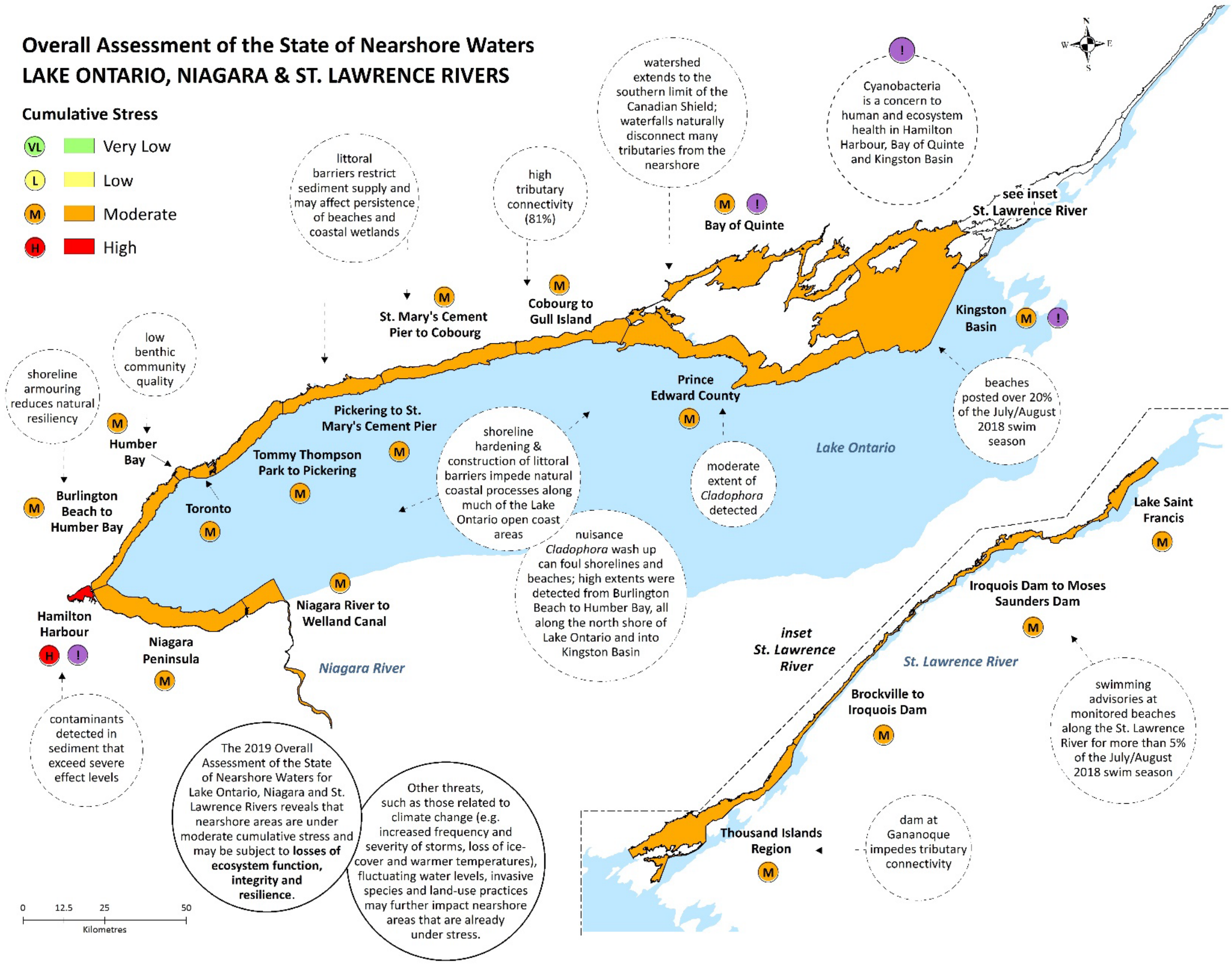
A **Weight of Evidence** approach was used to develop a structured decision making processes for the overall assessment. Weight of Evidence is a process for systematic and transparent integration of multiple datasets where "weight" (+ or ++) is assigned to each assessment measure based on a categorical rating of three factors: relevance, strength and reliability. Categories and measures include:

- Coastal Processes: Shoreline Hardening (+), Littoral Barriers (+), Tributary Connectivity (+)
- Contaminants in Water & Sediment: Water Quality (+), Sediment Quality (++), Benthic Community (++)
- Nuisance & Harmful Algae: *Cladophora* (+), Cyanobacteria (++)
- Human Use: Beach Postings (+), Fish Consumption (+), Treated Drinking Water (+)

For details on the assessment methodology, see the *Canadian Great Lakes Nearshore Assessment Detailed Methodology.*

Five Regional Units have a Great Lakes Area of Concern (AOC) within some or all of their boundary. AOCs were designated in the mid-1980's as the most degraded sites where beneficial uses were impaired; Remedial Action Plans have effectively dealt with many problems over the ensuing 30 years but ecological issues remain in the Lake Ontario (Hamilton Harbour, Toronto and Region, Port Hope and Bay of Quinte) AOCs as well as the Niagara River AOC and St. Lawrence River AOC.

Figure 5. Results of the Overall Assessment of the State of Nearshore Waters in Lake Ontario, Niagara River and St. Lawrence River



Coastal Processes

Map of category results in Figure 6, individual measure descriptions below.

Shoreline Hardening

Low Stress	<25% of the total length of shoreline in a Regional Unit is hardened
Moderate Stress	25-50% of the total length of shoreline in a Regional Unit is hardened
High Stress	>50% of the total length of shoreline in a Regional Unit is hardened

Thresholds based on best professional judgement.

Most – if not all – Regional Units in Lake Ontario and the St. Lawrence River have a populated area on the coast that has led to significant shoreline development and infrastructure. In all, just over 40% of the total length of shoreline has been hardened – and from the Niagara Peninsula to Toronto Regional Units, upwards of 70% of the shoreline is altered. In these areas, much of the nearshore, waters edge or back of beach is altered with engineered structures or artificial material and natural shoreline processes are likely modified. The Thousand Islands Region has nearly 40% shoreline hardening, primarily related to recreational and seasonal development as well as small marina infrastructure along the St. Lawrence River. Both the Brockville to Iroquois Dam and Lake Saint Francis Regional Units have over 50% shoreline hardening, mostly from small scale armouring that, cumulatively, is creating stress on the nearshore.

Shoreline hardening is lowest from Pickering to the Bay of Quinte, although still between 20 and 25%. In this section, the longest stretches of natural shoreline are at Tommy Thompson Park (Toronto Regional Unit) and from just east of Bond Head until Port Britain (St. Mary's Cement Pier to Cobourg Regional Unit) – both of which are approximately 17 km in length. Shoreline hardening and vegetation removal in the Tommy Thompson Park to Pickering Regional Unit have undermined the stability of the Scarborough Bluffs.

Across the lake, the longest section of natural shoreline is a 49 km stretch on the south side of Prince Edward County and around Prince Edward Point until just east of Prince Edward Bay in the Kingston Basin Regional Unit. The sheltered embayments in the Bay of Quinte also contain significant stretches of natural shoreline, such as around Hay Bay and Sawguin Creek Marsh.

Overall, shoreline hardening is a source of high stress in west side of the lake and moderate stress along the St. Lawrence River. The nearshore provides a unique set of conditions and processes that together meet the life-stage requirements of aquatic species and biological communities. When a shoreline is hardened, it can alter sediment dynamics, accelerate erosion or deplete coastal areas in need of sediment replenishment. These coastal processes also play a significant role in determining the distribution and health of fish populations through impacts to their habitat including migration corridors, spawning grounds, nursery and feeding areas. Hardening of the shoreline can reduce coastal resilience; in the absence of natural vegetation or features like coastal wetlands, the shoreline may no longer adapt to rising and falling water levels, leading to the physical reduction of available aquatic habitat.

Littoral Barriers

Low Stress	0 littoral barriers
Moderate Stress	1 littoral barrier
High Stress	>1 littoral barriers

Thresholds based on best professional judgement.

Littoral barriers are defined in the Overall Assessment of the State of Nearshore Waters as shore perpendicular features that are greater than 100 m in length and that disrupt the natural movement of sediment (littoral drift). Littoral drift is the natural movement of sand and gravel in the nearshore and in areas where this is an important physical process, the presence of littoral barriers can impede natural coastal processes related to sediment dynamics. In a resilient coastal system, there should be no littoral barriers and processes related to sediment supply and deposition should not be restricted. In a resilient coastal system, sediment is supplied to the littoral “cell” through a source such as cliff erosion or coastal dunes and then transported alongshore through wave action where it is either deposited or lost offshore. In Lake Ontario, coastal processes related to sediment drift and natural erosion have led to the formation of significant features like the Scarborough Bluffs and barrier protected coastal wetlands.

There are seven Regional Units where littoral drift is an important physical process, and in each of these areas littoral barriers are a source of high stress. From the Niagara River to Welland Canal, littoral drift is an important process only in the lake portion of the Regional Unit and there are no littoral barriers.

The Burlington Beach to Humber Bay Regional Unit has 12 littoral barriers, the most of any Regional Unit. Both the Niagara Peninsula and Tommy Thompson Park to Pickering Regional Units have six littoral barriers and Toronto, Pickering to St. Mary’s Cement Pier, St. Mary’s Cement Pier to Cobourg and Cobourg to Gull Island all have between two and four barriers. This results in significant stress on the entire north shore of Lake Ontario from the presence of littoral barriers that disrupt natural sediment flow. Processes related to sediment dynamics have been altered in the Toronto Regional Unit from the construction of the Leslie Street Spit (Tommy Thompson Park) which acts as a barrier restricting natural sediment supply to the Toronto Islands. As a result, extensive shoreline protection has been built in order to save the islands from erosion and flooding.

The Pickering to St. Mary’s Cement Pier Regional Unit is characterized by a series of headland outcrops and embayments that are impacted by littoral barriers altering natural coastal processes. Barrier beaches along the coast protect coastal wetlands, such as at McLaughlin Bay, however a lack of long-term sediment supply may affect the persistence of these beaches. The coast in the St. Mary’s Cement Pier to Cobourg Regional Unit features several large harbours that are interspersed by eroding bluffs that provide sand and gravel for local beaches, and the pier at St. Mary’s Cement restricts sediment from moving east into the Cobourg to Gull Island Regional Unit. Prior to shoreline development and the presence of littoral barriers at harbours in the west extent of the Cobourg to Gull Island Regional Unit, the large sand beach at Presqu’ile Provincial Park was a depositional zone for a large littoral cell extending all the way from Pickering.

The Niagara Peninsula is characterized by glacial till and shale bluffs that, historically, eroded and were a source of sediment for the barrier beach at Hamilton Harbour. However, the presence of six littoral barriers in this Regional Unit now disrupt this natural flow of sediment.

Tributary Connectivity

Low Stress	>75% of the total length of tributaries (excluding upstream of a waterfall) are connected to the Regional Unit
Moderate Stress	25-75% of the total length of tributaries (excluding upstream of a waterfall) are connected to the Regional Unit
High Stress	<25% of the total length of tributaries (excluding upstream of a waterfall) are connected to the Regional Unit

Thresholds based on the State of the Great Lakes Sub-indicator report for Aquatic Habitat Connectivity using Ontario Ministry of Natural Resources and Forestry Hydro Network data.

Tributary connectivity is a source of varying stress. The Niagara River to Welland Canal, Humber Bay, Toronto and Thousand Islands Regional Units all have less than 25% of tributaries connected to the nearshore due to the presence of one or more barriers (i.e. dams). The Humber Bay and Toronto Regional Units in particular have less than 5% tributary connectivity, which is a source of high stress.

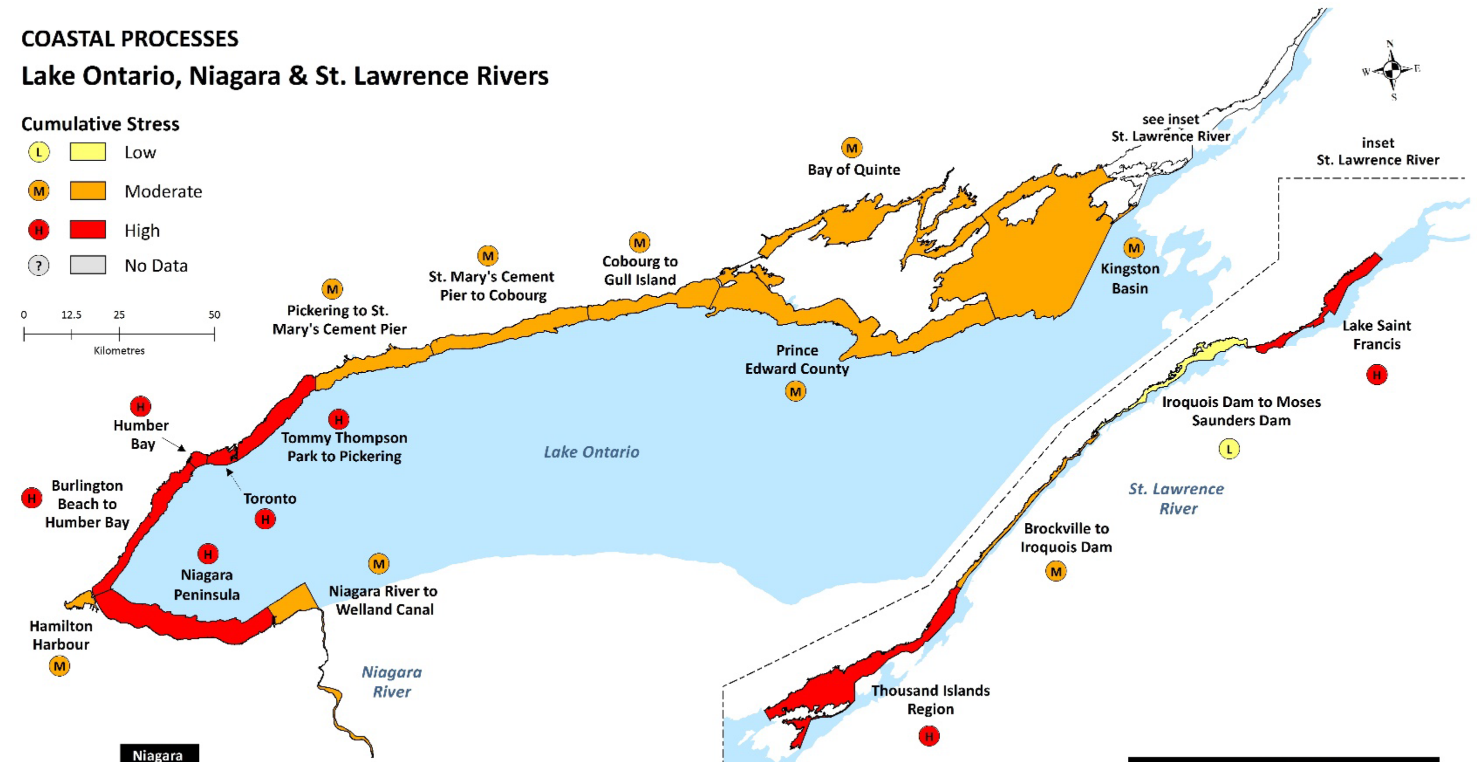
The Niagara Peninsula, Hamilton Harbour, Burlington Beach to Humber Bay and Bay of Quinte Regional Units all have waterfalls that act as natural barriers to connectivity. Tributaries upstream of a waterfall are considered to be naturally disconnected and not included in overall tributary connectivity as it is unlikely that the barrier (i.e. waterfall) would ever be removed. In the Hamilton Harbour Regional Unit, numerous waterfalls naturally disconnect around 320 km of tributaries, however overall connectivity remains high (81%). The Bay of Quinte Regional Unit has a very large watershed – extending nearly to the southern extent of the Canadian Shield – however waterfalls act as natural barriers to much of these and only 9% of tributaries not upstream of a waterfall are connected to the nearshore.

From Tommy Thompson Park to Pickering to the St. Mary's Cement Pier to Cobourg Regional Unit, tributary connectivity is a source of moderate stress. These Regional Units have 42% and 65% tributary connectivity.

The Regional Unit with the highest tributary connectivity (95%) is the Iroquois Dam to Moses Saunders Dam, although the total length of tributaries flowing into the Regional Unit is only about 250 km.

Barriers that limit tributary connectivity can have adverse impacts on the health of aquatic ecosystems by limiting access of fishes to spawning and nursery habitats, affecting nutrient flows and riparian and coastal processes. Although road crossings have not been included in this assessment, there have been several regional initiatives to identify and mitigate culverts that act as barriers and in future assessments they could be considered.

Figure 6. Results of the Coastal Processes category (N/A means that the measure does not apply in the Regional Unit)



	Niagara River													St. Lawrence River			
	Niagara River to Welland Canal	Niagara Peninsula	Hamilton Harbour	Burlington Beach to Humber Bay	Humber Bay	Toronto	Tommy Thompson Park to Pickering	Pickering to St. Mary's Cement Pier	St. Mary's Cement Pier to Cobourg	Cobourg to Gull Island	Prince Edward County	Bay of Quinte	Kingston Basin	Thousand Islands Region	Brockville to Iroquois Dam	Iroquois Dam to Moses Saunders Dam	Lake Saint Francis
Shoreline Hardening	41%	64%	84%	80%	66%	52%	55%	22%	20%	23%	25%	25%	36%	39%	55%	18%	60%
Littoral Barriers	0	6	NA	12	NA	2	6	4	3	2	NA	NA	NA	NA	NA	NA	NA
Tributary Connectivity	22%	51%	81%	39%	3%	6%	65%	47%	42%	81%	66%	9%	29%	13%	88%	95%	65%

Contaminants in Water & Sediment

Map of category results in Figure 7, individual measure descriptions below.

Water Quality

Low Stress	0 exceedances
Moderate Stress	1 or 2 exceedances
High Stress	>2 exceedances

Thresholds based on Provincial and Federal Guidelines and best professional judgement using data from the Ontario Ministry of Environment, Conservation and Parks Great Lakes Nearshore Water Chemistry.

Across Lake Ontario, water quality is a source of low stress. The MECP Great Lakes Water Chemistry data was assessed for any exceedances in published guidelines, and no contaminants were found to be in excess of those guidelines.

In the Niagara River to Welland Canal Regional Unit, there were no MECP Great Lakes Water Chemistry sites, however ECCC's Niagara River Upstream/Downstream Monitoring Program[10] recorded PCBs, Organochlorine Pesticides, PAHs and iron at Niagara-on-the-Lake. These results indicate high stress for water quality.

Sediment Quality

Low Stress	• PCBs < No Effect Levels • Organochlorine pesticides & PAHs < Lowest Effect Levels • Metals < Probable or Severe Effect Levels
Moderate Stress	• PCBs > No Effect Level OR, • Organochlorine pesticides & PAHs > Lowest Effect Levels but < Severe Effect Levels OR, • Metals > Probable Effect Levels but < Severe Effect Levels
High Stress	• Any contaminant > Severe Effect Levels

Thresholds based on Provincial and Federal Guidelines and best professional judgement using data from the Ontario Ministry of Environment, Conservation and Parks Great Lakes Nearshore Sediment Chemistry.

Across Lake Ontario, contaminants in sediment are a source of moderate stress (Table 2). Nearly all Regional Units have metals detected above Provincial Lowest Effect Levels (LELs), but this generally reflects background conditions and are not at levels of concern. Only Hamilton

[10] Hill, B. 2018. Niagara River Upstream/Downstream Monitoring Report 2005-2006 to 2014-2015. Environment and Climate Change Canada. For: Niagara River Monitoring Committee.

Harbour had metals detected at levels that exceed Federal Probable Effect Level (PEL) in addition to three metals at concentrations above Provincial Severe Effect Level (SEL). These include Iron, Manganese and Zinc.

PCBs were detected in sediment in nine Regional Units, in concentrations above the Provincial No Effect Level (NEL). This indicates a risk of bioaccumulation in the food chain. Exceedances of Organochlorine pesticides and PAHs affect the Hamilton Harbour, Burlington Beach to Humber Bay, Humber Bay, Toronto and Bay of Quinte Regional Units, where sediment quality is considered a source of moderate or high stress.

The Hamilton Harbour Regional Unit scored as high stress due to exceedances of guidelines in all four categories of contaminants (metals, PCBs, Organochlorine pesticides and PAHs). It should be noted that Hamilton Harbour is a Great Lakes Area of Concern (AOC) with localized contaminated sediment that is undergoing remediation as part of current management planning and action.

It should be noted that for many Regional Units, the level of stress was determined from a single sampling site; sediment quality in the nearshore is highly variable and sampling locations may not represent conditions for the entire Regional Unit.

Table 2. Number of contaminants that exceeded Federal or Provincial guidelines within each Regional Unit, for each category of contaminant; as a rule, LEL<PEL<SEL, so if the contaminant exceeds the PEL is also exceeds the LEL, and if it exceeds the SEL it exceeds the LEL and PEL

Regional Unit	**Metals**			**PCBs**	**Organochlorine Pesticides**			**Polycyclic Aromatic Hydrocarbons**		
	LEL	PEL	SEL	NEL	LEL	PEL	SEL	LEL	PEL	SEL
Niagara River to Welland Canal	No Sampling Station									
Niagara Peninsula	5	0		1						
Hamilton Harbour	3	3	3	1		1		2	10	
Burlington Beach to Humber Bay	8			1		1		5	1	
Humber Bay	4			1				4		
Toronto	9			1	1			7		
Tommy Thompson Park to Pickering				1						
Pickering to St. Mary's Cement Pier	No Recent Data									
St. Mary's Cement Pier to Cobourg	No Recent Data									
Cobourg to Gull Island	1			1						
Prince Edward County	No Recent Data									
Bay of Quinte	8			1	1			1		
Kingston Basin	10			1		2		3		
Thousand Islands Region	1									
Brockville to Iroquois Dam										
Iroquois Dam to Moses Saunders Dam	No Sampling Station									
Lake Saint Francis										

Benthic Community

Low Stress	Benthic community is condition is functional and of high diversity (top 67th percentile of scores)
Moderate Stress	Benthic community is condition is degraded but functional (33rd to 67th percentile of scores)
High Stress	Benthic community is condition is severely degraded and not functional (bottom 33rd percentile of scores)

Thresholds based on statistical analysis using data from Environment and Climate Change Canada (2006-2014) and the Ontario Ministry of Environment, Conservation and Parks (2006, 2009, 2012).

Benthic community composition can vary substantially due to natural habitat conditions and human stressors, but the general health of an ecosystem may be reflected in the benthic community. Across Lake Ontario, benthic community quality varies (Table 3/4).

From the Niagara Peninsula to Humber Bay Regional Units and in the Kingston Basin, benthic community is a source of high stress as the relative condition of benthic invertebrate communities was low. The Toronto and Tommy Thompson Park to Pickering Regional Units were both assessed as having moderate benthic community quality, as were the Prince Edward County and Iroquois Dam to Moses Saunders Dam Regional Units. Generally, this means that the benthic communities at these sites had lower total benthos, lower taxon richness and lower evenness.

Sites in the Cobourg to Gull Island, Bay of Quinte, Thousand Islands Region, Brockville to Iroquois Dam and Lake Saint Francis Regional Unit were assessed as being in the top percentile of the range of quality across all sites. In these Regional Units, benthic community is a source of low stress.

The Niagara River to Welland Canal, Pickering to St. Mary's Cement Pier and St. Mary's Cement Pier to Cobourg Regional Units had no MECP or ECCC sites for which to assess benthic community.

See Appendix A for details on the statistical analysis used to assess Benthic Community.

Table 3. Benthic community quality for Regional Units with MECP station, for each sample year; generally, higher quality corresponds to higher total benthos, higher taxon richness and higher evenness; there are only 30 samples since 2006, and the number within each Regional Unit is low, making it difficult to separate spatial and temporal variability in the MECP data

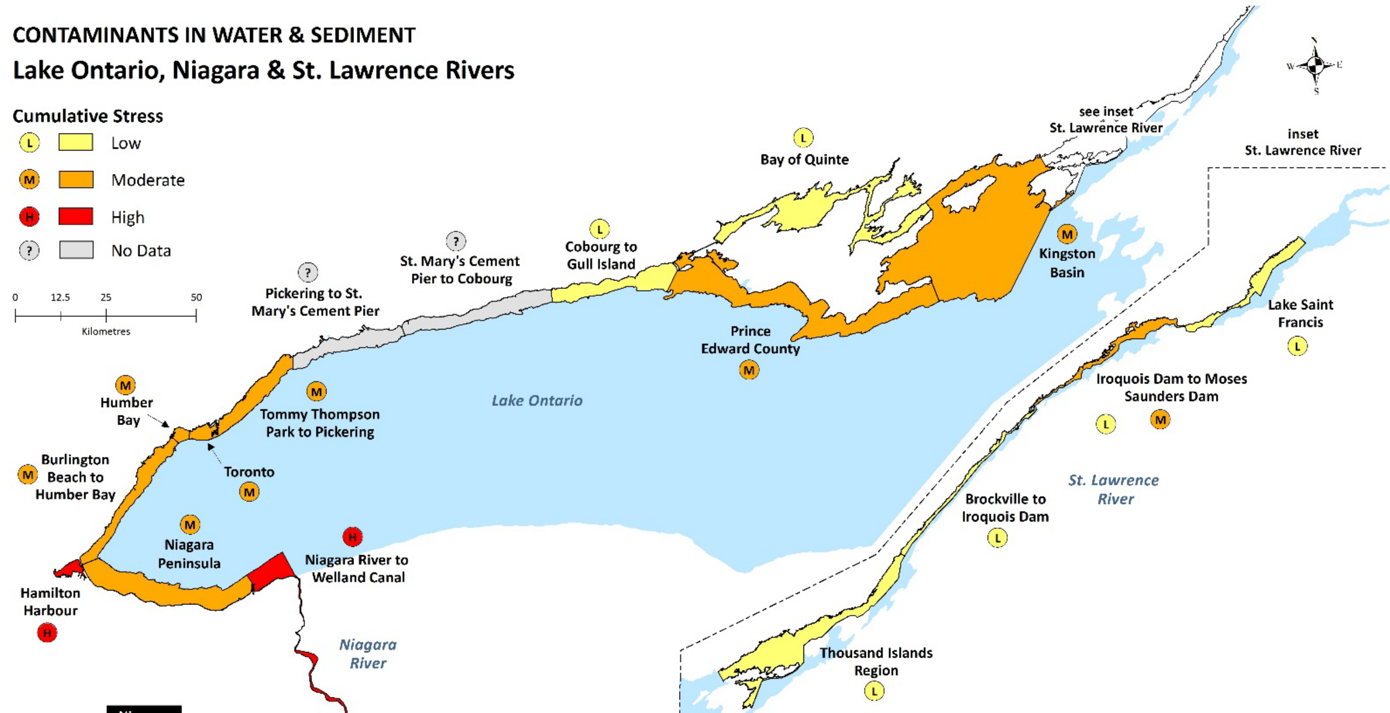
Regional Unit	Station	Year		
		2006	2009	2012
Niagara River to Welland Canal	No Data			
Niagara Peninsula	3045	No Data	Moderate quality	Low quality
Niagara Peninsula	3051	No Data	Moderate quality	Low quality
Hamilton Harbour	258	No Data	Low quality	Low quality
Burlington Beach to Humber Bay	9713	Moderate quality	Moderate quality	Low quality
Humber Bay	2047	Moderate quality	High quality	Low quality
Toronto	1364	No Data	Moderate quality	Moderate quality

Tommy Thompson Park to Pickering	708	High quality	Moderate quality	Moderate quality
Pickering to St. Mary's Cement Pier	No Data			
St. Mary's Cement Pier to Cobourg	No Data			
Cobourg to Gull Island	3509	No Data	High quality	No Data
Prince Edward County	2974	High quality	No Data	No Data
Bay of Quinte	462	No Data	High quality	High quality
Kingston Basin	64	No Data	Low quality	Moderate quality
Kingston Basin	3087	Low quality	Low quality	Low quality
Thousand Islands Region	424	No Data	High quality	High quality
Brockville to Iroquois Dam	128	No Data	No Data	High quality
Iroquois Dam to Moses Saunders Dam	No Data			
Lake Saint Francis	126	No Data	No Data	High quality

Table 4. Benthic community quality for Regional Units for ECCC stations, using 2006-2014 data; generally, higher quality corresponds to higher total benthos, higher taxon and higher evenness; ore samples w ithin each Regional Unit mean that regional differences are easier to detect how ever, w ith few er Regional Units containing samples, the spatial extent of the analyses is not as good as for the MECP analysis

Regional Unit		**Benthic Community Quality**				
	No. of Sites	Low	Moderate	High	Most Frequent	Median
Niagara River to Welland Canal	0					
Niagara Peninsula	0					
Hamilton Harbour	24	22	2	0	Low quality	Low quality
Burlington Beach to Humber Bay	0					
Humber Bay	0					
Toronto	0					
Tommy Thompson Park to Pickering	0					
Pickering to St. Mary's Cement Pier	0					
St. Mary's Cement Pier to Cobourg	0					
Cobourg to Gull Island	0					
Prince Edward County	11	2	4	5	High quality	Moderate quality
Bay of Quinte	14	3	6	5	Moderate quality	Moderate quality
Kingston Basin	9	4	5	0	Moderate quality	Moderate quality
Thousand Islands Region	0					
Brockville to Iroquois Dam	0					
Iroquois Dam to Moses Saunders Dam	11	0	6	5	Moderate quality	Moderate quality
Lake Saint Francis	25	0	9	16	High quality	High quality

Figure 7. Results of the Contaminants in Water & Sediment category



	Niagara River								
	Niagara River to Welland Canal	Niagara Peninsula	Hamilton Harbour	Burlington Beach to Humber Bay	Humber Bay	Toronto	Tommy Thompson Park to Pickering	Pickering to St. Mary's Cement Pier	St. Mary's Cement Pier to Cobourg
Water Quality	PCBs, organo-chlorine pesticides	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances
Benthic Community	No Data	low quality	low quality	low quality	low quality	average quality	average quality	No Data	No Data
Sediment Quality	No Data	PCBs > NEL	3 metals > SEL, PCBs > NEL, pesticide > PEL, 10 PAHs > PEL	8 metals > LEL, PCBs > NEL, 1 pesticides > PEL, 1 PAH > LEL	4 metals > LEL, PCBs > NEL, 4 PAHs > LEL	9 metals > LEL, PCBs > NEL, 1 pesticide > LEL, 7 PAHs > LEL	PCBs > NEL	No Data	No Data

					St. Lawrence River			
	Cobourg to Gull Island	Prince Edward County	Bay of Quinte	Kingston Basin	Thousand Islands Region	Brockville to Iroquois Dam	Iroquois Dam to Moses Saunders Dam	Lake Saint Francis
Water Quality	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	0 exceedances	No Data	0 exceedances
Benthic Community	high quality	average quality	high quality	low quality	high quality	high quality	average quality	high quality
Sediment Quality	1 metal > LEL, PCBs > NEL	No Data	8 metals > LEL, PCBs > NEL, 1 pesticide > PEL, 1 PAH > LEL	10 metals > LEL, PCBs > NEL, 2 pesticides > PEL, 3 PAHs > LEL	1 metal > LEL	0 exceedances	No Data	0 exceedances

Nuisance & Harmful Algae

Map of category results in Figure 8, individual measure descriptions below.

Cyanobacteria

Low Stress	No cyanobacteria bloom that exceeds 2% of the Regional Unit detected in any 10-day composite
Moderate Stress	Not applicable
High Stress	Cyanobacteria bloom exceeds 2% of the Regional Unit in any 10-day composite

Thresholds based on the World Health Organization cyanobacteria guidelines using satellite composites from NOAA's Harmful Algal Bloom Forecasting Branch (2016-2018).

Cyanobacteria is a concern to human and ecosystem health and a source of high stress in the Hamilton Harbour, Bay of Quinte and Kingston Basin Regional Units. In these Regional Units, a cyanobacteria bloom was detected in at least one ten-day composite during 2016, 2017 or 2018 that covered more than 2% of the surface area.

Cyanobacteria blooms detected were most extensive in Hamilton Harbour; in mid-August and September 2016 the bloom covered approximately 70% of the Regional Unit. In 2018, the bloom covered nearly 90% of the Regional Unit. A number of nutrient sources contribute to cyanobacteria blooms in the Hamilton Harbour Regional Unit, including sewage treatment plants that outlet into the harbour, an industrialized coast and agricultural watershed. Significant investment is being made to upgrade sewage treatment plants and reduce combined sewage overflow events into the harbour.

In the Bay of Quinte Regional Unit, cyanobacteria blooms covered more than 2% of the area in 2016, 2017 and 2018. The largest bloom was detected in 2016, when it covered over 30% of the Regional Unit area in August. Phosphorus loads from sewage treatment plants, storm water run-off and agricultural land use and internal loadings are likely contributing factors to the presence of cyanobacteria. Heavy precipitation can also exacerbate phosphorus loading into the area, as nutrients enter through run-off and the spring of 2017 saw record-breaking precipitation.

Although considered mild, in August 2017 a cyanobacteria bloom was detected in the Kingston Basin Regional Unit that covered just over 2% of the area.

Cladophora

Low Stress	<20% coverage
Moderate Stress	20-35% coverage
High Stress	>35% coverage

Thresholds developed using best professional judgement using 2016-2018 satellite-derived Submerged Aquatic Vegetation (SAV) Mapping from Michigan Tech Research Institute (MTRI).

Cladophora is filamentous green algae that grows on hard substrates in all of the Great Lakes. While not toxic, it is a nuisance and can pose threats to human health. Beyond clogging water intakes and degrading fish habitat, odorous rotting mats of *Cladophora* on beaches encourage the growth of bacteria and are a factor in beach postings. The *Cladophora* measure does not apply to Regional Units that are dominated by unconsolidated substrate, highly erosive coastlines and embayments characterized by coastal wetlands nor connecting channels. In areas where coastal wetlands are prevalent, it was assumed that areas classified as either sparse or dense SAV in the MTRI mapping may actually be wetland associated SAV and not nuisance *Cladophora.*

Conditions are suitable for *Cladophora* in 11 of the 17 Regional Units and it was assessed as a moderate to high source of stress on nearshore waters.

Cladophora vs. Submerged Aquatic Vegetation:
The best available dataset to measure the amount of *Cladophora* within nearshore waters is the Michigan Tech Research Institute satellite-derived Submerged Aquatic Vegetation (SAV) mapping. These maps represent the extent of SAV in the Great Lakes, acknowledging that much of it is *Cladophora*, with localized areas of vascular plants and other filamentous algae. Although the MTRI product has an overall accuracy of 83% based on comparison with ground truth data, this measure is not applicable in Regional Units where SAV is likely attributed to coastal wetlands or in other areas dominated by unconsolidated substrate.

In the Humber Bay Regional Unit *Cladophora* is a source of low stress however it is only 1% below the threshold for moderate (20%).

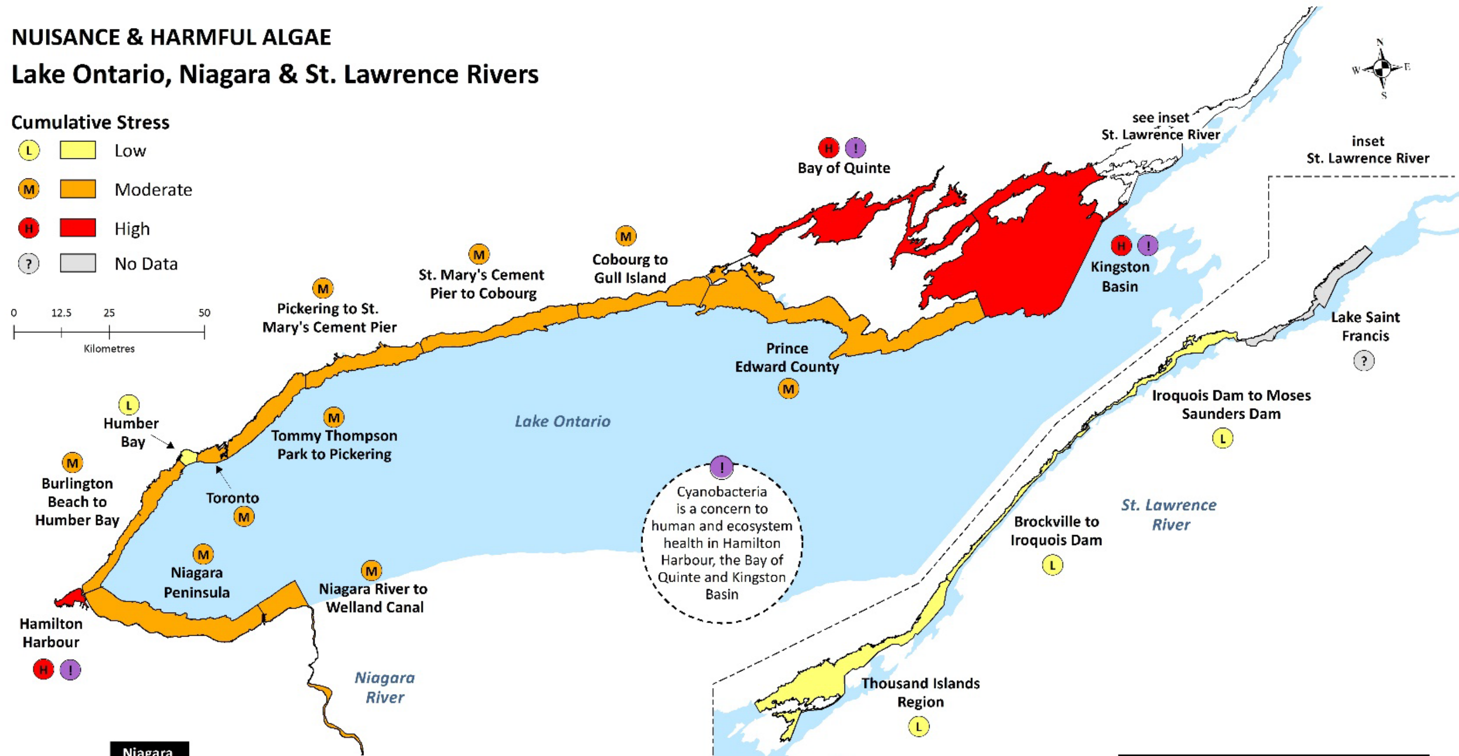
Regional Units with high coverage detected include the Niagara River to Welland Canal, Burlington Beach to Humber Bay, Toronto, Tommy Thompson Park to Pickering, Pickering to St. Mary's Cement Pier and Kingston Basin. In these areas *Cladophora* is considered to be a source of high stress. With the exception of Tommy Thompson Park to Pickering, which had 35.5% coverage, all of the high stress areas have over 40% coverage in the mapped area. These high extents are consistent with dry weight biomass samples collected at MECP and ECCC sentinel monitoring sites.

Within the Niagara River to Welland Canal Regional Unit, the mapped extent does not extend into the river however the area from the mouth of the river to Welland Canal is extensive (just under 50%) and a source of high stress. Considering that the largest phosphorus load to Lake Ontario is from Lake Erie via the Niagara River and that the substrate is suitable for *Cladophora* establishment, these results are not unexpected. In the Kingston Basin Regional Unit, *Cladophora* is known to grow in considerable quantities around Amherst Island.

The resurgence of the growth of *Cladophora* in Lake Ontario coincides with the timing of dreissenid mussel (zebra and quagga mussels) invasion. The mussels extend the hard substrate habitat available for *Cladophora* growth and break down particulate phosphorus to its bio-available form which is then readily taken up by *Cladophora*. *Cladophora* is also very dependant on adequate light for growth. As dreissenid mussels are filter feeders and improve water clarity, *Cladophora* has been found growing at even greater depths in the Lake Ontario since their invasion. A technical Binational Lake Ontario Task Team, formed under the GLWQA is currently assessing the state of knowledge around *Cladophora* to understand if actions to reduce land-based nutrient pollution would decrease *Cladophora* growth.

Cladophora is a known problem along the Burlington to Oakville coast, dating back to the 1990's. At that time, the Town of Oakville led a pilot project to cleanup and dispose of *Cladophora* wash-up from its beaches. The project was discontinued after two months however, as wash-up did not abate and it was prohibitively expensive to continue. Stakeholders and community members in the town of Ajax expressed their concerns for the high amount of *Cladophora* wash up on their shorelines and have advocated for increased research into the cause. The Pickering Nuclear Generating Station reported in July of 2018 that four reactor units were forced to shut down when significant amounts of *Cladophora* clogged the cooling water intake.

Figure 8. Results for the Nuisance & Harmful Algae category (N/A means that the measure does not apply in the Regional Unit)



	Niagara River													St. Lawrence River			
	Niagara River to Welland Canal	Niagara Peninsula	Hamilton Harbour	Burlington Beach to Humber Bay	Humber Bay	Toronto	Tommy Thompson Park to Pickering	Pickering to St. Mary's Cement Pier	St. Mary's Cement Pier to Cobourg	Cobourg to Gull Island	Prince Edward County	Bay of Quinte	Kingston Basin	Thousand Islands Region	Brockville to Iroquois Dam	Iroquois Dam to Moses Saunders Dam	Lake Saint Francis
Cyanobacteria	<2%	<2%	>2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	<2%	>2%	>2%	<2%	<2%	<2%	No Data
Cladophora	48% SAV extent	34% SAV extent	N/A	46% SAV extent	19% SAV extent	49% SAV extent	35% SAV extent	40% SAV extent	20% SAV extent	33% SAV extent	24% SAV extent	N/A	42% SAV extent	N/A	N/A	N/A	N/A

Human Use

Map of category results in Figure 10, individual measure descriptions below.

Fish Consumption

Low Stress	≥8 meals per month
Moderate Stress	1-7 meals per month
High Stress	<1 meal per month

Thresholds developed in consultation with the Ontario Ministry of Environment, Conservation and Parks using consumption advisories from the Guide to Eating Ontario Fish; average meals per month based on consumption advisories for Walleye, Northern Pike and Yellow Perch.

Fish from the Great Lakes provide a diverse and accessible source of food. They can however, be a source of contaminants and a risk to human health if consumption advisories are not considered. The province of Ontario provides consumption guidance based on a combination of fish size, species, location and contaminant (e.g. Mercury and PCBs). In the nearshore waters of Lake Ontario, Niagara River and St. Lawrence River fish species most targeted by commercial and recreational include Walleye, Yellow Perch and Northern Pike. The Guide to Eating Ontario Fish[11] provides consumption advisories for specific class sizes. The size classes most representative of fish caught and kept for consumption have been used to assess the Fish Consumption measure: size classes 35-55 cm for Walleye, 20-30 cm for Yellow Perch and 50-70 cm for Northern Pike.

Across Lake Ontario, Niagara River and St. Lawrence River, Fish Consumption advisories are a source of Low to Moderate Stress. The Humber Bay and Toronto Regional Units had the highest average number of meals per month, however there is no consumption advisory data for Walleye in these Units. With the exception of the Kingston Basin Regional Unit, the average number of meals per month is less than 7 from Tommy Thompson Park to Lake Saint Francis, putting these Regional Units in the Moderate Stress range for Fish Consumption advisories.

The consumption advisories vary between species as do the contaminants of concern (see Table 5). In the St. Lawrence River mercury is the primary contaminant of concern, but elsewhere across Lake Ontario and the Niagara River a mix of mercury and PCBs are recorded. Research suggests that overall trends indicate that reduced contaminant emissions have brought about positive changes in the fish contamination levels in Lake Ontario – in particular, a decreasing PCB trend in Walleye[12].

For specific information on the consumption advisories for the species assessed as part of the Fish Consumption measure, and for other fish species within the Great Lakes, please consult the Guide to Eating Ontario Fish (https://data.ontario.ca/dataset/guide-to-eating-ontario-fish-advisory-database).

[11] Ontario Ministry of Environment, Conservation and Parks. *Guide to Eating Ontario Fish* https://data.ontario.ca/dataset/guide-to-eating-ontario-fish-advisory-database

[12] Visha et al. 2016. Guiding fish consumption advisories for Lake Ontario: a Bayesian hierarchical approach. J. Great Lakes Res., 42(1): 70-82.

Table 5. Average fish consumption advisory for species within each Regional Unit and the associated contaminant of concern

	Walleye		Yellow Perch		Northern Pike		Average
Regional Unit	35-55cm	Contaminant of Concern	20-30cm	Contaminant of Concern	50-70cm	Contaminant of Concern	
Niagara River to Welland Canal	6	Mercury, PCBs	12	Mercury, PCBs	8	Mercury	9
Niagara Peninsula	5	Mercury	10	PCBs	0	PCBs	5
Hamilton Harbour	8	PCBs	10	PCBs	6	PCBs	8
Burlington Beach to Humber Bay	5	Mercury	9	PCBs, Mercury	5	Mercury, PCBs	6
Humber Bay	-		12	Mercury	9	Mercury, PCBs	11
Toronto	-		13	Mercury	10	Mercury, PCBs	12
Tommy Thompson Park to Pickering	4	Mercury, PCBs	13	Mercury	6	Mercury, PCBs	7
Pickering to St. Mary's Cement Pier	4	Mercury, PCBs	9	Mercury, PCBs	7	Mercury, PCBs	7
St. Mary's Cement Pier to Cobourg	0	Mercury, PCBs	11	PCBs	6	Mercury, PCBs	6
Cobourg to Gull Island	4	Mercury, PCBs	13	Mercury, PCBs	0	Mercury, PCBs	6
Prince Edward County	4	Mercury	7	Mercury, PCBs	2	PCBs	4
Bay of Quinte	6	Mercury, Dioxin-like PCBs	10	Mercury, Dioxin-like PCBs	5	Mercury	7
Kingston Basin	7	Mercury, Dioxin-like PCBs	10	Mercury, PCBs	6	Mercury, PCBs	8
Thousand Islands Region	8	Mercury	6	Mercury	3	Mercury	6
Brockville to Iroquois Dam	6	Mercury	4	Mercury	3	Mercury	4
Iroquois Dam to Moses Saunders Dam	5	Mercury	8	Mercury	5	Mercury	6
Lake Saint Francis	3	Mercury	4	Mercury	2	Mercury	3

Beach Postings

Low Stress	Beaches posted 5% or less of the time during July and August 2018
Moderate Stress	Beaches posted 5-20% of the time during July and August 2018
High Stress	Beaches posted more than 20% of the time during July and August 2018

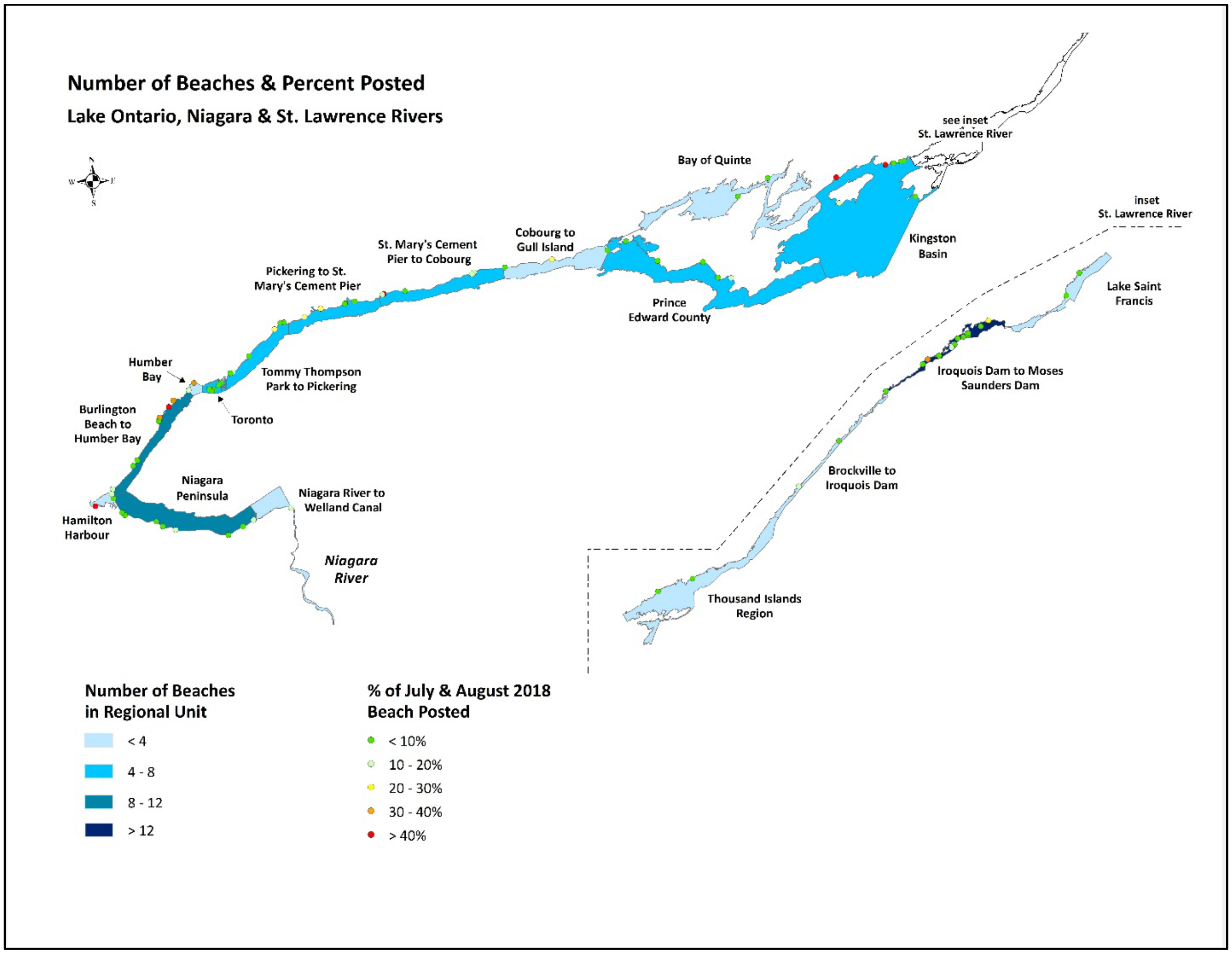
Thresholds developed using best professional judgement using data from Swim Drink Fish Canada.

This assessment included information on 81 publically monitored beaches on Lake Ontario and the St. Lawrence River (Figure 9). The average time the beaches were posted in a Regional Unit was higher in August than July from the Niagara River to Toronto and higher in July from Tommy Thomson Park to Bay of Quinte Regional Units. The St. Lawrence River saw a mix of postings in both months.

The Hamilton Harbour Regional Unit was found to be of the highest stress, where the single publically monitored beach (Pier4) was posted 55% of the time in July and August. This Regional Unit was impacted by Cyanobacteria blooms that accounted for a portion of the time that the beach was posted unsafe for swimming in 2018. The Humber Bay and Kingston Basin Regional Units were also found to be of high stress however they were still only posted half the amount of time as Hamilton Harbour with 27% and 24% of July and August respectively. Toronto and Bay of Quinte were the only two Regional Units that met the stringent criterion for low stress with postings less than 5% of July and August. Four Regional Units were very close to meeting this criterion with postings less than 6% of July and August: Niagara Peninsula, Prince Edward County, Iroquois Dam to Moses Saunders Dam and Lake Saint Francis.

At the individual Regional Unit scale, there was significant variation among beaches that make up the average for some Regional Units. For example of the three beaches in the Prince Edward County Regional Unit, two beaches (Presqu'ile Provincial Park and Victoria Beach) were not posted once in July and August of 2018 however the third (Wicklow Beach) was posted 23% of July and August making the average condition moderate stress for this Unit. Similarly, of the 13 beaches that are monitored in the Iroquois Dam to Moses Saunders Dam Regional Unit, 10 beaches had no postings in July and August of 2018 but the average conditions are of moderate stress due to postings at the remaining three beaches.

Figure 9. There are 80 publically monitored beaches across Lake Ontario and the St. Lawrence River; some Regional Units have a much higher number of beaches (e.g. Iroquois Dam to Moses Saunders Dam) and there is variation in the individual beach results that comprise the overall Beach Postings result for a Regional Unit



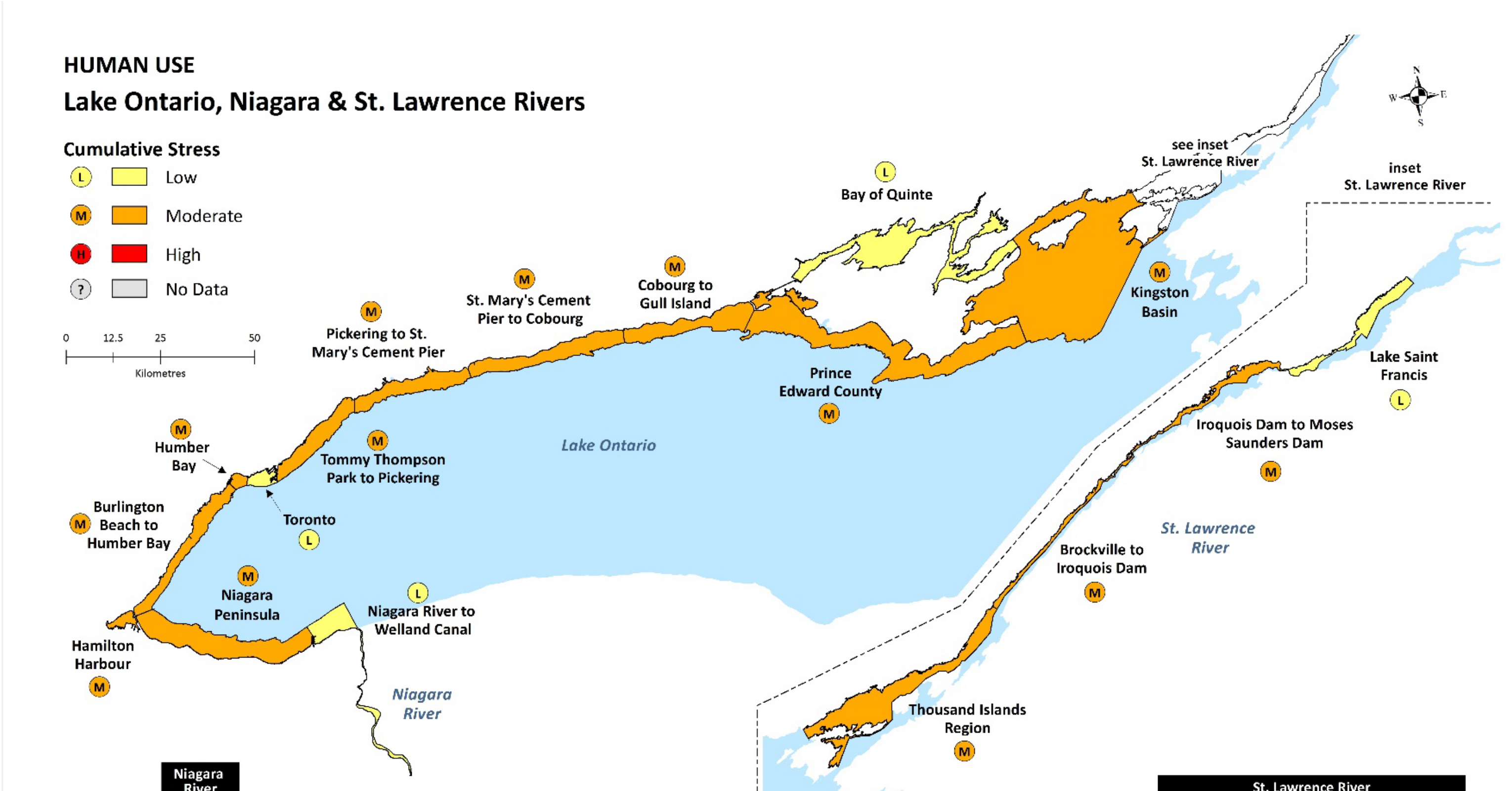
Treated Drinking Water Quality

Low Stress	No adverse water quality incidents
Moderate Stress	Does not apply - any incident is considered a high stress
High Stress	1 or more adverse water quality incidents

Thresholds based on Ontario Drinking Water Quality Standards.

All of the Regional Units in Lake Ontario, Niagara and St. Lawrence River's 17 water treatment plants had no adverse water quality incidents (AWQIs) during the years 2013-2017. There are no water treatment plants within the Hamilton Harbour and Humber Bay Regional Units.

Figure 70. Results of the Human Use category (N/A means that the measure does not apply in the Regional Unit)



	Niagara River													St. Lawrence River			
	Niagara River to Welland Canal	Niagara Peninsula	Hamilton Harbour	Burlington Beach to Humber Bay	Humber Bay	Toronto	Tommy Thompson Park to Pickering	Pickering to St. Mary's Cement Pier	St. Mary's Cement Pier to Cobourg	Cobourg to Gull Island	Prince Edward County	Bay of Quinte	Kingston Basin	Thousand Islands Region	Brockville to Iroquois Dam	Iroquois Dam to Moses Saunders Dam	Lake Saint Francis
Beach Postings	14% of July/Aug	6% of July/Aug	55% of July/Aug	20% of July/Aug	27% of July/Aug	4% of July/Aug	11% of July/Aug	18% of July/Aug	17% of July/Aug	8% of July/Aug	6% of July/Aug	5% of July/Aug	24% of July/Aug	10% of July/Aug	6% of July/Aug	6% of July/Aug	0% of July/Aug
Fish Consumption	9 meals per month	5 meals per month	8 meals per month	6 meals per month	11 meals per month	12 meals per month	7 meals per month	7 meals per month	6 meals per month	6 meals per month	4 meals per month	7 meals per month	8 meals per month	6 meals per month	4 meals per month	6 meals per month	3 meals per month
Treated Drinking Water	0 AWQI	0 AWQI	NA	0 AWQI	NA	0 AWQI	0 AWQI	0 AWQI	0 AWQI	0 AWQI	0 AWQI	0 AWQI	0 AWQI	0 AWQI	0 AWQI	0 AWQI	0 AWQI

Data Gaps and Limitations in Nearshore Science

Data used in the assessment has been obtained from existing monitoring programs, from a range of partners, and varies in type, format and resolution. Where available, data from long-term monitoring programs is used. Various monitoring and surveying programs were considered, and key considerations in the selection of data included the spatial and temporal resolution, the amount of processing required (e.g. technical expertise, software requirements) and the availability of the data. Considerable effort was given to identify high-quality data sets. Where possible, data from remote-sensing technologies were used as they provide high temporal resolution.

The first cumulative assessment of the nearshore waters of Lake Ontario, Niagara and St. Lawrence Rivers demonstrated some gaps in scientific data and information on nearshore water quality, physical processes and ecological health. This includes gaps in temporal and spatial coverage of monitoring programs as well as robust information on stressor interactions. Figure 11 shows which Regional Units had data gaps and the associated measure(s) that could not be assessed. Improved understanding of nearshore health may be advanced by:

- Increased spatial and temporal resolution of nearshore monitoring;
- Advancing science on remote sensing for ecosystem health data; and
- Continued commitment to existing long term monitoring programs.

Beyond the limitation of being unable to robustly assess cumulative stress for categories with insufficient data, limitations in nearshore monitoring and data for each Category – based on lessons learned from this assessment – are briefly outlined.

Coastal Processes

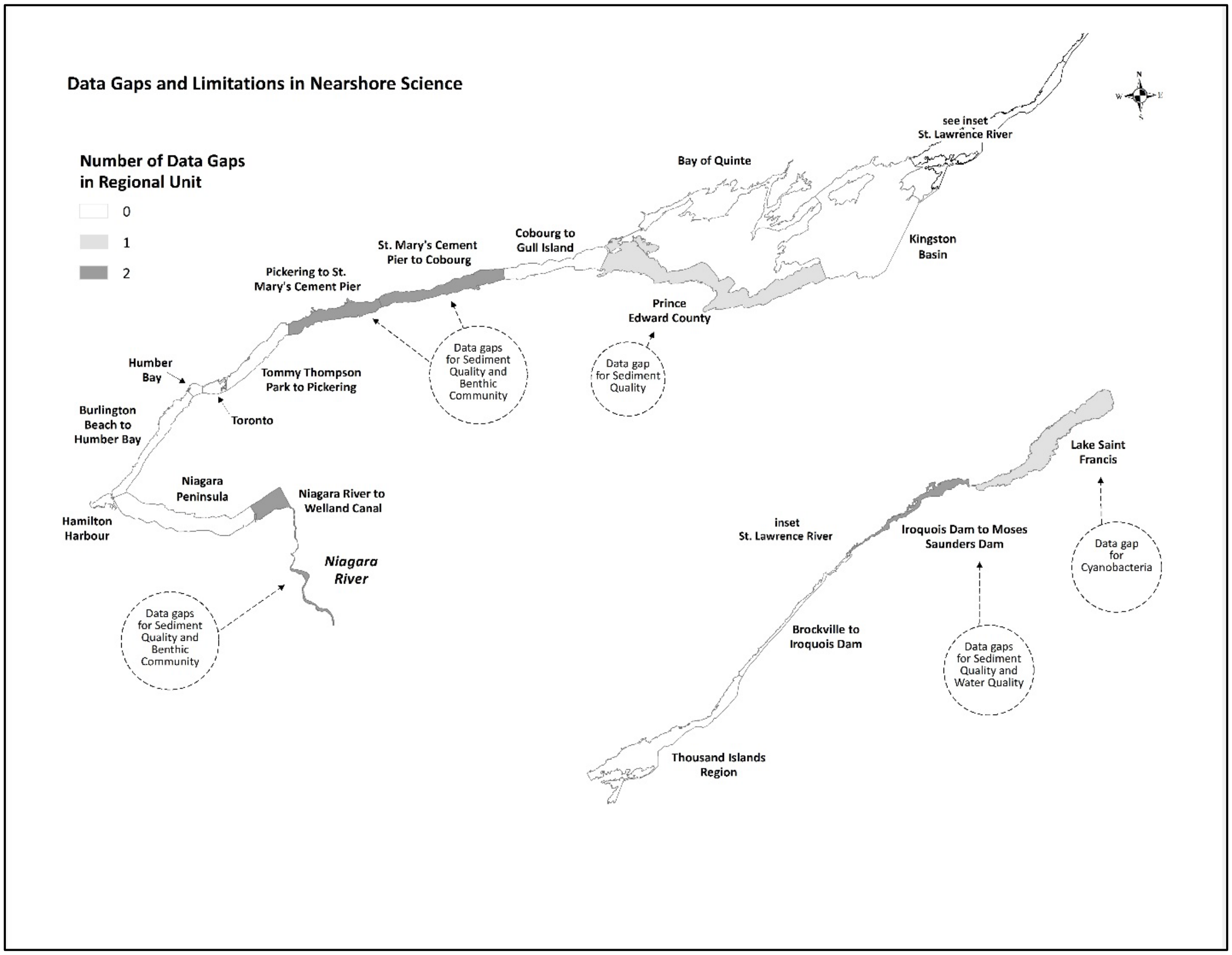
The MNRF Ontario Dam Inventory and the FishWerks database were used to evaluate barrier to tributary connectivity. Neither of these databases are regularly updated to reflect new dams or restoration of existing dams. This may affect the ability to assess changes over time to the Tributary Connectivity measure.

Contaminants in Water & Sediment

The overall assessment of nearshore waters relied on data collected by various ship-based sampling programs. This type of monitoring is typically limited spatially and temporally due to the size of the Great Lakes and weather that restricts sampling effort. Large research vessels typically used for this program cannot always access the nearshore waters due to depth limitations. Increasing monitoring locations would improve understanding of water and sediment quality, as well as benthic communities, at the Regional Unit scale.

Federal and provincial monitoring programs are designed to measure contaminants in all media (air, water, sediment, fish, birds and benthos) but the temporal and spatial coverage as well as the parameters measured and purpose of various monitoring programs is diverse. Despite the diversity of the various monitoring programs, there is limited data available to measure Contaminants in Water & Sediment at a scale that is regionally appropriate and offers coverage at the lake scale. Due to the geographic scale of the Great Lakes, the short weather windows for sampling and the high cost of laboratory analysis especially for organochlorine contaminants (e.g. dioxins and furans), very limited data is available to measure contaminant-related overall nearshore health. Many recent and emerging contaminants, such as Per- and polyfluoralkyl substances [PFAS], of which there are nearly 5,000 types (US FDA, 2020) are not understood well enough to set thresholds for safety or develop analysis methods. In addition, concentrations may be so low as to avoid detection with existing laboratory equipment.

Figure 11. The number of data gaps within Regional Units varies



Increased sampling effort at existing long-term monitoring stations would improve results for both the Sediment Quality and Water Quality measures. Not only would more sites benefit the assessment by adding spatial coverage, but site selection could consider areas where depositional sediment exists thereby improving the reliability of the data to reflect ambient conditions. Further, additional site selection for benthic community sampling as well as increases in temporal and spatial coverage are critically needed to increase confidence in the overall assessment of nearshore waters.

Nuisance & Harmful Algae

Supplementation of in-situ *Cladophora* sentinel site data and validation of satellite-based SAV interpretation has the potential to be improved using new remote sensing technology. The United States Geological Survey is currently investigating the utility of underwater, robot-deployed computer vision system capable of automatically classifying habitat types and mapping *Cladophora* biomass. An autonomous underwater vehicle, equipped with stereo cameras, captures images of the lake-bed, including *Cladophora*. Artificial intelligence models will be developed to automate the classification and prediction of *Cladophora* biomass using images of the lake-bed.

Locally, additional sentinel site monitoring could provide more insight, as ECCC & MECP monitoring records go back to the previous decade, and at that time, only moderate quantities of *Cladophora* were detected in the nearshore. In-lake sentinel site monitoring is a gap along the Welland Canal section of the nearshore.

A citizen science-monitoring program to track wash-up along the highly affected portions of the coast would assist in the understanding of this issue. While *Cladophora* is a problem to ecosystem health, it is also a nuisance to people who use and/or depend on the social and economic benefits derived from the shoreline and nearshore waters. Moreover, it has been noted by researchers that local patches of *Cladophora* growth, may not supply the *Cladophora* that is washing up, it may be transported from other areas.

Human Use

Not all areas accessible for swimming are regularly monitored for recreational water quality. There are some locations where people swim but at which Health Units do not monitor due to limited capacity. Health Units weigh multiple factors to decide where to best allot their resources to maximize the benefit to beach goers. Increasing the number of locations that are monitored would allow for a more thorough understanding of beach water quality at a Regional Unit scale. The number of sampling days per season varies between health units with some units sampling daily and others bi-weekly. In some cases the beaches will remain posted unsafe until the next sampling event even though the poor conditions may not have persisted for the whole time between sampling. More frequent sampling would allow for a more accurate count of the days that the water was actually unsafe for swimming since the duration of postings would be more reflective of actual conditions. There is potential to use modelling tools to predict beach water quality at a higher spatial and temporal scale to better understand where and when the nearshore is safe for swimming.

Next Steps

The overall assessment of Lake Ontario, Niagara and St. Lawrence River's nearshore waters will be repeated to monitor change over time. Areas of high ecological value and other habitat factors will be integrated to complete the comprehensive assessment. Results will be included in the 2023 Lakewide Action and Management Plan (LAMP) and provided to communities and stakeholders for collaboration on identification of management priorities and to take action by protecting areas of high ecological value that are or may become subject to stress. The Lake Ontario Lakewide Partnership and the Canada-Ontario Agreement partners may support collaboration opportunities under the Nearshore Framework.

Identified data gaps, such as the need to increase spatial and temporal resolution of nearshore monitoring and the need to support advancements in remote sensing will be considered in the Cooperative Science and Monitoring priority setting exercise for each lake (a component of the

Lakewide Management process). Progress continues on the Nearshore Framework to complete a cumulative assessment for each of the Canadian Great Lakes nearshore as respective LAMPs are developed.

In 2022, the Overall Assessment of the State of Canadian Nearshore Waters – including results from Superior, Huron, Erie and Ontario – will be the first cumulative assessment of the Canadian Great Lakes nearshore waters.

Appendix A

Benthic Community

Provided by Lee Grapentine (2019)
Environment and Climate Change Canada

Objective of the analyses:
The analyses described in this document were conducted to determine the relative condition (or quality or health) of benthic invertebrate communities sampled from 17 Canadian regional habitat units in Lake Ontario.

Available data
Multiyear benthic community data for stations (= sites) in the Lake Ontario nearshore were available from two sources:

- Ontario Ministry of the Environment, Conservation and Parks (MECP) long-term monitoring program; and
- Environment and Climate Change Canada (ECCC) Great Lakes Action Plan Area of Concern and reference sites assessments.

As these data were collected for other programs their sampling designs are not optimal for assessing benthic conditions in each of the regional unit conditions. Both the MECP and ECCC data sets offer limited spatial coverage of the regional units; MECP has data for recently sampled stations in 13 of the 17 regional units, but only 1 station per unit for most units and ECCC has data for recently sampled stations in only 6 regional units, but with multiple stations per unit.

Stations were sampled multiple times from 2006-14 (data from earlier than 2006 were considered to old to be relevant for the assessments of “current conditions”). Most MECP and ECCC stations were sampled more than once in this range. The MECP sampling design is more spatio-temporally balanced than the ECCC design, but has only about a third of the samples.

The MECP and ECCC data were collected by methods too different to allow pooling of the two data sets. The biggest difference is in the mesh size of the sieves used to sort invertebrates from sediment. MECP used a 0.600-mm mesh, whereas ECCC used a 0.250-mm mesh. As a result, sampling efficiencies for smaller organisms such as oligochaetes and some chironomids, which dominate sediment benthos, would be expected to differ for the two programs. Therefore, determinations of benthic community quality were done separately for each data set.

Habitat and stressor data, matched by station and year, were not available for the MECP benthos data, and were limited for the ECCC benthos data. Maps of exposure to GLEAM and GLEI stressor variables were not available, except for the cumulative stressor. However, the level of exposure to that stressor did not vary enough across Lake Ontario to test for a relationship to benthic community conditions. Stressor-benthos associations were therefore not examined due to the lack of sufficiently balanced sampling design and the low number of stations sampled.

Methods
The procedures for the Lake Ontario data analyses followed as closely as possible those used for the Lake Erie nearshore assessment analyses. Two important differences between the Ontario and Erie data sets necessitated changes in the analyses:

- The main Lake Erie data set used for the assessment of nearshore benthic conditions had observations from 280 locations, all from the same survey, with multiple locations in most of the regional units. In the Lake Ontario data sets, the number of stations per regional unit is much lower, and the station observation were obtained over multiple years. Therefore compared to the Lake Erie results, the Lake Ontario regional unit assessments will potentially be more uncertain or biased due to fewer observations per unit and effects of year-to-year variability.
- In the Lake Erie analyses, benthic community structure was characterized by several descriptors, including total benthos (density of all macroinvertebrates in a sample), taxon richness (number of lowest level taxa), average sensitivity to disturbance of the individuals present at a sample, and axes from a principal coordinates analysis (PCoA) of the benthos densities, which shows variation in the taxonomic composition of the sample. Appropriate taxon sensitivity values were not available for the Lake Ontario data sets, so in place of the average sensitivity to disturbance descriptor evenness was included. Evenness, ranging from 0 to 1, and is a measure of how individuals in a sample are distributed among taxa, where 1 indicates all taxa have the same number and the closer to 0 the more uneven the numbers among taxa. Low evenness is associated with low community quality.

Properties and preliminary calculations for the two data sets are described below.

For the MECP data set, benthos data for years 2006, 2009 and 2012 were used in analyses:

- 15 monitoring stations were sampled in 13 Regional Units
- 11 of the stations were sampled in more than 1 year
- The number of replicate samples per station visit ranged from 3 to 5
- Benthos data include densities for taxa identified to the lowest level of identification, then summed to genus level for analyses
- Replicate taxon densities (no. per m^2) were averaged

For the ECCC data set, benthos data for years 2006, 2007, 2010, 2011, 2012 and 2014 were used in analyses:

- 71 sites were sampled in 6 Regional Units
- 24 sites were sampled in 2 years; 71 sites were sampled once; number of samples = 95
- Benthos data include densities for taxa identified to the lowest level of identification, then summed to genus level for analyses

For each data set, the following analyses were conducted:

- Total benthos, taxon richness and Pielou's evenness (E = H'/ln(richness), where H' is the Shannon diversity index) were calculated for each Station-Year observation (i.e., sample) and plotted against Regional Unit
- A PCoA was conducted on a Bray-Curtis similarity matrix calculated from log(x+1)-transformed genus-level densities (all taxa included)
- A principal components analysis (PCA) was conducted on a correlation matrix calculated from log-transformed total benthos, log-transformed taxon richness, and evenness (not transformed); based on the first 2 axes from the PCA, a quality gradient aligning with increasing total benthos, increasing taxon richness and increasing evenness was calculated by:
    a. Ranging the first two ordination axes (PC1, PC2) from 0 to 1, and
    b. Calculating rangedPC1 × rangedPC2.

- Three benthos quality classes (low, moderate, high) were defined by calculating the 33rd and 67th percentiles for rangedPC1 × rangedPC2 values

For the MECP data, the quality class of each station-year sample was assigned. For the ECCC data the number of station-year samples falling in each quality class was tabulated for each Regional Unit, and then the class that divided the sites in half was identified to characterize the "median quality" of the Regional Unit. This procedure produces a relative measure of quality for the sites and samples, and does not account for any effects of habitat conditions.

Table A-1. Benthic community quality for Regional Units with MECP station, for each sample year; generally, higher quality corresponds to higher total benthos, higher taxon richness and higher evenness; there are only 30 samples since 2006, and the number within each Regional Unit is low, making it difficult to separate spatial and temporal variability in the MECP data

Regional Unit	Station	Year		
		2006	2009	2012
Niagara River to Welland Canal	No Data			
Niagara Peninsula	3045	No Data	Moderate	Low
Niagara Peninsula	3051	No Data	Moderate	Low
Hamilton Harbour	258	No Data	Low	Low
Burlington Beach to Humber Bay	9713	Moderate	Moderate	Low
Humber Bay	2047	Moderate	High	Low
Toronto	1364	No Data	Moderate	Moderate
Tommy Thompson Park to Pickering	708	High	Moderate	Moderate
Pickering to St. Mary's Cement Pier	No Data			
St. Mary's Cement Pier to Cobourg	No Data			
Cobourg to Gull Island	3509	No Data	High	No Data
Prince Edward County	2974	High	No Data	No Data
Bay of Quinte	462	No Data	High	High
Kingston Basin	64	No Data	Low	Moderate
Kingston Basin	3087	Low	Low	Low
Thousand Islands Region	424	No Data	High	High
Brockville to Iroquois Dam	128	No Data	No Data	High
Iroquois Dam to Moses Saunders Dam	No Data			
Lake Saint Francis	126	No Data	No Data	High

Table A-2. Benthic community quality for Regional Units for ECCC stations, using 2006-2014 data; generally, higher quality corresponds to higher total benthos, higher taxon and higher evenness; more samples within each Regional Unit mean that regional differences are easier to detect however, with fewer Regional Units containing samples, the spatial extent of the analyses is not as great as for the MECP analysis

Regional Unit		Benthic Community Quality				
	No. of Sites	Low	Moderate	High	Most Frequent	Median
Niagara River to Welland Canal	0					
Niagara Peninsula	0					
Hamilton Harbour	24	22	2	0	Low	Low
Burlington Beach to Humber Bay	0					

Humber Bay	0					
Toronto	0					
Tommy Thompson Park to Pickering	0					
Pickering to St. Mary's Cement Pier	0					
St. Mary's Cement Pier to Cobourg	0					
Cobourg to Gull Island	0					
Prince Edward County	11	2	4	5	High	Moderate
Bay of Quinte	14	3	6	5	Moderate	Moderate
Kingston Basin	9	4	5	0	Moderate	Moderate
Thousand Islands Region	0					
Brockville to Iroquois Dam	0					
Iroquois Dam to Moses Saunders Dam	11	0	6	5	Moderate	Moderate
Lake Saint Francis	25	0	9	16	High	High