Partnering in Phosphorus Control:

Achieving Phosphorus Reductions in Lake Erie from Canadian Sources

The Canada-Ontario Draft Action Plan

Gathering Ideas

A discussion document to assist in the engagement of key stakeholders, First Nations and Métis communities, and the public in action plan development

Prepared by the Canada-Ontario Agreement Partners
February 2017

Executive Summary

Lake Erie needs your help! Harmful and nuisance algal blooms and zones of low oxygen have been increasing in Lake Erie over the past decade, causing significant impacts to the environment and the Canadian economy.

Risks to human health are also a significant concern, as a result of biological toxins produced by harmful algae.

To tackle these issues, targets for reducing phosphorus loads from Canadian sources to the lake have been established. A tremendous amount of work has already been completed however more needs to be done to achieve these targets, involving engagement and collective action by all levels of government, First Nations and Métis communities, as well as by sector groups, conservation authorities, and the public.

This draft Action Plan begins the process of pulling our collective actions together. Its purpose is to open a dialogue with the Great Lakes community, share Canada and Ontario's proposed actions and to invite you to contribute your ideas and actions for inclusion in the Action Plan.

Readers are encouraged to consider the questions below to help guide their input for inclusion in the draft Action Plan. The information gathered through this process will help form the final Action Plan, which will be available for further public input in summer 2017. A final Action Plan is expected to be in place no later than February 2018. Please provide your feedback to letstalklakeerie.ca or Land.Water@ontario.ca.

Thank you for contributing your ideas, actions and resources to this important effort to help Lake Erie!

The development of the Action Plan is being led by the five federal and provincial government agencies:

Environment and Climate Change Canada
Agriculture and Agri-Food Canada
Ontario Ministry of the Environment and Climate Change
Ontario Ministry of Agriculture, Food and Rural Affairs
Ontario Ministry of Natural Resources and Forestry

Over the past decade, harmful and nuisance algal blooms and zones of low oxygen have been increasing in Lake Erie, causing significant impacts on the lake's environment and the Canadian economy. Water quality and fish and wildlife populations and habitats are degraded, beaches are fouled, pipes are clogged, and the lake's important commercial fishery is increasingly at risk. Human health is also a significant concern, as a result of biological toxins produced by harmful algae.

At the root of the problem is excess phosphorus, a naturally occurring element that is part of all plant and animal tissue. In a healthy ecosystem, phosphorus levels are low enough to limit the growth of harmful and nuisance algae. In Lake Erie, too much phosphorus is causing excessive algal growth and threatening ecosystem and human health. The financial, social, and ecological costs of these blooms are significant and growing, and action is urgently needed to reverse the trend.

For more than 40 years, Canada and the United States have worked together to reduce phosphorus loadings to Lake Erie, with the goal of decreasing harmful and nuisance algal blooms and improving dissolved oxygen levels. Concerted efforts resulted in significant water quality improvements through the 1970s and 1980s. Today, with a warming climate and significant changes in the lake ecosystem, as well as changes to land use and management, algal blooms have once again increased, and new approaches are warranted. Under the Canada-United States Great Lakes Water Quality Agreement, 2012, the two countries renewed their commitment to reducing phosphorus loadings and improving water quality and ecosystem health in Lake Erie. The challenge is significant, but with coordinated action there is hope for the future.

First Nations and Métis communities living within the Great Lakes basin have contributed to the protection of the Great Lakes ecosystem health. Their perspectives continue to enhance our understanding and stewardship responsibilities regarding the natural environment and water, including the Lake Erie basin and watershed.

This draft Action Plan presents Canada and Ontario's proposed actions to meet commitments under the Canada-U.S. Great Lakes Water Quality Agreement, 2012 and the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, 2014.

In order to achieve our goal it is important that government collaborates with First Nations and Métis communities, sectors, and organizations towards a solution. Additional actions from sectors and communities across the Lake Erie basin are going to be needed to achieve our goals. Changes will not happen overnight. Long-term collective action is required to restore the health of Lake Erie.

This draft Action Plan sets out a number of guiding principles, including shared responsibility and adaptive management. Proposed actions are organized into five categories: Reduce Phosphorus Loadings; Ensure Effective Policies, Programs and Legislation; Improve the Knowledge Base; Educate and Build Awareness; and Strengthen Leadership and Coordination.

An adaptive management approach will provide a mechanism to track progress and periodically adjust management strategies as necessary. Engagement of governments at all levels, First Nations and Métis communities, conservation authorities, academic researchers, stakeholder groups, and the general public is intended to ensure an open and accountable process throughout.

In addition to Ontario's joint effort with Canada, the Province has a number of other nutrient commitments relating to Lake Erie, which will also be delivered through this Action Plan for Lake Erie, including the *Great Lakes Protection Act, 2015,* Western Basin of Lake Erie Collaborative Agreement between the Premier of Ontario and the Governors of Michigan and Ohio, and the Great Lakes Commission's Joint Action Plan for Lake Erie with U.S. states.

Readers are encouraged to consider the questions below and provide feedback and suggestions:

Questions

1. Do you have any feedback or input on the proposed actions outlined in this document?

2. Many agencies, stakeholders, and other partners have a role in reducing phosphorus loadings to Lake Erie. What actions does your organization/community plan to undertake as part of the Action Plan?

3. How do you see regional or local planning initiatives linking with or fitting into the implementation of this plan?

4. What do you see as the most significant barriers to reducing phosphorus loadings to Lake Erie? Do you have any suggestions for overcoming these barriers?

5. As all sectors and communities within the Lake Erie basin need to take action to reduce phosphorus loads, do you have any recommendations on how to encourage collaborative action?

6. Tracking progress and adaptive management will be essential for ensuring that actions are making a difference to the health of the Lake Erie basin. Do you have any specific ideas for measuring progress towards achieving Lake Erie phosphorus load reduction targets?

7. Do you have any other suggestions for reducing, managing or treating phosphorus run-off and discharges, including innovative approaches or technologies for phosphorus removal or recovery?

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1 Introduction

Over the past decade, harmful and nuisance algal blooms and zones of low oxygen have been increasing in Lake Erie, causing significant impacts on Lake Erie's environment and economy. Water quality and fish and wildlife populations and habitats are degraded, beaches are fouled, pipes are clogged, and the lake's important commercial fishery is increasingly at risk. Human health is also a significant concern, as a result of biological toxins produced by harmful algae.

At the root of the problem is excess phosphorus, a naturally occurring element that is part of all plant and animal tissue. In a healthy ecosystem, phosphorus levels are low enough to limit the growth of harmful and nuisance algae. In Lake Erie, too much phosphorus is causing excessive algal growth and threatening ecosystem and human health. The financial, social, and ecological costs of these blooms are significant and growing, and action is urgently needed to reverse the trend.

It has taken time for Lake Erie to get to its present state, and because the environment of such a large lake takes time to adapt and respond to actions, it will take time to see improvements within the environment. Further, as there are many point and non-point sources of phosphorus entering Lake Erie, there is a need for immediate and collective action by all sectors and communities to achieve phosphorus load reductions.

Canada and the United States have worked together for more than 40 years to control the impacts of human activities on Great Lakes water quality and ecosystem health. In particular, these efforts have focused on controlling phosphorus loadings[1], especially in Lake Erie. Since the establishment of the first Canada-United States Great Lakes Water Quality Agreement (GLWQA) in 1972, governments at all levels, First Nations and Métis communities, conservation authorities, stakeholder groups, industries, and others have contributed to the achievement of dramatic improvements in the Lake Erie ecosystem.

In recent years, however, problems have resurfaced. There has been a resurgence of harmful cyanobacteria blooms in nearshore areas and in the western basin of Lake Erie; low oxygen levels in the deep waters of the central basin; and the reoccurrence of major nuisance algal blooms along the Canadian shoreline of the eastern basin. The causes are complex, and include factors such as a warming climate, altered hydrologic patterns, changes in land use and management, and the arrival of invasive zebra and quagga mussels. It is clear that past actions are not enough to manage the problem. A new approach is warranted.

In 2012, Canada and the United States (the Parties) renewed their commitments on phosphorus control and other Great Lakes initiatives under an amended Great Lakes Water Quality Agreement, 2012 (GLWQA). Under the amended Agreement, the two countries committed to updating phosphorus loading targets and developing phosphorus reduction strategies and

[1] Section 2 provides more detail on phosphorus in the Lake Erie ecosystem.

domestic action plans designed to meet the new targets and achieve specific nearshore and open water ecosystem objectives, starting with Lake Erie. The Parties are required to cooperate and consult with State and Provincial Governments, First Nations, Metis, Municipal Governments, watershed management agencies, other local public agencies and the public in developing these strategies and action plans.

In February 2016, the Parties adopted new phosphorus reduction targets for their respective country. Targets have been established for Lake Erie's western and central basins, with a target for the eastern basin under consideration. The new targets represent:

- A 40 percent reduction in spring loads of total phosphorus and soluble reactive phosphorus for the Maumee River to minimize harmful algal blooms in the western basin.
- A 40 percent reduction from 2008 loadings to the central basin, with a new target total binational loading of 6,000 tonnes per year of total phosphorus; and
- A 40 percent reduction in spring loads of total phosphorus and soluble reactive phosphorus for priority tributaries to minimize harmful algal blooms in the nearshore areas.

These targets and the Canadian share of each are discussed in more detail in Section 3.5.

Each country's action plan will include actions for achieving their respective targets for Lake Erie. These plans must be finalized by February 2018. The challenge is significant, but with coordinated action, we will improve the health of Lake Erie.

This initial draft of the Action Plan contains actions proposed by Canada and Ontario to reduce Canadian phosphorus loadings to Lake Erie. Its purpose is to open a dialogue with the Great Lakes community to invite their input and actions for inclusion in the final Action Plan.

1.1 The Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health

The Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, 2014 (COA) is the federal-provincial agreement that supports the restoration, conservation and protection of the Great Lakes basin ecosystem. Canada and Ontario and their partners work together through the COA to meet commitments under the GLWQA. Annex 1 (Nutrients) of the COA sets out specific goals related to the reduction of excess nutrients and harmful and nuisance algal blooms. COA is updated periodically; the most recent agreement was signed in 2014 and will remain in force until December 17, 2019. Current activities under the COA Nutrients Annex span a broad range of federal and provincial regulatory and policy initiatives.

The governments of Canada and Ontario have worked together since the first COA was signed in 1971 and through subsequent COAs to improve the water quality and ecosystem health of the Great Lakes, including Lake Erie.

The goal of this draft Action Plan is to articulate the actions necessary to achieve Canada's phosphorus loading reduction targets, with the goal of reducing nearshore harmful algal blooms, low dissolved oxygen levels (hypoxia) in the central basin of Lake Erie, and nuisance algal blooms in the eastern basin. The development of the Action Plan is being led by the five federal and provincial government agencies (Environment and Climate Change Canada, and Agriculture and Agri-Food Canada, and the Ontario Ministries of Environment and Climate Change, Natural Resources and Forestry, and Agriculture, Food, and Rural Affairs) in collaboration with First Nations and Métis communities, the agriculture sector, municipalities, conservation authorities, stakeholders, and the public.

Canada and Ontario are committed to working together and with others, through the COA, to develop one plan for Lake Erie to meet their collective and respective commitments. This draft Action Plan will also serve to deliver on the Province of Ontario's other nutrient commitments (see text box).

This draft Action Plan sets out a variety of proposed federal and provincial actions to be coordinated and implemented across jurisdictions and sectors. It is founded on robust scientific evidence and aims for cost-effective, high-impact actions that reflect collective responsibility for environmental management, and data and knowledge sharing.

Actions being undertaken by our partners such as agricultural organizations, municipalities, conservation authorities, and First Nations and Métis communities will be integral to the reduction of phosphorus in the Lake Erie basin. Such actions are not yet included in this draft Plan. The intention of this first draft is therefore to invite others to contribute their actions and ideas on how to reduce

Linking the Action Plan to Key Ontario Initiatives

Canada and Ontario are committed to working together and with others, through the COA, to develop one plan for Lake Erie to meet our collective and respective commitments. The Action Plan will also serve to deliver on the Province of Ontario's other nutrient commitments for Lake Erie. Ontario's *Great Lakes Protection Act, 2015* (GLPA) provides new tools that can help address algal blooms in Lake Erie. The Act enables partners to come together to achieve shared goals in a particular watershed or geographic area in the Great Lakes-St. Lawrence River Basin. Under subsection 9 (2) of the GLPA the Minister of the Environment and Climate Change is required to set at least one target by November 2017 to assist in the reduction of algal blooms in all or part of the Basin. To satisfy that obligation, in October 2016, the Minister adopted a target of 40 percent phosphorus load reduction by 2025 (from 2008 levels), using an adaptive management approach, for the Ontario portion of the western and central basins of Lake Erie, as well as an aspirational interim goal of a 20 percent reduction by 2020.

In keeping with the need for early action, Ontario also signed the Western Basin of Lake Erie Collaborative Agreement (Collaborative Agreement) with the States of Michigan and Ohio on June 13, 2015, collectively committing through an adaptive management process to a recommended 40 percent total load reduction in phosphorus entering Lake Erie's western basin by 2025, with an aspirational interim goal of a 20 percent reduction by 2020 (from a 2008 base year). Working with the bordering U.S. Lake Erie States of Ohio, Michigan, New York and Pennsylvania through the Great Lakes Commission, Ontario collaborated on the development of the Joint Action Plan, which aligns with other binational and domestic nutrient efforts currently underway.

phosphorus loadings from Canadian sources.

1.2 Geographic Scope

The geographic scope of this draft Action Plan is the Canadian portion of the Lake Erie basin; see Figure 1. It includes Canadian sources discharging to the St. Clair River, Lake St. Clair (which also experiences significant algal blooms), and the Detroit River – collectively termed the "Huron-Erie corridor" – which together carry flows from Lake Huron into Lake Erie, as well as Canadian sources which directly flow into the western, central, and eastern basins of Lake Erie. Actions will be distributed across the Canadian portion of the basin, and will focus on sources and tributaries that produce the largest contributions of phosphorus to the lake.

In addition, nearshore areas are affected by phosphorus loadings from local tributaries. In Canada, the Thames River and the small tributaries around Leamington have been identified as priority tributaries causing harmful algal blooms on the south shore of Lake St. Clair and the north shore of the western basin near Point Pelee. See Figure 1.

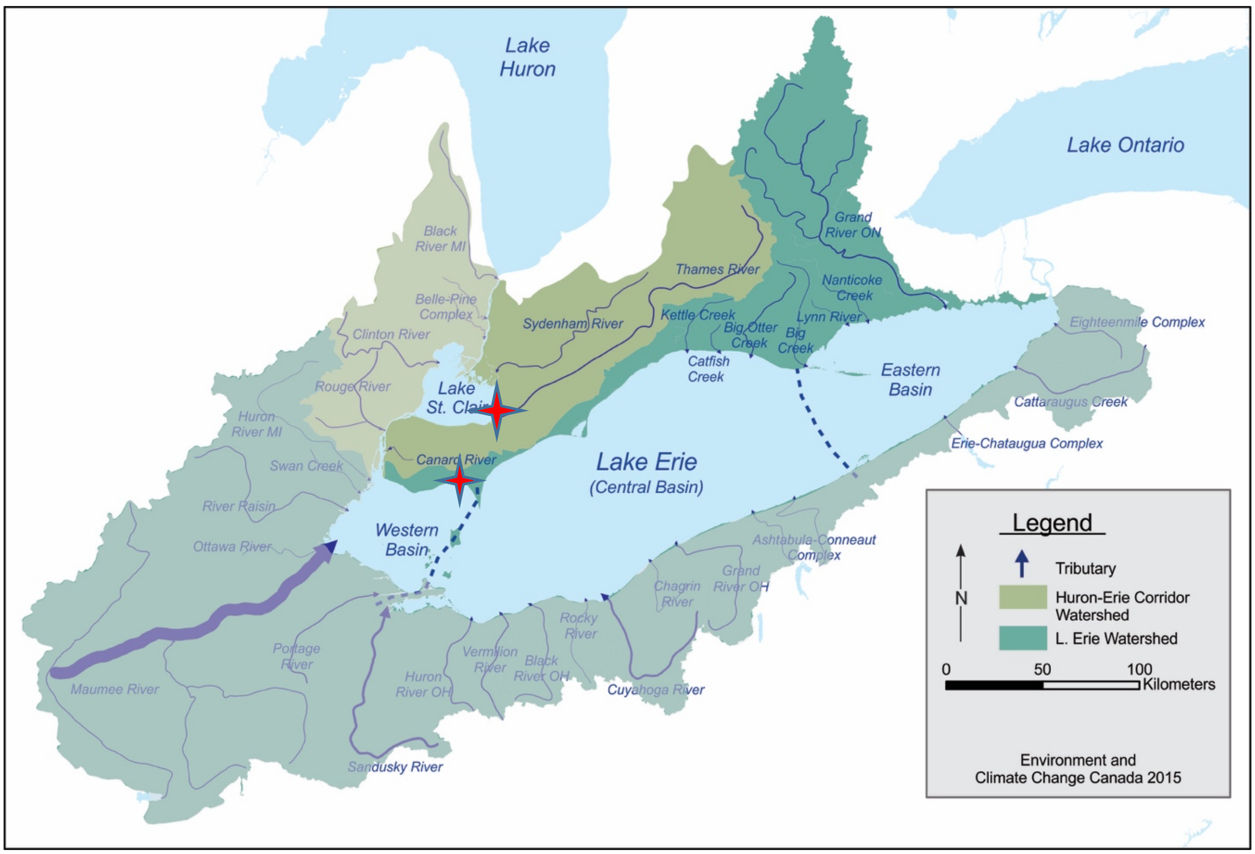

Figure 1: Map of Huron-Erie Corridor and Lake Erie, showing its three basins and major tributaries. The **Huron-Erie Corridor** is the term used to refer to the flows from Lake Huron through the St. Clair River, Lake St. Clair, and the Detroit River. On the Canadian side of the Basin, major tributaries include the Thames and Sydenham Rivers, both of which flow into Lake St. Clair. The red stars indicate priority tributaries that contribute to nearshore algal blooms.

1.3 Guiding Principles

This draft Action Plan is guided by four key principles aimed at improving the health of Lake Erie. Together, these principles are intended to ensure that actions are effective, balanced, and sustainable over time. The four principles are:

- Science-based
- Continuous improvement
- Shared responsibility
- Economically sustainable

Science-based

The actions and priorities contained in this draft Action Plan have been developed from a scientific foundation that includes more than 40 years of field data, published reports, and emerging research findings. A bibliography provided at the end of this document lists a wide variety of sources that contributed to the development of this draft Action Plan.

Continuous improvement

This draft Action Plan is a living document that will be reviewed and updated every five years as knowledge of Lake Erie improves and phosphorus reduction actions are implemented. Continuous improvement through an adaptive management framework is discussed in more detail in Section 5.1.

Shared responsibility

This draft Action Plan reflects the shared commitment of the governments of Canada and Ontario to the restoration, protection and conservation of the Canadian portion of Great Lakes waters, as articulated under the COA. It endorses a collaborative approach that values consultation and engagement of all levels of government, First Nations and Métis communities, as well as a range of stakeholders and partners, and the public. Consistent with water policy elsewhere in Canada and other parts of the world, it adopts a watershed perspective in evaluating potential actions and impacts.

Economically sustainable

This draft Action Plan is intended to be economically sustainable, aiming to mitigate negative economic impacts where they might occur and protect the economic value of Lake Erie's water quality and ecosystem integrity for future generations. It builds on and links existing activities, adding value and leveraging resources where possible.

2 Phosphorus in the Lake Erie Basin

Lake Erie is the most susceptible of the Great Lakes to eutrophication, the symptoms of excess phosphorus. These symptoms include harmful blooms of cyanobacteria (blue-green algae) in the western basin, low oxygen (hypoxia) in the central basin caused by the decomposition of dying algae that use up the oxygen at the lake bottom, and nuisance, fouling algae in the eastern basin that can clog water intakes, impede recreational uses, and degrade aquatic habitat. Cyanobacterial blooms can produce potent toxins that can threaten drinking water sources, fish populations, beach quality, coastal recreation, and the overall ecological health of the lake.

2.1 Lake Erie and Its Watershed

With a total surface area of 25,700 km^2 and an average depth of only 19 m, Lake Erie is the shallowest, smallest (by volume) and warmest of the Great Lakes, and the most reactive to weather changes and inputs. These characteristics also make it the most biologically diverse and productive, with more than 130 fish species, some of which, like walleye and yellow perch, support large commercial and recreational fisheries. The Canadian side of the Lake Erie basin accounts for about one third of the basin's land area, and supports 2.68 million people, 53 percent of them in eight urban areas with populations over 50,000, and the rest in smaller towns and rural areas. Agricultural production accounts for about three-quarters of the land use on the Canadian side of the basin. This Plan focuses on reducing phosphorus to Lake Erie. Other broad factors such as altered lake ecology will be addressed in the Lake Erie Action and Management Plan (LAMP) in 2018.

Lake Erie provides a number of important ecological and economic services, especially drinking water supply for over 680,000 municipal residents in the Canadian portion of the basin (the remainder of the population is served by private wells), diverse recreational and aesthetic opportunities, and important food and forage, spawning, nursery, and refuge habitat for aquatic and terrestrial species.

Human activities have contributed to the alteration of aquatic and terrestrial habitat throughout the Lake Erie basin, and changed its structure and function. One of the most significant human-induced changes in the lake is eutrophication: excess nutrients that encourage harmful and nuisance algal blooms, dissolved oxygen depletion, fish kills, and degradation of aquatic ecosystems.

There is broad consensus among the scientific community that the primary and most manageable driver of these impacts in Lake Erie is the nutrient phosphorus, which enters the lake from a number of Canadian and U.S. sources. This situation is further complicated by a changing climate, hydrological patterns, invasive species and shifting ecological systems.

2.2 Phosphorus Forms and Sources

Phosphorus is a naturally occurring and biologically active element that is a component of all biological tissue. It is a nutrient essential for plant and animal life, and some phosphorus is therefore important for maintaining a healthy lake ecosystem. Total phosphorus is a combination of dissolved and particulate forms. The dissolved form (termed soluble reactive phosphorus) is highly bioavailable and rapidly taken up by plants. High levels of soluble reactive phosphorus in water promote rapid growth of algae. Particulate phosphorus is bound to soil particles and is readily transported by water and wind erosion, but is much less bioavailable and is less accessible to plants and algae.

Phosphorus naturally cycles through air, water, and soil, and can change forms many times before it reaches Lake Erie. It is stored in and released from biological tissues and in mineral particles in soils and sediments in lake and stream bottoms, flood plains, and urban water systems and in soils in agricultural fields. These "legacy" sources of phosphorus can be re-mobilized and thus add to loadings, even when current practices are geared to phosphorus reduction. Actions to reduce phosphorus over time will help in reducing the amount of legacy phosphorus available to the Lake Erie ecosystem.

Phosphorus enters Lake Erie from point sources (typically treated effluent from municipal and industrial wastewater treatment facilities) and non-point sources, such as runoff from urban and agricultural landscapes. These sources contain a mixture of soluble reactive phosphorus and particulate phosphorus, with the proportion of each fraction dependent on the particular activity and geographic location.

Some sources of phosphorus, especially human sewage, animal manures and fertilizers, are very high in soluble reactive phosphorus and thus highly bioavailable. Controls of these sources can involve containment (e.g., manure storages, stormwater ponds) and often specialized treatment (e.g., wastewater treatment plants and septic systems). Effective control of non-point sources can be more complex and involves attention to prevention actions such as the right timing, placement and rate of manure and fertilizer application, in addition to addressing hydrological factors in the landscape.

By contrast, total phosphorus arising from soil erosion, streambank erosion, and similar sources contains much less soluble reactive phosphorus; most is particulate phosphorus bound to and transported with soil. Controlling these sources therefore means building soil health, increasing infiltration and reducing movement of water over open soils, to keep as much water and soil as possible on site. Snowmelt, winter rainfall and extreme storm events are of particular concern.

As much as 90 percent of the total phosphorus load to a river can be delivered during storm events, especially during the spring runoff period when soils are saturated and typically bare of vegetation. Water flowing over bare soils can facilitate the loss of manure or fertilizer that was surface-applied in the fall, winter or early spring. Figure 2 demonstrates that the majority of nutrient loadings occur outside the summer growing season.

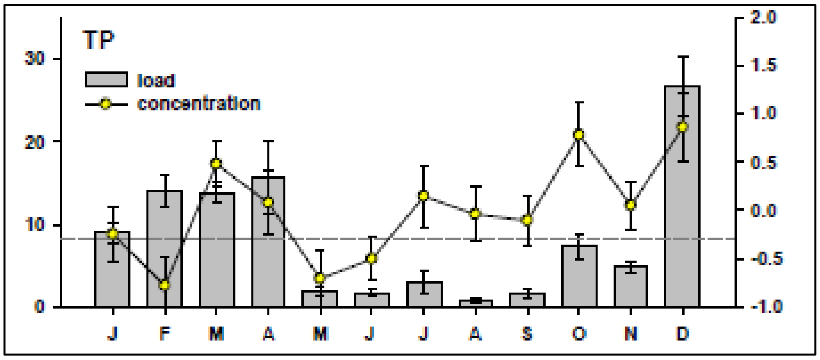

Figure 2: Phosphorus loadings and concentrations by month. Data depicted in this Figure are drawn from 15 streams in agricultural watersheds of southwestern Ontario (Lake Erie & Lake Huron) over the period 2004-2009. The dashed grey line represents the average annual load. Error bars are the standard error of the mean. Source: MOECC. Water quality of 15 streams in agricultural watersheds of Southwestern Ontario 2004-2009: Seasonal patterns, regional comparisons, and the influence of land use.

2.3 Lake Erie's Physical Structure and Function

Lake Erie's water quality is strongly influenced by two factors: its physical characteristics (shallow depth and stratification) and human activities in its watershed. The lake is naturally divided into three distinct basins, as illustrated in Figure 1: the western, central and eastern basins, each with different average depths and ecological conditions. The western basin is the smallest and shallowest, with an average depth of 7.4 m; the central basin has an average depth of 18.5 m; and the eastern basin has the greatest average depth, at 24.4 m. By comparison, the average depths of the other Canadian Great Lakes are much greater, with Lake Huron at 59 m; Lake Ontario at 86 m, and Lake Superior at 147 m; see Figure 3.

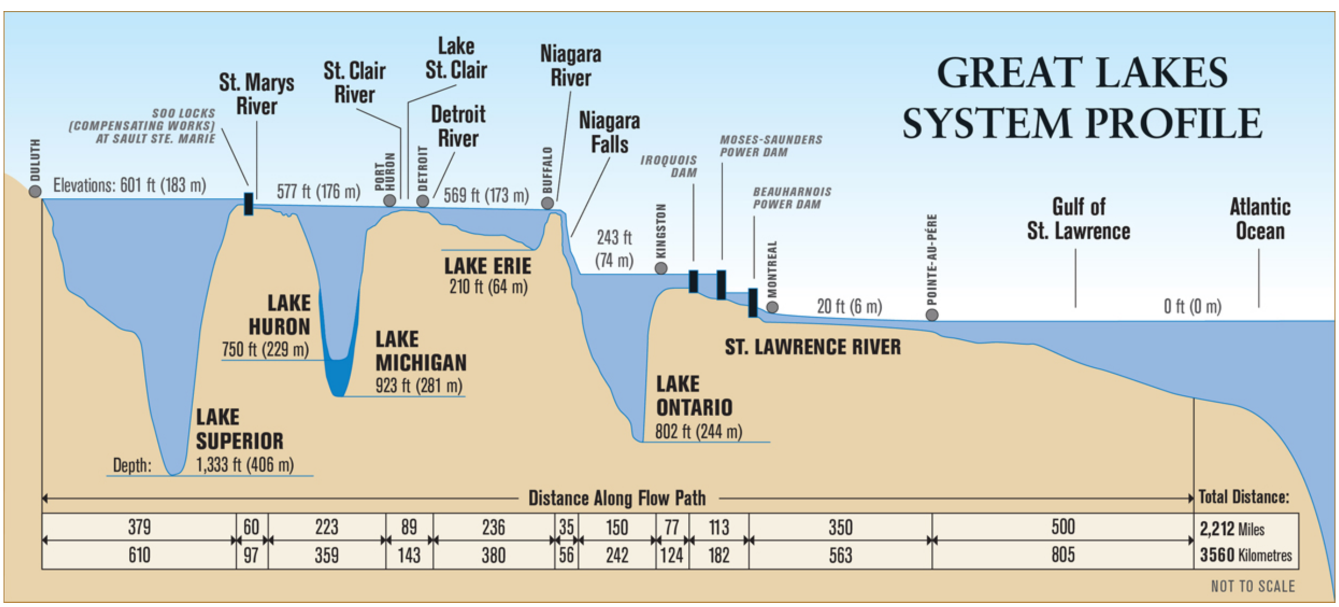

Figure 3: Relative depths of the Great Lakes. Lake Erie is by far the shallowest of the lakes. Source: Michigan Sea Grant.

Lake Erie's shallow depth allows its waters to mix thoroughly in spring and fall, warm rapidly in the summer, and freeze over in most winters. The central and eastern basins thermally stratify (form a warmer, less dense upper layer of water, the epilimnion, overlying a colder, denser bottom layer, or hypolimnion) every year in the summer. The western basin can also stratify, but its shallow depth means that it is easily mixed to depth by wind and wave action, so stratification usually does not last long. The presence or absence – and especially the persistence – of stratification is important because it can limit the capacity of bottom waters to mix with oxygen-rich surface waters. This in turn interferes with nutrient cycling and can result in low dissolved oxygen concentrations in deeper portions of the lake.

Concentration is the mass of a substance present in a given volume of water. It is expressed in units such as milligrams per litre. Concentration is particularly useful when a substance has biological consequences, such as toxicity or eutrophication.

Load is the total mass of a substance delivered to a water body over a given time period. Loading rate is expressed in units of mass per unit time (e.g., kg/year), and is calculated as the product of concentration (mass per unit volume) and flow rate (water volume per unit time). Load is a useful measure when there is potential for accumulation of a substance over time or when there is limited assimilative capacity in the receiving water. Load is also an important way of measuring the total pollutant contribution from a given source.

2.4 History of Phosphorus in Lake Erie

While phosphorus is a naturally occurring substance and essential for all life forms, excess quantities can result in nuisance and harmful algal blooms that in turn cause drinking water impairment, dissolved oxygen depletion, fish kills, and reduced recreational and aesthetic values.

Prior to European settlement, the estimated phosphorus load to Lake Erie from sources in Canada and the United States was about 3,000 tonnes total phosphorus per year. By 1900, it is estimated that the load had increased to about 9,000 tonnes per year. At that time, the majority of phosphorus entering the lake came from continuous inputs from untreated municipal and industrial sewage. A significant proportion also came from spring runoff to the western basin, conveyed via tributaries, largely as a result of land use changes that occurred after 1850[2].

From about 1900 onward, steady population growth resulted in rising total phosphorus loadings, largely from sewage and phosphorus-based detergents. Loadings from agricultural land also increased, especially after World War II, when innovations in agricultural technology and fertilizer production allowed the expansion of hybrid corn production and increased application of commercial fertilizers. By 1968, phosphorus loadings had reached a peak of approximately 28,000 tonnes per year and had a clear impact on algal blooms and hypoxia, resulting in media speculation that Lake Erie might be "dead."

First Nations and Métis communities, as well as others, have played a significant role in the protection and restoration of the Great Lakes. In addition, governments at all levels in Canada and the U.S. invested billions of dollars in the 1970s and 1980s in point source pollution control, especially sewage treatment plant upgrades. Governments also enacted legislation to limit phosphorus concentrations in household detergents, which came into effect in 1989 under the

[2] The phosphorus content of this runoff was largely attributable to soil chemistry rather than to added manure or fertilizer. Population density in rural areas was very low and agricultural sources of phosphorus at that time would have been minimal.

Canada Water Act, and these controls were continued under Canadian Environmental Protection Act (CEPA) in 1999. In 2010, under CEPA, limits on phosphorus concentrations were applied to additional products.

While the focus of total phosphorus controls through this period was largely on point sources, considerable work was also done to reduce non-point sources, especially agricultural runoff. In 1972, in response to a request from the International Joint Commission, the Parties established the Pollution from Land Use Activities Reference Group (PLUARG) that investigated the impact of land-based activities on pollutant loadings. PLUARG involved a significant experimental and data collection effort on a variety of watershed types, exploring how land management practices could be adjusted to reduce loadings of sediment and phosphorus. That work and a subsequent federal-provincial Soil and Water Environmental Enhancement Program (SWEEP) formed the basis for agricultural stewardship programs developed through the 1980s and 1990s to support farmers in implementing best/beneficial management practices to reduce non-point source pollution.

These bilateral efforts to control phosphorus loadings had a dramatic impact on the lake's water quality. By the mid-1980s, phosphorus loadings to Lake Erie were less than half the levels of the early 1970s (see Figure 4), and the frequency and extent of nuisance and harmful algal blooms had declined considerably. By the early 1990s, the annual phosphorus load to Lake Erie had dropped to 10,000 tonnes, and from 1981 to 2013, the GLWQA binational total phosphorus loading target (11,000 tonnes) was achieved in 19 of the 27 years (see Figure 4).

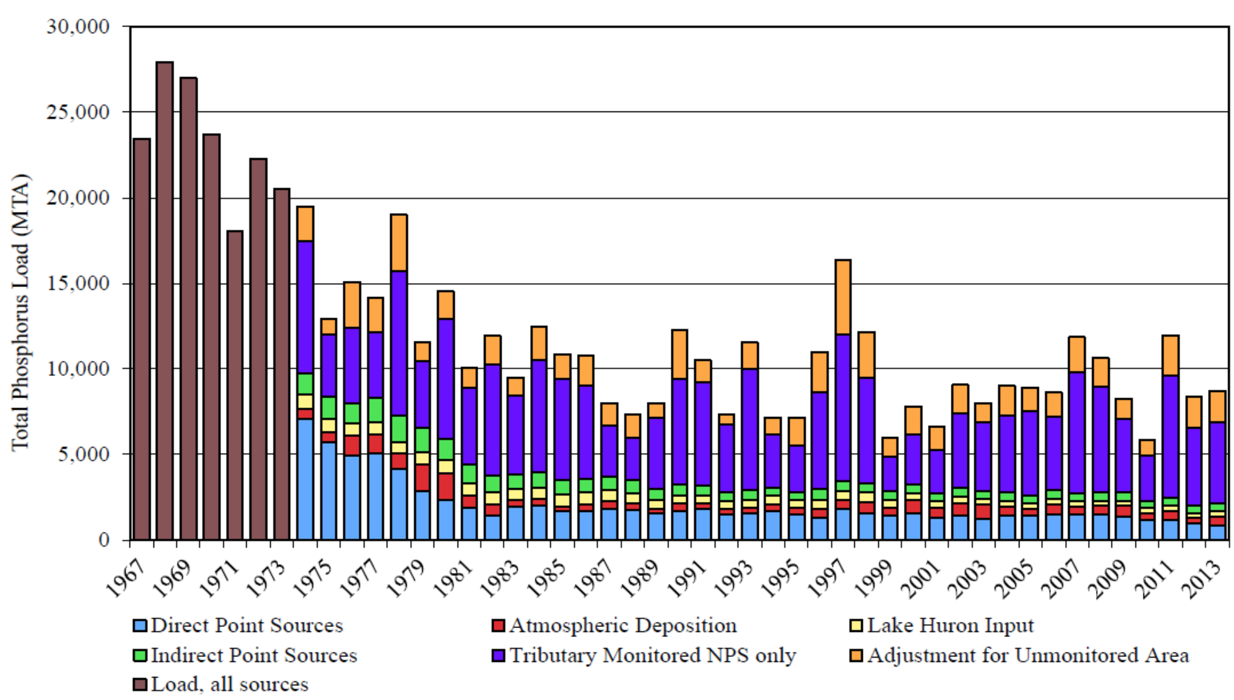

Figure 4: Annual loads of total phosphorus to Lake Erie from Canada and the U.S. Source: Maccoux et al. (2016).

Despite these successes, and without noticeable increases in loadings, by the mid-1990s eutrophication had re-emerged as a problem in Lake Erie and has continued to worsen over the years since then. Impacts now include widespread harmful algal blooms with the potential to cause significant human health impacts through production of cyanotoxins (biological toxins) produced mainly by the cyanobacteria species *Microcystis*. *Microcystis* blooms in Lake Erie have been increasing in size and frequency over the last twenty years, and mainly occur during warm, calm periods. Blooms are larger and more persistent in wet years, when tributary inflows of phosphorus are greater.

In dry years, such as 2012 and 2016, blooms are much smaller because there is less rainfall, less snowmelt, less runoff, and thus less phosphorus washing off the land surface into receiving waters. In 2015, heavy rainfall events followed by several days of warm temperatures resulted in an algal bloom that occupied most of the western basin and extended into the central basin.

2.5 Land Use and Watershed Characterization in the Lake Erie Basin

While Lake Erie's watershed is the most densely populated of the Great Lakes, most of that population is located in the U.S. portion of the basin. On the Canadian side, there are fewer urban centres, only eight of which have populations greater than 50,000.

About three-quarters of the land area in the Ontario portion of the basin is used for agriculture; the region's fertile soils, proximity to major water bodies, and temperate climate make it well suited to that purpose. By contrast, urban centres, settlements and roads make up 12 percent of land area, with natural areas accounting for another 13 percent. Figure 5 provides an overview of Lake Erie basin land use.

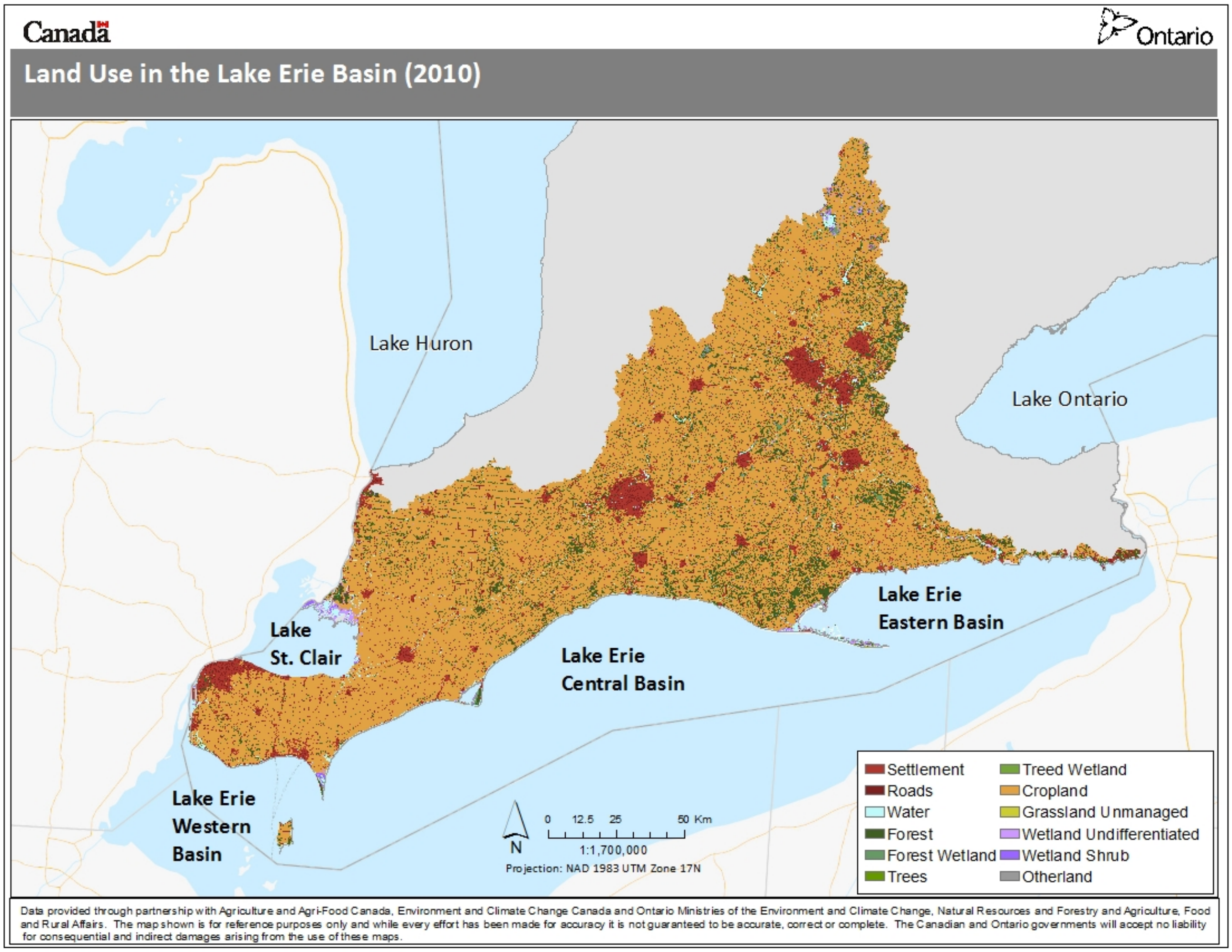

Figure 5: Overview of land use and land cover in the Lake Erie basin, 2010.

A good understanding of the type and location of the basin's varied land use and land activities must underlie phosphorus reduction strategies. Mid-sized (quaternary) watersheds within the Canadian portion of the Lake Erie basin have been characterized by the following land use/ activity categories: urban, agricultural-crop; agricultural-livestock; and, natural heritage; see Figure 6.

This categorization of watersheds does not mean that a watershed only has, or is dominated by the land use/activity category it is in. There can be varying levels of urban, agriculture types or natural heritage in each categorized watershed. These categories are also not mutually exclusive; that is, the same watersheds can fall into more than one category.

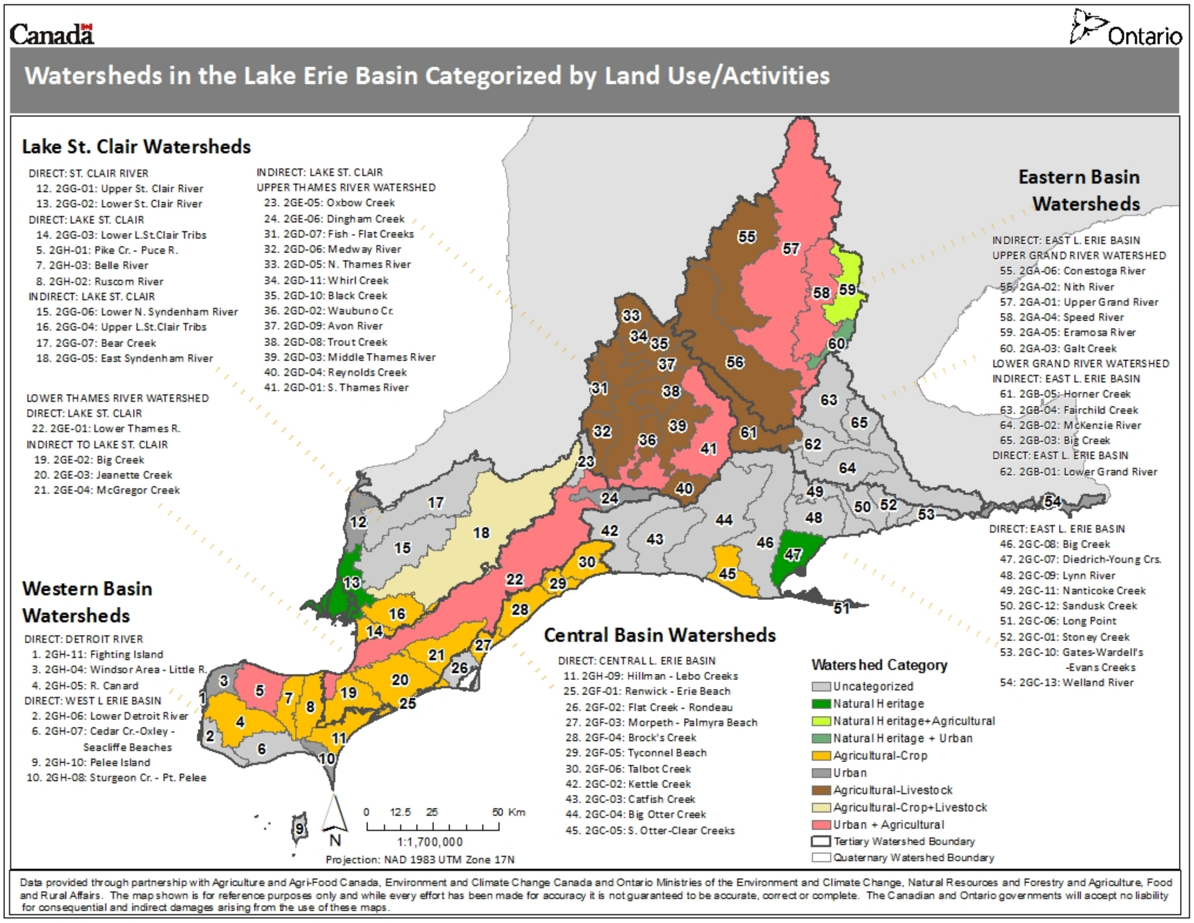

Figure 6: Lake Erie basin watersheds categorized by land use/activity. Note that characterization of a watershed does not mean that the watershed is only, or is dominated by, the particular land use/activity category it has been assigned.

The characterization process also identified landscape characteristics that could render a watershed more vulnerable to phosphorus loss, including the risk of soil erosion and the risk of surface runoff. The distribution of average total phosphorus concentration among watersheds was also mapped. For more information on the characterization process and results, see Appendix A.

2.6 What is Changing in the Lake Erie Basin: Challenges for Phosphorus Load Reduction

A number of key factors have changed in the Lake Erie basin since the first GLWQA was signed in 1972, and now confound phosphorus load reduction efforts. A changing climate, altered lake ecology, the increased presence of invasive species, and a range of human-related factors increasingly influence algal growth and hypoxia in the lake. With point sources well controlled, most of the phosphorus entering the lake now comes from non-point sources such as agricultural, rural and urban stormwater runoff; see Figure 4. Controlling those sources can be challenging because solutions require changes on thousands of individual sites instead of a small number of known point sources, and must be tailored to particular land management and biophysical site characteristics.

2.6.1 Climate Change

A warming climate is already increasing average water temperatures, reducing the duration and extent of winter ice, altering nutrient cycling dynamics and aquatic food web structure, and creating opportunities for new species invasions. The impacts of a changing climate are also already apparent in altered precipitation patterns and the timing and frequency of major storm events.

Extreme weather events are now more frequent, and have the potential to increase runoff volume and associated phosphorus. Current climate model projections suggest that over the next 25 years, Lake Erie will experience slightly greater precipitation during the winter, spring and fall. A warming climate is also expected to decrease snowfall events and increase rainfall events, which will increase runoff and stream flow in the winter. The summers will likely be drier with more frequent extreme storm events leading to flash floods. Increased rainfall and flooding could also lead to more combined sewer overflow or bypass events.

These patterns are of particular concern because of the potential for more extreme weather events to occur throughout the winter and early spring when soils are saturated, thawed, uncovered and do not support growing vegetation. During this period, bare saturated soil are more susceptible to runoff and erosion, which could result in a greater amount of phosphorus being carried off the land. The changing climate also creates uncertainty about the effectiveness of current agricultural, rural and urban stormwater runoff best/beneficial management practices for managing the volume of water and its quality.

The existing knowledge base for these practices and the interactions between practices need to be updated as climate change proceeds, consistent with an adaptive management approach.

The overall impact of climate change on phosphorus loadings is still highly uncertain. Multi-barrier approaches combined with adaptive management can help to offset these future uncertainties.

Warmer air will also result in warmer lake water temperatures over a longer period of the year, earlier in the spring and later in the fall. This longer warm period could encourage more algae production in the nearshore and harmful algal blooms elsewhere in the lake as well as increase the metabolic rate of bacteria, resulting in greater biological productivity, longer periods of stratification, and therefore more episodes of hypoxia.

2.6.2 Changing Lake Ecology

Invasive zebra and quagga (dreissenid) mussels first arrived in Lake Erie in the late-1980s, via ballast water from oceangoing ships. Zebra mussels were initially the dominant dreissenid mussel in Lake Erie but were outcompeted by the quagga mussel due to their ability to colonize deeper waters and soft substrates. Quagga mussels are now the dominant dreissenid mussel in Lake Erie and continue to alter the lake’s nutrient cycling and food web structures. The impact of dreissenid mussels is thought to be especially significant in promoting the growth of the attached nuisance algae species *Cladophora,* because their efficient filter feeding results in greater water clarity and allows *Cladophora* to grow at greater depths and therefore across a broader area than before mussel establishment. There is also some evidence that the presence of these mussels has resulted in an increase in the proportion of soluble reactive phosphorus in bottom waters near the lake bed.

2.6.3 Changing Agricultural Production Systems and Associated Land Use

Today, more than 90 percent of agricultural production in Ontario occurs in the Great Lakes basin. Agriculture in the Lake Erie basin exists over a wide variety of landscapes with different topography and soil types. As such, the area has some of the most diverse agricultural production in Canada, with many of Ontario's 200-plus commodities produced for domestic use and export.

The Lake Erie basin supports more than a third of Ontario's cropland and livestock, and more than two thirds of its greenhouse and vegetable area, underscoring its diversity and importance to the provincial and national economy.

Since the early 1980s, agricultural agencies have promoted a wide range of practices that conserve a farm's soil and water resources. Without adoption of practices such as conservation tillage, restricted livestock access to waterways, improved manure storage and application, improved crop nutrient management, and planting of buffer strips, it is likely that non-point source phosphorus loadings from Canada to Lake Erie would have been much higher than they are today.

Agricultural activities in the Lake Erie basin are changing in response to broader market trends. There is increasing pressure to consolidate farm land and intensify agricultural production to create more efficient food production and respond to demands of a growing population.

Over the last 30 years, beef production in the Lake Erie basin has declined, with a corresponding decline in the need for hay and pasture-land. Field crop production in the basin has also shifted. For example, soybean production increased from 16 to 34 percent of cropland from 1981 to 2011, respectively. Relative to most other crops there is less crop residue associated with soybeans after harvest, so more land in soybean production can result in less soil cover and less organic matter which can increase soil erosion.

The Canada-Ontario Environmental Farm Plan (EFP)

Environmental Farm Plans are assessments voluntarily prepared by farmers to increase their environmental knowledge in up to 23 different areas on their farm. Through the EFP workshop process, farmers identify their farm's environmental strengths and risks, and set reaslistic actions plans with timetables to improve environmental conditions. Cost-share incentive programs are available to assist in implementing on-farm projects addressing environmental risks once an EFP is complete. EFP cost-share incentive programs are supported by federal-provincial funding.

Average field size has increased as fencerows and windbreaks are being removed to accommodate larger equipment aimed at improving productivity, which can also increase the risk of soil erosion from agricultural fields. An increase in soil erosion risk can increase the risk of particulate phosphorus being conveyed to nearby surface waters.

Fertilizer use has also changed over the years. While the agricultural sector now uses significantly less fertilizer per unit of crop produced compared to the 1970-80s, historical applications of nutrients are responsible for accumulation of soil phosphorus in some parts of the basin. These legacy sources of phosphorus have the potential for ongoing contributions to phosphorus loadings.

Tile drainage continues to be installed beneath cropland to remove excess water from the soil profile to support field operations and to increase crop yield. While subsurface tile drainage will increase infiltration of water into the soil and reduce spring surface runoff and erosion, the tile drainage water will still carry phosphorus in solution or attached to soil particles. This water discharges into municipal drains, open ditches and natural watercourses.

Ontario's greenhouse vegetable production capacity nearly doubled between 2001 and 2011, with approximately 50 percent of production located in Essex County, located in the western basin of Lake Erie. Greenhouse operations rely on bioavailable nutrient solutions to allow plants to grow faster and to encourage higher yields. Most greenhouse operations now recycle the nutrient rich water allowing Ontario's greenhouse vegetable farmers to reduce their fertilizer consumption by 30-50 percent per acre since 2010. Research and investment in technology have enabled increased recirculation (currently used in 90 percent of acreage represented by Ontario greenhouse vegetable growers) and more efficient use of fertilizers within the greenhouse. However, some phosphorus still makes its way to Lake Erie. A working group comprised of industry and the province has been working together on an Ontario Greenhouse Environmental Strategy with the goal of enhancing environmental compliance while maintaining economic competitiveness. This group will continue efforts to reduce phosphorus discharge from greenhouse operations and contribute to a healthy Lake Erie.

Ontario farmers understand the importance of agricultural sources as a significant contributor to phosphorus loads to Lake Erie and continue to demonstrate environmental stewardship by incorporating BMPs on their farms to mitigate nutrient losses. Between April 1, 2005 and December 31, 2016, approximately 24,700 cost-shared environmental improvement projects were completed on Ontario farms with the assistance of federal and provincial programs. These projects resulted in multiple benefits including reduced nutrient loss, improved soil and pollinator health, and helped agricultural producers adapt to climate change.

2.6.4 Population Growth, Employment Trends and Land Use Trends

Over the next 25 years, the human population of the Ontario portion of the Lake Erie basin is expected to increase from 2.68 million (2016) to 3.31 million (2041), with most growth occurring in urban centres. This will result in higher sanitary sewage flows but also a small increase in basin impervious land surface (all in urban areas), and therefore slightly higher stormwater runoff volumes and peak flow rates. A small amount of agricultural land is expected to be lost to urbanization in this process, increasing the amount of impervious land surface.

Overall, no significant shifts in the patterns of employment location, and therefore land use or phosphorus release, are anticipated over the next 25 years.

2.7 Economic Implications of Harmful and Nuisance Algal Blooms

Harmful and nuisance algal blooms have a wide range of impacts on the natural environment, human health and Canada's economy. Among the most important of these are:

- Increased drinking water treatment costs, especially for municipal water treatment systems and recreational facilities, and water treatment costs for manufacturing, including food processing.
- Potential increased health care costs as a result of ingestion of or skin exposure to algal toxins, especially microcystin, the cyanotoxin produced by *Microcystis*.
- Altered food web structure and ecosystem function, including fish community structure (altered species mix, changes in average catch size and health). Fish communities including economically important recreational and commercial fisheries can also be impacted by low dissolved oxygen levels associated with dense algal blooms.
- Degradation of nearshore, wetland, and tributary habitats caused by excessive algal growth, especially *Cladophora,* and thus loss of the ecosystem services healthy habitats they provide.
- Reduced property values due to loss of recreational opportunities and impaired aesthetic value.
- Reduced tourism revenue due to beach closures, reduced fishing opportunities, and associated human health concerns.

One study[3] has estimated that the costs of harmful and nuisance algal blooms to the Canadian Lake Erie basin economy in a business-as-usual scenario could reach $272 million (CDN) annually. This estimate would be reduced significantly if phosphorus loading reduction targets are met. The greatest costs would be incurred by the tourism industry, property owners (because of reduced property values), and recreational users of the lake. Significant economic impacts on municipal drinking water treatment plants are also occurring and could worsen as a result of increased water treatment costs associated with harmful algal blooms. Physical clogging of water pipes by dense *Cladophora* growth imposes additional costs on municipal, industrial and agricultural water users. Finally, harmful and nuisance algae blooms reduce the value that society places on the existence of Lake Erie's clean water and healthy natural environment.

[3] *Economic Costs of Algal Blooms.* A consultancy report submitted to Environment and Climate Change Canada. Midsummer Analytics in collaboration with EnviroEconomics. 2015.

To date, algal blooms have had little impact on the economic health of the commercial fishery, of which the 2015 landed value alone (i.e., not including the value of associated food processing, packaging, and shipping industries), was greater than $30 million. However, the potential for direct and indirect negative impacts does exist. Algal biomass throughout the lake can foul commercial fishing gear, making the netting visible to fish and diminishing its effectiveness. This issue is particularly acute in the western basin, where the bulk of the fishery and the most prevalent cyanobacteria blooms co-occur. Algal blooms also have the potential to alter the distribution of fish species across the lake.

If ecological conditions in the lake deteriorate and cyanobacterial blooms become more common in the central and even eastern basins, changes to commercially important fish species are possible. The economic impact of these losses could exceed an additional $100 million over the next 25 years, and could be compounded if consumer demand is affected by perceptions of contamination.

2.8 The Importance of Natural Heritage Features

Natural heritage features are the "green infrastructure" of the natural environment. They include: structures such as natural channel form, wetlands, and the riparian zone – the area of land adjacent to tributaries and the lake, where vegetation may be influenced by flooding or elevated water tables. Each type of feature provides a range of ecosystem services, and plays an important role in trapping, storing, and processing phosphorus. For example, a healthy stream channel offers habitat for a range of aquatic species, but also provides essential nutrient processing services.

Wetlands, both along streambanks and shorelines and throughout the watershed, are of particular importance in filtering and retaining runoff. These areas are typically saturated most of the year and support plant and animal species adapted to those conditions. Significant quantities of snowmelt and runoff can be stored in these systems and gradually released over time, providing an important buffer against flooding and groundwater depletion. Wetlands are also recognized for their important role in carbon storage, an important factor in mitigating climate change. Wetlands provide some of the earth's most biologically diverse and useful habitat for plants and animals. Healthy and biologically diverse wetlands are public assets and important components of green infrastructure that provide multiple ecosystem services to Ontarians. Our province was once said to be a vast sea of contiguous forest, lakes, rivers and wetlands. Since the time of European settlement, the landscape has undergone significant changes due to various activities. The southern portion of Ontario has seen the most drastic change, with many wetlands being drained to accommodate agricultural, industrial and residential land uses. Estimates suggest that that 68 percent of the wetlands originally present were lost by the early 1980s, and an additional 4 percent has been lost since that time. One positive trend is an apparent reduction in the rate of wetland loss in southern Ontario over the last decade. Recent assessments show the number of wetlands in the Lake Erie basin total 64,487, covering 187,158 hectares. Efforts to improve the health and functions of ecosystems in southern Ontario are ongoing; however, more work is needed to increase extent of natural cover, including wetlands, in areas where losses have been highest, and address the cumulative impacts of pressures. Improvements in these areas will support ongoing phosphorus reduction efforts in the Lake Erie basin.

The riparian zone provides a critical connection between the land and the water, supporting a variety of habitats for aquatic and terrestrial species. Its complex vegetative structure protects against erosion and can control the runoff of sediment, phosphorus, and other pollutants, reducing impacts on water quality.

Natural heritage features can be impacted by human activities such as dredging, filling, channel hardening (such as concrete lining) and construction of dams and other water control structures. These changes can significantly reduce the resiliency of natural heritage features and limit their capacity to provide a full range of ecological functions. For example, disturbances to riparian areas most commonly arise from removal of vegetation and compaction of porous soils. These changes in turn degrade wildlife habitat, reduce shade and therefore cooling potential, and reduce the ability of the riparian zone to slow runoff and store water and associated pollutants. As a result, water from rainfall and snowmelt moves quickly over the land surface, causing more frequent and severe flooding, and little water is stored to replenish stream flows in dry weather. As the water flows, it picks up heat, sediment, microorganisms, and pollutants, including phosphorus. These patterns are most apparent in watersheds with a high proportion of impervious surface (e.g., roads, roofs, parking lots) and where streams have been straightened and hardened.

In the Lake Erie basin, healthy stream channels, wetlands, and riparian areas are important green infrastructure that traps and stores runoff and the sediment and phosphorus it contains. Protecting and restoring natural features such as riparian areas and wetlands from drainage and alteration provides an additional barrier to the discharge of phosphorus and other pollutants to Lake Erie. Perhaps equally important, green infrastructure protects the functionality of these systems and provides many co-benefits in terms of wildlife habitat, erosion protection, carbon storage, and other ecological services.

3 Phosphorus Loadings to Lake Erie

This draft Action Plan has been developed on a foundation of more than 40 years of science, research, and monitoring. That evolving knowledge base will continue to inform its implementation and adaptation over time. The following sections describe our current understanding of phosphorus loads by source, sector and basin.

3.1 Monitoring and Modelling of Phosphorus Loads

Routine and intensive monitoring of phosphorus loadings is essential for the development of science-based targets and management strategies. Computer simulation (modelling) of watershed and in-lake processes contributes to the understanding of the physical, chemical, and biological influences on harmful and nuisance algae blooms and hypoxia. A number of monitoring and modelling efforts currently underway by Environment and Climate Change Canada (ECCC), Agriculture and Agri-Food Canada (AAFC), Ontario Ministry of the Environment and Climate Change (MOECC), Ontario Ministry of Natural Resources and Forestry (MNRF), and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) are steadily improving the accuracy of information about Ontario's point and non-point loadings of phosphorus.

While some aspects of the system are well understood, it is clear that additional research is needed to understand the factors that influence the growth of harmful and nuisance algae; the relative importance of nearshore, offshore, and legacy sources of phosphorus; the role of invasive species in nutrient cycling; and how these factors may be affected by a changing climate.

3.2 Status of Phosphorus in Lake Erie Waters

3.2.1 Status of Phosphorus Loading

As illustrated in Figure 4, total phosphorus loads to Lake Erie vary considerably from year to year, largely as a result of hydrological influences. Loads typically exceed the new load reduction targets (see section 3.4) in years with higher precipitation and runoff. While estimates of phosphorus loading from Lake Huron, point sources and atmospheric sources have remained relatively stable since 1982, non-point sources discharged via the tributaries continue to contribute the largest portion of the phosphorus load and are mostly responsible for the periodic exceedances of the Lake Erie loading target during high flow years. Reductions in Canadian non-point sources are needed, especially in high flow years, to reduce nutrient-related algal blooms in nearshore waters and contribute to improvements to hypoxia in offshore waters.

3.2.2 Status of Phosphorus in Offshore Waters

Of all the Great Lakes, concentrations of total phosphorus are highest and most variable in Lake Erie. Since the 1970s, concentrations in Lake Erie have declined overall, but the recent temporal trend for total phosphorus in Lake Erie is unclear due to high variability both within and between years. The State of the Great Lake Nutrients in Lakes indicator rates Lake Erie's nutrient status as "poor" due to concentrations exceeding targets, and rates the trend as "deteriorating," due to a possible increase in concentrations and the resurgence of harmful and nuisance algal blooms. Similarly, the Canadian Environmental Sustainability Indicator on phosphorus levels in the Great Lakes rates the western and central basins of Lake Erie as "poor" due to concentrations that exceed water quality objectives.

3.2.3 Status of Phosphorus in Nearshore Waters

The nearshore phosphorus situation is complex and dynamic and varies widely across Lake Erie's three basins and many tributaries. The primary sources of phosphorus to the nearshore waters include loads from tributaries and inputs from shoreline land uses, runoff, and municipal wastewater treatment plant outflows. Nearshore waters tend to flow parallel to the shore and are strongly affected by local inputs, water currents, depth, water and sediment chemistry, and biology. Weather is also an important factor. High offshore winds can cause nearshore waters to mix with offshore waters, carrying sediment and phosphorus from the nearshore into the open lake. These processes are highly variable and difficult to predict, and are the focus of ongoing research and monitoring.

3.2.4 Status of Phosphorus in Tributaries

Most Ontario tributaries in the Lake Erie basin would benefit from reductions in phosphorus, as most of the monitored streams in the Lake Erie basin exceed the Provincial Water Quality Objective for phosphorus concentrations. Loadings to each of Lake Erie's basins are dominated by tributary loadings, which are highly variable from year to year as a result of hydrological and other factors. By contrast, point sources are relatively consistent from year to year.

Most of the current total phosphorus loading to Lake Erie is however the result of inputs from a few major tributaries, the locations of which are illustrated in Figure 1. In Canada, the most significant contributors are the Thames River, which flows into Lake St. Clair, and the Grand River, which flows into the eastern basin. The Sydenham River, which discharges to Lake St. Clair, and Kettle and Big Otter Creeks, which discharge to the central basin, are also significant sources. These larger rivers contain a mix of non-point source pollution, including rural and urban runoff, and point source pollution, including treated municipal sewage. Reducing the phosphorus load from the Thames River is a priority because it contributes to nearshore cyanobacteria blooms in Lake St. Clair and central basin hypoxia. The phosphorus load from the Grand River is potentially a factor in nuisance *Cladophora* blooms in the nearshore zone of the eastern basin.

Smaller tributaries are also important on more localized scales. In particular, a group of smaller tributaries in the Leamington area of Ontario contributes to adverse impacts to the Canadian shoreline and nearshore zone of the western basin. Greenhouse vegetable production in the area is a source of phosphorus delivered by these tributaries, which contributes to nearshore cyanobacteria blooms in the western basin, as well as central basin hypoxia. The industry-government working group is implementing its Ontario Greenhouse Environmental Strategy (see Section 2.6.3) to continue to reduce nutrient discharge from greenhouse operations and contribute to a healthy Lake Erie.

While more research and monitoring of these systems are necessary, especially to determine the status and trend of soluble reactive phosphorus, it is clear that some watersheds require focused action to reduce phosphorus loads. Figure 7 illustrates Canadian tributary loadings of total phosphorus by watershed; Figure 8 illustrates Canadian tributary loadings of soluble reactive phosphorus by watershed.

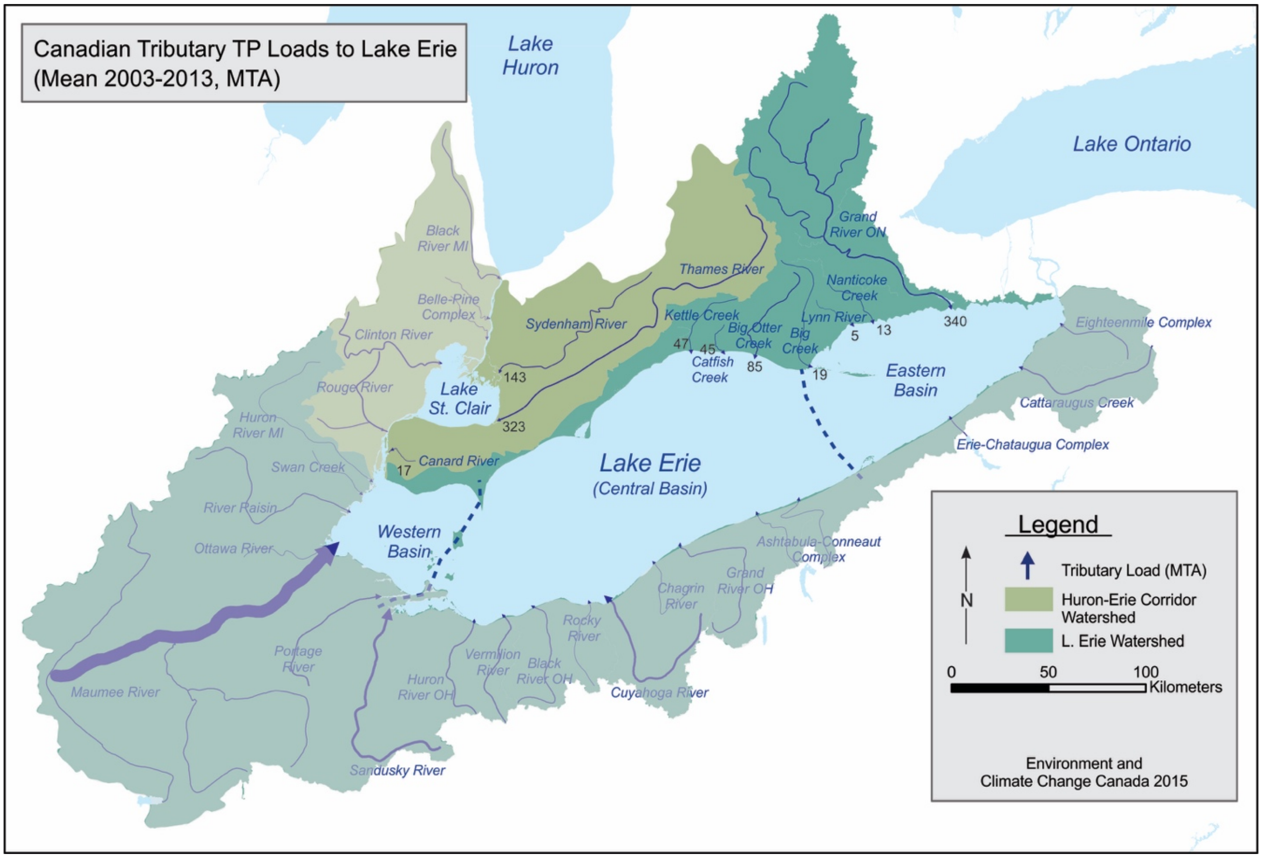

Figure 7: Canadian tributary annual loadings of total phosphorus (TP) in tonnes by watershed. Source: ECCC.

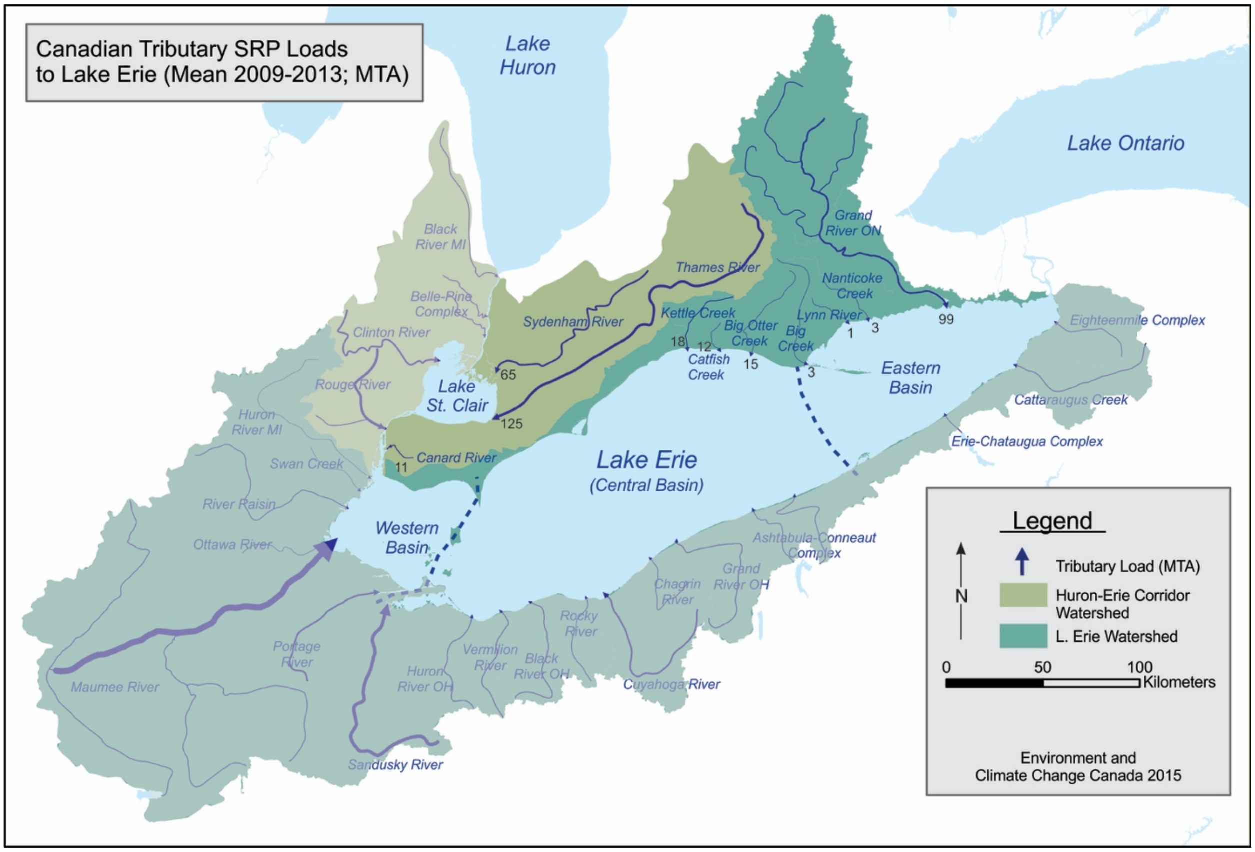

Figure 8: Canadian tributary loadings of soluble reactive phosphorus (SRP) by watershed. Source: ECCC.

The proportion of soluble reactive phosphorus in the total phosphorus load varies significantly from year to year and from tributary to tributary. For instance, in 2012, soluble reactive phosphorus was 50 percent of the total phosphorus load from the Thames River, but only 25 percent of the total load from the Grand River.

3.3 Current Point and Non-Point Sources of Phosphorus

The amount of phosphorus going into Lake Erie is variable and is dependent in large part on runoff from the land, and therefore is heavily influenced by weather which varies from season to season and from year to year. Phosphorus loads tend to be highest in late winter and spring, and years that receive more rain will generally have higher loads of phosphorus than drier years. Sources of phosphorus entering Lake Erie are generally considered to be either point sources (e.g., municipal and industrial wastewater treatment plants) or non-point sources (e.g., agricultural and stormwater runoff). For example, high runoff from land can cause high phosphorus loadings during wet weather, while loadings are lower in dry conditions. Given the number and types of sources, multi-jurisdictional and multi-stakeholder collaboration and partnerships are essential for reducing nutrient loads to Lake Erie.

Point sources tend to be measured on a regular basis and their variability is relatively low because treatment processes are controlled, resulting in discharges with a fairly constant quality. Non-point sources are highly variable in quality and quantity over the course of a year and loads are more difficult to measure.

In the Ontario portion of the Lake Erie basin, similar to the U.S. portion of the basin, a significant majority of the loads are from non-point sources.

In 2008, Canadian federal and provincial agencies undertook a significant data compilation effort to update loading information. Those results were further updated and reported in 2016. The estimated loadings reported below are based on this dataset, which is considered to be the most accurate and comprehensive available.

3.3.1 Estimated Current Phosphorus Loadings from Ontario Non-point Sources

Non-point sources include overland runoff and subsurface (tile) drainage from agricultural lands, and stormwater runoff from residential properties, golf courses, commercial and industrial property, as well as impervious surfaces. From 2003 to 2013, Canadian non-point sources contributed an average of 71 percent of the Canadian soluble reactive phosphorus load and 93 percent of the total phosphorus load. With about three quarters of Ontario's Lake Erie basin in agricultural production, farmland is considered a substantial contributor to the total non-point source phosphorus load.

3.3.2 Estimated Current Phosphorus Loadings from Ontario Point Sources

The relative contribution from urban point sources, including municipal wastewater treatment plants, combined sewer overflows (CSOs) and industrial direct discharges, is estimated to be only 10 to 15 percent of the total load across the basin despite the large volumes of discharge, as phosphorus discharges from Ontario's municipal wastewater treatment plants are currently well controlled.

Most of the 21 large (capacity of at least 3.78 million litres per day) secondary sewage treatment plants in the Lake Erie basin already meet the interim GLWQA monthly average discharge concentration limit of 0.5 mg/L. All municipal sewage treatment plants in the basin currently provide at least secondary treatment; a significant number of tertiary-level (advanced) treatment plants discharging to sensitive surface waters also provide enhanced phosphorus removal, below the 0.5 mg/L monthly average limit. Based on 2008 effluent discharge data, all 118 municipal STPs in the Lake Erie basin discharged 99 tonnes, 5.9 tonnes, and 40 tonnes of total phosphorus into the western, central, and eastern basins respectively. As a result of ongoing treatment plant upgrades and treatment process optimization in a number of municipalities, the corresponding loadings were 65 tonnes, 5.6 tonnes and 39 tonnes in 2014.

Primary sewage treatment is simply retention of sewage to allow some settling of solids.

Secondary treatment uses biological processes and additional settling to remove dissolved organic compounds that escape primary treatment.

Tertiary treatment involves specialized processes to remove specific compounds. Tertiary treatment for phosphorus removal can employ chemical methods, such as addition of alum or iron salts, or biological methods using polyphosphate accumulating organisms (PAOs).

CSOs result in the release of untreated effluents containing a mixture of sanitary and storm sewage into receiving waters. These discharges can be a significant source of sediment, phosphorus, bacteria, and other pollutants, especially where discharges are frequent and volume is high. CSOs mainly occur in older parts of large cities and are difficult and costly to control, although cities such as Windsor have recently undertaken system improvements to increase storage of wet weather flows and reduce the impact of CSOs on receiving waters. It is estimated that the total phosphorus loads contributed by CSOs and wastewater treatment plant bypasses basin-wide are a small fraction (10 to 15 percent) of the load coming from the treatment plants. However, in certain municipalities, the contribution of these wet weather sources may be much greater.

There are very few direct discharges of phosphorus to Lake Erie from industrial facilities. Many commercial and industrial plants discharge through municipal sewage systems.

3.4 Distribution of Phosphorus Loads by Basin

Binationally, the western basin receives almost two-thirds (61 percent) of the lake's annual phosphorus load, the central basin receives about 28 percent, and the eastern basin only 12 percent[4]. The direction of flow through the lake is west to east, so loadings to the western basin also have a significant impact on conditions in the central and eastern basins. Overall, approximately 84 percent of total phosphorus loads and 82 percent soluble reactive phosphorus loads to Lake Erie are contributed by the United States, with smaller contributions from Canadian sources. Canadian sources comprise approximately 32 percent of the load to the Huron-Erie corridor, less than 1 percent of the loads to the western basin (not including the corridor), and only 10 percent of the load to the central basin. In the eastern basin, Canadian sources contribute about 54 percent of the total total phosphorus load. (See Figure 9)

[4] Average over the period 2003-2013.

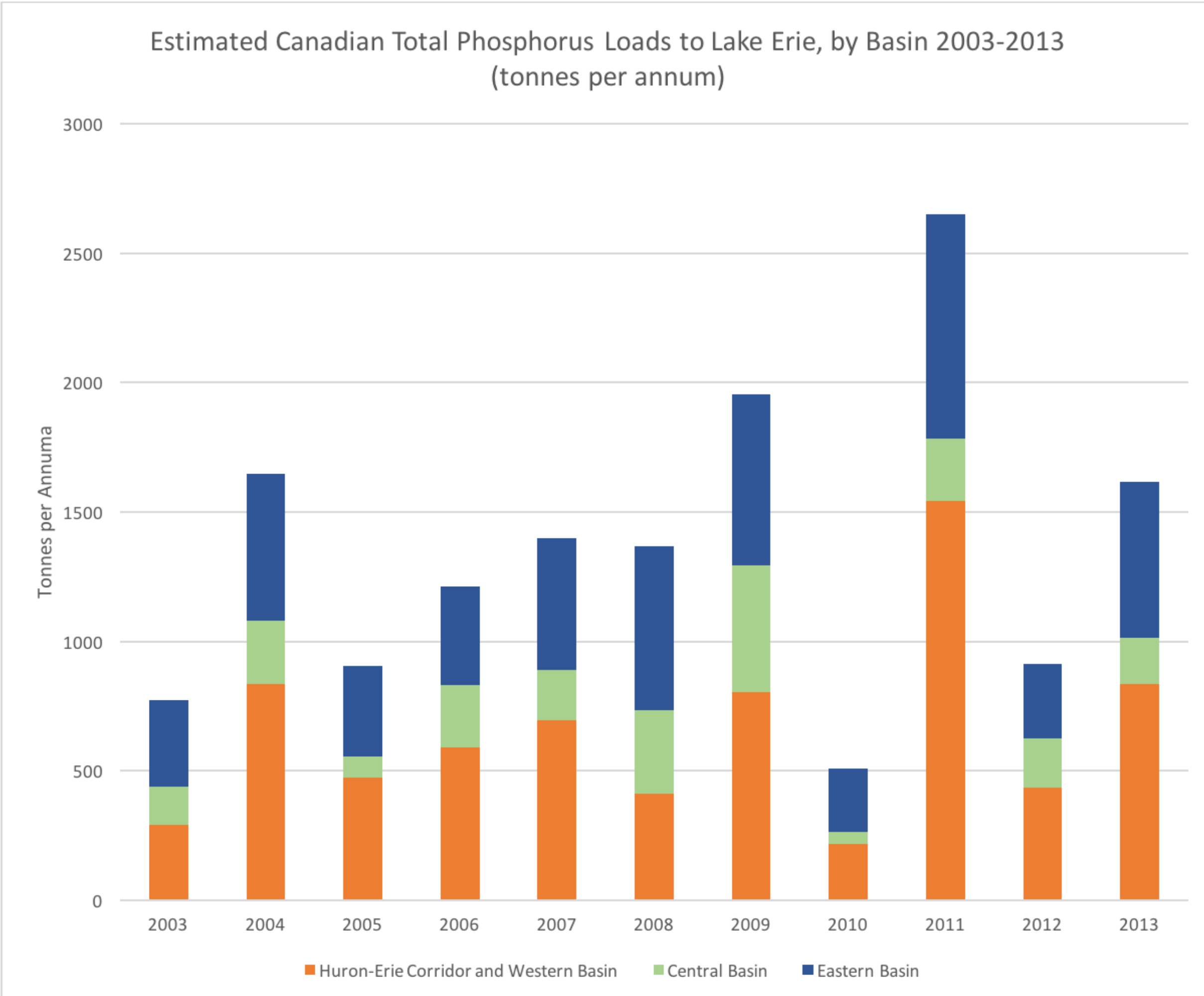

Figure 9: Total Canadian tributary phosphorus loads to Lake Erie divided by basin, 2003-2013. Note that these loads do not include contributions from atmospheric deposition or Lake Huron. Source: Maccoux et al. (2016).

Western Basin

The majority of total surface water inflow to Lake Erie's western basin (an average of 94 percent of total inflow over the period 2011-2013) arises from the Detroit River, the connecting channel that carries the combined outflows from Lakes Superior, Michigan, Huron, and St. Clair (the last including discharge from Ontario's Thames River) into Lake Erie. An additional 4 percent of flow enters the lake from the Maumee River, Ohio, with the remaining 2 percent contributed by smaller tributaries. Binationally the western basin receives on average 61 percent of the total Lake Erie phosphorus loads (5492 tonnes total phosphorus annually) with Canada contributing 647 tonnes (12 percent) and the U.S. contributing 4407 tonnes (80 percent). Of the western basin load, over 99 percent of the Canadian loads are discharged to the Huron-Erie corridor. In contrast the majority of the U.S. loads are discharged directly to the western basin (60 percent) and 22 percent to the Huron-Erie corridor.

Central Basin

Due to the small area of Canadian watershed draining to the central basin, all of the major sources of phosphorus to the central basin are U.S. tributaries, most of them located in Ohio. On average U.S. tributaries discharging to the central basin contribute 2,059 tonnes total phosphorus per year. These include the Sandusky, Huron, Vermillion, Cuyahoga, and Grand Rivers.

Canadian tributaries contribute approximately 8 percent of the total total phosphorus load to the central basin. In total, Canadian sources contribute an average of 229 tonnes per annum to the central basin, with the three largest tributaries, Kettle Creek, Catfish Creek, and Big Otter Creek, contributing 47 tonnes, 45 and 85 tonnes per annum, respectively.

Eastern Basin

Canadian sources contribute 54 percent of the total phosphorus load to the eastern basin, with the majority of this coming from one tributary, the Grand River. Due to its large watershed area, the Grand River contributed an average of 373 tonnes of total phosphorus per annum (approximately 35 percent of the total loading to the eastern basin of Lake Erie) for the period of 2003-2013, and is therefore a significant contributor to phosphorus loads in the lake.

3.5 Binational Phosphorus Targets and Objectives

The Canada-U.S. Great Lakes Water Quality Agreement sets out a number of lake ecosystem objectives (LEOs) it expects the parties to achieve by reducing phosphorus loads to the Great Lakes. For Lake Erie, the relevant lake ecosystem objectives are:

1. maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the Waters of the Great Lakes;

2. minimize the extent of hypoxic zones in the Waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie;

3. maintain the levels of algal biomass below the level constituting a nuisance condition; and

4. maintain algal species consistent with healthy aquatic ecosystems in the nearshore Waters of the Great Lakes.

The 2016 binational phosphorus targets reflect the complexity of the Lake Erie ecosystem and its sources of phosphorus by establishing targets for each of Lake Erie’s basins, based on the distinct characteristics of each. At the time of writing, there is insufficient information to allow a target for the eastern basin to be established, but as research and monitoring proceeds, it is expected that a target will also be established for that basin.

Three key metrics were established as ecosystem response indicators of the associated ecosystem objectives and have guided the development of the new reduction targets.

1. **Cyanobacteria blooms in the western basin and nearshore areas**: measured by the maximum 30-day western basin cyanobacteria biomass (metric tons (MT).
2. **Hypoxia in the central basin:** the average hypolimnion dissolved oxygen concentration during August and September, number of hypoxic days, and average area extent.
3. ***Cladophora* in the nearshore areas of the eastern basin:** measured by algal dry weight biomass and tissue phosphorus concentration.

3.5.1 Selection of Baseline Year

It was necessary to select a baseline year against which future loading reductions could be evaluated. The Parties selected 2008 as the baseline year because data for that year are the most recent, consistent, accurate and comprehensive available. Based on these data, the 2008 whole-lake annual total phosphorus load was 10,627 tonnes, which is very close to the Lake Erie target total phosphorus load of 11,000 tonnes per annum set in the 1978 GLWQA Amendment. The Parties therefore believe that 2008 is an appropriate baseline against which to measure reductions toward the new binational targets.

3.5.2 Phosphorus Loading Targets to Reduce Western Basin Cyanobacteria Blooms

For the western basin of Lake Erie, where cyanobacteria and their associated algal toxins are the predominant problem, meeting the relevant GLWQA LEO (#1 above), was quantitatively interpreted as reducing algae to below 2012 levels (considered to be non-severe levels) 90 percent of the time. To achieve this outcome, a 40 percent reduction (from 2008 levels) in the spring total and soluble reactive phosphorus loads from the Maumee River in the U. S. to the western basin is recommended.

3.5.3 Phosphorus Targets to Reduce Central Basin Hypoxia

For the central basin of Lake Erie, where amplification of the natural hypoxic zone above the lake bottom (the hypolimnion) is the predominant problem, meeting the relevant GLWQA LEO (#2 above) was quantitatively interpreted as maintaining dissolved oxygen levels at or above 2mg/L in the hypolimnion during August to September period. To achieve this outcome, an annual total phosphorus load of 6,000 tonnes entering the central basin of Lake Erie from the United States and Canada is recommended, which is equivalent to a 40 percent reduction from 2008 loads, and amounts to a reduction from the United States and Canada of 3,316 tonnes and 212 tonnes, respectively from 2008.

3.5.4 Phosphorus Targets to Reduce Nearshore Cyanobacteria Blooms

For nearshore areas of Lake Erie, including river mouths and embayments where excess algae occurs as the result of localized discharge from the up-stream watershed, a 40 percent reduction in spring total and soluble reactive phosphorous loads (from 2008 levels) from the following watersheds is recommended: in Canada, the Thames River and Leamington tributaries; and in the U.S., the Maumee River, River Raisin, Portage River, Toussaint Creek, Sandusky River and the Huron River.

3.5.5 Phosphorus Targets to Reduce Eastern Basin Cladophora

For the eastern basin of Lake Erie, where the accumulation of *Cladophora* (nuisance algae) on the lake bed, in water and along shores is the predominant problem, there is currently insufficient confidence in the existing science to allow for the quantification of the relationship between reductions in phosphorus loads and *Cladophora* levels. For this reason, a phosphorus reduction target for the eastern basin of Lake Erie is not recommended at this time. Science is ongoing and further analysis is required.

3.5.6 Reductions of Total Phosphorus versus Soluble Reactive Phosphorus

The proportion of soluble reactive phosphorus in the total phosphorus load is highly variable from one watershed to the next, and can range up to 50 percent of the total load. While reducing particulate phosphorus is important, soluble reactive phosphorus is virtually 100 percent bioavailable, so reducing soluble reactive phosphorus is an efficient way to reduce nuisance and harmful algal growth, and should be a priority in planning management strategies. Different non-point source reduction actions will emphasize different total phosphorus components and selection of phosphorus reduction actions should take those differences into account.

It would be prudent to aim for 40 percent reduction in Canadian soluble reactive phosphorus and total phosphorus loads, consistent with the overall goal of 40 percent loading reduction.

For more information about the 2016 binational phosphorus targets, please refer to the technical report and associated documents at binational.net

4 Actions to Achieve Phosphorus Reduction Targets

Once finalized, this draft Action Plan will reflect commitments by Canada and Ontario under COA, as well as past and proposed actions by many other stakeholders, including municipalities, First Nations and Métis communities, sector and commodity organizations, farmers and the broader agri-food industry, conservation authorities, non-government organizations, academic researchers, and others. A lot of good work has already been completed.

The following sections summarize the proposed strategic actions that comprise this plan, grouped under five categories. Each strategic action encompasses a number of tactics – specific actions that are underway or are planned for the future, to achieve the goals of this draft Action Plan, which has been summarized in Table 1 as follows:

Table 1: Summary of the Canada-Ontario Action Plan for Lake Erie

Goal: Reduce Canadian Phosphorus Loadings by 40 Percent				
Category of Action				
Reduce Phosphorus Loadings	**Ensure Effective Policies, Programs and Legislation**	**Improve the Knowledge Base**	**Educate and Build Awareness**	**Strengthen Leadership and Coordination**
Strategic Actions				
A1 Support watershed and nearshore-based strategies and community-based planning for reducing phosphorus loadings	B1 Support and strengthen policies, programs and legislation	C1 Conduct monitoring and modelling	D1 Enhance communication and outreach to build awareness, improve understanding and influence change	E1 Improve communication and coordination
A2 Reduce phosphorus loadings from urban areas[5]	B2 Strengthen decision-making tools	C2 Conduct research to better understand nutrient dynamics in the Lake Erie basin	D2 Share data and information	E2 Establish an adaptive management framework
A3 Reduce phosphorus loadings from agricultural and rural areas[6]		C3 Conduct research to better understand and predict the impact of climate change on the Lake Erie ecosystem		
		C4 Conduct research to improve existing practices and develop new innovative practices and technologies for phosphorus loss reduction		

Category A: Reduce Phosphorus Loadings

This draft Action Plan identifies a range of on-the-ground actions to reduce phosphorus loadings from urban, agricultural and rural lands, and to encourage good stewardship. These actions need to be coordinated and linked to current federal, provincial, municipal, conservation authority, sectoral and other initiatives.

[5] Managing the amount of phosphorus released from urban point sources (e.g., wastewater treatment plants) and non-point sources (e.g., stormwater runoff) will reduce the amount of phosphorus entering the lake.

[6] **Agricultural and rural actions** are directed at effecting changes to the ways in which nutrients, soils and water are managed. This includes:

- managing nutrients (manure and commercial fertilizer) applied to the farm field to optimize yield while minimizing losses to waterways (e.g., applied at the right time, place, rate and source).
- managing agricultural soils in ways that help build and sustain soil health, increasing infiltration and reducing nutrients loss, particularly in the non-growing season.
- improving runoff water quality by slowing the flow of water and increasing resilience in response to storm events on agricultural lands (drainage) and in rural municipal areas (rural stormwater) utilizing natural heritage features and green infrastructure.

A1: Support watershed and nearshore-based strategies and community-based planning for reducing phosphorus loadings

The nearshore zone is the area where shoreline discharges and tributary flows have the greatest impact. Along the Ontario shoreline, these impacts include algal blooms which produce cyanotoxins, including the toxin microcystin, which can have significant human health consequences if ingested or through skin exposure, and may also be toxic to other organisms. In addition, *Cladophora* blooms can clog water intake pipes and be a nuisance for commercial and recreational anglers. The physical, chemical, and biological dynamics of the nearshore zone in the lake are complex and require greater understanding.

Several watershed plans, such as the Grand and Thames Rivers, already exist for the tributaries throughout the Lake Erie basin. Supporting the development of additional plans, and linking them to nearshore-based strategies and other phosphorus reduction actions at a community level, avoids duplication of effort and ensures that resources are efficiently used.

1. Canada and Ontario will collaborate with landowners,municipalitiesconservation authorities, First Nations and Métis communities and others on a coordinated approach to watershed planning for reducing phosphorus loadings.
2. Canada and Ontario will work with partners to implement existing watershed plans focussed on reducing on reducing phosphorus loadings in the Lake Erie basin, and develop new ones where required.
3. Canada and Ontario will explore the development of a multi-agency program(s) that supports the implementation of local actions within high risk areas for phosphorus loadings in the western and central Lake Erie basins.
4. Canada will lead with Ontario's support the implementation of the binational nearshore assessment and management framework for Lake Erie.
5. Canada and Ontario will continue to participate in partnerships such as the Ontario Eastern Habitat Joint Venture to promote and conserve Ontario's wetlands.

A2: Reduce phosphorus loadings from urban areas

Municipal point sources are now well controlled, with all wastewater treatment plants in the Ontario portion of the basin having at least secondary treatment. However, there are still opportunities to optimize the performance of treatment plants, and to reduce the volume and frequency of bypasses and overflows and to reduce loads from urban stormwater. Since 2008, the baseline year upon which phosphorus reduction targets have been established, treated effluent quality has improved through a combination of treatment upgrades and operational improvements at many municipal sewage treatment plants.

Some of the actions below are intended to achieve further reductions from municipal sewage treatment plants; it is recognized that there may be new technology retrofits and/or and process modifications which can be made to existing secondary sewage treatment plants that can approach or match the effluent phosphorus concentrations attainable through conventional tertiary treatment (i.e., chemically-assisted filtration), but at a lower cost.

With regard to stormwater, action to promote green infrastructure and low impact development, as well as actions to reduce phosphorus at the source (e.g., elimination of phosphorus from most residential lawn fertilizers by the fertilizer industry) are expected to achieve phosphorus load reductions from urban landscapes. Stormwater green infrastructure and low impact development (LID) technologies and systems reduce phosphorus loads to lakes and streams by managing rain where it falls so that less phosphorus is washed off surfaces (e.g., from properties, streets) and transported into waterbodies. Overall, stormwater green infrastructure and LIDs help to maintain and restore the natural water cycle.

1. Ontario will work with municipal partners in establishing a legal effluent discharge limit of 0.5 milligrams per litre of total phosphorus for all municipal sewage treatment plants (STPs) in the Lake Erie basin that have an average daily flow capacity of 3.78 million litres or more per day (See Section B1).

   Ontario and its municipal partners will work towards reducing loadings, where feasible, through: (1) upgrades and other modifications to secondary STPs that have an average daily flow capacity of 3.78 million litres or more per day in the Lake Erie basin, with an objective of approaching the phosphorus effluent concentrations achievable through a tertiary level of treatment; (2) improvements to wastewater treatment and collection infrastructure to reduce combined sewer overflows and bypasses, and (3) improvements to stormwater management systems (including facility rehabilitation and incorporation of green infrastructure).

2. Ontario will collaborate with municipal partners to promote and encourage optimization of sewage treatment as a way for municipalities to improve treatment plant performance (including lower phosphorus discharges) and achieve operational efficiencies. Ontario will also continue supporting area-wide optimization programs for municipal STPs to reduce phosphorus loads, and make Lake Erie the priority geography for this effort.

3. Canada and Ontario will promote eligible investments for the reduction of excess phosphorus from point sources such as municipal wastewater treatments systems or municipal stormwater effluent under applicable infrastructure and other funding programs.

4. Ontario will work with developers, municipalities, conservation authorities, and others to promote and support the use of green infrastructure and low impact development (LID) for stormwater management, including clarifying and enhancing policies, and developing green standards. Ontario’s draft stormwater LID guidance manual is aimed at assisting proponents in implementing LID and green infrastructure, and will be available for public comment in early 2017.

A3: Reduce phosphorus loadings from agricultural and rural areas

There are many tools available to the agriculture and rural communities to support environmental sustainability including education and awareness, stewardship, cost-shared investments, and regulation. It is important to build on these and focus efforts for phosphorus reduction in the Lake Erie basin. Widespread action to adopt a multi-barrier approach (more than one BMP used in combination to reduce the risk of phosphorus loss at the farm scale), customizable to individual properties and agriculture operations, are critical to achieving targets.

A significant amount of work has been done over the past several decades to develop and implement BMPs that enhance nutrient, soil and water stewardship on privately owned agricultural and public lands. In Ontario, Environmental Farm Plans have been used voluntarily by farmers since the 1990s to help them identify and plan areas for improvement and various cost-share funding programs have assisted with the costs of implementing on-farm projects. Currently, through the Great Lakes Agricultural Stewardship Initiative (GLASI) and the Growing Forward 2 Funding Assistance Program for Producers, Canada and Ontario are providing cost-share funding to support on-farm improvements that enhance soil health and water quality.

A greenhouse environmental compliance plan was initiated to support the sector's efforts to reduce phosphorus discharges and drive water quality improvements. The plan includes support for education and awareness, investigating new technologies, annual water monitoring activities and inspections, which have encouraged progress towards environmental improvement. Where significant impacts were found, the Ministry of the Environment and Climate Change (MOECC) required operators to take action.

Ontario actively engaged the greenhouse sector when it developed a new Greenhouse Nutrient Feedwater regulation that came into effect in 2015 to provide a land application alternative requested by the greenhouse sector. By April 1, 2017, the MOECC will require greenhouses to submit applications for wastewater and stormwater discharge approvals to drive water quality improvements. After this date, the MOECC will continue addressing non-compliance using a risk-based approach.

The majority of the municipalities on the Canadian side of Lake Erie are rural. They are concerned about the impacts excess phosphorus is having on Lake Erie and their communities, and are taking action. Rural municipalities have partnered with the Province of Ontario in encouraging and implementing progressive design and construction of drainage systems that will help reduce the transport of phosphorus to the Great Lakes.

Through the Great Lakes and St. Lawrence Cities Initiative, municipalities have also partnered with the Ontario Federation of Agriculture on a collaborative strategy to reduce phosphorus loss from farmland by improving water management on private land and in the municipal drainage system.

1. There is also a need to prevent and control invasive species, because of their potential to alter riparian and wetland habitat and reduce its effectiveness in trapping and storing sediment and phosphorus. Canada and Ontario will continue to leverage existing funding initiatives to 2018 (e.g., Growing Forward 2, Great Lakes Agricultural Stewardship Initiative, and the Species at Risk Farm Incentive Program) to support implementation of agricultural BMPs and environmental investments in targeted regions of the Lake Erie basin.

2. Canada and Ontario will pursue, under the next agriculture policy framework, programming that supports a multi-BMP whole farm approach to achieve phosphorus runoff reduction from farmland in the western and central basin of Lake Erie.
3. Ontario will continue to support the development and implementation of an Ontario industry-led 4R program (right source of nutrients at the right rate, time, and placement) based on the internationally-recognized 4R Nutrient Stewardship system which helps farmers reduce nutrient losses into the environment through efficient nutrient application.
4. Ontario in collaboration with the greenhouse sector will continue working with greenhouse growers to encourage nutrient recycling and reduce phosphorus levels in discharges to watercourses that flow into Lake Erie with a priority on the Leamington area and Thames River. Actions include education, awareness, innovation, monitoring, cost-shared investments and regulatory compliance and enforcement. Ontario with Canada's support will work with the agriculture sector to harmonize and streamline planning tools (e.g., Environmental Farm Plan (EFP), Farmland Health Checkup, nutrient management planning) to support an integrated, whole-farm approach to environmental sustainability.
5. Ontario will work with the Lake Erie community to implement restoration of native habitats including wetlands, and riparian habitat; focusing efforts in priority watersheds where phosphorus loadings are high and natural cover is low.
6. Ontario will encourage stewardship activities on private lands that support phosphorus reduction in Lake Erie by providing incentives for landowners through programs such as the Conservation Land Tax Incentive Program (CLTIP) and the 50 Million Tree program.
7. Canada and Ontario will ensure public land is managed to minimize phosphorus losses.
8. Canada and Ontario will encourage dam owners to explore managing dams to reduce phosphorus outputs (without compromising aquatic invasive species management or hydroelectric power generation).

Category B: Ensure Effective Policies, Programs and Legislation

Policies and legislation are two effective tools for reducing phosphorus inputs to the environment. Over the years the federal and provincial governments have imposed requirements and developed various policies that reduce phosphorus loadings to Lake Erie. Examples include federal regulation of the phosphorus content of detergents under the *Canadian Environmental Protection Act*; municipal wastewater discharge quality requirements under the Ontario *Environmental Protection Act*, and the *Ontario Water Resources Act,* and nutrient management controls under the Ontario *Nutrient Management Act (NMA).* Work will continue to enhance and strengthen these tools to manage excess phosphorus inputs to aquatic ecosystems.

B1: Support and strengthen policies, programs and legislation

A first step in ensuring effective policies and legislation is to understand what currently exists and ensure that it is working to its full potential. There are also opportunities to identify gaps and explore innovative policy approaches for reducing phosphorus loadings.

1. Canada and Ontario will, in cooperation with the U.S. counterparts, develop phosphorus load reduction targets to reduce nuisance algae in the eastern basin of Lake Erie.

2. Ontario will consider further restrictions on the application of nutrients during the non-growing season.

3. Ontario will continue to phase in farms under the Nutrient Management Act through building permit approvals.

4. Ontario will finalize and implement a new Agricultural Soil Health and Conservation Strategy developed in collaboration with stakeholders, to support agricultural soil management practices that provide economic, environmental and social benefits to Ontario and maximize long-term carbon storage in soils while protecting their long-term productivity.

5. Ontario will, in 2018, begin a review of the province’s approach to rural stormwater and agricultural drainage management using an integrated watershed approach. This will include an examination of the interactions between runoff from rural lands and roads, outlet drainage from agricultural lands, and municipal drains with the objective of identifying opportunities to improve the sustainable management of water.

6. Ontario will provide updated guidance related to stormwater management and municipal planning to support the implementation of policies in the Provincial Policy Statement (2014).

7. Ontario will, in collaboration with partners, consider enhancing and clarifying regionalized requirements for mandatory pump-out and inspections of septic systems to increase protection of ground and surface water quality.

8. Ontario will, as part of the hauled sewage policy and program review, develop, and post in 2017 for public comment, a draft policy framework for managing hauled sewage in the province.

9. Canada will continue to work on revisions to the Feeds Regulations that would remove minimum nutrient levels for livestock feeds (including phosphorus). This is anticipated to be enacted in 2018 and will enable the industry to be more flexible and decrease levels of phosphorus in feeds, where it makes sense to do so. This is anticipated to result in a corresponding reduction in phosphorus content of manure.

10. Ontario will, through the implementation of the proposed *Wetland Conservation Strategy for Ontario*, improve wetland protection through strengthened policies to stop the net loss of wetlands and sustain ecosystem services, including improved water quality.

11. Ontario will work with partners to update provincial policies for Lake Erie, in order to provide the basis for establishing a legal effluent discharge limit of 0.5 milligrams per litre of total phosphorus for all municipal sewage treatment plants (STPs) in the Lake Erie basin that have an average daily flow capacity of 3.78 million litres or more per day.

12. Ontario will update existing wastewater policies (F-series Guidelines and Procedures), and develop stormwater management policies and supporting guidance (e.g., low impact development and green infrastructure) to enhance environmental protection, including reduction of nutrient loadings.

13. Ontario will streamline processes for environmental assessment and approvals related to Lake Erie municipal wastewater projects, where feasible.

B2: Strengthen decision-making tools

Continuous improvement of decision-support tools will strengthen capacity for science-based decision-making. Examples include development or enhancement of economic analysis tools, computer simulation (modelling) tools, and graphical and communication tools.

1. Ontario with Canada's support will, in 2018 make publicly available a digital elevation model of the Lake Erie watershed (based on LiDAR technology) to assist all members of the Lake Erie community in making evidence-based decisions (e.g., flood mapping, areas of soil erosion risk identification, precision agriculture) to ensure healthy lands and waters.

2. Ontario will work with municipalities to encourage the development of decision-making tools that help manage phosphorus in urban stormwater at the source.

Category C: Improve the Knowledge Base

A strong science and monitoring foundation underlies this draft Action Plan and will continue to inform its implementation. For example, Ontario has undertaken several monitoring and research studies as part of its Great Lakes Nearshore Monitoring Program. These studies include tracking the influence of the Grand River in the nearshore of Lake Erie's eastern basin (2010), investigating the impacts and causes of the 2012 fish kill along the north shore of the central basin, and monitoring the extent and causes of harmful algal blooms along the shoreline of the western and central basins (2013). Long term monitoring programs have provided essential data to track spatial and temporal changes in the nearshore waters of Lake Erie and in Lake Erie watersheds. These monitoring programs can be enhanced to gather information specific to particular sources or activities and new or enhanced monitoring tools can facilitate data collection. As part of adaptive management, available information and research questions continually evolve resulting in a need to coordinate research activities and share the information generated across government agencies, stakeholder groups, and other partners.

In addition, Canada through its Great Lakes Nutrient Initiative has made significant investments in monitoring to improve our understanding of phosphorus loadings from Canadian tributaries, and the health of biota and water quality conditions in the nearshore of Lake Erie. Models have been developed to assist in the development of phosphorus load reduction targets and to improve our understanding of the linkages between land types, use and management and phosphorus loadings to tributaries and ultimately Lake Erie. Numerous research studies have also been conducted to improve our understanding of the factors, including phosphorus, that contribute to the development of harmful algal blooms and toxin production, *Cladophora* growth and hypoxia.

C1: Conduct monitoring and modelling

Long-term monitoring is the cornerstone of an adaptive management approach. Programs in the Lake Erie watershed are continually being assessed to ensure priority locations and high-risk phosphorus loading conditions, such as large storm events, are being monitored. In some cases, emerging technology is being incorporated to enhance existing monitoring efforts.

1. Canada will measure phosphorus loads to Lake Erie from selected Canadian tributaries.
2. Canada will continue to monitor and assess biota and water quality conditions in Lake Erie through the Great Lakes Surveillance Program.
3. Canada will continue to collect and coordinate hydraulic and hydrologic data, including maintaining Canada's role on the Canada U.S. Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data to ensure accurate flow information is available to calculate seasonal and annual phosphorus loads.
4. Ontario will continue long-term monitoring programs including the Provincial Water Quality Monitoring Network, Provincial Groundwater Monitoring Network, Great Lakes Intake Monitoring Program, and Great Lakes Nearshore Monitoring Program.
5. Canada and Ontario will continue to deploy real-time monitoring systems in Lake Erie to monitor temperature, dissolved oxygen and algal pigments which allows tracking of hypoxia and lake stratification.
6. Canada will continue to produce an annual national field-scale crop inventory map using remotely-sensed imagery.
7. Canada will continue to develop Soil and Water Assessment Tool models for the Thames River which will allow for BMP scenario testing.
8. Canada will continue to improve models and tools at two scales for risk of phosphorus loss: soil-landscape scale (Indicator of Risk of Water Contamination by Phosphorus, IROWC-P) and the field scale (P-Index).

C2: Conduct research to better understand nutrient dynamics in the Lake Erie basin

There is a long history of research on nutrient dynamics and associated ecosystem changes in Lake Erie. A variety of research initiatives are currently underway, both in Canada and the United States, by government agencies, academic institutions, and non-government organizations. It is important to incorporate available knowledge and work with research partners to develop and refine research questions over time.

1. Ontario will continue a multi-watershed nutrient study, to assess the interaction between agricultural land use and nutrient loadings in streams in the Great Lakes basin.
2. Ontario will support and conduct research on the use of sensor-based technology for monitoring phosphorus and associated parameters.
3. Canada and Ontario will continue research to improve understanding of factors contributing to toxic and nuisance algae growth and their impacts on water quality and ecosystem health.

4. Ontario will lead, with Canada's support, the undertaking of a monitoring and research project in Lake St. Clair/Lower Thames to better understand the source and types of phosphorus that are contributing to algal growth.
5. Canada will lead, with Ontario's support, research and monitoring to improve understanding of invasive mussels and their influence on phosphorus dynamics and *Cladophora* growth in the eastern basin of Lake Erie.
6. Ontario will work with the Lake Erie community to conserve and manage aquatic habitat and the fish community to maintain fish population health and resiliency.
7. Ontario will lead research on the bioaccumulation of the algal toxin microcystin in fish tissue to better understand its impact on human health.

C3: Conduct research to better understand and predict the impact of climate change on the Lake Erie ecosystem

As the climate changes, earlier winter thaws, increased spring stream flows, and more intense rainfall events can result in more nutrients being washed into the lake. These, combined with longer warm water periods, have the potential for increased algal blooms. Climate change is a cross-cutting issue that needs to be integrated into research activities conducted in the Lake Erie Basin. In 2016, Ontario released the Climate Change Action Plan, a five-year plan that will help Ontario fight climate change over the long term. The plan outlines the actions to help Ontario households and businesses reduce harmful greenhouse gas pollution. Also in 2016, the federal government worked with the provincial and territorial governments to develop the Pan-Canadian Framework on Clean Growth and Climate Change, which is the Government of Canada's commitment and plan to reduce greenhouse gas emissions and build resilience to adapt to a changing climate. The Framework builds on the actions taken individually and collectively by provinces and territories, and works to ensure that Canadians are engaged to strengthen and deepen action on clean growth and climate change. The plan includes a pan-Canadian approach to carbon pricing, measures to reduce greenhouse gas emissions in all sectors, adaptation to climate impacts, and increased technology development and adoption to help Canada move toward a low-carbon economy.

The synergies and co-benefits of actions under both Climate Change Action Plans and the Canada-Ontario Action Plan for Lake Erie will be coordinated and maximized where possible. (e.g., stormwater green infrastructure planning under the Provincial Policy Statement and municipal Official Plans; Agriculture Soil Health and Conservation Strategy, science to understand the impacts of climate change on phosphorus loadings to Lake Erie)

1. Canada will run existing watershed simulation models under different climate change scenarios.
2. Ontario will consider climate change in all of its research and monitoring efforts relating to Lake Erie.

C4: Conduct research to improve existing practices and develop new innovative practices and technologies to reduce phosphorus loadings

Ongoing research to improve and develop new practices and technologies to reduce, recycle and recover phosphorus from point and non-point sources will be important for achieving the targets.

Canada and Ontario continue to invest in research and demonstration initiatives to improve knowledge and understanding of the effectiveness of best management practices on reducing nutrient loss and improving nutrient and water use efficiency in agriculture production.

Ontario and Canada provided funding to demonstrate greenhouse nutrient feedwater recycling. This has led to the adoption of new technologies and reduction of phosphorus loadings to the environment.

One of the most promising research areas relates to the development of innovative practices to capture, store, and in some cases recover phosphorus from point and non-point sources. In support of this, Ontario has partnered on an innovative technology competition (George Barley Water Prize) to reduce and recover phosphorus from water bodies and will host the pilot stage in Ontario to demonstrate cold climate application. In another example, Ontario is taking action to maintain its regulation-making authority, under the Ontario Water Resources Act, that could enable the use of water quality trading as a potential tool for managing phosphorus in the future. The proposed actions will build on a strong foundation of past and ongoing research supported through partner research projects.

1. Ontario will continue to leverage government research programs and initiatives (e.g., New Directions, OMAFRA - University of Guelph Partnership) to fund needed research and new technologies to test and improve agricultural BMPs for phosphorus reduction.

2. Canada and Ontario will continue to research the effectiveness of BMPs in reducing phosphorus losses from agricultural land during typical and extreme weather events.

3. Canada will continue to identify the capacity and progress of different agricultural production systems in implementing activities that reduce the risk of nutrient loss.

4. Canada will continue to develop and assess methods for evaluating sustainable phosphorus levels in soils.

5. Canada and Ontario will conduct research to improve modeling capability to quantify phosphorus reductions from BMPs at a landscape scale.

6. Canada and Ontario will investigate current (baseline) and future adoption of BMPs within the Lake Erie basin and within selected sub-watersheds to inform monitoring efforts and progress towards targets.

7. Ontario will investigate social, economic and environmental determinants impacting BMP adoption.

8. Ontario will support studies that improve understanding of the correlation between phosphorus load reduction and high uptake of low impact development/green infrastructure.

9. Canada and Ontario will work with partners to measure effectiveness of wetlands and other natural heritage features in reducing phosphorus through overland flow into watercourses.
10. Canada and Ontario will evaluate the feasibility of using economic instruments to achieve phosphorus reductions.

Category D: Educate and Build Awareness

All levels of government, conservation authorities, non-government organizations, and other stakeholder groups, and the public have worked hard to communicate the importance of reducing phosphorus loadings to Lake Erie. As audience needs and communication technologies evolve, there is a need to review and adjust communication strategies for maximum impact to ensure the message is reaching the intended audience.

D1: Enhance communication and outreach to build awareness, improve understanding and influence change

Through initiatives including the Farmland Health Check-up and the Environmental Farm Plan (EFP), Canada and Ontario have supported agri-environmental education and awareness initiatives to educate farmers about beneficial management practices and regulatory requirements to reduce their on-farm environmental risks. Over 70 percent of Ontario farmers have participated in the EFP program.

These actions focus on developing and advancing awareness of and knowledge about phosphorus sources and impacts as well as what can be done by the Lake Erie community to contribute to reducing phosphorus loadings.

1. Canada and Ontario will develop a digital marketing campaign to build awareness of the need for actions to reduce phosphorus in the Lake Erie basin.
2. Canada and Ontario will, in collaboration with the Lake Erie community, enhance the awareness of the impacts of phosphorus on aquatic ecosystems.
3. Ontario will work with the agriculture sector to communicate practices for responsible nutrient management, including soil testing to determine appropriate phosphorus requirements.
4. Ontario will, in partnership with the agriculture sector, continue to develop and deliver information and tools to increase cover crop use in the non-growing season to reduce soil loss and field runoff and to promote the application of nutrients at the right time through the "Timing Matters" initiative.
5. Ontario will deliver by 2018 enhanced drainage and erosion control education and training to increase awareness of causes of nutrient loading in runoff and how to manage drainage to reduce phosphorus loads.
6. Ontario will by 2018 develop a provincial award to recognize excellence, innovation and leadership in demonstrating environmental action at the farm level in the Lake Erie basin.
7. Ontario will facilitate an event, by March 2018, showcasing the adoption of leading municipal approaches to integrated stormwater management.

D2: Share data and information

Canada and Ontario are committed to making their data available to the public in an accessible form. As part of this commitment, Canada and Ontario intend to periodically report on progress in achieving the goals of the Action Plan.

1. Canada and Ontario will make relevant long-term data and information on Lake Erie public as it becomes available.
2. Ontario will work with its partners to provide an annual update on Lake Erie through its website, and report on Lake Erie as part of the progress report required every three years under Ontario's Great Lakes Protection Act, 2015.

Category E: Strengthen Leadership and Coordination

Effective leadership and coordination are essential for successful reduction of phosphorus loadings to Lake Erie. This coordination is already apparent in a variety of collaborative working arrangements, research partnerships, and similar initiatives. The strategic actions listed below are intended to enhance the current level of coordination by clarifying roles and responsibilities and strengthening the effectiveness of existing committees and other governance structure.

E1: Improve communication and coordination

Implementation of this Action Plan requires the engagement of a number of sectors and communities in the reduction of phosphorus from various sources. Therefore, it will be essential that there are mechanisms in place for the coordination of these efforts, and that opportunities exist to communicate on the progress that is being made.

1. Canada and Ontario will engage First Nations and Métis communities to facilitate their participation and input in the development and implementation of the Action Plan. This will include consideration of Traditional Ecological Knowledge from First Nations and Métis if offered.
2. Canada and Ontario will build on existing governance structures to implement the Action Plan.
3. Canada and Ontario will update the Great Lakes community on progress in implementing the Action Plan through opportunities such as webinars, forums and meetings.
4. Canada and Ontario will coordinate research, monitoring and modelling activities to improve scientific efforts towards phosphorus reduction on an annual basis.

E2: Establish an adaptive management framework

Adaptive management is a guiding principle of this draft Action Plan. It is a systematic, iterative process through which management objectives and approaches and policies can be adjusted and improved over time, providing a mechanism for continuous improvement. In an adaptive management system, the implementation and results of management actions are monitored and evaluated by regulatory agencies and partners, and used to inform the next cycle of monitoring and management, including the research agenda.

1. Canada and Ontario will assess and report on progress towards achieving phosphorus reduction actions and targets in 2023 and every five years thereafter.
2. Canada and Ontario will use the binational metrics developed to establish the phosphorus loading targets, as a foundation for establishing a suite of performance measures, and will adjust as necessary to ensure existing metrics are feasible and sustainable.
3. Canada and Ontario will develop land based performance measures to track changes to land use and management over time.
4. Canada and Ontario will work with the U.S. federal and state agencies and other partners to develop a binational information platform to track progress towards meeting the phosphorus reduction targets to reduce cyanobacteria in the western basin (e.g., through GLWQA Nutrients Annex and the Great Lakes Commission's ErieStat project).

5 Implementation

This draft Action Plan sets out strategic actions and tactics to meet Canada's phosphorus reduction commitments under the GLWQA. It is clear that phosphorus reduction targets will only be achievable with significant change across the basin and with the adoption of a multi-barrier approach across all phosphorus sources.

In order to achieve our targets, widespread on-the-ground action is needed urgently, but progress will not be apparent overnight. It will take time to implement actions to the extent that significant phosphorus load reductions are achieved, and it will take time for the aquatic environment to respond. Implementing the Action Plan therefore requires adaptive management, strong governance, effective engagement of accountable partners.

5.1 Adaptive Management

Natural systems are inherently variable, and the impacts of management actions are difficult to predict accurately across Lake Erie's diverse landscape. Uncertainty is even greater with a changing climate and changes in the ecosystems from invasive species. For these reasons, it will be important to implement the Action Plan with an adaptive management approach. This Action Plan focuses on phosphorus reduction. Other factors will be addressed through the development of the Lake Erie Lakewide Action and Management Plan in 2018.

An adaptive management plan, supported by a strong monitoring, research, and modelling effort for Lake Erie, will provide a framework for ongoing measurement of compliance with established target loads and adjustment of management strategies over time; see Figure 10. Implicit in this must be recognition that the legacy effects of past activities in urban and rural settings may delay the observable effects of implementation of new phosphorus mitigation activities. The proposed adaptive management strategy incorporates the following elements:

1. Annual routine monitoring of loads, total phosphorus and soluble reactive phosphorus concentrations in key Canadian tributaries leading into Lake Erie, and in-lake nutrient-eutrophication response indicators.

2. An intensive monitoring, research, and modeling program which will allow the plan partners to review progress every five years. This will include evaluation of whether phosphorus mitigation activities have been immediately effective in meeting targets, effective but with a delay in meeting targets due to legacy effects, or ineffective at current adoption levels.
3. Report every 5 years based on a series of performance measures. The intended outcomes are reduced extent and frequency of harmful algal blooms; reduced hypoxia in the Central Basin; and reduced nuisance algal blooms in nearshore zone of the Eastern Basin.
4. A five-year review cycle; see Figure 10.

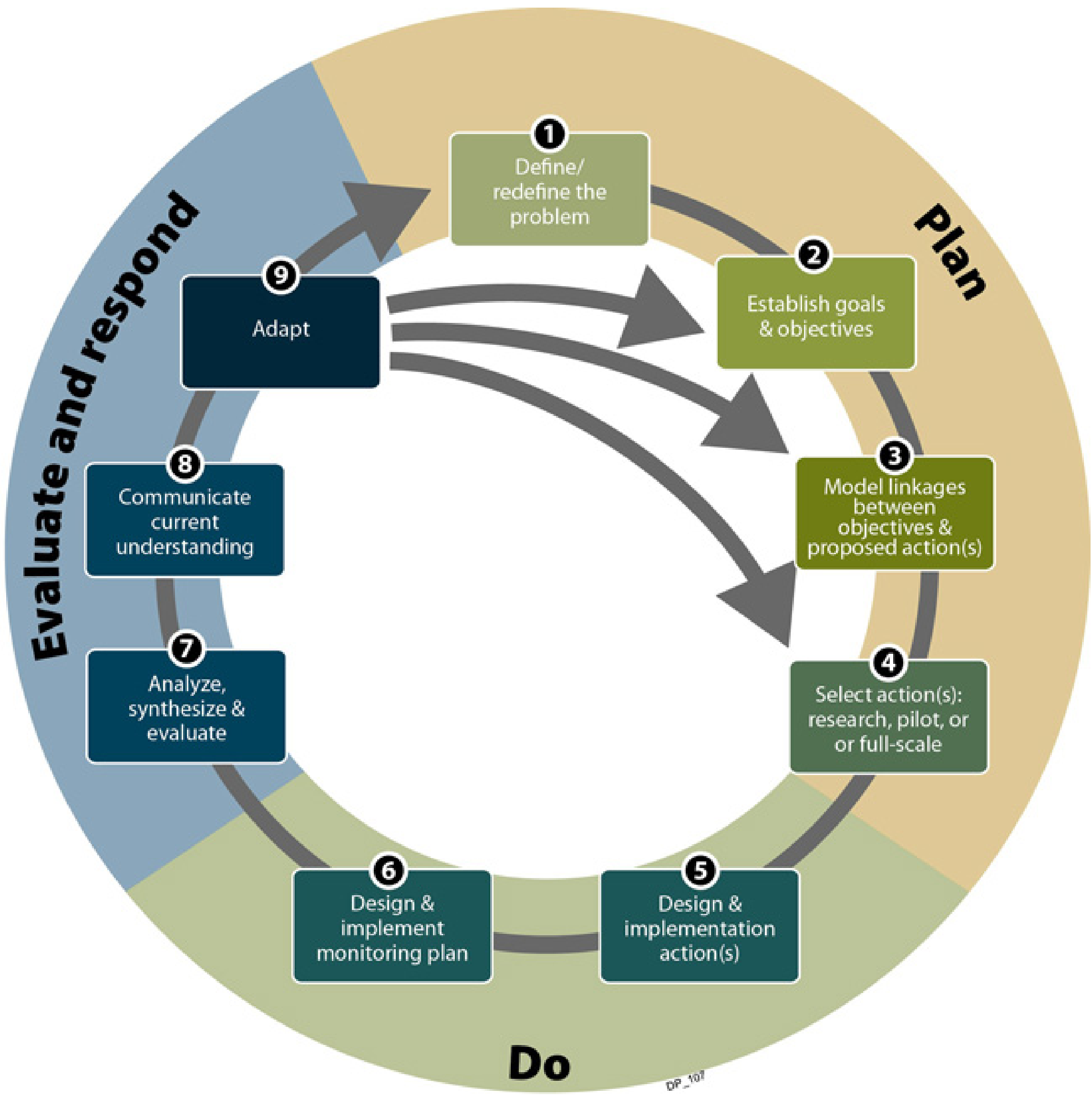

Figure 10: The adaptive management cycle.

5.2 Governance

Management of phosphorus loads to Lake Erie is a complex and challenging task that bridges many levels of government and multiple agencies as well as private sector organizations. A broad network of partners and stakeholders will be essential for successful implementation of the Action Plan. These include federal, provincial, and municipal governments and agencies; First Nations and Métis communities; conservation authorities; industries, agriculture and other businesses; the academic community; nongovernment organizations; property owners; and the general public. Roles and responsibilities must be clear. Canada and Ontario are exploring options to manage this complex problem with the objective of improving coordination between and enhancing existing mechanisms to the extent possible.

5.3 Stakeholder and Partner Engagement

Excess nutrients and associated algal blooms pose a threat to water quality and drinking water supplies for hundreds of thousands of Ontarians in the Lake Erie basin, so it is vital that effective engagement of stakeholders, partners, and the general public be an integral part of Action Plan development and implementation. To that end, a Lake Erie Nutrients Working Group has been established as a platform for sharing multi-sectoral perspectives, identifying potential actions, and for providing input and advice on the development of this draft Action Plan[7]. Membership of the Working Group includes representation from First Nations and Métis communities, municipalities, agriculture, conservation authorities, environmental non-government organizations, industry and commerce, academia, the tourism industry, cottage associations, commercial and recreational fisheries interests, and the general public. Canada and Ontario are committed to continued engagement with this working group, and the broader Great Lakes community in the development and implementation of the Action Plan. This may include additional engagement with First Nations and Métis based on their interest.

5.4 Reporting and Accountability

The Action Plan will be reviewed and revised in 2023 and every five years thereafter to align with COA reporting. It will be supported by and linked to other key documents, including LAMP reports, CSMI reports, but also related work such as the water quality and natural heritage components of conservation authority watershed plans and municipal natural heritage strategies; municipal and provincial reporting of wastewater treatment plant upgrades and optimization; and documentation of agricultural BMP adoption.

Each agency has its own system for data management and reporting, and each is committed to making data available to a broader audience through COA. Canada and Ontario will explore the potential of central web-accessible portals to support sharing of information across different

[7] In addition, the Nutrient Annex partners are also engaging a variety of sectors and interests through sector-based meetings and working groups, including those related to agriculture, municipalities, conservation authorities, First Nations and Métis communities, and others.

platforms. Reporting will be coordinated by Canada and Ontario through the COA Nutrients Annex Committee and made available to partners, stakeholders, and the public through the common portal. Information to be shared in this way could include scientific data, metadata (location, timing, contact information and so on associated with science data), and reports.

6 Moving Forward

Reducing phosphorus loadings to Lake Erie is a challenging task, and one that will require collective action by many partners throughout the basin. Factors such as climate change, legacy sources of phosphorus, and the changing human activities on the landscape make it difficult to predict the rate at which we could see significant changes in the lake.

While we continue to improve our knowledge of phosphorus and its impacts, it is critical that we take action now to improve the health of Lake Erie. We must undertake actions in recognition of that time lag, monitoring key performance measures to track progress toward loading reduction targets. As our knowledge of the lake ecosystem improves, adaptive management will encourage regular plan review and will guide adjustment of management strategies to increase their effectiveness and ensure continued progress.

The intention of this initial draft Action Plan is to generate ideas on how to reduce phosphorus loadings to Lake Erie from Canadian sources. Please consider the discussion questions that appear on page ii and provide your feedback and suggestions to letstalklakeerie.ca or Land.Water@ontario.ca. The information gathered through this process will form part of the dialogue as the Canada-Ontario Action Plan continues to be developed.

Thank you for taking the time to get engaged.

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Acronyms

AAFC	Agriculture and Agri-Food Canada
COA	Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, 2014
CSMI	Cooperative Science and Monitoring Initiative, a collaborative binational assessment of the Great Lakes conducted periodically with an intensive focus on one lake each year, with the full cycle completed every five years.
ECCC	Environment and Climate Change Canada
GLWQA	Canada-U.S. Great Lakes Water Quality Agreement, 2012
LAMP	Lakewide Action and Management Plan, as established under the Canada-U.S. Great Lakes Water Quality Agreement, 2012
MNRF	Ontario Ministry of Natural Resources and Forestry
MOECC	Ontario Ministry of the Environment and Climate Change
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PLUARG	Pollution from Land Use Activities Reference Group, a Canada-U.S. working group charged with investigating the impact of land-based activities on pollutant loadings. PLUARG operated from 1972 to 1978.
SWEEP	Soil and Water Environmental Enhancement Program, a collaborative Canada-Ontario research and outreach program that developed agricultural stewardship initiatives through the 1980s.

Glossary

Adaptive management	An iterative process through which management objectives, approaches and policies can be adjusted over time for continuous improvement, based on monitoring, performance measures, and evolving science and information.
Bioavailable	Readily assimilated by plants and algae and used for growth.
Biophysical characteristics	The living and non-living environmental factors that influence the growth of biological organisms.
BMPs	Best/Beneficial Management Practices are proven, practical and affordable approaches to conserving and/or protecting soil, water and other natural resources in urban and rural areas.
Cladophora	An attached algae species that can cause dense mats, clogging intake pipes, and fouling shorelines and recreational and fishing equipment. *Cladophora* is the primary cause of nuisance algal blooms in the eastern basin of Lake Erie.
Combined sewer overflows	A discharge to the environment from a combined sewer system (a single pipe system of sewers that carry both sanitary sewage and stormwater runoff) that usually occurs as a result of a precipitation event when the carrying capacity of the system is exceeded, and can contain high levels of floatables, pathogenic microorganisms, suspended solids, oxygen-demanding organic compounds, nutrients (including phosphorus), oil and grease, toxic contaminants and other pollutants. [Note: Combined sewer systems are designed to allow overflows in these cases, to protect residential, commercial and industrial property from sewer backups.]
Concentration	The mass of a substance present in a given volume of water, expressed in units such as milligrams per litre.
Cyanobacteria	Also called blue-green algae; a type of bacteria that undergoes photosynthesis and thus can be influenced by excessive phosphorus concentrations; an example is *Microcystis*. Cyanobacteria can produce toxic substances called cyanotoxins with the potential to harm humans and other organisms.
Cyanotoxins	Toxic biological compounds produced by cyanobacteria such as *Microcystis,* which produces the toxin microcystin.

	Cyanotoxins have potentially significant human health consequences if ingested or through skin exposure, and may also be toxic to other organisms.
Dreissenid mussels	A collective term used for zebra and quagga mussels, which are non-native, invasive species in the Great Lakes basin.
Ecosystem components	Biological organisms and the non-living parts of the environment in which they live, for example fish, plants, air, water, and soil.
Ecosystem services	The natural services provided by a healthy ecosystem. Ecosystem services include provisioning services, such as production of food, fiber, timber, oxygen and water, and production of pharmaceutical, biochemical and industrial raw materials; regulating services, including regulation of climate, flood and erosion control, water and air purification, and adsorption and storage of gases; cultural services, such as creating intellectual, artistic and recreational opportunities, aesthetic enjoyment, and spiritual fulfillment, and ecosystem support services including soil formation, photosynthesis, and nutrient cycling; pollinating crops and plants, and dispersing seeds.
Effluent	Discharge from municipal or industrial wastewater treatment plants following treatment.
Epilimnion	The oxygen-rich upper layer of water in a stratified lake; see stratification.
Eutrophication	Excess nutrient enrichment, causing nuisance and harmful algal blooms which in turn can cause low dissolved oxygen levels and associated fish kills.
Extreme weather event	A weather event that unexpected, unusual, severe or unseasonal; weather at the upper or lower extremes of the historical distribution—typically a 30-year period
Food web	The natural connections between species – what eats what – in a biological community.
Green infrastructure	Natural and human-made elements that provide ecological and hydrological functions and processes. Green infrastructure can include components such as natural heritage features and systems such as wetlands or riparian areas, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs.
Harmful algal blooms	See cyanobacteria.

Huron-Erie Corridor	A term used to refer to the flows from Lake Huron through the St. Clair River, Lake St. Clair, and the Detroit River. Flows from the Huron-Erie Corridor discharge into the Western Basin of Lake Erie.
Hypolimnion	The bottom layer of water in a stratified lake. In the summer, the hypolimnion is colder than surface waters. In the winter, surface waters are frozen or close to freezing, while the hypolimnion is somewhat warmer, typically a few degrees above freezing. The hypolimnion can experience low levels of dissolved oxygen under certain conditions; see stratification.
Hypoxia	Hypoxia is defined as an area with low levels of oxygen. Late summer hypoxia, the reduction of oxygen to less than 2 parts per million, occurs naturally in Lake Erie's central basin due to the stratification of layers by temperature, with the warmer layers on top.
Lakewide Action and Management Plan	Lakewide Action and Management Plan, as established under the Canada-U.S. Great Lakes Water Quality Agreement, 2012. Lakewide Action and Management Plans are lake specific binational action plans for restoring and protecting Great Lakes ecosystems.
Legacy sources	Phosphorus from past activities contained in biological tissues, and sediments in lake and stream beds, flood plains, and agricultural fields. Legacy sources of phosphorus can be re-mobilized and add to loadings, even when current practices are geared to phosphorus reduction.
Load	The total mass of a substance delivered to a water body over time, expressed in units of mass per unit time, such as tonnes per year. Load is the product of concentration (mass per unit volume) and flow rate (water volume per unit time).
Low impact development	Urban stormwater management measures that seek to retain rainwater on the site through collection and infiltration. Examples include rain barrels, green roofs, infiltration trenches, rain gardens, and permeable pavement.
Microcystis	A genus of cyanobacteria, known to produce the toxin microcystin.
Microcystin	Are toxins produced by cyanobacteria.
Natural heritage features	The green infrastructure of the natural environment; see green infrastructure. Natural heritage is defined by the Province of Ontario as features, areas and linkages intended

	to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species and ecosystems. It can include features such as wetlands, woodlots, valleylands and wildlife habitats.
Non-point source	Sources of pollution, including phosphorus that arise over a large area of land held by a number of landowners, for example stormwater runoff from urban areas or agricultural fields. Non-point sources are difficult to control because solutions must be geared to specific site conditions and require action by many landowners.
Nuisance algal blooms	Blooms of algae such as *Cladophora* that can cause fish kills (see eutrophication), degrade fish and wildlife habitat, clog water intake pipes, and foul shorelines and equipment, but which do not produce toxins.
Nutrient cycling	The natural movement and transformation of nutrients such as phosphorus through soil, water, and air, and in different chemical forms.
Point source	Sources of pollution that enter a water body through a pipe or similar outlet, such as a municipal or industrial wastewater treatment plant discharge. Point sources have usually undergone some level of treatment before discharge; an exception is most combined sewer overflows.
Riparian zone	The area of land adjacent to tributaries and the lake, where vegetation may be influenced by flooding or elevated water tables. A healthy riparian zone provides habitat for a variety of aquatic and terrestrial species. Its complex vegetative structure protects against erosion and can control the runoff of sediment, phosphorus and other pollutants, reducing impacts on water quality under certain conditions.
Runoff	Rainfall and snowmelt that runs off the land surface. In urban areas, a large proportion of runoff travels over hard, impervious surfaces such as roofs, roads, and parking lots, and is diverted into municipal sewer systems, carrying with it the sediment and pollutants, including phosphorus, that it contains. Urban runoff/stormwater may be discharged directly to surface waters without treatment, or may be treated in detention ponds, infiltration trenches, or similar infrastructure. In rural areas, runoff typically moves from agricultural fields, woodlots or other natural landscapes directly into receiving waters.

Soluble reactive phosphorus	Phosphorus in dissolved form. The term “reactive” refers to the reaction of phosphorus with a colour agent during the analysis of phosphate concentrations in a laboratory.
Thermal Stratification	The formation of layers in a lake, typically a well-mixed, warmer, oxygen rich surface layer (epilimnion); a transitional zone (metalimnion or thermocline); and deeper colder waters that can become oxygen-poor (hypolimnion). Strong winds in spring and fall thoroughly mix the waters of all but the deepest lakes. Stratification occurs in the summer, with a warm layer at the surface overlying colder waters, and in the winter, where colder waters or ice overlie somewhat warmer waters at depth. Shallow lakes may never stratify, or stratification may not persist.
Wetlands	A wetland is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem. The primary factor that distinguishes wetlands from other land forms or water bodies is the characteristic vegetation of aquatic plants, adapted to the unique hydric soil. Wetlands play a number of roles in the environment, principally water purification, flood control, carbon sink and shoreline stability. Wetlands are also considered the most biologically diverse of all ecosystems, serving as home to a wide range of plant and animal life.

Appendix A: Characterization of the Lake Erie Basin

An important basis for the development of actions under the Canada-Ontario plan for phosphorus reduction in Lake Erie is a good understanding of the type and location of land use and land activities within the basin. This is because the type of land use and/or land activity within an area, in combination with the susceptibility of the landscape to soil erosion or surface water runoff, can suggest different sources and pathways of phosphorus loss within that area. If all areas within the basin are characterized by the same method, then the inferred sources and pathways of phosphorus loss within the Lake Erie basin can be compared.

With this in mind, a multi-agency federal and provincial Science Subcommittee under the COA Nutrients Annex characterized watersheds within the Lake Erie basin according to the basin-wide distribution of distinguishing land use/activities. Watersheds within the Lake Erie basin were characterized by the following land use/ activity categories: urban, agricultural-crop, agricultural-livestock, natural heritage, or uncategorized.

The distribution among watersheds of landscape characteristics that could render a watershed more vulnerable to phosphorus loss was also identified and included the risk of soil erosion and the risk of surface runoff. The distribution among watersheds of an environmental quality parameter (water phosphorus concentrations) was also identified.

Selecting Datasets

The characterization of the Lake Erie basin was conducted at the quaternary watershed scale since it represents a uniform biophysical scale that can be rolled up into management units. Data was solicited from federal and provincial government agencies as well as from conservation authorities and municipalities within the Lake Erie basin. Criteria for dataset use included:

- Basin-wide
- Comparable among all quaternary watersheds
- Direct relationship to land use/activity or landscape vulnerability categories
- Unique (not redundant with other datasets)
- High quality (consistently collected and subjected to quality assurance and control)
- Recentness (2008 or later)

Based on these criteria 35 out of over 100 parameters from datasets from 5 federal and provincial government agencies[8] were selected for use in the characterization. Types of data included: field survey (soils, landscape), remotely sensed land use/crop type, measured loads (urban point sources), estimated loads (urban and agricultural non-point sources), estimated nutrient application rates, and measured water concentrations. The available provincial and federal soluble reactive phosphorus and total phosphorus loading data did not meet the

[8] Agriculture and Agri-Food Canada, Environment and Climate Change Canada and the Ontario Ministries of Agriculture, Food and Rural Affairs, Environment and Climate Change, and Natural Resources and Forestry.

selection criteria because there are no reliable basin-wide data and/or data suitable for comparing among quaternary watersheds.

The distribution of each of the 35 parameters among all watersheds within the Lake Erie basin was assessed using the Jenks natural breaks classification method[9], which groups data such that the variability within a class is less than the variability among classes. For each parameter 3 classes (high, medium and low) were created based on the statistical distribution of the data among all 65 Lake Erie quaternary watersheds. There is no inherent value or judgement to any class since the 3 classes are simply the low, medium and high ends of the data distribution within the Lake Erie basin for any given parameter. There were, however three exceptions where existing risk-based thresholds were used. Water quality, percent natural heritage cover, and soil erosion were grouped into 3 classes using predetermined thresholds that are based on aquatic health, ecological health and modelled risk thresholds, respectively.

Creating Categories

Once the data were grouped into high, medium and low classes, expert judgement was used to identify those parameters ,most directly related to landuse/activity categories and that were most descriptive or distinguishing so they could be used as criteria to allocate watersheds to categories. This process reduced the original 35 parameters to 10. Watersheds that fell into the high class in one or more of these 10 parameters were included in a given land use/activity category. Watersheds were selected by the high class because it is the most descriptive of what is (versus what is not) in the watershed as many of the parameters are not mutually exclusive.

The categorization of a watershed does not mean that a watershed only has, or is dominated by, the land use/activity category it is in; it means that characteristics in the watershed fall into the high end of the use/activity distribution across the Lake Erie Basin. There still can be varying levels of urban, agriculture types or natural heritage in each categorized watershed. These categories are also not mutually exclusive; that is, the same watersheds can fall into more than one category.

Land use/land activity categories were created using the following criteria:

Natural Heritage: watersheds with:

- > 30 percent natural heritage land cover (wetlands, forest and prairie)

This parameter was selected as it is a direct measure of natural heritage land cover; > 30 percent cover was considered the minimum threshold that could be linked to aquatic ecosystem health[10]. Data were derived from remotely sensed imagery (2010)[11].

[9] Jenks, JF. 1967. "The Data Model Concept in Statistical Mapping", International Yearbook of Cartography 7: 186-190, as cited in Esri, 2012. Esri. 2012. FAQ: What is the Jenks' optimization method? Article 26442. http://support.esri.com/ja/knowledgebase/techarticles/detail/26442 Last Modified: 5/5/2016

[10] Environment Canada. 2013. How much habitat is enough? Third Edition. ISBN 978-1-100-21922-6

Urban: watersheds in the high end of the distribution in any one of:

- Percent of watershed area in urban land use (> 13 percent)
- Total annual urban point source load of phosphorus (> 10,900 kg phosphorus)
- Total urban non-point source load of phosphorus (> 4840 kg phosphorus)
- Percent of total watershed phosphorus load from urban point source (> 27 percent)
- Percent of total watershed phosphorus load from urban non-point source (> 10 percent)

Parameters are from 2008-2010 datasets and include remotely sensed imagery, measured point source loads and estimated non-point source loads from land-use coefficients[12].

Agricultural-Crop: watersheds in the high end of the distribution in any one of:

- Percent of watershed area in continuous corn and/or continuous soybean and/or a corn-soybean rotation over 4 years (> 27 percent)
- Percent of watershed area in vegetable and/or potato in at least 1 of 4 years (> 13 percent)

These parameters were selected because they were distinctive of annual crop systems in the basin and represent production systems with potential nutrient and soil management challenges. Data were derived from remotely sensed imagery from 2012-2015[13].

Agricultural-Livestock: watersheds in the high end of the distribution in any one of:

- Rate of phosphorus applied from manure (> 13 kg phosphorus/ha)
- Total amount of phosphorus from manure applied in the watershed (> 638,000 kg phosphorus)

These parameters were selected because manure phosphorus is directly related to the management of livestock production systems. Data were derived from the 2011 interpolated Census of Agriculture[14].

Landscape vulnerability categories were developed by the same process using the criteria listed below. These categories describe the state of the physical environment in the watershed and as such are not indicative of inferred potential phosphorus loss from individual source types.

Landscape Vulnerability Categories

Risk of Soil Erosion: watersheds with high to very high risk of soil erosion (> 22 t soil/ha/yr)

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[11] Southern Ontario Land Resource Information System (SOLRIS) Version 2.0 https://www.ontario.ca/data/southern-ontario-land-resource-information-system-solris-20

[12] MOECC source data from Municipal Utility Monitoring Information System (UMIS) and Sample Results Data Store (SRDS).

[13] Annual Crop Map Inventory http://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9

[14] Interpolated Census of Agriculture http://open.canada.ca/data/en/dataset/1dee8513-5c73-43b6-9446-25f7b985cd00

- **High Runoff Soils:** watersheds in the high end of the distribution of percent of watershed area with soils in hydrological soil group (HSG) “D”. (> 54 percent)

These parameters were selected because they represent the two dominant transport pathways for phosphorus: erosion of soil by water and surface runoff. Data for the soil erosion risk parameter comes from an erosion risk model[15]. The parameter used to describe surface runoff was the percent of soils in hydrological soil group (HSG) D. HSG D soils have the highest potential for runoff because, once they are wet, water infiltrates (permeates) very slowly through these soils with the excess running over the soil surface[16]. Data for percentage of soils in HSG D were derived from the provincial soil database.

Environmental State Category

- **Water Quality:** The low, medium and high classes for this dataset (< 30 µg phosphorus/L, 30-90 µg phosphorus/L and > 90 µg/L) are based on the interim Provincial Water Quality Objective for phosphorus for streams and rivers (30 µg/L)[17].

The water quality dataset used was the total phosphorus concentrations from the MOECC Provincial Water Quality Monitoring Network database[18] from the time period 2009-2012. To determine the representative value for each quaternary watershed, the highest median (concentration median from each station between 2009 and 2012) from all the stations within a watershed was used. There are a number of watersheds for which there are no water quality data. Although this does not meet the dataset selection criteria, this database was deemed acceptable for use because the data exist for the majority of quaternary watersheds, are consistently collected and analyzed and there is a good understanding of what the PWQMN concentrations represent and how they can be interpreted.

Characterization Results

Using this process 44 of the 65 watersheds (70 percent of the Lake Erie basin) fell into one or more of the four land use/ activity categories. Of the 44 categorized watersheds, 35 fell into a single land use/ activity category (e.g., Natural Heritage , Urban) and 9 fell into two categories (e.g., Urban + Natural Heritage or Agricultural-Crop + Agricultural-Livestock)

To reiterate, categorization of a watershed does not mean that a watershed only has, or is dominated by, a land use/ activity; there still can be varying levels of urban, agriculture types or natural heritage in each categorized and uncategorized watershed. It also cannot be assumed that there is the same potential level of phosphorus loss within and among watersheds within a land use/ activity category.

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[15] Lobb, D.A., S. Li and B.G. McConkey. 2016. Soil Erosion. 77–89 in Clearwater, R. L., T. Martin and T. Hoppe (eds.) 2016. Environmental sustainability of Canadian agriculture: Agri-environmental indicator report series – Report #4. Ottawa, ON: Agriculture and Agri-Food Canada.

[16] Drainage Guide for Ontario - Publication 29 http://www.omafra.gov.on.ca/english/landuse/facts/drain_p29.htm

[17] https://www.ontario.ca/document/water-management-policies-guidelines-provincial-water-quality-objectives

[18] http://www.ontario.ca/data/provincial-stream-water-quality-monitoring-network

The distribution of watersheds that fell into the landscape vulnerability categories generally had a SW-NE bimodal distribution as would be expected from soil types and landscape features in the Lake Erie basin (Figure A.1). The 20 watersheds with high (>22 t soil/ha/year) to very high (> 33 t soil/ha/year) erosion risk represents 35 percent of the Lake Erie basin and the 12 watersheds with the greatest proportion of high runoff potential soils represents 11 percent of the Lake Erie basin.

There is no pattern among the average quaternary watershed total phosphorus concentrations (Figure A.2). This is not unexpected since 35 percent of the watersheds are not currently monitored under the provincial water quality monitoring network program (PWQMN). In addition, PWQMN data indicate base flow (low flow) conditions well, but do not capture spring/storm runoff events when the contribution of phosphorus from non-point sources would be expected to be greater.

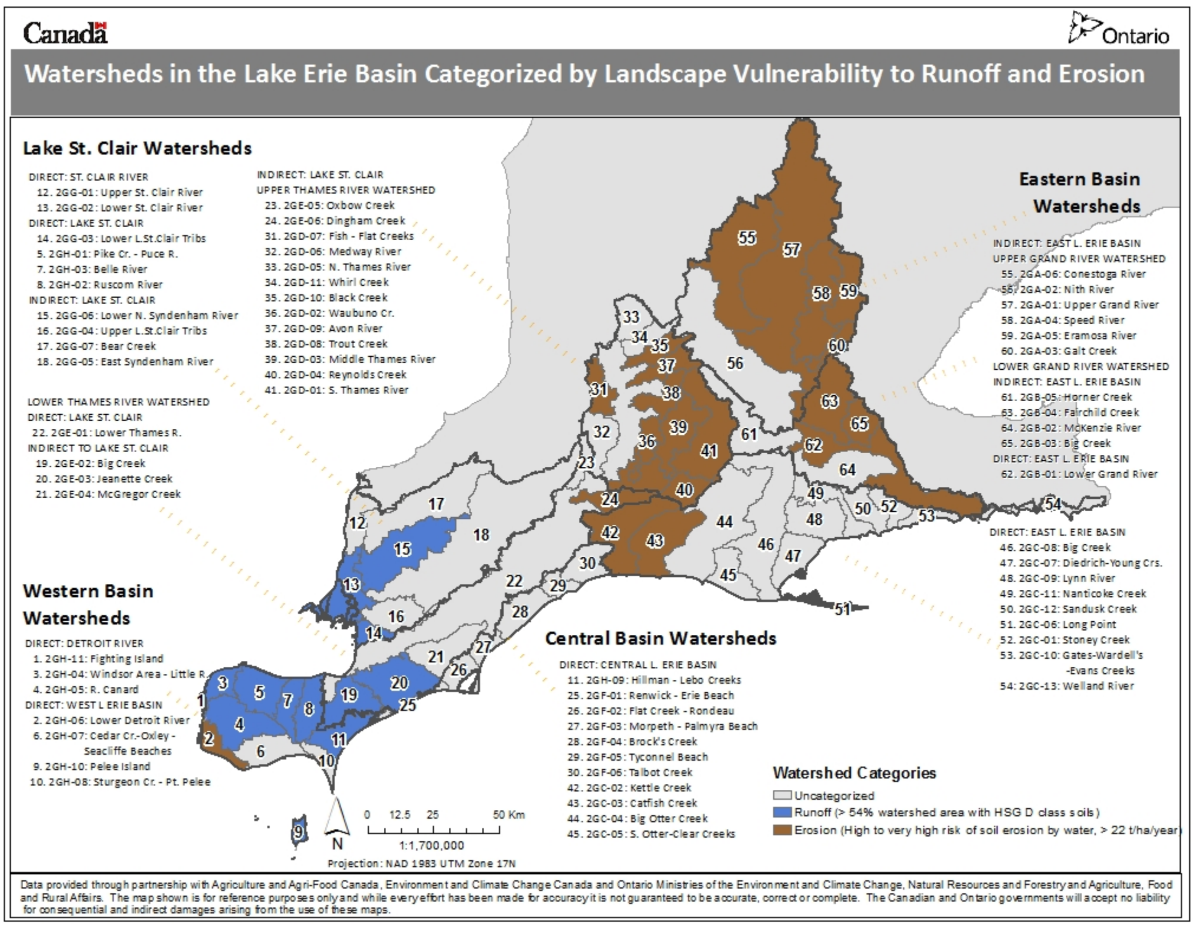

Figure A.1: Quaternary watersheds of the Lake Erie basin categorized by soil and landscape features related to phosphorus transport pathways of runoff and erosion.

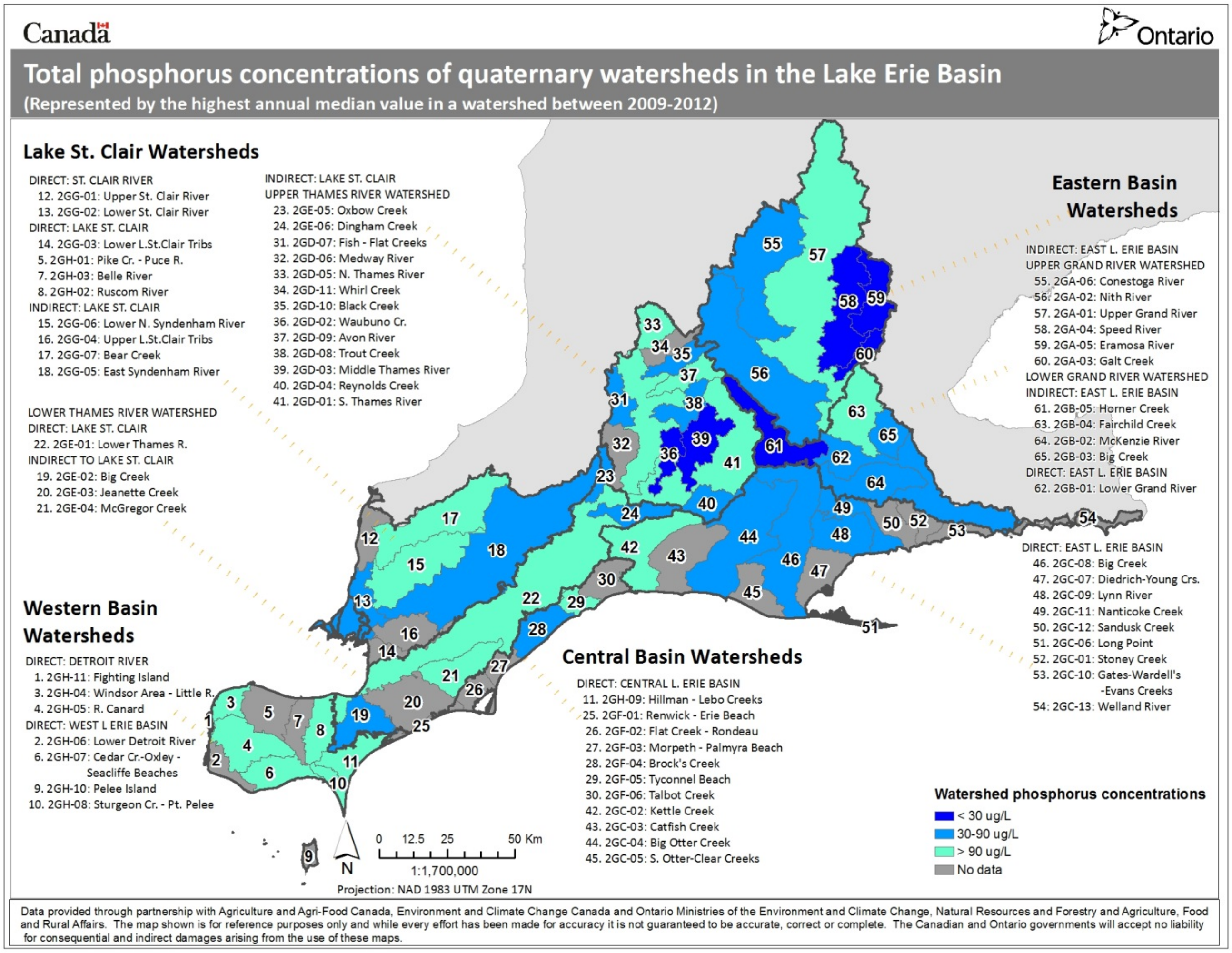

Figure A.2: Quaternary watersheds of the Lake Erie basin categorized by the average quaternary watershed concentration (average of the maximum median over the period of 2009-2012) of total phosphorus derived from the MOECC Provincial Water Quality Monitoring Network.