Assessment

of

Eutrophication or Undesirable Algae

Beneficial Use Impairment

in the Niagara River (Ontario) Area of Concern

October 2017

NIAGARA RIVER Remedial Action Plan

Executive Summary

Algae are tiny plant-like organisms that are an important part of the food web as they are the main source of food for planktivorous fishes and zooplankton. However, when algae are overabundant (often referred to as an algal bloom) they can cause disruptions to the aquatic ecosystem, result in fish kills, pose a risk to human health and/or impair recreational enjoyment of the waterbody (boating, swimming). This is the reason *Eutrophication or Undesirable Algae* is listed as one of the 14 potential beneficial use impairments (BUIs) in the Niagara River Area of Concern (AOC). Pollution from human sources such as municipal and industrial wastewaters, agricultural runoff, fertilizers on lawns and golf courses, and poorly maintained septic systems are sources of nutrients that can contribute to "eutrophication", a term that describes the enrichment of nutrients within a waterbody. Natural sources of nutrients from sediments (due to erosion) can also contribute to eutrophication.

The Niagara River is one of 36 remaining AOCs in the Great Lakes due to historical water quality pollution from human sources. The Remedial Action Plan (RAP) process guides restoration efforts with the ultimate goal of improved environmental conditions and subsequent removal of the river from the list of Great Lakes AOCs. Historically, the boundaries of the AOC included the Niagara River and its entire watershed. In 2012, the Great Lakes Water Quality Agreement was revised indicating that the focus of AOCs is to include the "Waters of the Great Lakes and the connecting river systems of St. Mary's, St. Clair, Lake St. Clair, Detroit, Niagara, and St. Lawrence at the international boundary or upstream from the point at which the river becomes the international boundary between Canada and the United States, including all open and nearshore waters." The boundary for the Niagara River AOC is now defined as the connecting channel itself flowing from the mouth of Lake Erie to Lake Ontario. Its tributaries are considered as a potential source of impairment instead of part of the AOC itself.

The *Eutrophication or Undesirable Algae* BUI was first listed as impaired in the 1993 Stage 1 RAP Report; however, it was considered in two parts. The *Eutrophication* component of the BUI was listed as "Impaired" due to issues in the Welland River; for *Undesirable Algae*, the Niagara River AOC and its largest tributary was designated as "Not Impaired" because there was no evidence of persistent algae. The status of the entire BUI was changed to "Impaired" during the RAP Stage 2 Update (2009) for the Niagara River and its largest tributary based on anecdotal evidence of poor water quality and observations of algae in the Welland River. Based on the refinement of the AOC boundaries and in the absence of a data review for the Niagara River, the RAP Team agreed to pursue an assessment of all relevant data to determine the status of the *Eutrophication or Undesirable Algae* BUI for the Ontario portion of the Niagara River.

The assessment initiated in 2014 examined all recent data (2003-2013) from multiple sources collected in the Niagara River (and Chippawa Creek/Niagara power canal) from multiple agencies for five key eutrophication metrics: total phosphorus (TP), phosphate/soluble reactive phosphorus (SRP), chlorophyll *a*, dissolved oxygen (DO) and Secchi disc depth. A scientific weight-of-evidence approach (as is used by other AOCs) was used to interpret data and determine the status of the *Eutrophication or Undesirable Algae* BUI. The results of the

assessment indicate that there is no eutrophication or undesirable algae impairment in the Niagara River.

Below is a summary of the scientific evidence indicating no eutrophication or undesirable algae impairment in the Niagara River AOC.

- The 90th percentiles of TP concentrations did not unequivocally meet the criterion of 30 ug/L; however, this was attributed to TP sources upstream from the Niagara River and out of scope of the RAP;
- Phosphate and chlorophyll *a* concentrations were generally equivalent to or less than those measured in unimpaired reference areas (SRP data were inconclusive);
- Dissolved oxygen (DO) concentrations were generally above the screening criterion of 6.5 mg/L. Of the two DO observations below 6.5 mg/L, impact to biota was not expected;
- Historical Secchi disc depth values in the Niagara River were generally on par with or better than current day values in unimpaired reference areas;
- The BUI is listed as Not Impaired on the New York side of the Niagara River (Niagara River New York RAP, 2012).

Therefore, it is recommended that the status of *Eutrophication or Undesirable Algae* for the Niagara River (Ontario) AOC be changed to "Not Impaired".

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1.0 Introduction

Algae, tiny plant-like organisms that are an important part of the food web, are the main source of food for planktivorous fishes and zooplankton. However, when algae are overabundant (often referred to as an algal bloom) they can cause disruptions to the aquatic ecosystem, result in fish kills, pose a risk to human health and/or impair recreational enjoyment of the waterbody (boating, swimming). Furthermore, cyanobacteria, also known as blue-green algae, can release a toxic chemical that may pose a risk to human health. This is the reason *Eutrophication or Undesirable Algae* is listed as one of the 14 potential beneficial use impairments (BUIs) in the Niagara River Area of Concern (AOC).

Eutrophication is the process by which a waterbody becomes overly enriched with nutrients. Pollution from human sources such as municipal and industrial wastewaters, agricultural runoff, fertilizers used on lawns and golf courses, and poorly maintained septic systems are sources of nutrients that can contribute to eutrophication of a waterbody. Natural sources of nutrients from sediments (due to erosion) can also contribute to eutrophication

The Niagara River is a 58 km binational connecting channel linking Lake Erie to Lake Ontario. Waters from Lake Erie, the most productive of the Great Lakes, flow rapidly into the Niagara River at a rate of 0.6 to 0.9 m/s and eventually discharge into Lake Ontario. Due to historical water quality pollution from human sources the Niagara River is one of 36 remaining Great Lakes Areas of Concern (AOCs) identified through the Canada-U.S. Great Lakes Water Quality Agreement (GLWQA) (refer to Appendix 1). As part of the requirement of the GLWQA, a Remedial Action Plan (RAP) was developed in collaboration with local residents, community groups, First Nations and Métis, government, scientists and industry to identify, guide and complete restoration efforts with the ultimate goal of improved environmental conditions and subsequent removal of the river from the list of Great Lakes AOCs, referred to as “delisting”. Delisting occurs when all locally-defined actions are completed and scientific evidence shows that beneficial water uses (be it ecological, recreational and economic) are restored. When something interferes with the functioning or enjoyment of a water use, it is called a beneficial use impairment (BUI). There are 14 potential BUIs (see list below) identified in the GLWQA (common to all AOCs) that the RAP uses to focus restoration needs, track progress and report on success. To find out more about the current status of all of the Niagara River’s BUIs and to track progress, visit our website: ourniagarariver.ca.

According to the Great Lakes Water Quality (2012), a BUI is **a reduction in the chemical, physical or biological integrity of the Waters of the Great Lakes to cause any of the following**:

1) restrictions on fish and wildlife consumption
2) tainting of fish and wildlife flavour
3) degradation of fish and wildlife populations
4) fish tumors or other deformities
5) bird or animal deformities or reproduction problems
6) degradation of benthos
7) restrictions on dredging activities
8) eutrophication or undesirable algae
9) restrictions on drinking water consumption, or taste and odor problems

10) beach closings
11) degradation of aesthetics
12) added costs to agriculture or industry
13) degradation of phytoplankton and zooplankton populations
14) loss of fish and wildlife habitat

Historically, the RAP defined the AOC as the Ontario side of the Niagara River including its watersheds extending to the headwaters of the Welland River (NRRAP, 1993). However, the boundaries of the Niagara River AOC were re-defined due to recent guidance from the GLWQA (2012) indicating the focus of AOCs is to include the "Waters of the Great Lakes and the connecting river systems of St. Mary's, St. Clair, Lake St. Clair, Detroit, Niagara, and St. Lawrence at the international boundary or upstream from the point at which the river becomes the international boundary between Canada and the United States, including all open and nearshore waters." The **Niagara River AOC is now defined as the connecting channel itself flowing from the mouth of Lake Erie to Lake Ontario** (Figure 1). The land area that drains into the river is referred to as the AOC watershed. Restoration efforts and the criteria for delisting the AOC are focused on the river itself but some projects are implemented in the AOC watershed, when deemed necessary, because of their potential impact to the River.

Although the Niagara River is identified as a bi-national AOC, there are separate but complementary RAP processes on both sides of the border. **This assessment is for the Ontario side of the Niagara River AOC only.**

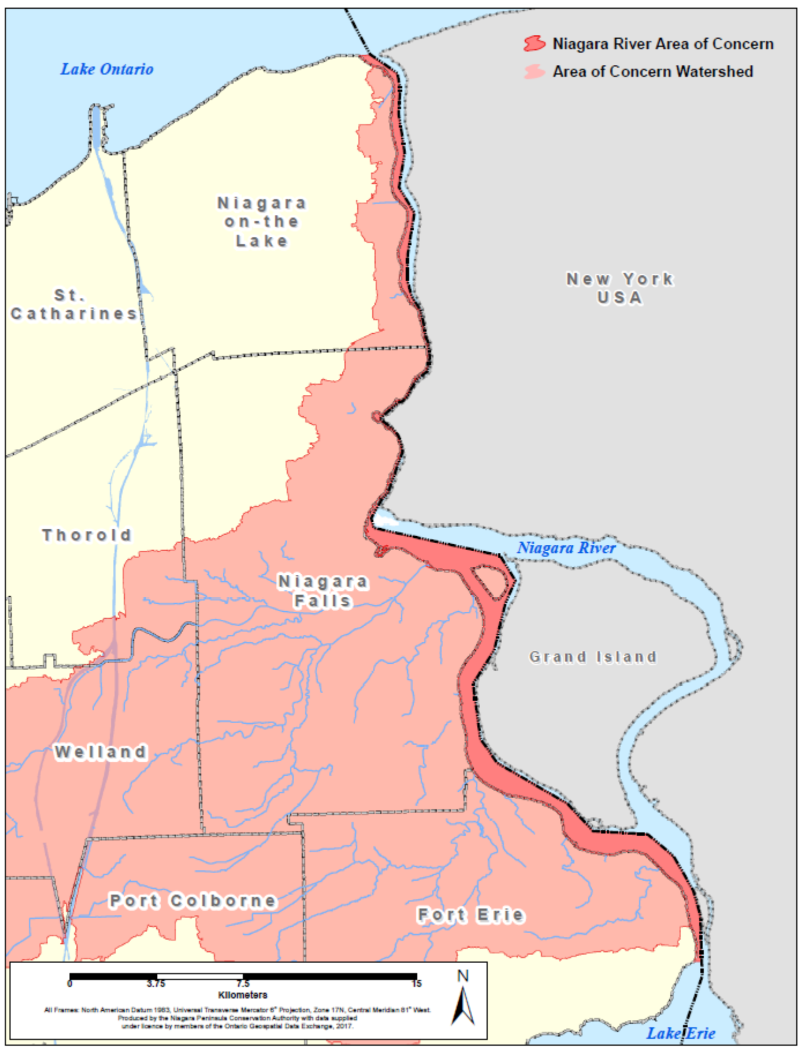

Figure 1 *(right)***:** Map showing the current extent of the Niagara River Area of Concern (Ontario side only) and a portion of its watersheds.

1.1 Historical review of the *Eutrophication or Undesirable Algae* BUI

According to the International Joint Commission (IJC), the Eutrophication and Undesirable Algae BUI applies "[w]*hen there are persistent water quality problems attributed to excessive nutrient discharges from point (end-of-pipe) or nonpoint (diffuse land uses) sources. Typically, the impairment manifests itself as nuisance or harmful algal blooms, dissolved oxygen depletion in bottom waters, and decreased water clarity"* (IJC, 2017). Locally-developed delisting criteria for this BUI were never historically developed. Instead, the RAP team recently used a scientific weight-of-evidence approach (as is used in other AOCs) to determine the status of *Eutrophication or Undesirable Algae* in the Niagara River (Ontario) AOC.

The Niagara River (Ontario) RAP process was initiated in 1989. Although a 1985 International Joint Commission (IJC) assessment indicated that the Niagara River did not suffer from eutrophication (NRRAP, 2013b), the status of the *Eutrophication or Undesirable Algae* BUI has undergone several status changes since the inception of the RAP (Table 1).

Table 1. A summary of the status of the *Eutrophication or Undesirable Algae* BUI in various RAP reports and the reason for the status.

Supporting Document	Status	Reason
1993 RAP Stage 1 Report	Eutrophication: Impaired	Accelerated eutrophication in the Welland River and tributaries of the Niagara River.
	Undesirable Algae: Not Impaired	Some algal species found but not at nuisance levels. Less desirable algae can be carried from Lake Erie but only occasionally.
1995 RAP Stage 2 Report	Eutrophication: Impaired	No change in status.
	Undesirable Algae: Not Impaired	
2009 RAP Stage 2 Update	Impaired	The Undesirable Algae portion was changed to Impaired (from "Not Impaired") because of observations of algae in the Welland River. No conclusion was given on the Niagara River. From this point on, the BUI was no longer considered in two parts.

The 1993 Stage 1 Report was the first major document to examine and identify environmental problems in the Niagara River AOC. The main concerns leading to the Niagara River being listed as an AOC were contamination in water, sediments and/or biota due to organic and/or inorganic substances, excluding phosphorus (NRRAP, 1993). Overall trends in the concentration of phosphorus in the Niagara River were examined between 1967 to 1981 which revealed a significant decrease of approximately 1 ug/L per year (NRRAP, 1993). However, the report indicated an exceedance of [Great Lakes] nutrient objectives for the Niagara River's tributaries, particularly for the Welland River due to low flow conditions and elevated nutrient levels in the summer months. The "Impaired" status of the *Eutrophication* component is linked to "accelerated eutrophication in the Welland River and parts of the Niagara River's tributaries", not the Niagara River itself. The report indicated very limited observations of algal growth and that no formal studies had been conducted to assess algal populations in the Niagara River. Filamentous algae were noted in an isolated area in the Welland River directly downstream of the Cyanamid plant but not at nuisance levels; therefore, the *Undesirable Algae* portion of the BUI was considered "Not Impaired" (NRRAP, 1993).

Immediately following the completion of the 1993 Stage 1 Report, the RAP Team began working on the Stage 2 Report to address the environmental concerns described in Stage 1. A concise set of 16 goals was outlined in the Stage 2 Report (Niagara River RAP, 1995). The status of the *Eutrophication or Undesirable Algae* remained unchanged from the 1993 Report but three of the goals included were related to the eutrophication impairment in the Welland River:

> *"Continually improve the quality of treated discharges of municipal and industrial sewage effluent with no spills or discharges causing fish kills or other undesirable impacts.*
>
> *Reduction and virtual elimination of Combined Sewer Overflows.*
>
> *Control nutrient loading levels to a point that excessive weed and algal growth do not occur."*

The goals in the 1995 Stage 2 Report were not finalized into an implementation plan until 2000 when the Niagara Peninsula Conservation Authority, Ontario Ministry of the Environment and Environment Canada entered into an agreement to coordinate the activities for the Niagara River RAP. A full review and update of the RAP Stage 2, including a technical review of the BUIs and their delisting criteria, began in 2004 with assistance from various local groups, industries, all levels of government and the general public. As a result of the review, the Stage 2 Update Report was completed in 2009 and provided science-based recommendations for changes to impairment status, delisting criteria (for BUIs other than *Eutrophication or Undesirable Algae*), and monitoring and assessment activities. Through the 2009 Stage 2 Update, the "Impaired" designation for the *Eutrophication* part of the BUI remained unchanged but the *Undesirable Algae* portion was changed to "Impaired" (from "Not Impaired") based on observations of algae in the Welland River (NRRAP, 2009). Furthermore, because there was an absence of key evidence of how the Welland River system was responding biologically to excess phosphorus, delisting criteria could not be recommended. Conditions in the Niagara River itself were not specifically discussed, and no evidence was presented which might suggest a new issue in the Niagara River proper (Niagara River RAP, 2013b).

Based on a recommendation in the Stage 2 Update, the Welland River Eutrophication Study Technical Working Group (TWG) was formed in 2008 to design and implement a project to collect further data towards the development of delisting criteria for the Welland River watershed Results from the 3-year study are summarized in the March 2011 final report (Diamond, 2011) and major findings were:

- The Welland River is a eutrophic watershed characterized by very high phosphorus concentrations. Mean total phosphorus (TP) concentrations ranged from 200% to 1500% greater than the Provincial Water Quality Objective depending on the subwatershed.
- Subwatersheds with especially high TP concentrations (mean > 0.4 mg/L) are Beaver Creek, Big Forks Creek and Oswego Creek.

- Biologically-available phosphorus concentrations generally increased as water moved downstream through the Welland River watershed but a decrease was noted in the lower reaches where mixing occurs with water from the Niagara River.

It is now recognized that the *Eutrophication and Undesirable Algae* issues of the Welland River (and largest tributary to the Niagara River) are not specific to the AOC and generally reflect conditions in Ontario with similar land use patterns (MOE, 2012). Also, the impact of the flow reversal near the mouth of the Welland River for hydroelectric power generation at the Sir Adam Beck Hydroelectric Generating Station contributes to the less than desirable water quality in the Welland River. However, the RAP Team recognizes that tributaries such as the Welland River can potentially contribute to adverse issues in the nearshore waters of the Great Lakes. As such, if a tributary is shown to be adversly affecting the Niagara River AOC, it will be investigated appropriately.

1.2 The U.S. Connection: Niagara River (New York) BUI status

The *Eutrophication or Undesirable Algae* BUI is “Not Impaired” for the U.S. side of the Niagara River AOC (Niagara River (NY) RAP, 2012). In summary, the 1994 Niagara River (New York) RAP report states that declines in phosphorus and chlorophyll *a* levels in Lake Erie between 1968 and 1985, along with high dissolved oxygen levels measured in the Niagara River and the absence of nuisance algal blooms or accumulation, are evidence that eutrophication is not a serious problem in the Niagara River (NYSDEC, 1994).

1.3 Purpose of Assessment

In keeping with the intent of the focus of GLWQA (2012) and due to absence of key evidence to confirm the status of the BUI in the Niagara River itself, the RAP Team agreed, in 2014, to pursue a science-based assessment. This study was commissioned to review all relevant data to determine the status of the *Eutrophication or Undesirable Algae* BUI for the Ontario portion of the Niagara River. If an impairment to this beneficial use was found, the assessment would also ascertain what impact, if any, does the Niagara River watershed (i.e., Welland River and other creeks that drain to the AOC) have on the Niagara River’s water quality.

2.0 BUI Assessment and Evaluation - Methodology

Evaluation of the status of a beneficial use in an Area of Concern (AOC) is typically conducted by comparing ambient monitoring data against specific delisting criteria. These criteria are developed by the Remedial Action Plan (RAP) for the AOC to reflect conditions deemed representative of a restored beneficial use. As outlined in Section 1.0 of this report however, the Niagara River RAP currently does not have delisting criteria for the Beneficial Use Impairment (BUI) *Eutrophication or Undesirable Algae.* Nonetheless, an evaluation of the BUI is still required to determine status because if impaired, it ultimately needs to be determined what remaining actions are still required to restore the beneficial use. As a first step in conducting an assessment of the *Eutrophication or Undesirable Algae* BUI in the Niagara River AOC, indicators that have been used in the evaluation of this impairment at other connecting channel AOCs were reviewed (Appendix III).

Based on their applicability and prevalence of use at other connecting channel AOCs, total phosphorus (TP), chlorophyll *a*, dissolved oxygen (DO) and Secchi disc depth were parameters selected for inclusion in the BUI evaluation for the Niagara River. In addition, any available ortho-phosphate (phosphate) and soluble reactive phosphorus (SRP) data were also included in this assessment, parameters which are measures of a more bioavailable form of phosphorus relative to TP. Although phosphate and SRP are not included in delisting criteria at other AOCs, the exclusion of these topical parameters at other AOCs is likely due to a lack of data or difficulty in their monitoring (Wetzel, 2001 in CCME, 2004) rather than the applicability or relevance of such indicators.

The parameters included in this assessment are comprehensive in nature as they measure various aspects of eutrophication including both chemical stressors and the response of the biological community. TP and phosphate and/or SRP are chemical stressors included as indicators and are measures of phosphorus, the nutrient which typically drives eutrophication (Schindler, 1977). As for measures of the biological response to eutrophication, chlorophyll *a* was included as it is a proxy for measuring algal density in water. Although not an ideal indicator for assessing primary productivity in a fast-flowing river, chlorophyll *a* is a standard metric among sampling programs and assessments of AOCs, and data on a potentially more meaningful biological metric for a river, such as periphyton density, are sparse or non-existent. Some of the potential negative impacts of eutrophication on water quality such as reduced water clarity (as measured by Secchi Disc depth) and low DO due to respiration from an overabundance of algae or the decomposition of such algae, were also included in the assessment.

Following the selection of indicators to be used in the assessment, the method for evaluating the data for these indicators was examined. Direct application of delisting criteria from other AOCs to the Niagara River AOC was not considered appropriate. For example, other AOCs likely have differences in underlying geology and biological response relative to the Niagara River. In addition, many delisting criteria for other AOCs describe conditions in both the adjacent watersheds and the connecting channel (e.g. St. Lawrence River (Cornwall) RAP), rather than just the connecting channel or “waters of the Great Lakes” in accordance with the

2012 Protocol (Appendix I). The spatial scope of this assessment is the Canadian side of the Niagara River proper from Fort Erie (FE) to Niagara-on-the-Lake (NOTL), as well Chippawa Creek and the Adam Beck power canal (Figure 2). Chippawa Creek and the Adam Beck power canal are included in this assessment because water in these areas is Niagara River water. At Chippawa, a flow reversal was historically engineered to divert water from the Niagara River to Chippawa Creek (lower Welland River) and subsequently the power canal, to meet the needs of the Adam Beck power plant. Other tributaries which outlet to the Niagara River were not considered in this evaluation unless it was demonstrated in the assessment the beneficial use is impaired in the Niagara River, and the tributaries could be directly linked to the impairment. As such, if conditions in the Niagara River are not considered degraded, the Niagara River watersheds were considered out of scope of this assessment.

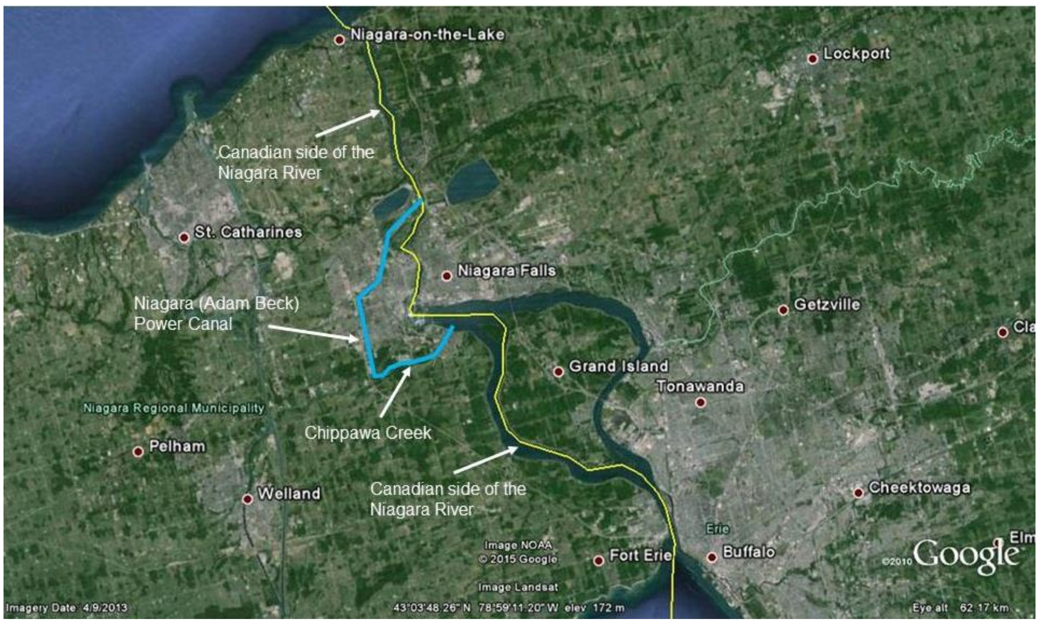

Figure 2: Map of the geographical scope of the *Eutrophication or Undesirable Algae* assessment for the Niagara River (Ontario) AOC, including the Canadian side of the Niagara River, the Niagara (Adam Beck) Power Canal and Chippawa Creek. Canada-United States international border is shown by a yellow line bisecting the Niagara River.

Although most indicators in this assessment were selected based on their use at other AOCs, the evaluation methods for the data were not based on what has been conducted at the other connecting channel AOCs (Appendix III). A method for evaluating the data for the five selected *Eutrophication or Undesirable Algae* indicators was required for the Niagara River AOC. A BUI evaluation method recently developed by the Toronto RAP, termed the “Tiered” approach, was considered highly applicable and pragmatic for use in the Niagara River. The “Tiered” approach was developed to assess beneficial uses in the absence of clear delisting criteria, and can be used for any indicator.

2.1 Application of “Tiered” Approach to BUI Assessment

The Toronto RAP’s “Tiered” approach is a transparent, science-based framework for assessing the impairment status of beneficial uses, and is especially relevant in the absence of clear delisting criteria (Toronto RAP, 2011). In addition to use by AOCs, this framework has also been used to develop watershed-specific targets in the Grand River watershed (Grand River Water Management Plan, 2013). This framework sets out the order in which three potential data evaluation methods, or “tiers”, are to be applied, and then based on the outcomes of these evaluations, makes a recommendation to the status of impairment and potential re-designation of the beneficial use (Figure 3). The tiers in order of their application in this framework are:

- Tier 1 – Acceptable guidelines or standards against which AOC conditions can be compared
- Tier 2 – Identification of appropriate reference sites against which AOC conditions can be compared
- Tier 3 – Weight-of-evidence - An unstructured approach to evaluating AOC conditions which makes use of available data to form lines-of-evidence towards an overall assessment of the potential for impairment. Lines-of-evidence may include identification of anomalies, temporal trends, spatial trends, etc.

This framework was used to evaluate the data selected for inclusion in the Niagara River *Eutrophication or Undesirable Algae* assessment, namely the TP, phosphate/SRP, chlorophyll *a*, DO and Secchi disc depth data. As the nature of each of these indicators or metrics differ in the availability of applicable guidelines or standards, or availability of similar data collected at an appropriate reference site, the tier against which each of these indicators will be evaluated is described in turn below.

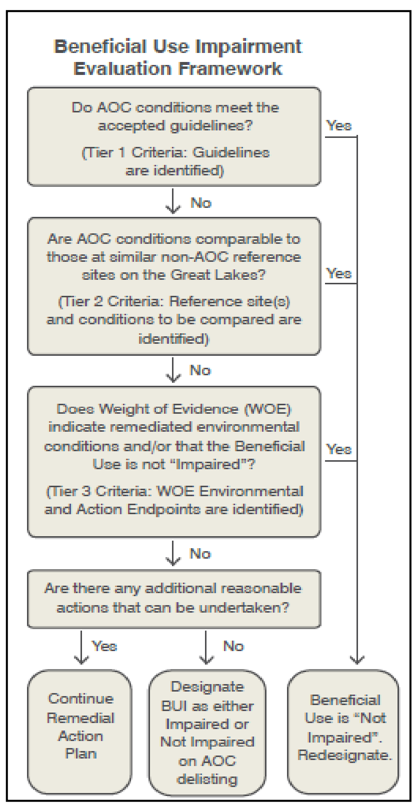

Figure 3 (*right*): Toronto RAP’s “Tiered” Beneficial Use Impairment Evaluation Framework
Source: Toronto RAP, 2011, p.9.

2.1.1 Tier 1 Assessment of Total Phosphorus (TP) and Dissolved Oxygen (DO)

A Tier 1 assessment of TP and DO concentrations in the Niagara River was conducted as there are relevant guidelines against which TP and DO concentrations can be evaluated. The TP concentrations were compared to the interim Provincial Water Quality Objective (PWQO) of 30 ug/L for TP in rivers which was set to prevent excessive plant growth (MOEE, 1994a). TP concentrations in the Niagara River were considered to meet the guideline if the majority (i.e. 90^{th} percentile) of recent data were below this benchmark. The choice of using the 90^{th} percentile over a mean or median value is a more conservative approach as it does not allow extreme values to occur as frequently. Relative to "average" conditions, extreme TP concentrations are more of a concern for eutrophication as they are believed to be a major driver behind the formation and/or promotion of algal blooms. Water quality guidelines and standards are designed such that each individual measurement can be evaluated for context against the benchmark, however, not all observed TP concentrations are required to be below the 30 ug/L target. It is recognized that some degree of environmental variability occurs naturally, and further, not all TP concentration peaks have a direct biological consequence. That is, elevated TP concentrations do not always result in an accumulation of undesirable algae as algal growth is determined by a number of different factors, not TP concentrations alone. Use of the 90^{th} percentile in an overall assessment is consistent with the allowable exceedance frequency endorsed by the US EPA (i.e. 10% allowable exceedance; US EPA, 1997). It is also consistent with recent changes and updates by the Hamilton Harbour Remedial Action Plan (HH RAP) to their TP concentration goal. Following a recent review, the HH RAP now allows a 10% exceedance frequency during each year's monitoring season to the TP goal of a maximum of 20 ug/L (HH RAP, 2012). It is important to note that use of the 90^{th} percentile is more conservative (protective) than the Ontario Ministry of the Environment's "Green Book" default of using a 75^{th} percentile standard to determine acceptable background water quality in evaluations of surface water bodies in Ontario (MOEE, 1994b).

Other relevant phosphorus benchmarks were also examined, but were not considered appropriate for the context of the Niagara River Eutrophication Assessment. While there is a Great Lakes Water Quality Agreement (GLWQA) TP target of 10 ug/L, this target is for the open waters of the lower Great Lakes and use of it in a connecting channel such as the Niagara River is not an appropriate application of the target. TP processes differ between lakes and rivers, as reflected by the higher PWQO for TP in rivers and streams of 30 ug/L relative to the PWQO for TP in lakes of 10-20 ug/L. There is no GLWQA target for connecting channels, which themselves are unique surface water bodies due to the vast volume of water moving quickly between the lakes.

Additionally, there is no federal Canadian Water Quality Guideline (CWQG) for phosphorus, although the Canadian Council of Ministers of the Environment (CCME) do have a guidance framework which accommodates the non-toxic endpoint associated with phosphorus loading and permits site-specific management of phosphorus based on desired trophic status and pre-defined "trigger ranges" (CCME, 2004). Because use of the CCME approach requires that reference conditions are established to determine which "trigger range" will be used for comparison to the site of interest, this approach is more consistent with a “Tier 2” rather than “Tier 1” assessment. Nonetheless, the PWQO of 30 ug/L is in the CWQG “meso-eutrophic” trigger-range of 20 – 35 ug/L for lakes and rivers, thus use of the PWQO is consistent with the CWQG approach whereby TP concentrations below 30 ug/L should prevent eutrophication. Alternative TP targets have recently been developed through other processes and resulted in the Ontario Ecoregion Phosphorus Guidelines (Gartner Lee Limited, 2006) and the National Agri-Environmental Standards Initiative (NAESI) (Chambers et al., 2008). Application of these guidelines are also not applicable, however, as the frame of reference for these approaches is undisturbed conditions (Grand River Water Management Plan, 2013) which is inconsistent with the goals of a RAP which are intended to restore beneficial uses, not restore water quality to pristine or pre-colonial conditions.

The DO concentrations in the Niagara River were also compared to relevant guidelines, specifically the PWQOs, as well as the federal CWQGs. DO guidelines are designed to be protective of fish, and are based on the different habitat needs of warmwater and coldwater fish communities. As the Niagara River supports a diversity of fish communities including coldwater species such salmon and trout which have more stringent DO requirements, selection of coldwater DO guidelines is the more conservative approach. The coldwater species PWQO is a range in DO concentrations spanning different ambient temperatures; at the upper end of the temperature range, DO concentrations should be a minimum of 5 mg/L at 25°C, and at the lower end of the range, DO should have a minimum concentration of 8 mg/L at 0°C (MOEE, 1994a). Similarly, the coldwater CWQG for DO has more than one guideline, but is based on life stage, with a minimum DO concentration of 9.5 mg/L for early life stages, and 6.5 mg/L for all other life stages (CCME, 1999). Due to the differences in recommended DO concentrations by the available guidelines and the variable nature of DO needs pending ambient temperatures and/or biotic life stage, DO concentrations in the Niagara River were initially screened against the CWQG of 6.5 mg/L for non-early life stages, which corresponds to the PWQO for coldwater biota down to a temperature of 5 – 10°C. The more conservative CWQG of 9.5 mg/L and PWQO of 8 mg/L at 0°C, both for coldwater species, were not used in the initial screening as these DO guidelines were considered overly conservative given the context of the assessment. RAPs are intended to mitigate BUIs, rather than restore water quality to pristine conditions. For any measured DO concentrations below 6.5 mg/L, further analysis was then conducted to assess whether a less stringent DO guideline might be appropriate due to the ambient temperatures at the time of the measurement, or if data in fact suggested potential stress on aquatic biota.

During this assessment, the context of DO as a secondary indicator of eutrophication was considered. The PWQO and CWQG for DO reflect the direct habitat needs of fish and are not designed to be indicative of an oxygen deficit due directly to eutrophication processes. The DO guidelines are nonetheless still relevant for indicating if DO concentrations in the Niagara River are less than optimal, and thus, impaired. If DO concentrations were to be considered impaired, other lines-of-evidence would be needed to determine whether nutrient-driven processes were the cause of low DO, or if other factors outside the scope of this assessment (e.g. high loadings of substances with high biological oxygen demand (BOD), nitrogeneous oxygen demand (NOD) or chemical oxygen demand (COD)) were likely the primary cause of hypoxia or anoxia.

2.1.2 Tier 2 Assessments of Phosphate and Chlorophyll *a*

There are no relevant guidelines against which phosphate and chlorophyll *a* concentrations in a river or connecting channel can be evaluated. As a result, a Tier 2 assessment of phosphate and chlorophyll *a* concentrations in the Niagara River was conducted using data collected in reference areas. Other AOCs are generally not recommended for use as reference sites as specified in the “Tiered” approach (Figure 2), however, all connecting channels on the Great Lakes have AOCs which suggests that a Tier 2 approach cannot be used for connecting channels on the Great Lakes. In this assessment focused on one BUI however, other connecting channels will be used as reference sites because *Eutrophication or Undesirable Algae* is not impaired in the Detroit River and St. Clair River AOCs, and in the main channel of the St. Lawrence River (Cornwall) AOC (only watersheds are impaired); the rationale for the unimpaired status of this BUI at these three AOCs are outlined in Appendix III. As such, available phosphate and chlorophyll *a* data from the Detroit River, St. Clair River and St. Lawrence River were considered reference site conditions for the Niagara River in the strict context of evaluating the beneficial use *Eutrophication or Undesirable Algae*. Important to note in this report, the St. Lawrence River as a reference area only refers to the Ontario portion of the river, that is, from Wolfe Island to Cornwall. Conditions in the Niagara River were considered unimpaired with regard to *Eutrophication or Undesirable Algae* if recent data were comparable to or better than current day conditions in the connecting channel reference areas.

2.1.3 Tier 3 Assessment of Soluble Reactive Phosphorus (SRP) and Secchi Disc Depth

Reference area data for soluble reactive phosphorus (SRP) concentrations were not available so a Tier 3 assessment on the Niagara River data was conducted. A spatial comparison was conducted to determine any increases in SRP concentration along the length of the river which might suggest a Niagara River source. SRP data were evaluated by comparing all available data for each location and monitoring program against one another. Statistically significant differences among locations were determined by the Kruskal-Wallis statistical test and subsequent Mann-Whitney pairwise comparisons. Statistics were run in the PAST software package (Hammer, 2009) and results were considered statistically significant for p-values less than 0.05. Time trends in SRP concentrations were also examined as increasing concentrations over time may be indicative of a problematic SRP source.

A Tier 3 or weight-of-evidence approach was also used to evaluate Secchi disc depth as recent (collected within the past decade) Secchi disc depth data were not available for the Niagara River. Historical data are however available, and these data were examined for long-term temporal trends as a line-of-evidence on the impairment status of this indicator. In addition, the magnitude of historical Secchi disc depths were compared to those recently measured in reference areas as another line-of-evidence. Instead of using the 90th percentile to evaluate whether the majority of the data reflected desirable water clarity, the 10th percentile was used as greater Secchi disc depths (greater water clarity) are more desirable than smaller depths (reduced water clarity), the converse of the situation when examining chemical parameters such as TP concentrations. A spatial trend along the length of the river (i.e. a comparison between upstream and downstream concentrations) was not conducted because it was hypothesized that the falls and turbulence of the lower Niagara River increase suspended sediment concentrations which in turn influences Secchi disc depth. As such, it is suspected that a comparison of water clarity between the upper and lower Niagara River would not reveal meaningful data on any difference in algal density between these two stretches of the Niagara River as water clarity data may be overwhelmed by inorganic particulate which is a result of the hydrology of the River.

Further to this caveat about use of Secchi disc depth as a non-ideal proxy for algal density in an environment such as the Niagara River, this assessment further acknowledges that use of this metric is not ideal simply due to the high velocity of the Niagara River. In many cases, only rough estimates of Secchi disc depth could be made by survey crew, especially in the Upper Niagara River. The deployed Secchi disc extended out behind the survey vessel at some distance due to the strong currents, and due to the extreme angle of the line, the gauged depths were not accurate (C. DeBarros, 2013, pers. comm.). The extensive nature of caveats for use of Secchi disc depth suggest that little would be lost from eliminating this metric from the suite of indicators used in this assessment, however, Secchi disc depth data that are available are presented to be consistent with use of this indicator at other AOCs and to ensure due diligence was conducted in this assessment. Care was taken to not over-interpret the available Secchi disc depth data, and caution was employed to ensure that any conclusions based on this metric followed common sense given trends observed for other metrics and parameters.

2.1.4 Evaluation of all Indicators to Form Overall Impairment Status

Following the independent assessments of TP, phosphate/SRP, chlorophyll *a*, DO and Secchi disc depth data, findings from each of these five assessments were used together to form an holistic evaluation of the *Eutrophication or Undesirable Algae* beneficial use. Nutrient concentrations were interpreted with caution because as mentioned previously, elevated nutrient concentrations do not always result in an accumulation of undesirable algae. This is especially relevant for rivers where scouring due to high flow or flow through may prevent formation of local algal blooms. It is the biological response which is the utmost concern, as controlling levels of the chemical stressors such as TP and phosphate/SRP are only a means to an end, as understood through the context of the PWQO for TP which was set for the protection against "excessive plant growth" (MOEE, 1994a).

In addition, it is reasonable to assume that one or more metrics may be more greatly influenced by factors other than eutrophication, and may be reflecting issues out of scope of this assessment. For example, low DO concentrations can result from the presence of oxygen-demanding chemicals in the water, rather than the decomposition of algae near the sediment bed. Similarly, low Secchi disc depths or water clarity can result from high concentrations of seston (suspended solids), rather than high algal densities. Further, the geographical scope of this assessment was another caveat in the interpretation of data. Designation of a BUI is contingent on the source of the issue being within the boundary of the AOC. As illustrated in Figure 3, the final question in the "Tiered" approach is "Are there any additional reasonable actions that can be undertaken?" If a source is shown to originate upstream from the AOC boundary, it is also out of scope as the source cannot be addressed by management actions of the Niagara River RAP. Thus, it is the impairment status suggested by the majority of the indicator assessments and emphasis on the biological-response metrics and geographical scope that was used to determine the overall status of *Eutrophication or Undesirable Algae* for the Niagara River AOC.

2.2 Data Sources

Existing data collected by Environment Canada (EC), the Ontario Ministry of the Environment and Climate Change (MOECC), the Niagara Peninsula Conservation Authority (NPCA), New York State Department of Environmental Conservation (NYSDEC) and State University of New York (SUNY) at Brockport were used to assess the eutrophication status of the Niagara River. Data collected over the past 10 years (2003 to 2013) were used to characterize current conditions, and any historical data (collected up to and including 2002) were only used in in the assessment if there was a gap in the dataset for the past decade. Although not within the Niagara River (Ontario) AOC boundary, data collected from the American side of the lower Niagara River were also considered in this assessment to increase sample size and to be as comprehensive as possible given scarcity of data for some parameters. Although the data collected by NYSDEC and SUNY at Brockport were a vital part of this assessment due to data gaps in the Canadian monitoring programs, there is a caveat to the inclusion of data collected from the American side of the Niagara River. "While there have not been any definitive source inputs identified along the lower reach of the river, any contaminant inputs downstream of the rapids would not be well mixed and would tend to flow along the shoreline from which they were released" (Hill and Klawunn, 2011).

Programs and data sources that were used in the *Eutrophication or Undesirable Algae* assessment for the Niagara River include:

- EC's Upstream/Downstream (US/DS) monitoring program;
- MOECC's Great Lakes Unit monitoring data;
- MOECC's Drinking Water Surveillance Program (DWSP);
- NPCA's monitoring data for Chippawa Creek/Niagara power canal;
- NYSDEC data;
- SUNY Brockport data.

Additional data sources that were considered for this study include MOECC's West Central Region Technical Support Section's monitoring data, and the MOECC's Great Lakes Intake Program data; however, no data within scope were available from these monitoring programs. The Niagara Falls drinking water plant is not included in the Great Lakes Intake Program which focuses on long-term trends of nutrient status and phytoplankton in the Great

Lakes. Fort Erie's Rosehill water treatment plant is included in the Great Lakes Intake Program, however, data from this plant was determined to be outside of the geographical scope of this eutrophication assessment as water is drawn from Lake Erie, not the Niagara River. All the data sources used in this eutrophication assessment are described in turn below.

2.2.1 Environment Canada's Upstream/Downstream (US/DS) Program

For the past few decades, Environment Canada has collected water quality data at monitoring stations at Fort Erie (FE; upstream location) and Niagara-on-the-Lake (NOTL; downstream location) with the primary goal of quantifying Niagara River sources of contaminants. Details of the upstream/downstream (US/DS) program including frequency of sampling, sampling protocols and analytical methods are described elsewhere (Hill and Klawunn, 2011). TP and SRP data collected since 1975 were compiled for this evaluation; EC has no data for chlorophyll *a*, DO or Secchi disc depth.

2.2.2 Ontario Ministry of the Environment and Climate Change's Great Lakes monitoring data

The MOECC's Great Lakes monitoring staff have been collecting water quality data in the Niagara River for the past few decades for a variety of projects and surveys. These data were initially collected by the Ontario Water Resources Branch, but are now collected by the Great Lakes Monitoring Unit at the MOECC's Environmental Monitoring and Reporting Branch. Data collected since 1967 were available for the Niagara River eutrophication assessment and included data on TP, phosphate, chlorophyll *a*, DO and Secchi disc depth.

Phosphate, chlorophyll *a* and Secchi disc depth data from the Detroit River, St. Clair River and St. Lawrence River, also collected through MOECC Great Lakes monitoring programs, were used in the Niagara River eutrophication assessment to establish reference area conditions where appropriate. Important to note is that DO data collected by the MOECC are spot measurements and not from deployment of continuous data loggers.

2.2.3 Ontario Ministry of the Environment and Climate Change's Drinking Water Surveillance Program

The MOECC's Drinking Water Surveillance Program (DWSP) was initiated in 1986 and collects raw water samples from intakes at select water treatment plants (WTPs) in Ontario for research purposes. The WTP for the City of Niagara Falls, Ontario, is included in the DWSP program, and is described as follows:

The Niagara Falls Water Treatment Plant (WTP) draws its water from the Chippawa Creek, which is the portion of Welland River just upstream of the point of confluence with the Niagara River. At this point, the normal flows of the Welland River have been artificially reversed by an Ontario Power Generation hydroelectric plant diversion. The plant's raw water is therefore taken from the Niagara River (P. McInnis, 2013, pers. comm).

Chlorine is occasionally added to the raw water to address zebra mussel fouling of the water intake pipes at the WTP, and as such, many of the raw water samples are chlorinated. As chlorine is a strong oxidant and can impact the nature of the ambient water quality, samples in the database were flagged as to whether each raw water sample had been chlorinated for zebra mussel control. The detection of any one of the following chemicals indicates chlorination:

- *Total trihalomethanes (THMs)*
- *Chloroform*
- *Bromodichloromethane*
- *Dibromochloromethane*
- *Bromoform*
- *Dichloroacetonitrile*
- *Field free chlorine residual*
- *Field combined chlorine residual*
- *Field total chlorine residual* (P. McInnis, 2013, pers. comm.)

Samples which showed evidence of chlorination were flagged, but were still included in the assessment of eutrophication of the Niagara River. TP and phosphate data collected under the DWSP program did not demonstrate any clear bias according to whether the sample had been chlorinated (Figure 4).

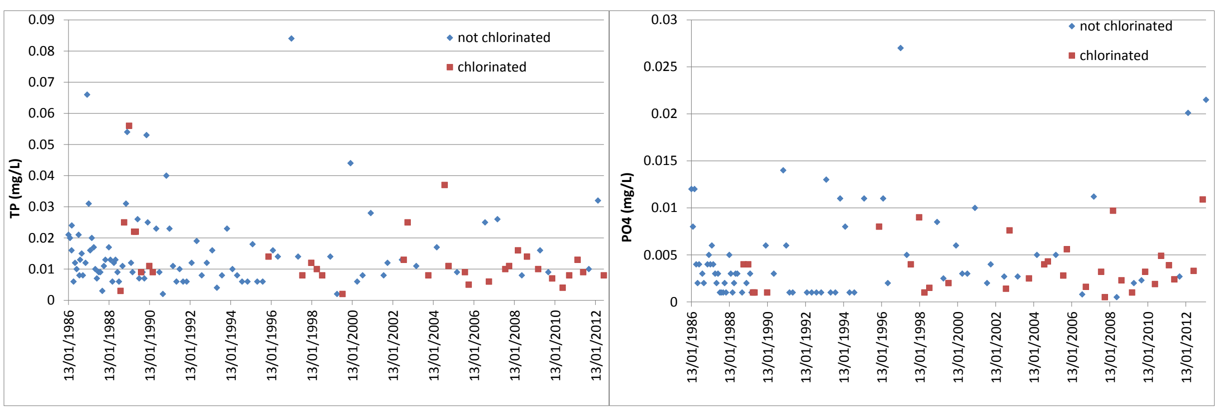

Figure 4: Time series of TP (left) and phosphate (right) concentrations in raw intake water at the Niagara Falls WTP, as presented by samples that were and were not chlorinated for zebra mussel control.

In addition to the WTP for the City of Niagara Falls, additional WTPs that participate in the DWSP program were also included in the eutrophication assessment as reference areas for phosphate concentrations. These reference WTPs have source water from the St. Clair, Detroit and St. Lawrence Rivers as outlined in Table 2.

Table 2: Water Treatment Plants included in the DWSP program that have source water from the St. Clair, Detroit or St. Lawrence Rivers and were sampled in 2003 - 2013

Water Treatment Plant Name	Source Water
Amherstburg Drinking Water System	Detroit River
Brockville Drinking Water System	St. Lawrence River
Chatham-Kent Drinking Water System - Wallaceburg	St. Clair River via Chenal Ecarte
City of Windsor Drinking Water System	Detroit River
Glen Walter Drinking Water System	St. Lawrence River
Lambton Area Water Supply System	St. Clair River
Prescott Drinking Water System	St. Lawrence River
Tecumseh Water Treatment Plant	Detroit River
Walpole Island Water Treatment Plant	St. Clair River via Chenal Ecarte

2.2.4 Niagara Peninsula Conservation Authority's monitoring data for Chippawa Creek/Niagara power canal

In 2012 and 2013, the NPCA in collaboration with the Region of Niagara conducted water quality monitoring at a number of stations in the Niagara Region. Station PR001 (43.125°N, 79.081°W) is located within the geographical scope of this assessment as it is in the Chippawa Creek/Niagara power canal at Whirlpool Road, Niagara Falls. Water quality samples collected from this station were submitted for analysis for a broad suite of parameters, including TP and phosphate. In-situ water quality measurements were also collected using a YSI probe, and the DO data collected in this monitoring was also included in the Niagara River eutrophication assessment. Important to note is that these DO data are spot measurements and not from deployment of continuous data loggers.

2.2.5 New York State Department of Environmental Conservation (NYSDEC) monitoring data for the Niagara River

NYSDEC has a sampling station in the Niagara River near Youngstown, New York (Station ID: 21NYDECA), which has water column samples collected 6 times each year in the time period from April to October (M. Novak, 2013, pers. comm.). Samples have been collected at the site for approximately 25 years. The data are maintained on the United States

Environmental Protection Agency (US EPA) STORET national data warehouse, which can be accessed from the EPA website or through the national water quality portal at http://www.waterqualitydata.us/.

2.2.6 State University of New York (SUNY) at Brockport monitoring data for the Niagara River

Water quality data were collected 4 to 16 times per year from two locations in the Niagara River by SUNY at Brockport for 2003-2005, 2007, 2009 and 2013. Both stations are located near Youngstown, New York, although one station is located near the shoreline (43.2597° N, 79.0580° W) and one is located mid-channel (43.2576° N, 79.0602° W), close to the Canada-United States international border. The 2013 mid-channel data were collected by the United States Fish and Wildlife Service. All the water quality analyses were done in the SUNY Brockport ELAP certified lab (J. Makarewicz, 2013, pers. comm.).

3.0 BUI Assessment and Evaluation – Results and Discussion

3.1 Total Phosphorus

Total phosphorus (TP) concentrations underwent a Tier 1 assessment and samples collected from the Niagara River over the past decade were compared to the PWQO of 30 ug/L. TP concentrations demonstrated high variability among datasets, and variability was high even within a single sampling station and dataset. As such, there was inconsistency in results among the datasets as the 90th percentile of TP concentrations collected through MOECC's DWSP monitoring, NYSDEC's monitoring, and SUNY's Brockport monitoring (both shoreline and mid-channel) met the PWQO of 30 ug/L, while the 90th percentile of TP concentrations collected through NPCA's Chippawa Creek/Niagara Power Canal monitoring and EC's US/DS monitoring program (FE and NOTL) did not meet the PWQO of 30 ug/L (Table 3).

Initially in this eutrophication assessment, TP data collected through EC's US/DS program were flagged as potentially anomalous as these TP concentrations were substantially higher relative to results collected through other agency monitoring programs. In particular, the comparison between TP concentrations measured at EC's NOTL station with NYSDEC and SUNY Brockport samples was notable given two-fold higher TP concentrations at NOTL despite the close proximity with the monitoring stations on the US side of the Niagara River.

In part due to the large difference in TP concentrations obtained through the US/DS program relative to other Niagara River data, EC initiated a Quality Assurance/Quality Control (QA/QC) investigation into their dataset. Initial findings have suggested that TP concentrations collected under the auspices of EC's US/DS monitoring program are valid (B. Hill, 2015, pers. comm.). Although a final report on EC's QA/QC investigations is pending, the preliminary assessment of the US/DS dataset has suggested that TP concentrations may be higher relative to other sampling programs because the higher sampling frequency of the US/DS program is capturing more of the peak or extreme TP concentrations occurring in the Niagara River (B. Hill, 2015, pers. comm.). Peak concentrations may be driven by storm events or other infrequent incursions not readily captured through *ad hoc* or infrequent monitoring programs.

Table 3: Summary table of recent TP concentrations (ug/L) in the Niagara River according to data source and/or dataset.

Data source/Program (Agency)	Spatial extent	Years included	Number of data points (n)	90th Percentile	Mean (standard deviation)	Min	Max
DWSP (MOECC)	Niagara Falls WTP intake, Chippawa Creek	2003 - 2013	27	25.4	12.9 (8.1)	4	37
Chippawa Creek/Niagara Power Canal monitoring (NPCA)	Chippawa Creek/Niagara Power Canal	2012 - 2013	10	40	19.0 (12.0)	<10 (less than detection limit)	40
US/DS program (EC)	Fort Erie (FE) station	2003 - 2013	474	75	33.1 (37)	2.8	367
US/DS program (EC)	Niagara-on-the-Lake (NOTL) station	2003 - 2013	465	65.5	35.1 (34.7)	3.5	305
NYSDEC	Youngstown, NY station	2003-2007; 2009-2010; 2012	48	17.5	11.6 (5.3)	4.8	30.9
SUNY Brockport	Shoreline station near Youngstown, NY	2003-2005, 2007, 2009, 2013	29	24.5	17.4 (13.4)	6.5	60.8
SUNY Brockport	Mid-channel station near Youngstown, NY	2013	11	21.7	15.2 (5.9)	7.1	27.6

Notes:
No recent TP data for MOECC's Great Lakes Monitoring Program in the Niagara River. NPCA dataset had one of 10 datapoints less than detection limit (<10 ug/L); this value was assumed to be at the detection limit of 10 ug/L to calculate the 90th percentile, mean and standard deviation of the dataset, so summary stats represent an upper limit.

Additionally, the US/DS monitoring program collects samples year-round, while many other monitoring programs are focused only on the summer ice-free season, typically from May to September. Empirical evidence that many of the TP concentration spikes occurred during the October to April period was observed in the US/DS dataset (Figure 5), further lending support to seasonal variability as an explanatory factor for differences in results among sampling programs. Watershed sources of TP can be as high in winter as other seasons (Long et al., 2014) or even higher than other seasons (MOE, 2012), meaning year-round sampling programs such as the US/DS program are needed to capture the full range of TP concentrations present in the Niagara River. The nature of the differences among sampling programs may also explain why recent TP concentrations collected under the US/DS program also appear higher than the historical (1969 – 1983) TP range of 13 ug/L to 40 ug/L along the length of the Niagara River (Chan and Clignett, 1978; Kuntz, 1988; Post et al., 1987; Kauss, 1983; OWRC, 1970). As TP concentrations are highly variable, sampling conditions should be similar between any two datasets for a comparison to have meaningful results.

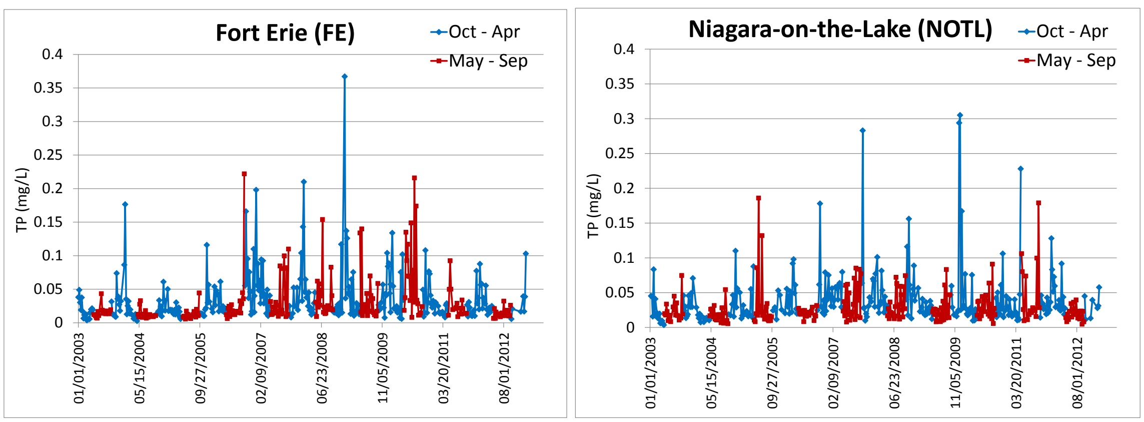

Figure 5: Recent (2003 – 2013) TP concentrations measured through Environment Canada's Upstream/Downstream (US/DS) monitoring program at Fort Erie (FE) and Niagara-on-the-Lake (NOTL).

As the US/DS monitoring program dataset is the largest and most comprehensive dataset included in this assessment, further analysis was conducted to obtain greater context on the data and its meaning to the assessment of the BUI. A full spatial analysis of the data collected within the AOC is beyond the scope of this assessment, however; the upstream and downstream locations of the FE and NOTL monitoring stations on the Niagara River provide greater context to the data especially with regard to scoping local AOC versus upstream or regional TP sources. The 90^{th} percentile of TP concentrations collected under the US/DS program fail the criterion of 30 ug/L at Fort Erie, the location where water first enters the Niagara River AOC. These findings suggest that upstream sources are contributing high levels of TP to the Niagara River AOC; potential sources include the Buffalo waste water treatment plant (WWTP) / Buffalo River (OWRC, 1970; Kauss, 1983; Plumb and Sweeney, 1980) and the nearshore of eastern basin of Lake Erie where Cladophora are problematic (Lake Erie LaMP, 2009).

Additionally, there was no significant difference between 2003-2013 TP concentrations at the FE and NOTL stations ($t = 0.85$, $p_{(two\text{-}tailed)} = 0.39$) suggesting minimal TP sources being contributed from within the AOC boundary relative to upstream sources. This finding is consistent with historical investigations on the Niagara River which demonstrated an absence of major phosphorus sources in the Chippawa Channel of the Niagara River (the Canadian side of Grand Island in the upper Niagara River) and the lower Niagara River (Kauss, 1983). That is, although the Welland River and other tributaries to the Niagara River may have local impacts, they do not appear to be overall directly impacting TP concentrations in the Niagara River; TP concentrations at the Niagara River inflow is equivalent to that at the outlet. Should a desire exist to reduce TP concentrations in the Niagara River, management actions will need to target upstream sources which are outside the scope of the Niagara River (Ontario) RAP.

Another important consideration in placing the TP concentrations into context is that during the time period when the AOC was being declared and the establishment of the Niagara River RAP Stage 1 Report, *Eutrophication or Undesirable Algae* was considered unimpaired for the Niagara River proper (see Section 1.1.3). The little change in TP concentrations between historical conditions considered as "unimpaired" relative to recent conditions at both FE and NOTL (Figure 6) are another line-of-evidence that TP concentrations should remain considered as "unimpaired".

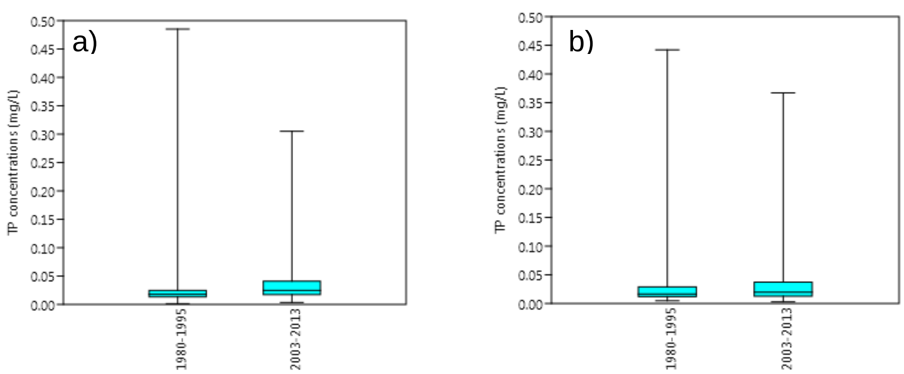

Figure 6: Boxplot comparison of historical (1980-1995) versus recent (2003-2013) TP concentrations collected under EC's US/DS program for: a) Niagara-on-the-Lake (NOTL) station; and b) Fort Erie (FE) station.

3.2 Phosphate and Soluble Reactive Phosphorus (SRP)

As mentioned in Section 2 of this report, one reason phosphate and soluble reactive phosphorus (SRP) have not been incorporated into the suite of delisting parameters at other AOCs is the challenge associated with the monitoring and analysis of these forms of phosphorus. Variability in sampling and analysis protocols among the different agencies and labs which have collected samples and reported phosphate and SRP data was an issue that was encountered in this assessment as well. It was found that the differences in reporting among laboratories were not always clear and further, it is questioned if results were different among labs and studies because there was a real difference in phosphate or SRP concentrations, or if results were simply not directly comparable between labs. For example, some labs reported “phosphate as P” and others “phosphate as PO_4”, and if it was known which of these two analysis methods was used, a conversion factor was used to standardize the reported results to “phosphate as P”. Such was the case for the NPCA phosphate data, and “phosphate as PO_4” as reported by the lab was converted to “phosphate as P” for use in this report by multiplying by 0.326 (J. Diamond, 2013, pers. comm.). This increased the comparability of the NPCA data; however, often labs do not specify the reporting metric making such anomalies in other datasets unknown.

Other reasons why data may not be directly comparable include the resolution of the reporting increments, and differences in detection limits. While such issues are always present when comparing data among different labs and agencies, it is especially pronounced for phosphate. For example, the NPCA dataset has phosphate reported in increments of 10 ug/L and has a detection limit of 30 ug/L; because the resolution in the reporting increments is large relative to the actual magnitude of ambient phosphate concentrations in the Niagara River, and the detection limit is the same as the PWQO for total phosphorus (of which a portion is composed of phosphate), little can be gained from data at this resolution except for using the results to screen for anomalously high phosphate concentrations indicative of a clear problem. This reporting framework introduces a high degree of imprecision into the reported data. Despite all these noted data quality concerns, the available phosphate and SRP data are reported with caveats in this report, and because of the overall uncertainty in the results, a greater difference between Niagara River data and reference area data would be required to declare an impairment, relative to other parameters where uncertainty in the reported results is not as great.

Recent phosphate concentrations were available for Chippawa Creek as well as the main channel of the Niagara River (Table 4). The 90^{th} percentile phosphate concentration was 11.0 ug/L for the Niagara Falls WTP intake and 8.9 ug/L for the NYSDEC data collected at Youngstown, NY; a 90^{th} percentile was not calculated for the NPCA Chippawa Creek/Niagara Power Canal dataset as 6 of the 9 datapoints were less than the detection limit, and results would not be meaningful. As there is no water quality guideline for phosphate, a Tier 2 assessment was undertaken in that Niagara River phosphate concentrations were compared to those in the Detroit River, St. Clair River and St. Lawrence River references areas (Table 5).

Table 4: Summary table of recent phosphate concentrations (ug/L) in the Niagara River.

Data Source/Program	Spatial extent	Years included	Number of data points (n)	90th Percentile	Mean (standard deviation)	Min	Max
DWSP (MOECC)	Niagara Falls WTP intake, Chippawa Creek	2003 - 2013	29	11.0*	4.9 (5.2)*	<0.5 (less than detection limit)	21.5
Chippawa Creek/Niagara Power Canal monitoring (NPCA)	Chippawa Creek/Niagara Power Canal	2012 - 2013	9	n/a (6 of 9 datapoints below detection limit)	n/a (6 of 9 datapoints below detection limit)	<10 (less than detection limit)	10
NYSDEC	Youngstown, NY station	2006-2009; 2011-2012	36	8.9*	5.5 (4.6)*	<2 (less than detection limit)	25.1

Notes: No recent phosphate data for EC's US/DS program or MOECC's Great Lakes Monitoring Program in the Niagara River. NPCA phosphate data was reported as "phosphate as PO4"; these values were converted to "phosphate as P" for reporting in this table by multiplying "phosphate as PO4" results by 0.326. NYSDEC phosphate data was a mix of numerous reporting metrics (phosphate as P, phosphate as PO4, total, dissolved, etc.); as such, those metrics that were not believed to be comparable to the rest of the dataset were removed from the above summary.

*DWSP (MOECC) dataset had 2 of 29 datapoints less than detection limit (<0.5 ug/L) and the NYSDEC dataset had 6 of 36 datapoints less than detection limit (<2 ug/L). The <DL values were assumed to be at the detection limit to calculate the 90th percentile, mean and standard deviation of each dataset, so summary stats represent an upper limit.

Table 5: Summary table of recent phosphate concentrations (ug/L) in reference areas (St. Clair, Detroit and St. Lawrence Rivers).

Data Source/Program (Agency)	Spatial extent	Years included	Number of data points (n)	90th Percentile	Mean (standard deviation)	Min	Max
Great Lakes Monitoring Program (MOECC)	Detroit River (Station 176)	2004, 2007, 2010	16	5.4	2.5 (1.2)	DL (0.5)	6.3
Great Lakes Monitoring Program (MOECC)	St. Clair River	2004, 2007	7	1.5	0.84 (0.83)	DL (0.5)	2.7
Great Lakes Monitoring Program (MOECC)	St. Lawrence River (Stations 126, 128, 424)	2006, 2009, 2012	29	4.7	2.1 (1.6)	DL (0.5)	5.4
DWSP (MOECC)	Amherstburg Drinking Water System	2003 - 2013	29	24.2	11.5 (11.1)	1.8	46.6
DWSP (MOECC)	Brockville Drinking Water System	2003 - 2013	30	5.3	3.2 (1.8)	DL (0.5)	7.5
DWSP (MOECC)	Chatham-Kent Drinking Water System - Wallaceburg	2003 - 2013	36	6.5	2.7 (2.3)	DL (0.5)	8.2
DWSP (MOECC)	City of Windsor Drinking Water System	2003 - 2013	57	25.2	11.4 (12.5)	DL (0.5)	67.5
DWSP (MOECC)	Glen Walter Drinking Water System	2003 - 2013	29	5.9	3.5 (1.9)	DL (0.5)	6.9
DWSP (MOECC)	Lambton Area Water Supply System	2003 - 2013	30	2.9	2.0 (2.3)	DL (0.5)	10.1
DWSP (MOECC)	Prescott Drinking Water System	2003 - 2013	30	5.6	3.3 (1.9)	DL (0.5)	7.9
DWSP (MOECC)	Tecumseh Water Treatment Plant	2003 - 2005	10	8.7	4.0 (3.7)	DL (0.5)	10.6
DWSP (MOECC)	Walpole Island Water Treatment Plant	2003 - 2013	39	3.5	1.9 (1.6)	DL (0.5)	7.0

Notes: Values less than the detection limit were assumed to be at the detection limit to calculate the 90th percentile, mean and standard deviation of each dataset, so summary stats represent an upper limit. Duplicates were averaged prior to calculating summary statistics.

The 90th percentile phosphate concentrations for the Amherstburg WTP (24.2 ug/L) and the City of Windsor WTP (25.2 ug/L), both sourced from the Detroit River, were over twice that observed in the Niagara River datasets (11.0 ug/L, 8.9 ug/L). Additionally, MOECC's DWSP Chatham-Kent Drinking Water System – Wallaceburg on the St. Clair River via Chenal Ecarte (6.5 ug/L), and MOE's DWSP Tecumseh Water Treatment Plant on the Detroit River (8.7 ug/L) had 90th percentile phosphate concentrations close to those measured in the Niagara River. Given that two datasets from the Detroit River reference area had phosphate concentrations clearly above those in the Niagara River, and two datasets from two of the three reference areas had phosphate concentrations on par with those in the Niagara River, this comparison suggests that phosphate concentrations in the Niagara River are on par with the variability seen in reference areas.

To further assist in interpretation of the overall status of forms of phosphorus in the Niagara River, SRP data collected under EC's US/DS program and by SUNY Brockport were also examined. The 90th percentile of SRP concentrations was 8.5 ug/L at FE, 12.0 ug/L at NOTL, 10.3 ug/L at Youngstown (shoreline) and 12.2 ug/L at Youngstown (mid-channel) (Table 6). Interesting to note is that EC's US/DS SRP data are not any higher than the SUNY Brockport data despite two-fold differences in TP concentrations between these two datasets (see Section 3.1). As SRP data were not available for reference locations, a Tier 3 assessment was conducted by examining both spatial and temporal trends in the available data to form lines-of-evidence on whether SRP concentrations are suggestive of an eutrophication impairment.

Table 6: Summary table of recent soluble reactive phosphorus (SRP) concentrations (ug/L) in the Niagara River according to data source.

Data source/ Program (Agency)	Spatial extent	Years included	Number of data points (n)	90th Percentile	Mean (standard deviation)	Min	Max
US/DS program (EC)	FE station	2012 - 2013	17	8.5	3.1 (3.6)	0.2	13.3
US/DS program (EC)	NOTL station	2012 - 2013	20	12.0	5.1 (4.2)	0.8	13.1
SUNY Brockport	Shoreline station near Youngstown, NY	2003-2005, 2007, 2009, 2013	28	10.3	5.6 (4.5)	1.2	22.3
SUNY Brockport	Mid-channel station near Youngstown, NY	2013	11	12.2	7.0 (4.0)	2.6	14.2

SRP concentrations observed at upstream (FE) and downstream (NOTL and Youngstown) locations were compared to assess if there is a clear Niagara River source of SRP. Although the 90th percentiles of NOTL and Youngstown SRP concentrations were greater than that observed upstream at Fort Erie, statistically significant differences ($p<0.05$) were only observed between EC's FE and SUNY Brockport's stations (Kruskal-Wallis Test; Mann-Whitney pairwise comparisons). As the EC and SUNY Brockport data were collected and analyzed under different methods, and do not represent the same time period, the meaning of these differences in SRP concentration is not clear. It is more important to note that there was no statistically significant difference between EC's paired FE and NOTL SRP concentration data ($p = 0.48$), which suggest the lack of a clear Niagara River source of SRP. Also important to note is that the datasets are not representative of long-term trends as three of the four datasets examined represent less than a year's worth of monitoring, and the data that were collected demonstrated high variability.

When examining the time series of SRP concentrations at the upstream and downstream locations measured under EC's US/DS program, paired concentrations were higher at NOTL relative to FE at the beginning of the dataset (April – October 2012), but SRP concentrations at FE were on par with or greater than those at NOTL towards the end of the dataset (December 2012 – January 2013) (Figure 7); reasons for this are not known. Overall temporal trends in SRP concentrations were considered for another line-of-evidence in the Tier 3 assessment, however, no clear time trends were observed. In summary, the lack of clear trends and high uncertainty in the SRP dataset do not unequivocally demonstrate a conclusion either way; more data would be needed to determine with higher certainty if SRP concentrations in the Niagara River are indicative of an eutrophication impairment.

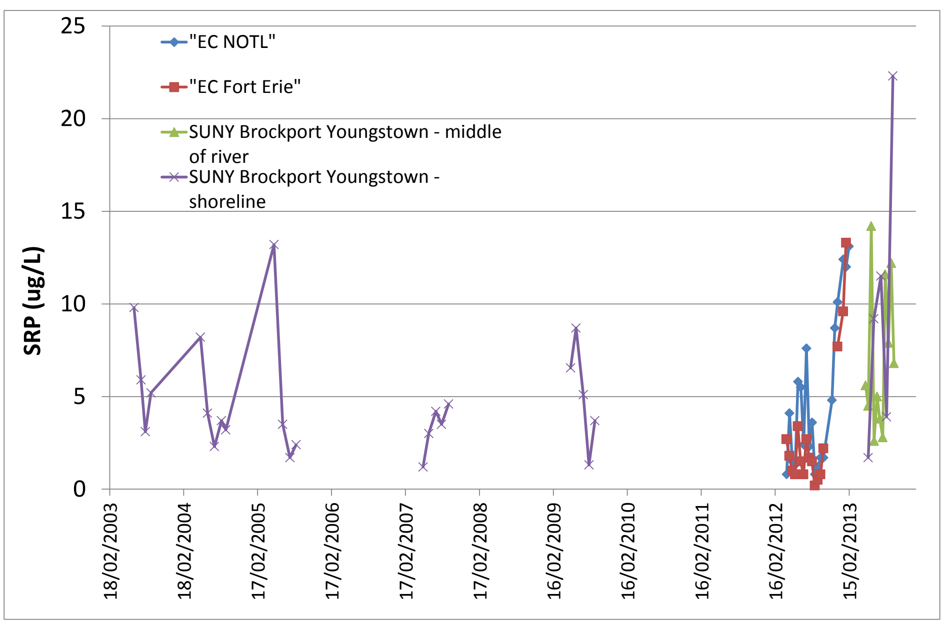

Figure 7: Recent SRP concentrations in water from EC's Fort Erie (FE) and Niagara-on-the-Lake (NOTL) stations, and SUNY Brockport's Youngstown stations.

3.3 Chlorophyll *a*

There are no recent chlorophyll *a* data collected under EC's US/DS program, MOECC's Great Lakes Monitoring Program, MOECC's DWSP program, NPCA's Chippawa Creek/Niagara Power Canal monitoring or NYSDEC monitoring; however, recent chlorophyll *a* data are available through the SUNY at Brockport monitoring program (Table 7). Chlorophyll *a* concentrations measured in the Niagara River were compared to concentrations measured in the Detroit River, St. Clair River and St. Lawrence River reference areas as part of a "Tier 2" assessment.

Table 7: Summary table of recent chlorophyll *a* concentrations (ug/L) in the Niagara River according to data source

Data source/ Program (Agency)	Spatial extent	Years included	Number of data points (n)	90th Percentile	Mean (standard deviation)	Min	Max
SUNY Brockport	Shoreline station near Youngstown, NY	2003-2005; 2007, 2009; 2013	28	2.9	1.6 (0.9)	0.1	4.1

Notes: chlorophyll *a* concentrations were not noted to be corrected or total values, so concentrations assumed to be total chlorophyll *a*.

The chlorophyll *a* 90th percentile concentration for the Niagara River was 2.9 ug/L, which is less than the 90th percentile for the St. Clair River (7.8 ug/L), equivalent to the 90th percentile for the St. Lawrence River (2.9 ug/L), and greater than the 90th percentile for the Detroit River (2.3 ug/L) (Table 8). Further, the mean chlorophyll *a* concentration of 1.6 ug/L in the Niagara River is less than the mean concentration in all three reference locations. These data are a line-of-evidence that (planktonic) algal densities in the Niagara River are generally equivalent to or better than reference conditions, suggesting a lack of impairment.

Table 8: Summary table of recent chlorophyll *a* concentrations (ug/L) in the St. Clair, Detroit and St. Lawrence Rivers according to data source.

Data source/Program (Agency)	Spatial extent	Years included	Number of data points (n)	90th Percentile	Mean (standard deviation)	Min	Max
Great Lakes Monitoring Program (MOECC)	Detroit River (Station 176)	2004, 2007, 2010	16	2.3	1.8 (0.5)	1	2.4
Great Lakes Monitoring Program (MOECC)	St. Clair River (Stations 43, 244)	2004, 2007	7	7.8	3.2 (5.5)	0.5	15.5
Great Lakes Monitoring Program (MOECC)	St. Lawrence River (Stations 126, 128, 424)	2006, 2009, 2012	30	2.9	1.7 (0.7)	0.7	3.0

Notes: Duplicates were averaged prior to calculating summary statistics. Chlorophyll *a* (total) concentrations are shown; chlorophyll *a* (corrected) concentrations were not included in the above summary.

The chlorophyll *a* data which do not suggest an algal issue in the Niagara River are consistent with the expectation based on the literature which suggests high velocity rivers like the Niagara tend not to have eutrophication problems. For example, thermal stratification was a determinant in cyanobacteria bloom formation in a major river in Australia (Maier et al., 2001) and in Anabaena bloom formation in the St. Lawrence River (A. Bramburger, 2013, pers. comm). The development of thermal stratification in a riverine system is controlled by a number of factors (e.g. prolonged low mean wind speed, low flow velocity, etc.; Maier et al., 2001), and because thermal stratification isn't expected to occur in the Niagara River due to persistent high flow velocities and the falls, the naturally existing conditions in the Niagara River are not favourable for bloom formation.

3.4 Dissolved Oxygen

Dissolved oxygen (DO) concentrations in the Niagara River underwent a Tier 1 assessment as all measured DO concentrations were compared to the screening target of 6.5 mg/L. Datapoints that did not meet this target underwent a more detailed analysis for potential biological impacts. Although DO concentrations demonstrated variability at most locations sampled, the minimum DO concentration measured in all datasets except one was above the screening target 6.5 mg/L (Table 9). For the MOECC Upper Niagara River dataset which had a minimum DO concentration of 5.7 mg/L and did not meet the screening target of 6.5 mg/L, this dataset was more thoroughly assessed to determine if the DO concentrations measured below the screening criterion of 6.5 mg/L may have had biological effects.

Table 9: Summary table of recent DO concentrations (mg/L) in the Niagara River according to data source.

Data source/ Program	**Spatial extent**	**Years included**	**Number of data points (n)**	**10th Percentile**	**Mean (standard deviation)**	**Min**	**Max**	**% of observations < 6.5 mg/L**
Great Lakes monitoring program (MOECC)	Upper Niagara River	2003-2004	32	7.5	8.6 (1.0)	5.7	10	6.3
Great Lakes monitoring program (MOECC)	Lower Niagara River	2003-2004	8	8.9	9.9 (0.8)	8.9	10.8	0
Chippawa Creek/ Niagara Power Canal monitoring (NPCA)	Chippawa Creek/ Niagara Power Canal	2012 - 2013	11	9.8	11.5 (2.2)	6.7	15.0	0
NYSDEC	Youngstown, NY station	2003-2012	58	8.7	10.8 (2.1)	7.2	16.2	0
SUNY Brockport	Shoreline station near Youngstown, NY	2003-2005; 2007; 2009; 2013	25	7.5	9.0 (1.6)	6.7	13.6	0

Notes: No recent DO data for EC's US/DS program & MOECC's DWSP program. The 10^{th} percentile is used in the summary statistics instead of the 90^{th} percentile as higher DO concentrations are more desirable than lower DO concentrations.

The DO concentrations that did not meet the screening target of 6.5 mg/L were collected in the Upper Niagara River on August 14, 2003 (5.7 mg/L) and August 14, 2004 (5.7 mg/L). Accompanying measured water temperature data were not available for these two datapoints, so water temperature was assumed to be at least 15°C based on observed water temperature of 19.1°C measured in the Upper Niagara River in August 1980 (Plumb and Sweeny, 1980). The more conservative PWQO for coldwater biota at 15°C is 6 mg/L and for warmwater biota is 5 mg/L (MOEE, 1994a) and the more conservative CWQG for coldwater biota (non-early life stages) is 6.5 mg/L and for warmwater biota (non-early life stages) is 5.5 mg/L. The early life stage CWQGs were not used in this assessment because “the early life stage guideline should be applied at those times and places where salmonid spawning and invertebrate emergence are known, or are likely, to occur" (CCME, 1999). Salmonid spawning is not expected to occur in the upper Niagara River in August, and invertebrate emergence is generally mid-May to the end of June (CCME, 1999).

The measured DO concentration of 5.7 mg/L in August 2003 and August 2004 may have placed some stress on coldwater species if such concentrations persisted over a prolonged period of time, but are not expected to have impacted warmwater biota. It is not clear however if the area of the upper Niagara River where these data were collected is coldwater fish habitat, and further, the other data collected do not suggest that DO concentrations remain below 6 mg/L for a prolonged period of time. It is important to note that the PWQO and CCME CWQG are not acute limits, that is, mortality is not expected to occur for DO concentrations measured below these thresholds. Thus, the recent DO monitoring data suggest that DO concentrations in the Niagara River during the past decade have not been impaired. This conclusion and assessment is consistent with historical findings by Plumb and Sweeney (1980) who also found lower DO concentrations in the Niagara River in August, which were attributed to seasonal warming of the River; however, the authors also stated that there was no indication of an acute problem as dissolved oxygen concentrations were generally acceptable. Also important to note is that DO is a secondary indicator of eutrophication, as any less than ideal DO concentrations could be due to oxygen demanding substances in the water column (e.g. chemical oxygen demand, nitrogenous oxygen demand, etc.) rather than the decay of algae at the sediment water interface.

3.5 Secchi Disc Depth

There are no recent Secchi disc depth data collected under EC's US/DS program, MOECC's Great Lakes Monitoring Program, MOECC's DWSP program, NPCA's Chippawa Creek/Niagara Power Canal monitoring, NYSDEC monitoring or SUNY at Brockport monitoring. Secchi disc depth data were however collected historically under MOECC's Great Lakes Monitoring Program (Table 10). As such, Secchi disc depths from 1967 to 1993 were examined for long-term temporal trends and for the magnitude of values relative to those recently measured in reference areas, both as lines-of-evidence for a "Tier 3" assessment on whether data suggest an impairment for this parameter.

Table 10: Summary table of historical (1967 - 1993) Secchi disc depth (m) in the Niagara River according to data source

Data source/ Program (Agency)	**Spatial extent**	**Years included**	**Number of data points (n)**	**10th Percentile**	**Mean (standard deviation)**	**Min**	**Max**
Great Lakes monitoring program (MOECC)	Upper Niagara River	1967-1976; 1978; 1980 – 1982; 1988	1066	1.0	2.3 (1.2)	0.1	8.5
Great Lakes monitoring program (MOECC)	Lower Niagara River	1967-1974; 1976-1982; 1988-1991; 1993	574	0.9	1.8 (0.8)	0.2	6.0

Notes: Duplicates were averaged prior to calculating summary statistics. The 10th percentile is used in the summary statistics instead of the 90th percentile as higher Secchi disc depths (higher water clarity) are more desirable than lower Secchi disc depths (lower water clarity)

The long-term temporal trends for Secchi disc depths in the upper and lower Niagara River were examined and there was no discernable trend (Figure 8). While a trend of improving water clarity over time may be desired, it needs to be reiterated that the eutrophication status in the Niagara River was purportedly never impaired (see Section 1), so historical baseline data could itself be representative of “unimpaired” conditions. Time trends for Secchi disc depths appeared more variable for the lower Niagara River relative to the upper Niagara River; reasons for this are not known at this time, and could be due to any number of factors. In particular, water clarity and hence Secchi disc depth in the lower Niagara River may be more greatly influenced by seston (particulate) due to the erosive forces of the falls and rapids, a factor outside the scope of this eutrophication assessment focused on potential reduction in water clarity due to algal density.

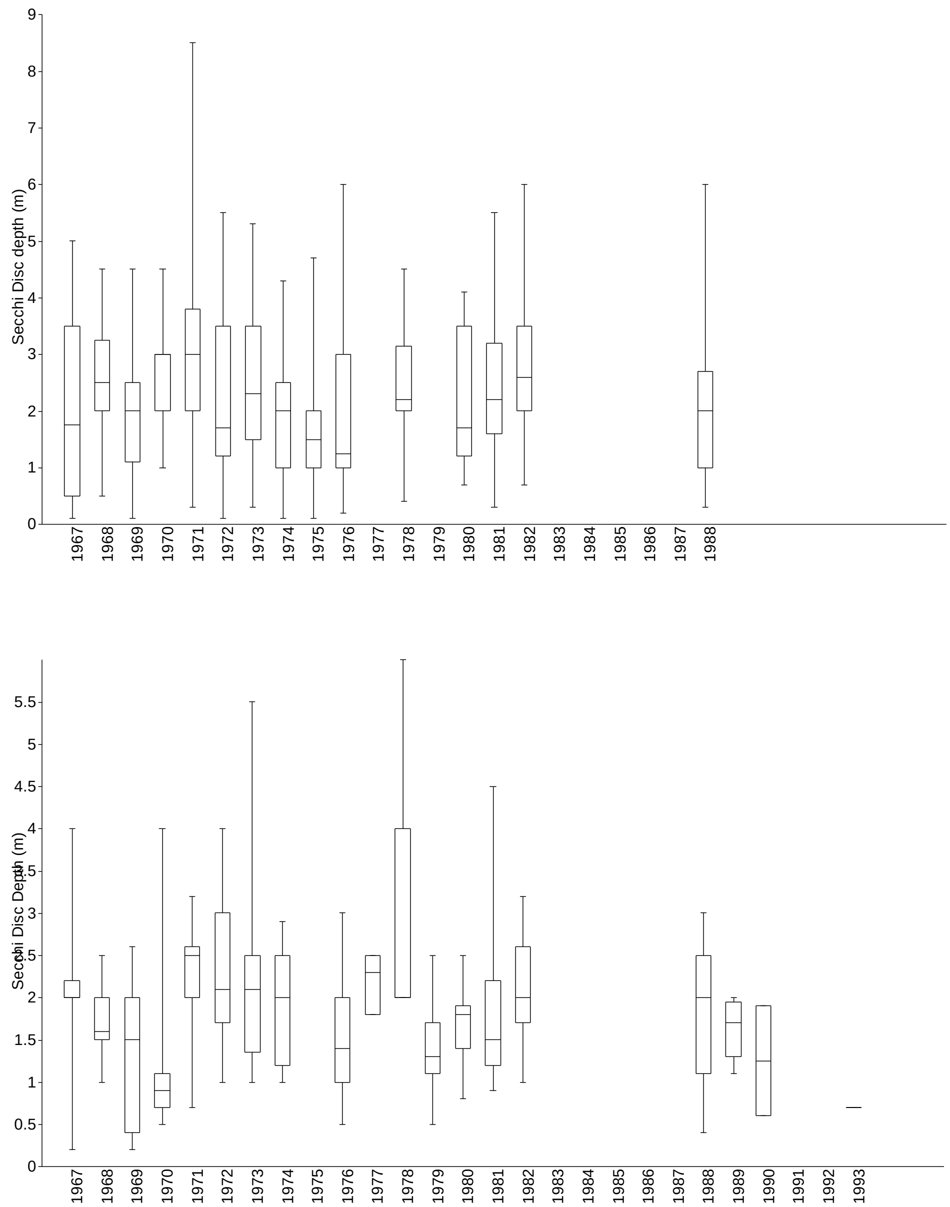

Figure 8: Time series of annual Secchi disc depths from the Upper Niagara River (upper) and Lower Niagara River (lower)

Notes: The boxes show the 25th and 75th quartiles, the median is shown with a horizontal line inside the box and the whiskers denote the minimum and maximum values for each year.

The historical Secchi disc depths in the Niagara River (Table 10) were compared to current day values in three reference areas - the St. Clair River, Detroit River and St. Lawrence River (Table 11). The 10th percentile and mean values in the upper and lower Niagara River were better than values in the Detroit River, better than or on par with values in the St. Clair River, and worse than values in the St. Lawrence River. As historical Secchi disc depths from the Niagara River are on par with or better than those recently measured in two of the three reference areas, this indicator does not suggest a water clarity impairment in the Niagara River, even if water clarity hasn't improved since the late 1980s/early 1990s (Figure 8).

Table 11: Summary table of recent Secchi Disc Depths (m) in the St. Clair, Detroit and St. Lawrence Rivers according to data source.

Data source/ Program (Agency)	Spatial extent	Years included	Number of data points (n)	10th Percentile	Mean (standard deviation)	Min	Max
Great Lakes Monitoring Program (MOECC)	Detroit River (Station 176)	2004, 2007, 2010	8	0.7	1.1 (0.3)	0.6	1.7
Great Lakes Monitoring Program (MOECC)	St. Clair River (Stations 43, 244)	2004, 2007	5	1.0	1.9 (1.1)	0.6	3.5
Great Lakes Monitoring Program (MOECC)	St. Lawrence River (Stations 126, 513)	2004, 2006, 2012	7	2.6	4.9 (2.1)	1.0	7.4

Notes: Duplicates were averaged prior to calculating summary statistics

4.0 Conclusion

Water quality data collected from the Niagara River over the past decade were examined to determine the overall impairment status of the beneficial use *Eutrophication or Undesirable Algae* in the Niagara River (Ontario) AOC. The five metrics used in the assessment were TP, phosphate/SRP, chlorophyll *a*, DO and Secchi disc depth and were assessed using the "Tiered" approach. Based on the weight-of-evidence, **this assessment concludes that *Eutrophication or Undesirable Algae* is Not Impaired in the Niagara River (Ontario) AOC**. The lines-of-evidence investigated in this assessment which support this conclusion include:

- The 90th percentiles of TP concentrations did not unequivocally meet the criterion of 30 ug/L; however, this was attributed to sources upstream from the Niagara AOC and out of scope of the Niagara River RAP;

- Phosphate and chlorophyll *a* concentrations in the Niagara River are generally equivalent to or less than those measured in unimpaired reference areas (SRP data were inconclusive);

- DO concentrations in the Niagara River are generally above the screening criterion of 6.5 mg/L, and for the two observations below 6.5 mg/L, impact to biota was not expected;

- Historical Secchi disc depth values in the Niagara River are generally on par with or better than current day values in unimpaired reference areas.

The conclusion of this assessment is consistent with other lines-of-evidence which have also suggested the lack of impairment for *Eutrophication or Undesirable Algae* in the Niagara River (Ontario) AOC. These include:

- the literature which has suggested that high flows such as those in the Niagara River are unlikely to support undesirable algal growth (Dodds, 2006; Maier et al., 2001);

- the lack of pervasive public opinion that algae is a problem in the NR;

- The historical "Not Impaired" status of this beneficial use in the Niagara River (Ontario) AOC (Niagara River RAP, 1993), and little evidence that eutrophication indicators have since changed (Figure 6); and

- The "Not Impaired" status for *Eutrophication or Undesirable Algae* in the Niagara River (New York) AOC. The Niagara River (New York) RAP has stated that the American side of the Niagara River is not impaired according to the following rationale:

  Declines in phosphorus and chlorophyll a levels in Lake Erie between 1968 and 1985 along with high dissolved oxygen levels measured in the Niagara River and the absence of nuisance algal blooms or accumulation are evidence that eutrophication is not a serious problem in the River. (NYSDEC, 2008)

Thus, the finding of an unimpaired status in this assessment should not be considered a novel description of the trophic status of the Niagara River AOC.

In conclusion, it is recommended that the Niagara River (Ontario) RAP change the status of *Eutrophication or Undesirable Algae* to "Not Impaired".

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Appendix I: The 2012 Protocol of the Great Lakes Water Quality Agreement.

Under the 2012 Protocol, the commitment to ensure that RAPs are developed, periodically updated, and implemented for each AOC is laid out in Annex 1. Each RAP will:

- Identify beneficial use impairments (BUIs - see section 1.1.1) and causes
- Include criteria for restoring beneficial uses to be established in consultation with the local community. "Delisting criteria" are measurable environmental conditions or performance measures that must be achieved for each BUI in order to conclude that the BUI has been completely addressed. The delisting criteria assist the RAP stakeholders to determine when the work of the RAP has been completed and accomplished its objectives;
- Identify remedial measures to be taken and entities responsible for implementing these measures. These actions are undertaken by public, private and community organizations. The scale of these projects can range from outreach and education programs to complex environmental remediation or public infrastructure projects. Funding comes from both public and private sector sources.
- Summarize how remedial measures have been implemented and provide updates on the status of the beneficial uses; and
- Describe surveillance and monitoring processes to track effectiveness and confirm restoration of beneficial uses (Government of the United States of America and the Government of Canada, 2012; Annex 1).

The Protocol also changed the previous reporting requirements for Remedial Action Plans. Up to this point the Niagara RAP met the previous requirements. A Stage 1 report defined the environmental problems of the AOC and the ways in which use and enjoyment of the Great Lakes has been affected by degraded water quality. The Stage 2 and Stage 2 Update reports provided recommendations for actions to restore the beneficial uses that were impaired and defined in the Stage 1 report. In the 2012 GLWQA Protocol, the emphasis is to report on incremental progress and to provide evidence the BUIs are being restored in a timely fashion. Progress is to be reported to the IJC every three years through the Progress Report of the Parties. Further information on the Great Lakes Water Quality Protocol of 2012 is found in http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=45B79BF9-1

An AOC is delisted when the beneficial use impairments have been addressed. At this point all remedial actions have been completed and monitoring has confirmed that water quality and ecosystem health (i.e., the beneficial uses) have been restored. Or, the status of the AOC could be changed to Area in Recovery if all actions had been implemented and time was needed for the ecosystem to recover. It should be noted that when an AOC is delisted, it means that the water quality issues that caused the AOC to be originally designated at Stage 1 have been addressed. Therefore, conditions in the AOC are comparable to surrounding watersheds. It does not mean that the area has been restored to pristine or pre-settlement conditions. After delisting, it is anticipated that local stakeholders, including government agencies, will continue to maintain and enhance the environmental gains made under the RAP.

The decision to delist a Canadian AOC is made by the Government of Canada in consultation with the Province of Ontario, local RAP partners and the public and, for Niagara, with the U.S. RAP state and federal officials. It is possible for one side of the River to delist before the other.

Delisting an AOC is also undertaken with input from the International Joint Commission.

Figure A1: Map showing the location of Areas of Concern around the Great Lakes Basin.

Appendix II: Summary of activities that address Stage 2 Goals to reduce nutrient inputs to the Niagara River AOC.

- 1988. The Region of Niagara voluntarily implemented a Sewer Use Program under the Municipal Act through the enactment of a Sewer Use Bylaw.
- 1990. The NPCA implemented the Ministry of Environment and Energy's "Clean Up Rural Beaches" program (CURB). The program existed until 2001 and its purpose was to prevent pollution from rural sources to reduce the frequency of rural beach postings in Ontario. Under CURB, the ministry made funds available for nutrient related projects such as improving manure storage, milkhouse washwater disposal systems, fencing and crossings to restrict livestock access, and private sewage systems.
- The Friends of Fort Erie's Creeks conducted the Frenchman's Creek Stream Rehabilitation project, 1995-2000. The group also implemented a natural channel design project and riparian restoration of Black Creek in the 1990s.
- 1991. The NPCA's GIS restoration database was initiated and it contains data on # restoration project types (Non-Point Source) and locations within the AOC.
- 1993. The Environmental Farm Plan (EFP) program was introduced by the Ontario Farm Environmental Coalition with the goal to have in place an Action Plan for every farm in Ontario by 2000. Farmers in the AOC have participated in the program.
- 1994. Environment Canada, through the Great Lakes Cleanup Fund, provided funding to the NPCA to support the development of a rural non-point source monitoring and remediation program for the Niagara River (Ontario) AOC – the "Rural Clean Water Program".
- 1994 -1996. The NPCA conducted water quality monitoring through the Niagara River AOC Tributary Monitoring Program to collect long-term surface water quality data for AOC tributaries.
- 1998. The NPCA, together with watershed partners, initiated the Welland River Watershed Strategy with a 10-year Watershed Action Plan "To restore the ecological health of the Welland River and its watershed" (NPCA, 1999).
- 2001 - 2005. The NPCA sampled and reported on water quality data for AOC tributaries through the Niagara River AOC Tributary Monitoring Program.
- 2003. Phosphorous loading from urban stormwater, agricultural land, and other lands, was determined by mass balance modeling by Niagara Region and MOE's MISA Effluent Monitoring Results and Load Calculations.
- 2006. Niagara Region conducted an audit and evaluation of CSOs under the Niagara Water Strategy. The CSO Management Action Plan was approved by Regional Council in 2007.
- In response to Ontario Procedure F-5-5 for management of wet weather flows, AOC municipalities (i.e. Niagara Falls, Welland, Niagara-on-the-Lake and Fort Erie) have completed Pollution Control Plan studies & implemented facility upgrades, improved operations and used innovative technologies. For example, in 2007, the Niagara Region and the City of Niagara Falls completed construction of a new joint Central Pump Station – High Rate Treatment (HRT) facility, eliminating the Muddy Run CSO discharge to the Niagara River and significantly reducing the number of discharges of untreated waste water

to the environment. The municipalities are obliged to report to MOE under Procedure F5-5 on progress on their CSO improvements.

- In 2007, the NPCA entered into an agreement with OPG to implement “soft engineering” restoration strategies along the Welland River to mitigate the impact of flow reversal and improve habitat, etc. An example of the NPCA’s work in restoring and rehabilitating wetlands to protect water quality is provided by the E.C. Brown Wetland.
- Various restoration activities by partners on Upper Niagara River tributaries have made improvements to Frenchman’s Creek, Black Creek, Ussher’s Creek and Beaver Creek.

Appendix III: Status and Delisting Objectives for the BUI *Eutrophication or Undesirable Algae* in Binational, American and Canadian Connecting Channel and River* Areas of Concern (AOCs)

Area of Concern	Status and Delisting Objectives for “Eutrophication or Undesirable Algae”
St. Mary’s River AOC, Binational AOC	Status: Impaired • All embayment waters have persistent total phosphorus concentrations of <20 ug/L, a secchi disc transparency of >1.2 m, dissolved oxygen at saturation, chlorophyll concentration of<10 ug/L, and unionized ammonia <0.02 ug/L. • Phosphorus load from East End Water Pollution Control Plant <I mg/L with a consideration of seasonal variability in receiving water sensitivity. All plants to consistently meet Certificate of Approval limits or MI permit system limits. • Any failure to meet these targets must not be attributable to cultural eutrophication (ie., nutrient inputs from human sources such as sewage). • Conditions above to be maintained for at least five years prior to delisting. • Mean monthly values for delisting targets should be met throughout the river, with sampling points representative of different river reaches and in proximity to known significant sources. (Source: North-South Environmental Inc., 2003)
St. Clair River AOC, Binational AOC	Status: Not impaired 1991 Stage 1 RAP: Little work has been done on smaller phytoplankton; larger species are typical of oligotrophic waters 1995 Stage 2 – Recommended Plan: The waters of the St. Clair river are mesotrophic and algae do not occur at nuisance levels. (Source: Mayne, 2003)

Area of Concern	Status and Delisting Objectives for "Eutrophication or Undesirable Algae"
Clinton River AOC, American AOC	Status: Impaired (localized) Restoration Criteria An AOC water body will be considered restored for the eutrophication impairment if monitoring nutrients, chlorophyll, dissolved oxygen, and secchi depth using the protocols of Michigan's Cooperative Lakes Monitoring Program in any 2 of 3 years indicates that: • There are no growths of undesirable algae in quantities which interfere with a water body's designated uses as defined in Rule 323.1100 of the Michigan Water Quality Standards (e.g., inhibits swimming due to the physical presence of algal mats and/or associated odor; inhibits the growth and production of warm water fisheries and/or indigenous aquatic life and wildlife). Undesirable algae species which may indicate impairment include toxic-producing cyanobacteria (e.g., Microcystis), noxious bloom-forming phytoplankton (e.g., Aphanizomenon), or benthic algae (e.g. *Cladophora*); and • The water body meets the minimum D.O. standards listed in Rule 323.1064 in the Michigan WQS; and • Any deviation from Rule 323.1064 is a direct result of vegetation; and • The waterbody is no longer listed as impaired due to nutrients on the Clean Water Act Section 303(d) list for the state. MDEQ is currently in the process of developing nutrient criteria for the surface waters of the state which will be adopted into the Michigan WQS. BUI restoration will be expanded to include adherence to this nutrient criteria when it is officially adopted (Source: Environmental Consulting & Technology Inc., 2005)

Area of Concern	Status and Delisting Objectives for "Eutrophication or Undesirable Algae"
Detroit River AOC, Binational AOC	Status: Not impaired Delisting Criterion When the nutrient status of the waters of the Detroit River will support the establishment of mesotrophic conditions in the Western Basin of Lake Erie, and the shoreline of the river will support minimal grown of attached algae (e.g., Cladophora). Design and Rationale This BUI has been designated not impaired since the 1991 RAP Report, and as a result, delisting criteria are not required. However, they are provided as rationale for maintaining the not impaired status and to help guide monitoring efforts. The focus of future monitoring for this beneficial use (no undesirable algae) will be on the potential for impacts to Lake Erie. This BUI is closely linked to Degradation of Phytoplankton and Zooplankton Populations in that over 98% of the water flowing through the Detroit River comes from the oligo-mesotrophic Lake Huron and moves through the Huron-Erie corridor very quickly. Furthermore, the target load of 11 tonnes of phosphorus per year (IJC 1987) has been met through industrial/municipal controls. (Source: Green et al., 2010)
Rouge River AOC, American AOC	Status: Middle Branch Impoundments Impaired, in summer 1. Algae species in Middle Branch impoundments characteristic of mesotrophic conditions, for 3 consecutive summers 2. No interference with recreational activities from algae blooms (Source: Rouge River Remedial Action Plan, 2004)

Area of Concern	Status and Delisting Objectives for “Eutrophication or Undesirable Algae”
St. Lawrence River (Cornwall) AOC, Canadian AOC	Status: Environmental conditions improved; partially restored 1. Provincial Water Quality Monitoring Network (PWQMN) Reduction: Demonstrate a reduction in phosphorus concentrations at St. Lawrence River tributaries as measured at PWQMN sites. [Criteria #1 has been met] 2. Lake St Francis: The mean annual TP concentration in Lake St Francis should not exceed 20 ug/L in waters between the two-metre nearshore contour and the open channel. [Criteria #2 has been met] 3. Algal Blooms: No evidence of sustained and widespread undesirable algae blooms in the St. Lawrence River, source-specific to the AOC, whether free-floating or attached to surfaces. Site specific occurrences at tributary mouths and in developed areas should be monitored and nutrient control programs put in place. [Criteria #3 has been met] 4. Tributaries: The long term goal is to prevent further degradation of the water quality in the tributaries and ensure that all practical measures are taken through implementation of source control programs and best management practices to achieve site-specific annual mean TP concentrations as listed in Table 7 of the AECOM report Evaluation of Remedial Action Plan Tributary Nutrient Delisting Criteria for the St. Lawrence River, Cornwall Area of Concern (April 2009). See Appendix 7.2. [Criteria #4 has not been met for AOC Tributaries. On-going restoration and monitoring is required.] (Source: SLRRC, 2012)

Notes: Not all AOCs on rivers are included in the above table; connecting channels in the Great Lakes and tributaries to those connecting channels are included above.