March 2013

NIAGARA RIVER AREA OF CONCERN

Assessment of Contaminated Sediment Areas in Relation to the Delisting Criteria for BUI Degradation of Benthos

Submitted to:
Niagara Peninsula Conservation Authority
250 Thorold Road, 3rd Floor
Welland, Ontario

REPORT

Report **Number:** 13-1118-0004

Distribution:

5 copies - Niagara Peninsula Conservation Authority

2 copies - Golder Associates Ltd.

Table of Contents

TABLES

1.0 INTRODUCTION

In 1972, in order to provide a co-ordinated approach to addressing environmental concerns in the Great Lakes, the Canadian and U.S. governments signed the Great Lakes Water Quality Agreement. The original Agreement focused on phosphorus and associated problems regarding eutrophication. In 1978, the Agreement was revised to focus on toxic compounds, and promoted an ecosystem approach to addressing water quality concerns. The 1978 Great Lakes Water Quality Agreement was amended by Protocol signed in November 1987, and contained a number of additional provisions, including Annex 14, which committed both parties to undertake action to remedy areas of contaminated sediments.

In 1985, based on recommendations by the states and provinces, the Water Quality Board of the International Joint Commission (IJC) identified 43 areas in the Great Lakes where contaminant concerns existed. These Areas of Concern formed the priorities for environmental actions. The assessment of Areas of Concern was based on a list of 14 designated beneficial use impairments (BUIs). While the BUIs noted the major area of environmental impairment in each of the Areas of Concern, they also identified the issues that would need to be addressed for the area to be de-listed as an Area of Concern. In many of these areas, contaminated sediments were identified as a primary cause of the use impairments.

In their 1985 report, the IJC's Water Quality Board identified a number of use impairments in the Niagara River that formed the basis of the listing of the River as an Area of Concern in the Great Lakes. The Stage 1 RAP Report Update (Niagara River RAP 1995) has identified the degradation of benthos BUI as directly related to contaminated sediments.

The RAP Stage 1 Update identified 13 areas on the Canadian side of the Niagara River that should be investigated. Additional studies were completed at these sites, beginning in 2003 and the results are described in Golder (2004), Golder (2005), and Golder (2008), and included sediment contaminant assessment, sediment toxicity tests, and ecological risk assessment.

In 2009, the Stage 2 Update Report provided a new set of delisting criteria to assess the BUI "degradation of benthos". This review provides an assessment of benthic communities at 13 sites within the Niagara River AOC against these delisting criteria to determine whether the listed sites meet the current delisting criteria for the Degradation of Benthos beneficial use impairment.

The revised delisting criteria note that the benthic community will be assessed against the following conditions:

- When acute and chronic toxicity, community composition and abundance in the benthic community are similar to non-AOC reference sites.
- When benthic invertebrate tissue contaminant (PCBs and dioxin-like PCBs) concentrations are comparable in the AOC to those at a suitable non-AOC reference sites for contaminants that biomagnifies in the aquatic food chain and/or in cases where benthic invertebrate tissue contaminant concentrations are greater than reference sites but are below concentrations considered to impair the beneficial uses associated with the consumption of fish and wildlife.
- OR if a contaminated site (as designated by the Niagara River Contaminated Sediment Technical Advisory Group*) fails to meet the criteria described above in regard to degradation of benthos, then a Contaminated

Sediment Management Strategy must be in place including a risk management approach with appropriate monitoring and mitigation measures and/or administrative controls.

2.0 ASSESSMENT METHODOLOGY

The assessment of the 13 sites against the delisting criteria provided in Section 1 focuses on the effects of contaminated sediments on the benthos. The assessment is based on a number of studies conducted in the AOC since 2003 that assessed sediment contamination and the potential effects on benthic organisms.

The assessment of the BUI is based on the understanding that the Niagara peninsula has undergone a long period of development in which the landscape of the pre-colonial period has been substantially altered. These changes in the landscape have resulted in significant changes in aquatic habitats that, over time, have affected the composition of both benthic and fish communities. Clearing of the land for first, extensive agricultural development, and subsequently urbanization, has changed the character of most waterbodies in the area. The land use changes that have occurred are considered irreversible, and the changes to the benthic communities as a result of these would similarly not be reversible. It is not the intent of this assessment to assess the effects of these land use changes on the benthic communities within the Niagara River watershed. Rather, the intent of the BUI assessment is to understand whether the presence of contaminants in sediments from various historic sources has resulted in the degradation of benthic communities within the AOC.

Benthic community density and diversity are highly dependent on habitat characteristics such as substrate type, stream flow, and stream size. As a result, benthic community composition among sites can be highly variable due to natural factors, as well as due to general alteration of the landscape. Therefore, the interpretation of changes in benthic communities can be influenced by factors associated with land use, as well as by contaminant concentrations in sediment. Comparison with reference areas requires that water bodies similar in habitat characteristics but without the contaminant influences are available, which is generally not the case in the Niagara peninsula, since the area has a long history of agricultural, urban and industrial development that has affected most waterbodies in the area. The aquatic habitats considered in this assessment range from small streams such as Pell Creek, to larger slower flowing rivers such as the Welland River, through to large fast flowing rivers such as Chippawa Creek and the Niagara River, as well as lentic habitats such as the Sir Adam Beck reservoir. Finding comparable reference sites for all of these different habitat types within the Niagara peninsula was not considered practicable during the sediment and benthic studies conducted since 2003.

The use of the benthic community structure metric assesses both the effects of historic land use changes, and the effects of any contaminants, thus potentially confounding the interpretation of contaminant effects. As a result, changes in benthic community composition and abundance provide a less robust assessment of the effects of contaminants than direct toxicity testing since the results can be confounded by other factors such as land use changes. Therefore, the assessment against the delisting criteria has focused on potential toxicity of the contaminants of concern (COCs) identified at each Site to determine whether the benthic communities have been degraded due to exposure to contaminants. The approach is based on the assumption that if contaminant concentrations do not pose a risk to benthic communities, then there are no factors beyond the land use changes that can potentially affect benthic communities and benthic community composition and abundance would be similar to reference sites under similar land use conditions. The approach avoids the difficulties of finding comparable habitats that have not been affected by historical sources of contaminants and assumes that the broad landscape changes that have affected stream habitats and hence, benthic communities, are irreversible.

The ability of benthic organisms to accumulate some contaminants that can biomagnify (e.g., PCBs, PCDD/Fs) means that even if there is no direct toxicity to benthic organisms from these substances, and benthic community composition and abundance are unchanged, there could be risks to higher trophic level receptors that feed upon benthic organisms. Since these substances do not occur naturally, there are no background levels for these chemicals, and tissue residues in reference sites would be below typical laboratory detection limits. Therefore, measurable tissue residues in benthic species would be considered a potential concern that would need to be assessed through an ecological risk assessment. As a result, the potential effects on fish and terrestrial consumers of benthos from exposure to benthic organism tissue residues have been included in the assessment.

The assessment was accomplished through a multi-step process:

- Sediment concentrations were initially screened against the Provincial Sediment Quality Guidelines (PSQGs). Since the guidelines were based on a co-occurrence assessment of sediment contaminants and benthic species distribution, the guidelines are considered suitable for assessing the effects of contaminants on benthic organisms.
  - Sediment concentrations below the MOE PSQG Lowest Effect Level (LEL) were considered to result in no adverse effects on benthic organisms and would not contribute to the degradation of benthos beneficial use impairment (BUI).
  - Sediment concentrations above the LEL but below the Severe Effect Level (SEL) guidelines were considered to have potential to adversely affect some benthic species, and were assessed as described below.
  - Concentrations above the SEL were considered to have potential to adversely affect a number of benthic species, and additional testing of sediments would be warranted at these sites.
- For all classes of contaminants, where the guidelines levels were exceeded additional assessment was undertaken:
  - Where the LEL was exceeded, sediment concentrations were compared to existing toxicity data to assess the potential for contaminants to elicit an adverse response in benthic species. The data included studies from the peer reviewed literature, as well as other studies conducted by the MOE and/or Environment Canada.
  - Where the SEL was exceeded, sediment was collected for direct assessment of toxicity through sediment toxicity tests.
- In addition, for substances with potential to biomagnify (e.g., mercury, PCBs, dioxins and furans), an ecological risk assessment was conducted to assess whether benthic organisms could accumulate tissue residues that could present risks to organisms at higher trophic levels. The assessment was based on potential for bioaccumulation and biomagnification of contaminants by benthic organisms. The assessment of bioaccumulation was typically based on measured tissue residues in benthic species.

Higher tissue residues of contaminants were not considered to be a potential concern if these did not result in predicted adverse effects on other receptors. Organisms possess a number of physiological mechanisms by which they can neutralize the effects of contaminants, such as depuration, detoxification and sequestration. As a result, elevated tissue concentrations do not necessarily present a risk to aquatic life.

As noted, toxicity was assessed on the basis of sediment toxicity tests. These were conducted to standard protocols (either the Environment Canada or MOE protocols), and all tests were conducted as long term tests that typically assess chronic exposure. All tests included both laboratory controls and Site reference locations. The following definitions were used in assessing the results:

- Sediments with elevated COCs in which there was statistically significant mortality in test sediments relative to controls were considered to be toxic, and would contribute to degradation of benthos;
- Sediments with elevated COCs in which there were sublethal effects such as growth reduction in test sediments, could contribute to degradation of benthos only if there was correlation between the test results and contaminant concentrations. Where there was poor correlation between organism responses and sediment COC concentrations, the observed effects were considered to be due to other factors. This approach minimized the influence of confounding factors, such as test conditions or substrate factors; and
- Sediments which elicited no statistically significant difference in outcomes in test sediments compared with control sediments were considered to not contribute to degradation of benthos.

Based on this assessment, the ability of each site to meet the delisting criteria was assessed against the delisting criteria developed for the Niagara River AOC:

- Condition 1: When acute and chronic toxicity, community composition and abundance in the benthic community are similar to non-AOC reference sites;
- Condition 2: When benthic invertebrate tissue contaminant (PCBs and dioxin-like PCBs) concentrations are comparable in the AOC to those at suitable non-AOC reference sites for contaminants that biomagnify in the aquatic food chain; or
- Condition 3: In cases where benthic invertebrate tissue contaminant concentrations are greater than reference sites but are below concentrations considered to impair the beneficial uses associated with the consumption of fish and wildlife; and
- Condition 4:If a contaminated site (as designated by the Niagara River Contaminated Sediment Technical Advisory Group) fails to meet the criteria described above in regard to degradation of benthos, then a Contaminated Sediment Management Strategy must be in place including a risk management approach with appropriate monitoring and mitigation measures and/or administrative controls.

The delisting criteria were assessed on the following basis:

- Under Condition 1, if the assessment showed no acute and/or chronic toxicity in the majority of the test organisms, then the condition was deemed to be met. Similarly, if benthic community composition and abundance were similar to reference sites, or at those sites where no direct benthic community assessment was undertaken if there was no acute or chronic toxicity to benthic species, then the benthic community composition and abundance was considered to be unaffected by contaminants, and the condition was deemed to be met.
    - If the contaminants present did not include those that could biomagnify, then further assessment was not considered necessary, and the general criteria for Condition 1 were met then the benthic community was considered to be unimpaired.

- If the contaminants present included those that could biomagnify, then the benthic community assessment proceeded to assess the ability of the benthic community to meet Condition 2.

- Under Condition 2, if detectable tissue residues were found for contaminants that could biomagnify, then this condition was considered to not be met. Tissue residues of these substances in reference areas would be expected to be below detection limits since these substances do not occur naturally. Therefore, the presence of detectable concentrations in benthic organism tissue residues would be considered as evidence that this condition has not been met regardless of whether reference site data were available, and the assessment would proceed to evaluating the ability to meet Condition 3.
- Under Condition 3, if tissue residues did not result in predicted risk to fish or terrestrial consumers of benthic organisms (e.g., mallard ducks), then this condition was considered to be met. If unacceptable risks were predicted then the assessment proceeds to evaluating the ability to meet Condition 4.
- Under Condition 4, if a plan has been developed to manage sediment contaminants so as to minimize risks to aquatic and terrestrial species, then this condition has been met.

Section 3 of this review provides an assessment of the benthic community conditions with respect to the contaminants identified at each site and the method described in this section.

Section 4 provides a summary of benthic community conditions with respect to each of the delisting criteria identified in Section 1, assessed using the method described in this section.

3.0 ASSESSMENT OF BUI: DEGRADATION OF BENTHOS

The Niagara River Stage 1 Update identified 14 contaminated sediment sites based on previous data or known concerns regarding sediment contaminant concentrations. Sites were classified as Level One, Level Two or Level Three sites reflecting the contaminants of concern, and the measured concentrations, with the understanding the some contaminants are potentially more toxic due to either the nature of the substance or the measured concentrations. The classification has been followed in this review.

3.1 Level One Sites

Level One Sites were those areas where there was a known potential risk due to measured concentrations of contaminants in sediments. Four locations were identified in the RAP Stage 1 Update as Level 1 sites:

- Welland River at Atlas Steel
- Lyons Creek West
- Lyons Creek East
- Welland River from Port Robinson to Power Canal

Of the four sites, the Welland River at Atlas Steel was remediated in 1995 and is not assessed further. Post remediation conditions were assessed in 2000 (Jaagumagi 2003) Therefore, three sites remained to be assessed as Level One Sites.

Beginning in 2003, additional assessment was undertaken at each site, as discussed below.

3.1.1 Lyons Creek West

Lyon's Creek West is the small remnant watershed that resulted from the construction of the Welland Canal By-Pass in the 1970's. The canal cut across the upper reaches of Lyons' Creek, with the result that the watershed area to the west of the canal was severed and was subsequently routed to discharge into the Welland Canal By-Pass. The existing watershed is contained between the Old Welland Canal to the west, and the new Welland Canal to the east. Flows to the east portion of Lyon's Creek, known as Lyons' Creek East, were maintained through pumping of water from the Welland Canal. Due to the loss of a substantial portion of the headwaters, Lyons Creek West consists of a small area of open water habitat and as a result the available benthic habitat is reduced to a small area near the mouth of the creek. During low water periods much of the area where the higher PCB concentrations were detected consists of small isolated pools.

The Lyons' Creek West watershed drains the south-eastern section of the City of Welland, and within the drainage area are included an Ontario Hydro (Hydro One) transformer substation (Crowland Transformer Station) at Humberstone Rd., the StelPipe Page Hersey Works tube works, and urban storm drainage from the south-eastern section of the City of Welland.

Contamination of soils and sediments in Lyons' Creek was first identified in 1991, when PCBs were detected in the wetland area adjacent to the Welland Canal during site characterization studies by MTO for Hwy 406 construction. Subsequently, PCBs were also detected in the stormwater ditch from the south-eastern section of the City of Welland. The City removed ditch sediments in 1991.

A number of potential sources were identified as contributors of PCBs to the wetland. A transformer leak at the [then] Ontario Hydro Crowland Transformer Station on Humberstone Rd in 1990 resulted in a spill of PCB contaminated fluids to the ditch draining to the wetland from the south. Concentrations up to 8 ppm of PCBs were detected in this ditch/tributary. A cleanup of the area of the spill was subsequently undertaken by Ontario Hydro. Additional remediation was undertaken in selected areas both on the Ontario Hydro property, and off-site in Lyons' Creek.

Studies undertaken in 1992 (reviewed in Golder 2004) included additional sampling data, as well as a summary of existing data on PCB contamination within the wetland and Lyons' Creek. The study found elevated levels of PCBs within the wetland and the ditches draining to the wetland from the city as well as the Crowland station. PCBs were also found in sediments in the ditch draining the wetland to the Welland Canal. Analysis of the PCBs from the wetland indicated that Aroclors other than those used in the transformers were present in wetland soils and sediments, and indicated that other sources had likely contributed PCBs to the wetland.

Since PCBs were the main substance of concern, the assessment considered not just direct toxic effects on benthic organisms, but also the potential for bioaccumulation of PCBs to levels that could pose a risk to organisms at higher trophic levels.

Sediment toxicity testing (Golder 2005) showed that sediments up to 25 µg/g PCB did not result in chronic or acute effects on benthic organisms. PCB contamination in Lyons Creek West includes a wide range of PCB congeners, of which the most toxic are the dioxin-like PCBs. However, studies (Loonen et al 1997) have shown that benthic organisms are relatively insensitive to the more toxic PCBs (i.e., the dioxin-like PCBs). These studies indicate that while benthic organisms are not likely to be directly affected by PCBs they can accumulate tissue residues that can present a risk to consumers of benthic organisms.

Sediment toxicity tests assess the direct effects of exposure of benthic species to contaminants, but these tests are not able to assess risks to other species since PCBs are known to bioaccumulate and biomagnify through the food web. As a result, potential bioaccumulation by benthic organisms could present a risk to terrestrial biota (e.g., mallard ducks), that may feed on benthic organisms. Therefore, an ecological risk assessment was conducted to assess the potential for PCBs to accumulate in benthic organism and present a risk to terrestrial receptors.

In order to address biomagnification concerns, the assessment considered potential accumulation of PCBs by benthic organisms as a pathway of exposure for receptors at higher trophic levels that would typically consume benthic invertebrates. Due to the limited aquatic habitat available on the site sufficient tissue mass of benthic organisms could not be obtained to assess uptake from sediments in Lyons Creek West. Therefore, potential for accumulation of PCBs was assessed by extrapolating benthic organism accumulation data collected at Lyons Creek East. Since the origin of the PCBs and the substrate characteristics of the two sites would be similar, this was considered to provide a reasonable assessment of potential tissue residues. The results indicated that benthic organisms would accumulate PCBs that could be passed on to consumers of benthos.

The assessment predicted that benthic organisms would accumulate PCBs to levels in tissue that could pose a risk to wildlife species that may feed on benthic organisms. Since risks are present due to the sometimes high concentrations of PCBs present in sediments, a management strategy is currently under development for this site. However, since the available habitat in Lyons Creek West is limited to small areas of open water, the risks to wildlife would be considered minimal. Waterfowl would be expected to only occasionally feed in this area, limiting exposure..

3.1.2 Lyons Creek East

As noted in Section 3.1.1, the construction of the Welland Canal By-Pass in 1971 severed the Lyons Creek watershed, and created two separate watersheds: Lyon's Creek West, which drains to the Welland Canal By-Pass and contains those headwaters of Lyons Creek that remained after construction of the original canal and development in the City of Welland, and; Lyon's Creek East which, after construction of the By-Pass, has its headwaters in the Welland Canal. As part of the construction of the By-Pass, a pumping station was installed on the Canal at the upstream end of Lyon's Creek East that maintains a steady flow of water through Lyons' Creek East.

Sediment sampling in Lyons' Creek East commenced in 1991, and has been conducted at various times since. In 2005 additional sampling along a number of transects was completed to define PCB distribution in both surficial and subsurface sediments (Golder 2008). The study found that surficial sediment concentrations of PCBs were much lower (average of 4-5 µg/g) than in the deeper sediments and sediment distribution strongly suggested a historical source for the PCBs. The results of the sediment sampling conducted indicated that sediment contamination in Lyons' Creek East by PCBs predated the construction of the Canal By-Pass. The construction of the Canal By-Pass coincided with the reduction in use of PCBs, which were banned in 1977. Therefore, it appears likely that the construction of the Canal By-Pass also severed Lyons' Creek East from the main source of PCBs. That residual contamination still occurs in the surficial layers of the sediments is likely due to periodic re-suspension and downstream transport of sediment during periods of higher flows, such as spring snow-melt and rainfall event runoff, and bioturbation.

Additional sediment sampling commenced in 2005 to better define PCB distribution in the creek (Golder 2008). The assessment included core samples in order to characterize PCB distribution at various depths in the sediment. The results indicated that there was a progressive increase in sediment concentrations of PCBs to approximately the 20-40 cm depth (based on compressed length of the cores), below which concentrations appeared to rapidly decrease. Sediment concentrations of PCBs were highest in the reach from the Canal By-Pass to Hwy 140, and averaged around 5 µg/g in the surficial sediment layers (0-10 cm section).

Direct assessment of the benthic community was undertaken by EC and MOE (Milani and Fletcher 2005). Milani and Fletcher (2005) found reduced survival of benthic organisms in sediment toxicity tests at three locations within the reach from the Canal By-Pass to Hwy 140, though correlation of organism survival with PCB concentrations in sediments did not identify the PCBs as the source of toxicity. The results suggest that factors other than PCB concentrations were responsible for the observed responses, which is consistent with the observations of Loonen et al (1997), who noted that benthic organisms are relatively insensitive to the effects of PCBs.

The sediment data available from 1991 to 2005 were subsequently used in the conduct of an ecological risk assessment to delineate the extent of PCB contamination of sediments. In addition, fish tissue residues and benthic tissue data were available from studies conducted by the MOE. These were used in the ecological risk assessment to predict the potential effects of sediment PCB exposure on terrestrial receptors that may be exposed to PCB sources in sediment, benthic organisms, and fish (Golder 2008).

In predicting potential effects of benthic invertebrate tissue residues of PCBs on fish, both sediment and benthic organism tissue PCB concentrations were used. The U.S. EPA has developed toxicity reference values (TRVs) (NOEC of 3.1 µg/g w.w. and LOECof 9.3 µg/g w.w.) for fish tissue residues as part of the assessment of PCB contamination in the Hudson River (Barnthouse et al. 2009). Barnthouse et al. (2009) also found that there was no correlation between maternal PCB tissue residues in white perch and reproductive success up to tissue concentrations in excess of 50 µg/g w.w. Mean forage fish tissue residues in Lyons Creek East were generally below the NOEC of 3.1 µg/g w.w. The exception was one reach where the mean PCB concentration was 10.2 µg/g w.w. Since this is below the no effects levels reported by Barnthouse et al. (2009), no adverse effects on fish populations are anticipated as a result of exposure of fish to sources of PCBs in sediment and benthic organisms (the measured concentrations in fish from Lyons Creek East would reflect exposure to both of these sources).

The risk assessment also considered terrestrial receptors that could be exposed through consumption of invertebrates (e.g., mallard ducks) as well as fish-eating birds and mammals. Therefore, the risk assessment considered those species that would be directly exposed to PCBs in sediments, and those that would indirectly be exposed through the food chain. MOE data on benthic organism tissue residues showed that benthic organisms had accumulated higher tissue residues of PCBs than benthic organisms in areas where there was no record of PCB contamination (and where tissue residues were below detection limits). However, the risk assessment predicted that there would be negligible risks to terrestrial receptors from the combined effects of PCBs in sediments and benthic organisms to higher trophic levels. The risk assessment demonstrated that benthic organism tissue residues did not result in unacceptable levels in terrestrial species, and that the marginal risks predicted for some receptors were due to the consumption of fish, which generally had higher tissue residues than benthic organisms.

Since sediment concentrations in the deeper layers of the sediment were much higher (up to 255 µg/g), increased risks to biota could occur through exposure to these sediments. As a result, to ensure that sediments would not be disturbed, an administrative controls strategy is being implemented by regulatory agencies for the site and surrounding watershed.

3.1.3 Welland River – Port Robinson to Chippawa Power Canal

The Welland River downstream of the Welland Canal By-Pass was identified in the RAP Stage 1 Update as an area requiring additional investigation. The Welland River downstream of the Canal By-Pass has historically received discharges from the industries located along the river. As well, a number of sources existed in the river upstream of the Canal By-Pass of which the RAP Stage 1 Report (1996) identified the Atlas Specialty Steel site in the City of Welland as one of the largest single sources of contaminants to the river. River sediments below the Atlas Steel site were found to be contaminated with high concentrations of chromium and nickel, and elevated concentrations of these metals, as well as elevated levels of PAH compounds (reviewed in Golder 2004) persisted in sediments downstream of the Canal By-Pass as determined by studies conducted by the MOE and Environment Canada (reviewed in Golder 2004). In 1995, a cleanup project was initiated that resulted in the removal of the most contaminated areas, but elevated levels of both chromium and nickel remained adjacent to, and downstream of, the remediated areas.

In addition to being influenced by the Atlas Steel operations, there was potential for the sediments in the lower section of the river, from the Canal By-Pass to the Chippawa Power Canal, to also be affected by a number of industrial sources, even though much of this area is rural/agricultural. Potential industrial sources along the river included:

- the Oxy Vinyl LP site (formerly Geon, and before that, B.F. Goodrich) (assessed separately in Section 3.3.1);
- the Cytec (formerly Cyanamid) Welland Plant (assessed separately in Section 3.2.2); and
- the former Ford Glass Plant.

The RAP Stage 1 Update identified the major concern in this section of the river to be due to the presence of oil and grease below the former Ford Glass plant. As well, a number of metals, such as nickel, chromium, copper and silver were also identified in sediments in river sediments, many of which would be associated with the Atlas Steel site.

Municipal sources to the river included the sewage lagoons located at Port Robinson that discharge to the Welland River below where the river crosses the Welland Canal. The site commenced operation in 1990, and monitoring after start-up indicates that trace levels of arsenic, as well as variable levels of lead were detected in the effluent (MOE 1993c). However, the MOE-EC study of 1996 (reviewed in Golder 2004) did not show an increase in either lead or arsenic in sediments below the Lagoons.

Furthest downstream was the Ford Glass Plant, which was located on the south side of the river approximately 0.5 km upstream from the Chippawa Power Canal. The plant was decommissioned in 1994 and as part of the site decommissioning, Beak undertook a study of the site (Beak 1994, reviewed in Golder 2004). The study noted that while both chromium and nickel were elevated in sediments adjacent to the site, concentrations of these metals there were higher at upstream locations as well. As noted above, both metals have been associated with the Atlas Steel site.

The Beak 1994 study also noted elevated levels of oil and grease in sediments below the site, which had also been associated with the Atlas Steel site. The MOE-EC 1996 study did not include analysis for oil and grease or polycyclic aromatic hydrocarbons (PAHs) below this site, but sampling upstream, below the confluence of Thompson's Creek, indicated low concentrations (<LEL) of total PAH in river sediments.

Based on these reviews, the primary compounds of concern in the Welland River appeared to be the metals, mainly chromium, copper and nickel, though a number of other metals exceeded the MOE LEL guidelines including arsenic, cadmium, mercury, lead and zinc.

In 2003, additional sampling was conducted along the Welland River from Port Robinson to the Chippawa Power Canal (Golder 2004). A total of 30 locations were sampled along a series of transects across the river (10 transects with 3 samples per transect). The sampling results yielded three metals, chromium, copper and nickel, that exceeded the respective SELs, with chromium and nickel exceeding the guideline in more that 50% of the samples (52% of Cr and 62% of Ni samples were greater than the SEL). The potential toxicity to benthic organisms was assessed on the basis of toxicity studies that had been conducted by the MOE in 1995-6 at the Atlas Steel site, upstream, of the Canal By-Pass. Both chromium and nickel were identified at the Atlas Steel site as primary contaminants of concern. Sediment toxicity tests conducted at the Atlas Steel site in 1994 found that concentrations of nickel, chromium and copper that ranged up to 470 µg/g, 550 µg/g and 330 µg/g respectively, did not result in either chronic or acute effects on any of the three test organisms (mayflies, chironomids and fathead minnows). Follow-up studies undertaken in 2000 similarly found that sediments with nickel and chromium concentrations of 2000 µg/g and 1300 µg/g respectively did not result in measurable effects on the three test organisms used in the previous tests (Schroeder 2003). From these studies, toxicity reference values (TRVs) that define concentrations that would have no predicted effects on benthic organisms were developed for copper (813 µg/g), chromium (1690 µg/g) and nickel (950 µg/g), based on the 90^{th} percentile distribution of the no effects concentrations (i.e., concentrations that resulted in no measurable change in test organism responses).

In 2004, sediments were collected a number of sites in the Welland River from the Canal By-Pass to Chippawa Creek for additional toxicity testing. A total of 4 sites were assessed in which copper concentrations ranged up to 228 µg/g, chromium concentrations ranged up to 436 µg/g and nickel concentrations ranged up to 284 µg/g in sediment toxicity tests with mayflies and chironomid midges, following the MOE test protocol. No acute toxicity was noted in any of the tests, and while lower growth was noted in two of the samples for the mayfly test, the results did not correlate with sediment concentrations of the metals of concern (i.e., growth was not affected in the samples with the highest metals concentrations).

Based on 1994 data for accumulation of metals by benthos below the Atlas Steel site, uptake factors of 0.002 for nickel and 0.03 were calculated for nickel and copper respectively (data were not available for chromium). Extrapolating to the 2004 data, the predicted tissue residues in benthos would be 0.6µg/g for nickel and 6.8 µg/g for copper. Sediment bioassay testing conducted in 1994 found that fathead minnows exposed to sediment from the Welland River of 760 µg/g nickel and 190 µg/g copper accumulated 64.3 µg/g w.w. for nickel and 16.4 µg/g w.w., for copper. Exposure to these sediment concentrations, and accumulation of these tissue residues did not result in any measurable adverse effects on the test fish. Therefore, it is likely that there would be no adverse effects on fish exposed to the much lower concentrations predicted for benthos.

3.2 Level Two Sites

Those sites where contaminant concentrations were elevated over background levels, but did not exceed the MOE Severe Effect Level (SEL) guideline were classified as Level Two Sites.

3.2.1 Sir Adam Beck Reservoir

The Sir Adam Beck Reservoir was created in the 1940's as part of the expansion of hydro-electric generating capacity in the Niagara Falls area. The Reservoir was constructed with a clay liner, and is fed by a canal system that diverts water from the Welland River, and the Niagara River, by way of Chippawa Creek (as the lower section of the Welland River, below the Power Canal has come to be known).

Since flows to the Reservoir are comprised of combined flows from the Welland River and Chippawa Creek, the potential contaminants entering the reservoir include those identified in these watercourses. As well, the Cyanamid (Niagara Falls) plant, which operated from 1907 until it was mothballed in 1992, discharged cooling water and partially treated process waters to the Power Canal.

In 1983, the MOE conducted a study of sediments within the reservoir (Kauss and Post 1987, cited in Golder 2004). The 1983 study found no exceedances of the SEL for any of the compounds, though a large number of metals exceeded the LEL.

In 1998, Environment Canada (Williams *et al.* 2003, cited in Golder 2004) conducted a sediment investigation of the Reservoir, re-sampling the locations sampled in 1993. Despite differences in analytical methods (the

Environment Canada samples were analysed by a combined extraction with hydrofluoric acid and Aqua Regia), concentrations of metals did not differ substantially. While a number of metals exceeded the LEL, no exceedances of the SEL were noted.

Concentrations in 1983 samples exceeded the LELs for a number of metals but, none of the parameters exceeded the SELs (maximum metals concentrations measured in 1983 were 13 µg As/g, 36 µg Cr/g, 32 µg Cu/g and 46 µg Ni/g). The assessment was based on the 1983 samples since the 1998 survey used hydrofluoric digestion for the analysis, which would yield values that are not comparable with the PSQGs, which were developed on the basis of Aqua Regia extraction.

In 2011, additional sediment sampling was conducted in the reservoir by Ontario Power Generation. The additional sampling yielded sediment concentrations the same or lower than reported previously.

Sediment concentrations were slightly above PSQG LELs for some metals, but concentrations were well below the TRVs cited in Section 3.1.3. As a result, no chronic or acute effects are predicted on benthic communities in the Sir Adam Beck Reservoir.

3.2.2 Thompson’s Creek

Cytec Canada operates a plant along the north side of the Welland River, between the Welland Canal and the Chippawa Power Canal. The plant is situated between the Welland River and Thompson's Creek to the north, with discharges from the plant directed to Thompson's Creek. Until 1993, the facility was operated as the Cyanamid Canada Welland Plant, and produced inorganic chemicals, primarily inorganic nitrogen and phosphorus products such as ammonia and dicyanimide (reviewed in Golder 2004). Records indicate that the plant has been at the present site since 1907. The facility is currently owned by Cytec, which operates the plant as Cytec Specialty Chemicals. The plant produces phosphine compounds and derivatives for use as solvent extraction reagents, chemical and catalyst intermediates, flame retardants, reagents in mineral ore recovery and in pharmaceutical, agricultural and electronics manufacturing.

The single sample collected at the mouth of Thompson's Creek resulted in exceedances of the LEL for a number of metals, including copper, chromium and nickel. Of these, only copper exceeded the SEL. Concentrations of copper in these sediments are not anticipated to result in adverse effects on biota. Comparison of sediment concentrations with no-effects concentrations calculated from bioassay studies indicates that levels are below those likely to result in adverse effects. The TRV for copper of 813 µg/g developed for the 2003 study based on chronic effects of copper in sediments in sediment bioassay tests conducted by the MOE is well above the measured concentration of 271 µg/g recorded in the creek.

In 2004, sediment samples were collected in Thompson’s Creek, and a maximum concentration of copper of 357 µg/g was recorded at one site while concentrations at sites downstream were at or below 46 µg/g. Based on the above noted TRV (Section 3.1.3), there is no predicted toxicity to benthic organisms due to copper. Additional sampling was conducted in 2005, and included sediment bioassay testing. The tests showed no changes in growth or survival of the benthic species used in the tests (*Chironomus tentans* and *Hexagenia*).

3.2.3 Frenchman’s Creek

The Fleet Manufacturing facility in Fort Erie was identified as a potential source of metals to the Niagara River by the Niagara River Toxics Committee (NRTC 1984). In 1996, Fleet became a division of Magellan Aerospace, though the site continued to manufacture aircraft components. In early 2003, Magellan announced a decision to close the operation and transfer production to other facilities, though the facility continued to operate at the time of the 2003 study.

Canadian Oxy Chemical - Durez Division operated a facility in Fort Erie that produced phenol-formaldehyde resins, moulding compounds, furfuryl alcohol-formaldehyde resins and furan resins for use in the automotive industry, among others. The major water use has been for cooling water. Cooling water from the phenol-formaldehyde resin area was recycled through cooling towers, while the distillates from the recycling were stored on-site. These were shipped off-site for disposal or recovery. Non-contact cooling water from other areas of the facility were, in the past, discharged without treatment to Frenchman's Creek. In 1993 the entire process was closed looped eliminating further discharge to Frenchman's Creek.

Sampling by the MOE in 1987 (reported in Golder 2004) indicated low concentrations of dioxins and furans (as total TEQs) in creek sediments below the CanOxy site that could be related to use of furan resins on the site. Sampling included a single site in Frenchman's Creek and a second sample at the mouth of the creek in the Niagara River. Mussel biomonitoring as part of the same study detected low concentrations of PAHs and some pesticides below the CanOxy site.

Gould National Battery was located further upstream on the same tributary as CanOxy, and while the site is removed from the creek, it has in the past discharged to the creek via a ditch. The facility produced lead-acid batteries using lead, antimony, lead oxide and sulphuric acid as raw materials. Process water was used for battery washing, washing of castings and in battery charging areas. The system was closed looped in 1993, but discharged to the creek until 1987 after which the discharge was routed to the WPCP.

In 2003,8 locations (including an upstream control) within the Frenchman's Creek watershed were sampled. Sampling in Frenchman's Creek included:

- Heavy metals at all sites
- Dioxins and furans at selected sites,
- PCBs at all sites.

Of the 8 locations, three sites exceeded the PSQG SEL for cadmium and chromium, while one site exceeded the CCME PEL for dioxins and furans. Sediment toxicity testing conducted in 2004 (Golder 2005) showed no statistically significant changes in benthic organism survival due to exposure to cadmium and chromium, and no chronic or acute effects are indicated from sediment metals.

The initial assessment in the Phase III study (Golder 2005) of potential effects of dioxins/furans was considered on the basis of a benchmark of 5.0 pg/g for protection of lake trout eggs. This was considered to be a very conservative benchmark, since lake trout are unlikely to occur in Frenchman's Creek. Effects on benthos were considered to be unlikely. Loonen et al. (1997) noted that invertebrates are not considered susceptible to the toxic effects of PCDD/Fs and dl-PCBs, since these organisms appeared to lack the aryl hydrocarbon (Ah) receptor through which the effects of these COCs are expressed. Loonen et al. (1996) and West et al. (1997) both note that benthic invertebrates lack the Ah receptor through which the effects of PCDD/Fs and dl-PCBs are expressed, and therefore, these substances are unlikely to exhibit toxicity to aquatic invertebrates.

Subsequent to the Phase III study, Steevens et al. (2005) calculated a species sensitivity distribution (SSD) of 57 pg/g w.w. for protection of 99% of fish species. The SSD denotes the concentration in the exposure media (water, sediment or benthic tissue) that would be protective of 99% of the fish species. The maximum concentration in Frenchman's Creek was 51.1 pg/g total TEQ at one site, with the remaining sites reporting total TEQs of less than 10 pg/g. Studies conducted in the lower Trent River (Bay of Quinte AOC) (Dillon 2007) showed that benthic species will typically accumulate 10% of sediment concentrations of dioxins and furans from sediments high in silt/organic carbon content. Therefore, benthic invertebrates at Frenchmans Creek could accumulate tissue residues of dioxins and furans of up to 5 pg/g of dioxins and furans. This value is lower than the 57 pg/g benchmark to protect fish species, as mentioned above (Steevens et al. (2005)). Therefore benthic invertebrate tissue residues are unlikely to affect fish species. Therefore, while benthic organisms are predicted to accumulate PCDD/Fs from sediment to levels higher than in areas where no contamination is present, predicted tissue residues are not likely to result in adverse effects on consumers of benthos.

3.3 Level Three Sites

3.3.1 Welland River at Geon

The RAP Stage 1 Update identified the Welland River at the Geon (currently Oxy Vinyl LP) site on the basis of a study that had noted an increase in chironomid mouthpart deformities adjacent to the Geon site. The study was unable to identify whether contaminated sediments, or water quality, was the cause of the increased deformity rate. In subsequent studies at this site, only iron has exceeded the SEL.

In 2004, three samples were collected along a transect located at the downstream end of the site. All samples had chromium and nickel at concentrations above the LEL and two of the site exceeded the respective SELs. Maximum sediment concentrations were 131 µg/g chromium and 110 µg/g nickel. A number of other metals exceeded the LELs, as well as total PAHs and as a result in 2005, a sediment sample was collected for sediment toxicity testing. No changes in benthic organism growth or survival were noted at this location at a chromium concentration of 194 µg/g and a nickel concentration of 156 µg/g based on the outcome of the toxicity tests. Therefore, there are no predicted chronic or acute effects on benthos due to sediment contaminants.

3.3.2 Black Creek Mouth

The Black Creek mouth has been included primarily due to slightly elevated levels of arsenic in Niagara River sediments at the mouth of Black Creek in 1983 (reviewed in Golder 2004). A review of potential sources within the watershed indicated that there were no known industrial discharges to the creek, and the land use within the watershed is primarily agricultural.

Black Creek was recently sampled by the MOE and EC at two locations (discussed in Golder 2004). Arsenic concentrations at both locations in the creek were below detection limits, and although the limits were relatively high (5 µg/g), these were below the PSQG LEL of 10 µg/g. Concentrations of all other parameters were low, though a number of elements such as copper, chromium, lead, and nickel exceeded the PSQG LEL at one or more sites. The exceedances were generally minor, and concentrations were generally within 2-times the LEL.

Due to the low concentrations of metals, additional toxicity testing was not undertaken at this site, and potential for contaminants to result in degradation of benthos was assessed against the TRVs reported above (Section 3.1.3). Based on this assessment no impairment of the benthic community due to contaminants was indicated at this site.

3.3.3 Pell Creek Mouth

Pell Creek was included in the list of sites for additional consideration on the basis of a sediment sample collected at the mouth of the creek in 1983 (Hart 1986, reviewed in Golder 2004).

Pell Creek is a small tributary of Chippawa Creek (Welland River) that joins the creek along the north bank of the river, west of the St Gobain (Norton Ceramics) site. Pell Creek has received discharges from both the Norton Ceramic and Washington Mills Electro Mineral sites which are located upstream in the watershed.

Samples collected in Pell Creek in 2003 reported slight exceedances of the LEL for copper (maximum 49 µg/g), chromium (maximum 27 µg/g) and total PAHs (maximum 12.7 µg/g). The concentrations, when assessed against the TRVs reported previously did not identify risk of toxicity to benthic organisms.

3.3.4 Chippawa Creek

Chippawa Creek refers to the section of the Welland River from the Power Canal east to the Niagara River. This section of the Welland River has been altered such that the main flow in Chippawa Creek is from the Niagara River, west to the Chippawa Power Canal. As noted above, a number of industries discharge, either directly or indirectly to Chippawa Creek, including Saint-Gobain Ceramics (formerly Norton Advanced Abrasives), Washington Mills Electro Minerals (WMEM), and Washington Mills (formerly Canada Carborundum).

The inclusion of this site is based primarily on an increase in the rate of chironomid deformities in the area of historic coal tar contamination (in Niagara River RAP 1996). The coal tar site was located adjacent to the Kane dock and was remediated in 1989.

A total of 6 locations were proposed for sediment sampling in Chippawa Creek and like the sampling program proposed in the Welland River upstream of the Power Canal, each sampling location consisted of a transect, with three sampling locations along the transect: near the north bank, in the middle of the channel, and near the south bank. However, of the 6 locations proposed, samples could not be obtained at a number of locations in the middle of the river since high flows precluded the deposition of sediments in these areas. The strong flows in the Creek have resulted in heavy scour and exposed bedrock in most locations in the open main channel. The sampling locations where samples were obtained included the mouth of Pell Creek and the Stanley CSO (both Washington Mills and WM Electro Minerals have discharged partly to the Stanley CSO).

Sampling results showed that concentrations of all substances of potential concern were low. A few metals slightly exceeded the LEL (copper, maximum 37 µg/g, chromium, maximum 23 µg/g, nickel, maximum 30 µg/g), but concentrations were well below levels associated with chronic or acute effects on benthic species.

3.3.5 Chippawa Power Canal

The Chippawa Power Canal has been included in the list of potentially contaminated sites as a result of a single sample collected in 1983 (Hart 1986) in which cadmium exceeded the LEL by a minor amount (0.8 µg/g as compared to the LEL of 0.6 µg/g). The Power Canal exists as two very different segments. The lower section is broad and is similar in width to the Welland River (access to the lower canal is prevented for safety reasons). Approximately 2 km from the start of the Canal at the Welland River, the Canal narrows to a straight, concrete lined channel that flows through the west side of the City of Niagara Falls before turning northeast towards the

Sir Adam Beck Reservoir. The Canal flows to the Sir Adam Beck generating stations, but with a connection to the Reservoir.

There are no direct discharges to the lower section of the Power Canal, and flows in this section are from combined flows in the Welland River and Chippawa Creek. No landfill sites have been identified in this area and as a result, the only potential sources of contaminants in this section of the Canal would be from suspended sediments and dissolved contaminants transported from sources upstream on the Welland River and Chippawa Creek and from the limited number of storm water ditches that drain to the Canal. As a result sediment concentrations at the margins of the Canal (strong flows preclude accumulation of sediment within the main flow channel) showed slight exceedances of the PSQG LELs for a few metals (chromium 40 µg/g, copper 25 µg/g, nickel 31 µg/g). These concentrations are well below effects levels for benthic organisms.

Within the City of Niagara Falls a number of potential sources to the Power Canal have been identified. These include the Cyanamid Niagara Falls plant, which was shut down in 1992, and associated landfill sites, and the Niagara Falls WPCP. This section of the canal is channelized, with strong flows that preclude the deposition of materials. As a result, contaminants released to the Canal, or transported from upstream sources will be carried to either the Sir Adam Beck Reservoir, or to the Niagara River.

The high flows through this area would suggest that there is little opportunity for contaminated materials to accumulate in the Power Canal. The high flows would also preclude establishment of benthic communities in the Canal. The major concerns would relate to discharges to the Canal, which could add to contaminant loads transported to the Reservoir and the Niagara River. The sampling undertaken in the 1980's indicates that sediments are not contaminated, and that the minor exceedance of the LEL noted above would not likely result in any adverse effects on biota.

3.3.6 Niagara River at Queenston

Major sources to the Niagara River at Queenston are those that contribute to the Power Canal, and upstream sources on both the Canadian and U.S. side of the Niagara River.

Upstream sources on the Power Canal include a number of historical sources such as the Cyanamid (Niagara Falls) plant, the Niagara Falls WPCP, a number of landfill sites (Cyanamid Landfill) as well as direct sources to the Niagara River (e.g., CN Landfill).

The dynamic nature of the Niagara River at Queenston precludes the long-term deposition of sediments except in protected areas. Within the main channel of the river, the sediments that accumulate will typically be transient, and most materials are ultimately carried to Lake Ontario. Therefore, existing contaminant levels in sediments of the Niagara River will reflect current loadings, rather than historical deposition. However, the depositional areas along the banks of the river could accumulate and retain sediments for extended periods of time. The presence of accumulated materials below points of land in small embayments protected from the main current of the river, and the development of submergent vegetation in these areas suggests that these areas are relatively stable and would be the most likely areas for contaminants to accumulate.

Historical sediment sampling at Queenston indicates that a small number of parameters exceeded the MOE LEL guidelines. Sampling conducted by the in the early 1980's (NRTC, 1984), and by the MOE in 1983 (reported in Golder 2004), shows that of the metals, only nickel, cadmium, zinc, iron and mercury exceeded the LELs. For all of these metals, the exceedances were only marginally above the LEL. A small number of organic parameters also exceeded the LEL of the PSQGs, and included PCBs, mirex and hexachlorobenzene (HCB). Both mirex and HCB likely originate along the U.S. side since there are no documented sources along the watersheds studied as part of this project.

In 2003, an additional 4 sampling locations, near the Canadian shore of the river, from Queenston to Niagara-on-the-Lake were sampled. Sampling included analysis for metals, PCBs (since these exceeded the LEL in 1979 and 1983 samples) and dioxins and furans (see discussion below in Section 3.3.7).

Sediments collected in 2003 exceeded the CCME ISQG at all 4 locations for dioxins and furans with a maximum concentration (expressed as total TEQ) of 28.7 pg/g. Loonen et al. (1997) note that pelagic invertebrates are not considered susceptible to the toxic effects of PCDD/Fs and dl-PCBs, since these organisms appear to lack the aryl hydrocarbon (Ah) receptor through which the effects of these COCs are expressed. Loonen et al. (1996) and West et al. (1997) both note that benthic invertebrates lack the Ah receptor through which the effects of PCDD/Fs and dl-PCBs are expressed, and therefore, these substances are unlikely to exhibit toxicity to aquatic invertebrates. An ecological risk assessment conducted at the mouth of the Trent River in 2007 (Dillon 2007) to assess the effects of dioxin and furan concentrations in sediment found levels similar to those in the Niagara River did not result in levels in benthic organism tissues that presented a risk to fish or other receptors.

3.3.7 Niagara River at Niagara-on-the-Lake

The potential for sediments to accumulate at the mouth of the Niagara River is determined by two factors: the flow of the river, which at this point broadens out to flow across a rocky shelf, and the action of waves from Lake Ontario, that will continually re-distribute materials. As such, there are very limited areas where sediments could accumulate, and contaminant issues could exist. These are primarily adjacent to structures built into the river, such as docks and piers, that intercept river flow and create quiescent areas.

The Niagara River at Niagara-on-the-Lake was identified as a potential concern due to the detection of mercury in sediments above the LEL in 1983 (reported in Golder 2004). At two of the locations sampled, mercury was marginally above the LEL of 0.2 µg/g. A review of the data indicates that levels of HCB and PCBs were also in excess of the LEL.

No direct discharges to the Niagara River occur at Niagara-on-the-Lake. Rather, contaminated sediments appear to be deposited in this area from upstream sources, and occur primarily where backeddies favour sediment deposition. A number of potential sources occur within the Niagara River watershed. The primary sources along the Canadian site of the river have been identified in the Niagara River Toxics Committee study (NRTC 1984) and were included in the Niagara River RAP Stage 1 Report. In addition, a number of sources exist along the U.S. side of the river.

In addition to the compounds identified in the NRTC study, a survey by MOE in 1993 (Richman 1994) found high levels of dioxins and furans in sediments at the mouth of the Niagara River. Total TEQs were 136,000 pg/g, and represent a potential concern. This is much higher than the CCME PEL guideline of 21.5 pg/g TEQ for sediment.

Sediments were collected at a total of 2 locations in 2003 due to the lack of depositional areas along the margins of the river, and only one of these was retained for analysis (the other sample consisted entirely of sand). The analytical parameters included metals and nutrients, PCBs, and dioxins and furans.

Sediments collected in 2003 exceeded the CCME ISQG at 1 location for dioxins and furans with a concentration (expressed as total TEQ) of 55.5 pg/g. Comparing this result to the results of the ecological risk assessment conducted at the mouth of the Trent River in 2007 (Dillon 2007) to assess the effects of dioxin and furan concentrations in sediment found concentrations similar to the level in the Niagara River sediment did not result in levels in benthic organism tissues that presented a risk to fish or other receptors.

Comparison to the SSD of 57 pg/g total TEQ for the protection of fish species discussed in Section 3.2.3 indicates that there would be no risks to fish species. Using the ratio of dioxin/furan accumulation from sediment by benthic invertebrates determined from the Trent River study, the predicted concentration in benthic organisms would be 5.6 pg/g total TEQ.

4.0 FINDINGS AND CONCLUSIONS

The findings described in the previous section for each of the 13 sites in the Niagara River AOC are summarized in this section with respect to the delisting criteria described in the Section 1. The assessment is conducted according to the method described in Section 2.

4.1 Level One Sites

4.1.1 Lyons Creek West

Sediment concentrations of PCBs were found to be sufficiently elevated that these could result in accumulation of tissue residues in benthic species that could pose a risk to fish and terrestrial receptors that may consume benthos. Sediment toxicity in Lyons Creek West could not be related to the distribution of the contaminants in creek sediments, and indicated that concern with PCBs was primarily due to potential bioaccumulation and transfer to higher trophic level consumers. Due to the small area of habitat affected, it is recognized that risks to waterfowl that may consume benthos would be limited, and likely negligible.

Based on the sediment concentrations measured at the site, Lyons Creek West does not meet the delisting criteria due to elevated concentrations in sediment and benthic organism tissues. The predicted tissue residues in benthic organisms could present a risk to fish and terrestrial receptors that could be exposed to benthic organisms.

Therefore, assessing the benthic invertebrate conditions in Lyons Creek West against the de-listing criteria results in the following assessment:

- Condition 1: Sediment concentrations were not sufficiently elevated to meet effects thresholds for PCBs as determined by sediment toxicity tests. However, since benthic invertebrates are not particularly susceptible to PCBs, the threshold for PCB toxic effects is likely to be higher than the threshold for other species. Thus, the lack of toxic effects on benthic organisms would not necessarily be protective of other species. Since PCBs can biomagnify, the assessment proceeds to Condition 2.
- Condition 2: Accumulation of PCBs is predicted to be higher than in reference areas and therefore the assessment proceeds to Condition 3.
- Condition 3: Fish and terrestrial species could accumulation of PCBs to levels that may result in low risks to fish and terrestrial species that may consume benthos. As a result the assessment proceeds to Condition 4.
- Condition 4: A management plan should be developed for the site.

Based on the above assessment, benthic communities in Lyons Creek West are considered to be impaired since there is potential for bioaccumulation of PCBs from benthic organisms. However, the actual risk to fish and waterfowl from exposure to tissue residues is benthos is limited by the available habitat and is likely to be low. Nonetheless, a management strategy should be developed for this site.

4.1.2 Lyons Creek East

Sediment toxicity in Lyons Creek East could not be related to the distribution of the contaminants in creek sediments, and the results of the risk assessment showed that benthic tissue residues do not present a risk to terrestrial receptors. Marginal risks to some receptors, which were based on conservative assumptions, were due mainly to exposure to fish, which generally had accumulated higher tissue residues than benthic invertebrates.

Tissue residues were found to be higher in benthos than at non-PCB affected sites. However, the accumulation of PCBs in benthic organisms has not resulted in prediction of risks to terrestrial species that feed on benthic organisms. An administrative controls protocol has been developed for the site, and a long-term monitoring program is currently under development. Both sediments and benthic organism tissues would contribute to the elevated tissue residues in fish that have been measured in Lyons Creek East.

Therefore, assessing the benthic invertebrate conditions in Lyons Creek East against the de-listing criteria results in the following assessment:

- Condition1: Sediment concentrations were not sufficiently elevated to meet effects thresholds for PCBs as developed from other studies (e.g., Lyons Creek West). However, since benthic invertebrates are not particularly susceptible to PCBs, the threshold for PCB toxic effects is likely to be higher than the threshold for other species. Thus, the lack of toxic effects on benthic organisms would not necessarily be protective of other species. Since PCBs can biomagnify, the assessment proceeds to Condition 2.
- Condition 2: Benthic organism tissue residues were elevated relative to control sites, and areas further downstream that had low concentrations of PCBs. Therefore, the assessment proceeds to Condition 3.
- Condition 3: Benthic organism tissue residues did not result in the prediction of unacceptable risks in terrestrial receptors such as waterfowl that consume benthic organisms.
- Condition 4: Notwithstanding the assessment under Condition 3, a Contaminated Sediment Management Strategy is being implemented for Lyons Creek East to ensure that sediments are not disturbed. Sediment disturbance could potentially expose higher concentrations of PCBs that are currently isolated in the deeper sediments.

Based on the above assessment and particularly Condition 4, benthic communities in Lyons Creek East can be considered as not impaired due to sediment contaminants.

4.1.3 Welland River – Port Robinson to Chippawa Power Canal

Sediments in the Welland River showed elevated levels of chromium, copper and nickel that can be traced back to the operation of the Atlas Steel site upstream on the Welland River. As well, isolated areas of where observed where PCB concentrations slightly exceeded the PSQG LEL, though the measured concentrations are not predicted to result in risks to biota.

Sediment toxicity tests did not yield measurable responses in test organisms, and there was no indication that sediments would result in acute or chronic toxicity to benthic organisms.

Therefore, assessing the benthic invertebrate conditions in the Welland River against the de-listing criteria results in the following assessment:

- Condition 1: Sediments had elevated levels of some metals but did not result in chronic or acute effects on benthic test organisms.

- Condition 2: Contaminants with potential to biomagnify (PCBs, PCDD/Fs) have not been identified as a concern in the Welland River. Therefore, no further assessment is required.
- Condition 3: Not applicable
- Condition 4: Not applicable

The benthic communities in the Welland River from Port Robinson to the Chippawa Power Canal can be considered to be not impaired due to sediment contaminants.

4.2 Level Two Sites

4.2.1 Sir Adam Beck Reservoir

Concentrations of all substances in the reservoir were low. Some metals exceeded the respective PSQG LELs, but concentrations were well below levels that have been found to result in effects on biota at other sites within the Niagara River AOC. Bioaccumulative substances such as PCBs and PCDD/Fs have not been identified as a concern in the reservoir.

Therefore, assessing the benthic invertebrate conditions in Sir Adam Beck Reservoir against the de-listing criteria results in the following assessment:

- Condition 1: Sediment concentrations of some metals were slightly above the MOE PSQG LELs but are not predicted to result in chronic or acute effects on benthic test organisms based on sediment bioassay tests from other locations within the AOC.
- Condition 2: Contaminants with potential to biomagnify (PCBs, PCDD/Fs) have not been identified as a concern in the reservoir. Therefore further assessment is not required.
- Condition 3: Not applicable
- Condition 4: Not applicable

The benthic communities in the Sir Adam Beck Reservoir can be considered to be not impaired due to sediment contaminants.

4.2.2 Thompson’s Creek

Thompson’s Creek was primarily identified with elevated copper concentrations in sediments. Toxicity testing indicated that there were no risks to benthic organisms due to copper concentrations. Bioaccumulative substances have not been identified as a concern in Thompson’s Creek.

Therefore, assessing the benthic invertebrate conditions in Thompson’s Creek against the de-listing criteria results in the following assessment:

- Condition 1: Sediments had elevated levels of some metals, particularly copper, but did not result in chronic or acute effects on benthic test organisms.
- Condition 2: Contaminants with potential to biomagnify (PCBs, PCDD/Fs) have not been identified as a concern in Thompson’s Creek. Therefore further assessment is not required.
- Condition 3: Not applicable.

- Condition 4: Not applicable.

The benthic communities in Thompson's Creek can be considered to be not impaired due to sediment contaminants.

4.2.3 Frenchman's Creek

Sediment concentrations of cadmium, chromium and dioxins/furans were identified as potential concerns. Sediment toxicity tests indicated that cadmium and chromium did not elicit a response in the sediment bioassay tests, and that acute and/or chronic effects on benthos were not present. The higher concentrations of dioxins/furans are not likely to result in toxic effects on benthic species, but could be accumulated in benthic organism tissues that may present a risk to higher trophic levels.

A risk assessment concluded that tissue residues that could be expected in benthic species would not present a risk to fish or terrestrial species (birds and mammals) that may consume benthic organisms.

Therefore, assessing the benthic invertebrate conditions in Frenchman's Creek against the de-listing criteria results in the following assessment:

- Condition 1: Sediments had elevated levels of some metals, particularly cadmium and chromium, but did not result in chronic or acute effects on benthic test organisms.
- Condition 2: Accumulation of PCDD/Fs in benthic tissues is predicted to be higher than in reference areas and the assessment proceeds to Condition 3.
- Condition 3: Benthic organism tissue residues did not result in the prediction of unacceptable risks in fish or terrestrial receptors such as waterfowl that consume benthic organisms. Therefor, no further assessment is required.
- Condition 4: Not applicable.

Benthic communities in Frenchman's Creek are considered to be not impaired due to sediment contaminants.

4.3 Level Three Sites

4.3.1 Welland River at Geon

Sediment concentrations of chromium and nickel were identified as a potential concern, and distribution along the Welland River was consistent with the Atlas Steel site as the likely source. Sediment toxicity test results indicated there was no acute or chronic toxicity to benthic test organisms. Bioaccumulative substances were not identified as a potential concern at this site.

Therefore, assessing the benthic invertebrate conditions in the Welland River at Geon against the de-listing criteria results in the following assessment:

- Condition 1: Sediments had elevated levels of some metals, particularly chromium and nickel, but did not result in chronic or acute effects on benthic test organisms.
- Condition 2: Contaminants with potential to biomagnify (PCBs, PCDD/Fs) have not been identified as a concern in the Welland River at the Geon site. Therefore further assessment is not required.

- Condition 3: Not applicable.
- Condition 4: Not applicable.

Benthic communities in the Welland River at Geon are considered to be not impaired due to sediment contaminants.

4.3.2 Black Creek Mouth

Slight exceedances of the PSQG LEL were noted for a number of metals, but concentrations were well below levels associated with chronic or acute effects in benthic test organisms form other sites within the AOC. Bioaccumulative substances have not been identified as a potential concern at this site.

Therefore, assessing the benthic invertebrate conditions at the mouth of Black Creek against the de-listing criteria results in the following assessment:

- Condition 1: Concentrations of some metals slightly exceeded the PSQG LELs at some site but were well below levels associated with chronic or acute effects on benthic species.
- Condition 2: Bioaccumulative substances have not been identified as a potential concern at this site. Therefore further assessment is not required.
- Condition 3: Not applicable.
- Condition 4: Not applicable.

Benthic communities in Black Creek are considered to be not impaired due to sediment contaminants.

4.3.3 Pell Creek Mouth

Sediment samples collected in Pell Creek have low concentrations of a few metals and PAHs. Based on the TRVs developed for the project, sediments would not be expected to be toxic (chronic or acute) to benthic organisms.

Therefore, assessing the benthic invertebrate conditions at the mouth of Pell Creek against the de-listing criteria results in the following assessment:

- Condition 1: Concentrations of some metals and PAHs slightly exceeded the PSQG LELs but were well below levels associated with chronic or acute effects on benthic species.
- Condition 2: Bioaccumulative substances have not been identified as a potential concern at this site. Therefore further assessment is not required.
- Condition 3: Not applicable
- Condition 4: Not applicable

Based on the above assessment, benthic communities in Pell Creek are considered to be not impaired due to sediment contaminants.

4.3.4 Chippawa Creek

Strong flows in Chippawa Creek have confined areas of sediment accumulation to the margins of the channel where small pockets of sediment have accumulated in more protected areas. Concentrations in sediments in these areas showed slight exceedances of the PSQG LELs for some metals.

Therefore, assessing the benthic invertebrate conditions in Chippawa Creek against the de-listing criteria results in the following assessment:

- Condition 1: Concentrations of some metals slightly exceeded the PSQG LELs at some site but were well below levels associated with chronic or acute effects on benthic species.
- Condition 2: Bioaccumulative substances have not been identified as a potential concern at this site. Therefore further assessment is not required.
- Condition 3: Not applicable
- Condition 4: Not applicable

Based on the above assessment benthic communities in Chippawa Creek are considered to be not impaired due to sediment contaminants.

4.3.5 Chippawa Power Canal

High flows through the lower section of the Chippawa Power Canal would preclude the establishment of benthic communities, as well as prevent the deposition of contaminated sediments in the Canal. The upper part of the Power Canal is a constructed channel running through bedrock. As a result, the canal is not considered to be natural habitat.

Therefore, assessing the benthic invertebrate conditions in the Chippawa Power Canal against the de-listing criteria results in the following assessment:

- Condition 1: Not applicable since benthic communities would be absent in the lower Canal due to the high flows and in the upper canal due to lack of suitable habitat.
- Condition 2: Not applicable, since there is no opportunity for suspended sediments to be deposited in the Canal. Therefore further assessment is not required.
- Condition 3: Not applicable
- Condition 4: Not applicable

Based on the above assessment benthic communities in the Chippawa Power Canal are considered to be not impaired due to sediment contaminants.

4.3.6 Niagara River at Queenston

Sediments in the Niagara River were generally absent except for areas along the margin of the river where local headlands resulted in protected areas downstream. Sediment accumulating this areas showed accumulation of low concentrations of some metals (slight exceedances of the PSQG LEL for chromium and copper at some sites), and the presence of dioxins and furans.

Therefore, assessing the benthic invertebrate conditions in the Niagara River at Queenston against the de-listing criteria results in the following assessment:

- Condition 1: Concentrations of a few metals exceeded the LEL but there were no exceedances of the PSQG SEL. As a result, there is no predicted chronic or acute toxicity. However, elevated concentrations of dioxin and furans were noted, that could affect other species through bioaccumulation.
- Condition 2: Tissue residues of dioxins and furans are predicted to be higher than in areas where sediment concentrations are low.
- Condition 3: Tissue residues of dioxins and furans are predicted to be below levels that could affect fish or other receptors that may feed on benthic organisms. Therefore further assessment is not required.
- Condition 4: A Contaminated Sediment Management Strategy was not considered necessary.

Benthic communities in the Niagara River at Queenston are considered to be not impaired due to sediment contaminants.

4.3.7 Niagara River at Niagara-on-the-Lake

Strong flows in the Niagara River at the mouth, as well as the lack of headlands that would provide for protected areas that would permit sediment deposition and accumulation, resulted in only a single area of sediment accumulation. Sediment metals were below the PSQG LELs. PCBs and dioxins and furans were above guidelines (PSQGs and CCME CSQGs).

Therefore, assessing the benthic invertebrate conditions in the Niagara River at Niagara-on-the-Lake against the de-listing criteria results in the following assessment:

- Condition 1: Concentrations of a number of metals exceeded the LEL but there were no exceedances of the PSQG SEL. As a result, there is no predicted chronic or acute toxicity. However, elevated concentrations of dioxin and furans were noted, that could affect other species through bioaccumulation.
- Condition 2: Tissue residues of dioxins and furans are predicted to be higher than in reference areas where sediment concentrations are low.
- Condition 3: Tissue residues of dioxins and furans are predicted to be below levels that could affect fish or other receptors that may feed on benthic organisms. Therefore further assessment is not required.
- Condition 4: A Contaminated Sediment Management Strategy was not considered necessary.

Benthic communities in the Niagara River at Niagara-on-the-Lake are considered to be not impaired due to sediment contaminants.

4.3.8 Summary and Conclusions

The results of the above assessment are summarized in Table 1.

Table 1: Summary of Assessment of BUI "Degradation of Benthos" with Respect to Delisting Criteria.

Site	Condition 1	Condition 2	Condition 3	Condition 4	Conclusion
Lyons Creek West	No chronic or acute toxicity to benthic organisms from PCBs.	Tissue residues of PCBs predicted to be higher than reference areas.	Low potential for adverse effects on fish and wildlife due to benthic tissue residues.	Sediment management strategy should be developed.	Impaired but risks likely to be low .
Lyons Creek East	No chronic or acute toxicity to benthic organisms from PCBs or metals.	Tissue residues of PCBs are higher than reference areas.	No predicted risks to fish or wildlife due to benthic tissue residues.	Administrative controls implemented.	Not impaired with implementation of administrative controls
Welland River- Pt Robinson to Chippawa Power Canal	No chronic or acute toxicity to benthic organisms.	Biomagnifying substances have not been identified as a potential concern.	Not applicable	Not applicable	Not impaired
Sir Adam Beck Reservoir	No chronic or acute toxicity to benthic organisms.	Biomagnifying substances have not been identified as a potential concern.	Not applicable	Not applicable	Not impaired
Thompson's Creek	No chronic or acute toxicity to benthic organisms.	Biomagnifying substances have not been identified as a potential concern.	Not applicable	Not applicable	Not impaired
Frenchman's Creek	No chronic or acute toxicity to benthic organisms.	Tissue residues of PCDD/Fs predicted to be higher than reference areas.	No predicted risks to fish or wildlife due to benthic tissue residues.	None required.	Not impaired
Welland River at Geon	No chronic or acute toxicity to benthic organisms.	Biomagnifying substances have not been identified as a potential concern.	Not applicable	Not applicable	Not impaired
Black Creek Mouth	No chronic or acute toxicity to benthic organisms.	Biomagnifying substances have not been identified as a potential concern.	Not applicable	Not applicable	Not impaired
Pell Creek Mouth	No chronic or acute toxicity to benthic organisms.	Biomagnifying substances have not been identified as a potential concern.	Not applicable	Not applicable	Not impaired
Chippawa Creek	No chronic or acute toxicity to benthic organisms.	Biomagnifying substances have not been identified as a potential concern.	Not applicable	Not applicable	Not impaired
Chippawa Power Canal	No benthic community	Biomagnifying substances have not been identified as a potential concern.	Not applicable	Not applicable	Not impaired

Site	Condition 1	Condition 2	Condition 3	Condition 4	Conclusion
Niagara River at Queenston	No chronic or acute toxicity to benthic organisms.	Tissue residues of PCDD/Fs predicted to be higher than reference areas.	No predicted risks to fish or wildlife due to benthic tissue residues.	None required	Not impaired
Niagara River at Niagara-on-the-Lake	No chronic or acute toxicity to benthic organisms.	Tissue residues of PCDD/Fs predicted to be higher than reference areas.	No predicted risks to fish or wildlife due to benthic tissue residues.	None required	Not impaired

Report Signature Page

GOLDER ASSOCIATES LTD.

Rein Jaagumagi
Senior Environmental Specialist

RJ/jm

n:\active\2013\1118\13-1118-0004-niagara peninsula-assessment-niagara\3.0 reporting\final report\13-1118-0004 niagara aoc bui assessment april 2013 final.docx

5.0 REFERENCES

Barnthouse, L.W., D. Glaser and L. DeSantis. 2009. Polychlorinated Biphenyls and Hudson River White Perch: Implications for Population-Level Ecological Risk Assessment and Risk Management. Integ. Environ. Assess. Manag. 5 (3): 435-444.

Dillon. 2007. Ecological Risk Assessment for the Trent River Mouth Sediment Depositional Areas. Report to Ontario Ministry of the Environment. May 2007.

Golder (Golder Associates Ltd.). 2004. Niagara River Area of Concern Contaminated Sediment Site Assessment Phase I and Phase II. Report to Niagara Peninsula Conservation Authority. May 2004.

Golder (Golder Associates Ltd.). 2005. Niagara River Area of Concern Contaminated Sediment Site Assessment Phase III. Report to Niagara Peninsula Conservation Authority. May 2005.

Golder (Golder Associates Ltd.). 2008. Niagara River Area of Concern Phase IV: Sediment Management Options for Lyons Creek East and West. Report to Niagara Peninsula Conservation Authority. August 2008.

Jaagumagi, R. 2003. Welland River: Post-Remediation Assessment, September, 2000. Report to Environment Canada, Ontario Region. May 2003.Loonen, H., D.C.G. Muir, J.R. Parsons and H.A.J. Govers. 1997. Bioaccumulation of Polychlorinated Dibenzo-p-dioxins in Sediment by Oligochaetes: Influence of Exposure Pathway and Contact Time. Environ. Toxicol. Chem. 16 (7): 1518-1525.

Loonen, H., C. van de Guchte, J.R. Parsons, P. de Voogt and H.A.J. Govers. 1996. Ecological hazard assessment of dioxins: hazards to organisms at different levels of aquatic food webs (fish-eating birds and mammals, fish and invertebrates). Sci Tot. Environ. 182: 93-103.

Niagara River Toxics Committee (NRTC) 1984. Report of The Niagara River Toxics Committee. October 1984.

Steevens, J.A., M.R. Reiss and A.V. Pawlisz. 2005. A Methodology for Deriving Tissue Residue Benchmarks for Aquatic Biota: A Case Study for Fish Exposed to 2,3,7,8-Tetrachlorodibenzo-p-Dioxin and Equivalents. Integ. Environ. Assess. Manag. 1 (2): 142-151.

West, C.W., G.T. Ankley, J.W. Nichols, G.E. Elonen and D.E. Nessa. 1997. Toxicity and Bioaccumulation of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Long-Term Tests With the Freshwater Benthic Invertebrates *Chironomus tentans* and *Lumbriculus variegatus*. Environ. Toxicol. Chem. 16 (6): 1287-1294.

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario, L5N 7K2
Canada
T: +1 (905) 567 4444