SNC·LAVALIN

DETAILED WORKPLAN FOR THE COMPLETION OF THE RISK ASSESSMENT FOR PERFLUORINATED COMPOUNDS (PFCs)

WELLAND RIVER WATERSHED DOWNSTREAM OF THE HAMILTON INTERNATIONAL AIRPORT, HAMILTON, ONTARIO

Public Works and Government Services Canada

ENVIRONMENT & WATER

22| 07 | 2015

FINAL REPORT (V3) /616807

EXECUTIVE SUMMARY

A risk assessment will be completed in the spirit of provincial requirements to evaluate perfluorinated compounds in surface water, groundwater, sediment, soil and tissue, and will include an assessment of both human health and ecological risk offsite of the Hamilton International Airport in the downstream area of the upper Welland River watershed. The overall framework for the proposed human health and ecological risk assessment will follow a staged approach and proceed through a series of steps and decisions comprised of the following key components:

- **Stage 1: Supplementary Site Investigation and Interim Detailed Quantitative Risk Assessment** Undertake the required desktop studies (such as toxicity reference value identification, screening criteria, and transfer factor identification), supplemental investigations, data collection and analysis identified for Stage 1 in this workplan document and complete the evaluation consistent with a detailed quantitative risk assessment (e.g. measured vs. modelled concentration data and multiple lines of evidence, where available). The Supplemental site investigation investigations will be undertaken in part for the purpose of providing multiple lines of evidence and tissue residue concentration data required to complete an interim detailed quantitative risk assessment. An aquatic reference site characterization study will be conducted to assist in further study area definition and confirmation sediment, surface water and HIA groundwater sampling and analysis will be conducted. It is expected that a preliminary species and ecological resource survey will be completed at this stage to assist in identification of valued ecosystem components to be evaluated in the risk assessment. Based on the collected data, a detailed quantitative risk assessment report would be completed for the study area. It is anticipated that the report would be interim and the outcome will identify gaps or uncertainties requiring further evaluation. At this stage, the risk assessment would be expected to identify receptors, pathways and individual perfluorinated compounds not requiring further evaluation based on the outcome from Stage 1 and would not be subject to further analysis in a final detailed quantitative risk assessment (Stage 2).
- **Stage 2: Further Supplemental Site Investigation and Final Detailed Quantitative Risk Assessment** - Complete additional supplementary investigations required to complete a final detailed quantitative risk assessment. The Stage 2 work program will focus on implementing any additional uncertainty reduction programs and study refinements, such as collection of additional line of evidence data to evaluate the reasonableness of risks identified in Stage 1, and will deliver a final detailed quantitative risk assessment report for the final study area.

The preliminary management goal consists of ensuring that soil, sediment, surface water and groundwater in the study area are of a quality acceptable for ecological health, recreation and human health. Based upon the information collected to date, the risk assessment area represents an area within approximately 1.3 km downstream of the HIA. Further downstream from this limit, PFC inputs to the Welland River from sources not directly associated with the HIA appear to be contributing to elevated PFC concentrations in the watershed. The risk assessment limit is based on the extent of the upper Welland River watershed where there is a clear decrease in sediment and surface water PFC concentrations from the HIA to a point where concentrations fall within the range of PFC identified in tributaries which do not drain the HIA and enter into the upper Welland River downstream of the HIA.

This document consists of a workplan prepared by the Environment & Water business unit of SNC-Lavalin Inc. to offer recommendation and guidance on how to undertake a risk assessment and the supporting site assessments in the spirit of the O.Reg. 153/04 for the elevated levels of PFCs found outside of the HIA. This document will support the preparation of the tender package which will be prepared to retain a consultant to undertake the risk assessment.

A report documenting the findings and recommendations from each stage will be prepared at the end of each stage.

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1 INTRODUCTION

The Environment & Water business unit of SNC-Lavalin Inc. (SNC-Lavalin) was retained by Public Works and Government Services Canada (PWGSC), on behalf of Transport Canada (TC), to undertake a planning exercise to identify a comprehensive approach and a detailed workplan for completing a risk assessment (RA) in the spirit of the provincial requirements in the vicinity of the John C. Munro Hamilton International Airport (HIA), Hamilton, Ontario. The subject area generally consists of the Welland River Watershed downstream of the HIA. The principal chemicals of concern (COC) for this assessment are perfluorinated compounds (PFCs). Results of SNC's background review, and preliminary site investigation, and the recommended scope and detailed approach for the proposed risk assessment are provided in this document.

Investigations conducted previously in 2010 and 2011 by the Ontario Ministry of the Environment and Environment Canada have identified PFCs in surface water, sediment and biota between approximately Lake Niapenco and the HIA. Water and sediment sampling near a closed local landfill in the watershed (Glanford Landfill), observed no measurable PFOS contribution from the landfill to water and sediment quality nearby, therefore it was surmised by the Ontario Ministry of the Environment that the HIA represents a likely source of PFOS found in the downstream region of the Welland River (MOE 2012). In addition, the Ontario MOE Sport Fish Consumption Advisory for the public was adjusted to reflect elevated levels of PFOS in fish from Lake Niapenco (Binbrook Reservoir) and further downstream in the Welland River.

Transport Canada was the registered owner of the HIA until 1996 at which time the land was transferred to the Regional Municipality of Hamilton Wentworth. Two (2) former firefighter training areas (FFTA) were historically operated at the HIA. Both FFTAs were clay bermed and lined.

Transport Canada has committed to undertake an RA off-site of the HIA that is intended to be completed in the spirit of the Ontario Ministry of Environment (MOE) RA requirements as per O.Reg 153/04 (as amended).

1.1 General Use and Properties of Perfluorinated Compounds

1.1.1 Usage of PFCs

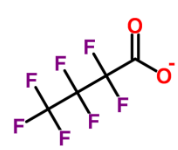
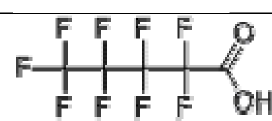
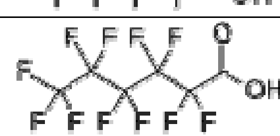
Perfluorinated compounds (PFCs) are a class of anthropogenic chemicals that have been used in numerous commercial and industrial applications since the 1950's (Paul et al., 2009). PFCs are a family of perfluoroalkyl acids (PFAAs) that contain a fluorinated carbon backbone and a charged carboxylate or sulfonate functional group (Key et al., 1997). The carbon-fluorine bonds which hold the atoms together forming the molecule are among the strongest in organic chemistry (Lau et al. 2007). The strength of these bonds produces compounds that are resistant to photolysis, hydrolysis, microbial degradation and metabolism by animals and as a consequence renders them persistent in the environment (Key, 1997).

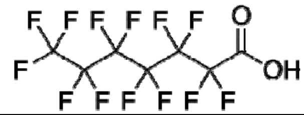
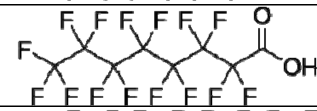
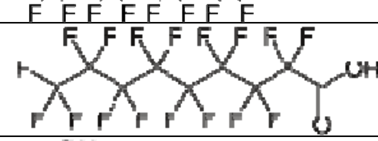
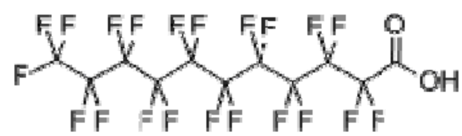
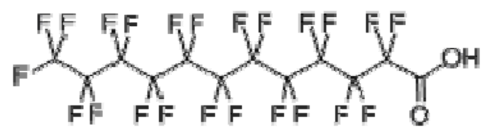
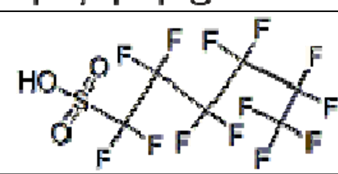
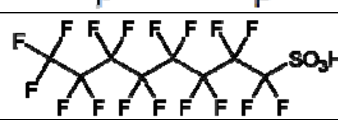
PFCs have excellent surfactant capabilities. They are stable, and they are amphiphilic, i.e. they have both hydrophobic and hydrophilic properties (Giesy et al. 2009). PFCs have been used as surfactants in aqueous film forming foams (AFFF) to extinguish hydrocarbon fuel fires (Moody and Field, 1999). At fire training areas that routinely used AFFF mixtures residual PFCs frequently remained, impacting soil, groundwater, and surface water. In addition to fluorinated compounds used in firefighting foams, PFCs have been used as surfactants and surface protectors in carpets, leather, paper, food containers, fabric, and upholstery, floor polishes, and shampoos (Giesy and Kannan 2002). There are also other historical uses of PFCs including: at least one type of aviation hydraulic fluid (Skydrol^{TM}) which contains small quantities of PFOS, the chromium electroplating sector (e.g. for anodizing and reverse etching and as a mist suppressant in the chrome plating process), as a surfactant in processing photographic film, and in the electronics industry as an etching agent for compound semi-conductors and ceramic filters.

1.1.2 PFC Fate and Transport Properties

The PFCs under investigation in this proposed risk assessment consist of perfluoroalkyl substances (PFASs) composed of an alkyl chain (a fully fluorinated carbon chain) and a functional group at one end of the chain. In this document, they are referred to as PFCs, rather than PFAS or their individual carboxylic or sulfonic acids. The general PFC formula is CnF2n+1-R, where n is the number of carbons and R is the functional group (either COOH or SO_3H) (Buck et al, 2011). PFC structure and carbon chain lengths are identified in the table below.

Table I: PFC General Chemistry

Analyte	Acronym	Formula	Carbon Number	Structure
Perfluoroalkyl Carboxylic Acids				
Perfluorobutanoate	PFBA	$C_4HF_7O_2$	4	
Perfluoropentanoate	PFPeA	$C_5HF_9O_2$	5	
Perfluorohexanoate	PFHxA	$C_6HF_{11}O_2$	6	

Perfluoroheptanoate	PFHPA	$C_7HF_{13}O_2$	7	
Perfluorooctanoate	PFOA	$C_8HF_{15}O_2$	8	
Perfluorononanoate	PFNA	$C_9HF_{17}O_2$	9	
Perfluorodecanoate	PFDA	$C_{10}HF_{19}O_2$	10	
Perfluoroundecanoate	PFUnA	$C_{11}HF_{21}O_2$	11	
Perfluorododecanoate	PFDoA	$C_{12}HF_{23}O_2$	12	
Perfluoroalkyl Sulfonic Acids				
Perfluorobutane sulfonate	PFBS	$C_4HF_9O_3S$	4	
Perfluorohexane sulfonate	PFHxS	$C_6HF_{13}O_3S$	6	
Perfluorooctane sulfonate	PFOS	$C_8HF_{17}O_3S$	8	
Perfluorooctane sulfonamide	PFOSA	$C_8H_2F_{17}NO_2S$	8	

The functional group at the head is either a carboxylic acid (COOH) or a sulfonic acid (SO_3H). PFCs are therefore further classified as perfluoroalkyl carboxylic acids (PFCAs) and perfluoroalkyl sulfonic acids (PFSAs), depending on their functional group. (Buck et al, 2011). They are strong acids that dissociate to their conjugate bases at almost all environmental conditions and are expected to primarily exist as anions in the environment (ATSDR, 2009). The carboxylic acid then becomes a carboxylate ion and the sulfonic acid becomes a sulfonate ion. The PFC carbon chain has minor negative charge, therefore the PFC molecule has a weak negative charge. Electrostatic attraction between the negatively charged PFC compounds and positively charged soil component surfaces (e.g. PFOS and minerals such as goethite, Tang et al., 2010) results in variable retardation of PFC in groundwater. Adsorption of PFC to organic carbon appears to be the dominant controlling sequestration factor in soil-groundwater and sediment-surface water systems, although pH calcium, clay and iron content are modifying factors controlling partitioning (Zareitalabad et al., 2013). PFC sorption behaviour is related to carbon chain length, with longer chain PFC displaying increased partitioning to organic carbon, although at equivalent carbon number, PFSAs tend to sorb stronger than PFCAs (Gellrich and Knepper, 2012). Short chain PFC have been observed to display little adsorption to soil matrix material in column adsorption studies (Gellrich and Knepper, 2012).

The PFC hydroxyl or carbonyl functional groups can bind to water molecules, resulting in moderate water solubility's for PFC. The solubility in water differs with the length of the carbon chain, whereas short chain PFCs possess higher water solubility's compared to long chain PFCs (Rayne and Forest, 2009) because of the larger hydrophobic moiety (fluorocarbon chain CF_2 moiety) that arises with longer chains.

Environment Canada (2012) identifies long chain PFCAs as those that contain greater than or equal to nine carbon atoms in the PFC formula (the US EPA regulatory distinction is seven to twenty carbon atoms (US EPA, 2013)). Long chain PFSA are considered to be those PFCs with greater than five carbon atoms (US EPA (2009c)). Long chain PFCs represent a greater environmental concern relative to short chain PFCs due to their increased bioaccumulation potential.

PFCs are mobile in groundwater and surface water and shorter chain PFCs are expected to be the dominant PFCs identified in groundwater. The compounds are moderately water soluble and are not expected to be behave as a dense non-aqueous phase (e.g. gravity flow) in the subsurface. PFCs will sorb to mineral surfaces and organic carbon to varying degrees, therefore retardation mechanisms will impede groundwater plume transport velocity relative to groundwater velocity. The degree of groundwater retardation is uncertain since sorption is not strictly organic carbon partitioning controlled, unlike other organic chemicals. The PFCs listed above are considered essentially non-volatile in their disassociated ionic form, which is the form expected to be present in the environment.

2 BACKGROUND

Historical background documents pertaining to the site and surrounding properties were reviewed in early 2014. A detailed list of documents reviewed and significant findings are presented in this section.

2.1 List of Reviewed Background Documents

This review was generally limited to information which was primarily pre-divestiture (i.e. earlier than 1996) and as such does not capture post divestiture activities that may have occurred following transfer of HIA property ownership to the regional municipality of Hamilton-Wentworth. PFCs are considered emerging contaminants and as such were not considered COC in environmental studies completed in support of transfer.

Documents reviewed included:

- City of Hamilton, 2005. Information Report: Status Report on City's Closed Landfills;
- Decommissioning Consulting Services Limited. 1992. Geophysical Survey Report, Hamilton Airport Fire Training Area;
- Decommissioning Consulting Services Limited. 1995. Surface and Groundwater Monitoring Program at the Hamilton Airport Fire Training Area;
- EXP Services Inc. (EXP), 2011. Initial Subsurface Investigation – Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoate (PFOA). Former Fire Training Facility, 9800 Airport Road, Hamilton, ON;
- Golder Associated Ltd, 1997. Remedial Action Plan. Hamilton International Airport, Mount Hope, Ontario.
- Hamilton Public Health Services (HPHS), 2011a. Public Health Concerns Regarding Perfluorooctanesulfonic acid (PFOS) in Lake Niapenco and Propylene Glycol in the Headwater Creeks of the upper Welland River (Airport Area). April 27, 2011;
- Hamilton Public Health Services (HPHS), 2011b. Hamilton Public Health Services Update Regarding PFOS & Glycols. June 13, 2011. Summary of Reviewed Documents;
- J.C. Munro Hamilton International Airport, Environmental Management. Accessed January 12, 2014;
- Ontario Ministry of Environment, 2012. PFOS in the Welland River and Lake Niapenco;
- Ontario Ministry of Environment, 2011. PFOS in the Welland River and Lake Niapenco;
- S.R. de Solla, A.O. De Silva, R.J. Letcher. Highly elevated levels of perfluorooctane sulfonate and other perfluorinated acids found in biota and surface water downstream of an international airport, Hamilton, Ontario, Canada, Environment International 39 (2012) 19–26;
- Transport Canada Civil Engineering Safety and Technical Services, 1991, Edited 1995. Fire Training Area, AK-70-05;
- Transport Canada. Canadian Aviation Regulations (CARs). Accessed January 12, 2014;

- XCG Consultants, 1996. Remedial Action Plan, Environmental Baseline Study, Hamilton Airport, Mount Hope, Ontario;
- XCG Consultants, Ltd., 1996. Baseline Study Summary Report, Environmental Baseline Study, Hamilton Airport, Mount Hope, Ontario;
- XCG Consultants, Ltd., 1996. Detailed Investigation Report Environmental Baseline Study Hamilton Airport, Mount Hope, Ontario;
- XCG Environmental Services Inc., 1996. Field Screening Report, Environmental Baseline Study Hamilton Airport, Mount Hope, Ontario;
- XCG Environmental Services Inc., 1996. Phase I Environmental Baseline Study Final Audit Report, Volume 1;
- XCG Environmental Services Inc., 1996. Phase I Environmental Baseline Study Final Audit Report, Volume 2 – Working Papers;
- XCG Environmental Services Inc., 1996. Phase I Environmental Baseline Study Final Audit Report, Volume 3 – Working Papers;

2.2 Background Document Review Findings

Results of the document review are summarized in Appendix A. In general, detectable concentrations of metals (lead and zinc), petroleum related products (benzene, toluene, ethylbenzene, and xylenes), polycyclic aromatic hydrocarbons (benzo(a)pyrene, and dibenzo(a,h)anthracene), inorganics (nitrite) and PFCs (PFOS) were identified in various media (i.e. soil, groundwater, sediment, and surface water) at and in the vicinity of the HIA. Historical sampling locations are illustrated in Figures 2A to 2C.

The occurrence and distribution of PFC and investigation findings are generally limited to six (6) documents (i.e. EXP, 2011; HPHS, 2011a; HPHS, 2011b; MOE, 2011; MOE, 2012; and Solla et al, 2012). The following sub-sections provide a summary of available PFC related environmental data and potential sources of PFC.

Efforts were made to identify possible sources which potentially contribute(d) to the elevated PFC concentrations in Welland River. Section 2.2.1 provides a discussion of potential PFC sources at HIA. A discussion related to identification of other potential PFC sources in the Welland River and vicinity is presented in Section 2.4

2.2.1 PFC Sources at the HIA

The HIA included two (2) FFTAs, the first (FFTA-1) of which operated from 1970 to 1984 and the second (FFTA-2) operated from approximately 1985 to 1994. FFTA-1 was redeveloped in 1992 while FFTA-2 was reportedly decommissioned in 2005 although the berm and mockup fuselage still remain at their historical locations. Both FFTAs were reportedly clay bermed and lined. The location of both FFTAs are indicated on Figure 2B

- Based on the literature review, a potential source of PFCs at the HIA includes the storage and use of AFFF at the HIA. The historical use of PFC-containing AFFF has been documented at one of the two (2) former fire training areas (FFTA-2).
- No information is available regarding post 1996, fire training activities conducted at the site. PFOS "free" foams may contain other perfluorinated compounds, some of which are, or may degrade to PFC analytes of interest (e.g. PFBS, or PFOA from 8:2 FTOH AFFF), depending on AFFF type.
- A creek located southeast of FFTA-1 was dammed to create a reservoir to supply fire fighting water. The reservoir bank was situated within 20 m of FFTA-1. No documentation concerning releases of AFFF to the reservoir was encountered. FFTA-1 appears to have been decommissioned (1984) by excavating the material and filling the reservoir with fill and debris in 1986.
- At FFTA-2, a perimeter surface water capture system drained to a retention pond which in turn drained to an ephemeral stream flowing offsite. Two main streams were located near the FFTA with the stream immediately east of the FFTA receiving all surface drainage from FFTA-2.

2.2.2 Environmental Data on PFCs

Based on the historical document review, the occurrence and distribution of PFCs in the study area is limited to data found in six documents (HPHS, 2011a; HPHS, 2011b, MOE, 2012; MOE, 2011, Solla et al, 2012 and EXP, 2011):

- Water well and surface water sampling conducted by Hamilton Public Health Services (HPHS, 2011a; HPHS, 2011b) (25 wells, 9 of which are dug wells, and 6 surface water locations);
- Sediment and surface water sampling completed by the Ontario Ministry of Environment (MOE, 2012; MOE 2011) (16 surface water and sediment sample locations);
- Aquatic invertebrate tissue, snapping turtle plasma and surface water sampling completed by de Solla et al, 2012; and,
- Surface water, sediment, soil and groundwater sampling at FFTA-2 (EXP, 2011).

Within these reports, PFC data is available for:

- Surface water;
- Groundwater;

- Sediment;
- Aquatic invertebrates; and,
- Snapping turtle plasma.

Sampling of plasma, tissue, surface water and sediment for PFC was conducted by Solla et al (2012). Based on data in Solla et al (2012), a decline in surface water PFOS concentrations with distance from the HIA is evident. This decline in surface water PFOS concentrations is not fully mirrored in the amphipod tissue data which increase near the east side of Lake Niapenco relative to the west (upstream) side of the lake. This may reflect a difference in sediment PFOS concentrations throughout the lake, although the closed Binbrook landfill is also located near the east side of the lake. This small landfill was closed in 1980 and received mostly domestic waste and very little commercial waste.

The MOE (2011; 2012) sampled a number of tributaries of the Welland River around the HIA, the Welland River and Lake Niapenco, and several reference site tributaries. An apparent decline in PFOS concentrations in surface water and sediment was identified when moving away from the FFTA-2 retention pond towards Lake Niapenco. A tributary draining FFTA-1 appears to also possess an elevated PFOS concentration in surface water. PFOS concentrations measured by EXP (2011) in pond sediment and surface water (FFTA-2) are consistent with that measured by the MOE (2011; 2012).

Based on the results of the background review, a preliminary site investigation was recommended to confirm previous results, supplement available data, and to evaluate local background/reference levels to assist with workplan development for the proposed off-site risk assessment. More specifically, a preliminary site investigation was developed and carried out in June 2014 by SNC-Lavalin to address the following issues and challenges with available historical data for PFCs:

- Need to confirm previous PFC concentrations and the reported distributions in sediment, groundwater or surface water in the Welland River Watershed prior to initiating the proposed RA. A decrease in surface water PFOS concentrations with distance from the HIA was previously reported while the amphipod tissue data reported to increase near the east (downstream) side of Lake Niapenco relative to the west (upstream). However, a number of the historical data sources did not provide tabulated analytical data and quality control results.
- Since PFCs are ubiquitous in the environment at low levels, with widespread historical use, there was a need to determine background/reference PFC levels to help discern the spatial limits of the HIA-impacted watershed to be included in the scope the off-site risk assessment The scarcity of the screening criteria and/or threshold values made identification of the affected areas also difficult.

- To establish water quality in specific tributaries that are not influenced by the HIA (*i.e.* tributaries with subwatersheds which do not comprise the HIA), but could potentially represent additional sources of PFC input into the upper Welland River.

In interpreting PFC results, the analytical results from the latest preliminary site investigation (June 2014) took precedence over data from historical sources. Results of the investigation are summarized in Section 2.3.

2.3 Summary of Recent Preliminary Site Investigation Findings

Surface water samples were collected from fourteen (14) locations in the upper Welland River watershed and sediment samples were collected at each of the surface water sample stations. Surface water and sediment sampling locations are provided on Figure 4A.

Surface water PFC concentrations were compared to available federal guidelines, guidance and screening values. Freshwater sediment guidelines for PFCs have not been developed. Surface water and sediment PFC concentrations are summarized in Appendix C. Bar charts of surface water and sediment PFC concentrations are also provided in Appendix C. Sample locations are provided on Figure 4 to Figure 6.

2.3.1 Discussion of Surface Water Results

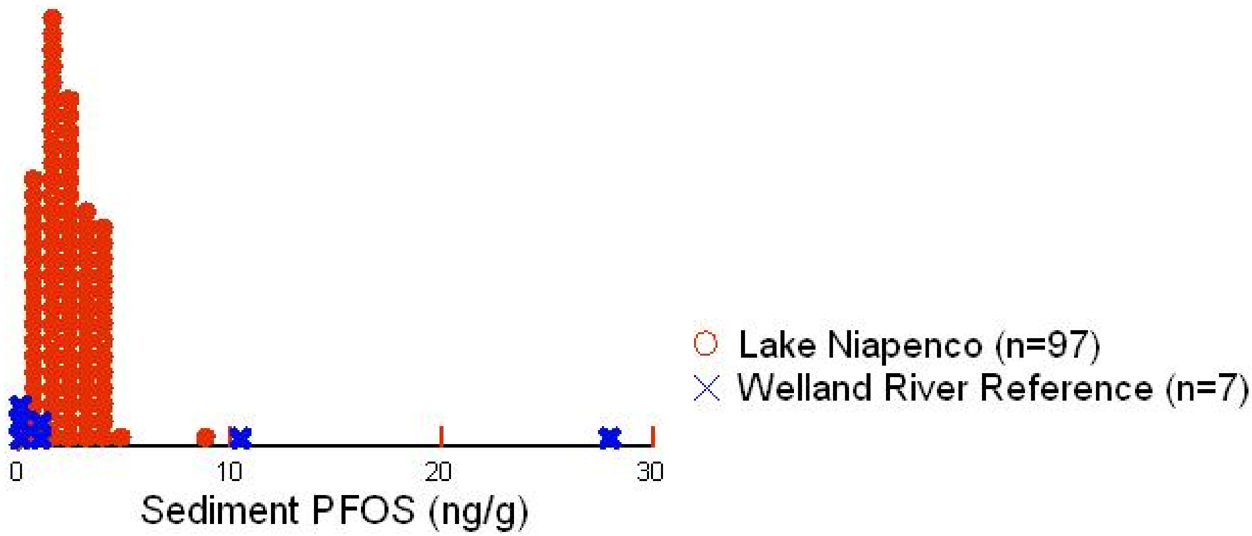
Preliminary sampling results indicate that the concentrations of PFCs in surface water entering the Welland River from tributaries which drain non-HIA lands downstream of the HIA in the watershed are similar to Welland River composition downstream of sample station WS-4 (please refer to the bar charts in Appendix C). This relationship generally appears to be present for PFBA, PFHpA, PFNA, PFBS and PFOSA and is clearly evident for PFOA and PFOS.

Three (3) PFCs consisting of PFPeA, PFHxA and PFHxS do not conform to this relationship, although two or more of the tributary sampling stations (outside of the influence of the HIA) possess detectable concentrations of PFPeA and PFHxA which indicates input to the Welland River from an unidentified source. PFHxS was not detected in WT (upper Welland River tributary) or WR series (reference site) samples. The decline in concentration with distance appears to be present between the HIA and sample station WS-4 located downstream of the HIA. Downstream of WS-4, potential additional inputs of PFC from drainage within the upper Welland River watershed is evident and suggest there are non-HIA sources of PFCs to the upper Welland River watershed. Seven (7) reference site samples comprising samples WT-1, WT-2, WT-3, WR-2, WR-3, WR-4 and WR-5 were analysed. The reference site surface water PFC concentration range and central tendency measures are provided in the table below

Surface Water PFC Reference Characterization					
		Average	Median	Minimum	Maximum
PFC	Unit				
PFBA	ng/L	7.52	8.82	3.18	11.9
PFPeA	ng/L	12.88	14.3	3.93	20.4
PFHxA	ng/L	6.44	4.005	2.36	12.9
PFHpA	ng/L	7.23	4.3	1.58	15.8
PFOA	ng/L	12.24	2.33	1.63	49.4
PFNA	ng/L	2.28	2.28	2.28	2.28
PFDA	ng/L	na	na	< 0.986	< 1.14
PFUnA	ng/L	na	na	< 0.986	< 1.14
PFDoA	ng/L	na	na	< 0.986	< 1.14
PFBS	ng/L	5.465	5.465	3.41	7.52
PFHxS	ng/L	na	na	< 1.97	< 2.28
PFOS	ng/L	232	232	232	232
PFOSA	ng/L	2.91	2.91	2.91	2.91

2.3.2 Discussion of Sediment Results

Sediment concentrations of PFCs generally approach trace or non-detectable concentrations a short distance from the HIA at WS-4 (approximately 1.3 km away from HIA) and further downstream locations. In certain cases, reference station sediment chemistry is similar to or higher in PFC concentrations than stations 1.3 km from the HIA. Therefore the off-site extent of sediment impact which may be associated with the HIA appears to be limited at present to upstream areas from WS-4. PFCs are observed in sediment from tributaries entering the upper Welland River which do not drain the HIA property, suggesting of other possible external sources. Welland River reference sediment chemistry is characterized from a limited number (seven (7)) of samples collected by SNC-Lavalin. The figure below provides a comparison of Lake Niapenco sediment PFOS concentration (red dots, 97 samples (MOE, 2012) – refer to Figure 2D for sample locations) compared to reference sediment sample PFOS concentrations (three of which possessed non-detectable PFOS concentrations and are represented at ½ detection limit). Reference sediment PFOS concentrations span a wide concentration range which covers the range observed at Lake Niapenco. The source for PFCs identified in reference station surface water and sediment is speculative. The drainage area for the tributaries which do not drain the HIA (WT series of sample stations) appears to be agricultural. A potential source for PFC in this area could be the result of biosolids applications, if spreading has taken place in this area in the past. If biosolids application has taken place, seasonal or yearly variation in sediment and surface water quality could be expected.



2.3.3 Investigation of Other PFC sources

Other potential commercial/industrial regional point sources of PFC can include chrome electroplating operations, carpet manufacturers, paper product manufacturers, or photographic or semi-conductor industries. However, none of these types of operations were identified in the upper Welland River watershed during the historical review. A closed landfill in the area east of Lake Niapenco (Binbrook Landfill) is a potential, but unlikely source of PFC given the type of waste reportedly disposed at the site (i.e. residential waste *vs.* commercial/industrial waste) and commentary from the MOE (MOE, 2011). Potential regional non-point sources of PFC could include agricultural fields in the area that have received biosolids. Biosolids are known to be, or have been, applied on farmland in the Hamilton area and it is understood that landfill leachate from at least one Hamilton landfill is directed for treatment at a Hamilton waste water treatment plant. Landfill leachate may contain PFCs originating from such products as disposed carpeting and paper products. Southern Ontario wastewater treatment plant effluents with up to approximately 200 ng/L PFOS have been recorded (Furdui et al., 2008) as well as biosolids with 72 ng/L to 600 ng/g PFOS (Crozier et al., 2005). PFOS was the highest concentration PFC identified in southern Ontario biosolids (Crozier et al., 2005). The City of Hamilton initiated land application of sewage sludge in approximately 1996 as a result of prohibitive costs associated continued incineration. These sludges were indicated to have been primarily applied to agricultural land. A preliminary sampling program completed by SNC-Lavalin was conducted in part to identify PFC concentrations in surface water and sediment in upper Welland River tributaries, including tributaries which do not drain the HIA. Based on tributary sampling (WT series samples summarized in Appendix C), and elevated PFC concentrations associated with at least one tributary draining an agricultural area, it is anticipated that biosolids application, in the absence of any other identifiable source, in the area may have influenced tributary PFC composition. If biosolids application is a potential additional PFC source in the upper Welland River watershed, it is anticipated that the source biosolids would have to have been enriched in PFCs relative to biosolids reported by Crozier et al., 2005 given that the WT-2 surface water PFOS concentration is similar to the maximum wastewater treatment plant effluent PFOS concentration reported in Furdui et al., 2008. The tributary sampled at WT-2 also differs from other reference tributaries sampled in that WT-2 represents the only sample station with detectable PFOS and PFOSA.

3 SITE INVESTIGATION AND RISK ASSESSMENT APPROACH

The risk assessment will be completed in the spirit of provincial requirements to evaluate PFCs in surface water, groundwater, sediment, soil and tissue, and will include an assessment of both human health and ecological risk. The overall framework for the proposed human health and ecological risk assessment will follow a staged approach and proceed through a series of steps and decisions comprised of the following key components:

- **Stage 1: Supplementary Site Investigation and Interim Detailed Quantitative Risk Assessment** Undertake the required desktop studies (such as toxicity reference value identification, screening criteria, and transfer factor identification), supplemental investigations, data collection and analysis identified for Stage 1 in this workplan document and complete the evaluation consistent with a detailed quantitative risk assessment (e.g. measured vs. modelled concentration data and multiple lines of evidence, where available). The Supplemental site investigation investigations will be undertaken in part for the purpose of providing multiple lines of evidence and tissue residue concentration data required to complete an interim detailed quantitative risk assessment. An aquatic reference site characterization study will be conducted to assist in further study area definition and confirmation sediment, surface water and HIA groundwater sampling and analysis will be conducted. It is expected that a preliminary species and ecological resource survey will be completed at this stage to assist in identification of valued ecosystem components to be evaluated in the risk assessment. Based on the collected data, a detailed quantitative risk assessment report would be completed for the study area. It is anticipated that the report would be interim and the outcome will identify gaps or uncertainties requiring further evaluation. At this stage, the risk assessment would be expected to identify receptors, pathways and individual perfluorinated compounds not requiring further evaluation based on the outcome from Stage 1 and would not be subject to further analysis in a final detailed quantitative risk assessment (Stage 2).
- **Stage 2: Further Supplemental Site Investigation and Final Detailed Quantitative Risk Assessment** - Complete additional supplementary investigations required to complete a final detailed quantitative risk assessment. The Stage 2 work program will focus on implementing any additional uncertainty reduction programs and study refinements, such as collection of additional line of evidence data to evaluate the reasonableness of risks identified in Stage 1, and will deliver a final detailed quantitative risk assessment report for the final study area.

Components for each stage of the assessment are discussed in further detail in Sections 3, 4, and 5 of this report. A report will be prepared after each stage of the RA documenting the findings, and the recommendations for consideration in the subsequent stages.

3.1 Preliminary Definition of the Study Area and Resources

3.1.1 Preliminary Identification of the Study Area and Risk Assessment Area Limits

The study area is located within the upper Welland River Watershed in the vicinity of HIA, which falls within the boundary of the City of Hamilton and Haldimand County. Recent investigation results (Section 2.3 of this report) indicate the area requiring further evaluation (i.e. the area of potential off-site impact associated with the FFTAs at HIA) is restricted to a limited distance from the HIA upstream of Lake Niapenco. Based on available data, the initial study area boundaries consist of the upper Welland River, consisting of tributaries from the HIA to Lake Niapenco (Figure 1). The risk assessment area represents an area within approximately 1.3 km downstream of the HIA and within the study area. Further downstream from the risk assessment study area limit, PFC inputs to the main channel of the Welland River from sources not directly associated with the HIA appear to be contributing to elevated PFC concentrations in the watershed. The risk assessment area limit (Figure 1B) is based on the extent of the upper Welland River watershed where there is a clear decrease in sediment and surface water PFC concentrations from the HIA to a point where concentrations fall within the range of PFC identified in tributaries which do not drain the HIA and enter into the upper Welland River downstream of the HIA. The risk Assessment Area also covers lands between the two main tributaries draining FFTA-1 and FFTA-2 and additional areas to the east of FFTA-2 that may require evaluation in Stage 2 of the risk assessment. The study area and risk assessment area will be reviewed and refined as additional data becomes available. Discussions in the following text with regards to the study area are intended to provide context for the risk assessment area

3.1.2 Identification of Sub-study Areas

Limited data is available to allow for a preliminary definition of the study area. The study area has been divided into two substudy areas consisting of lands of the upper Welland River Watershed upstream of the HIA (Area 1), and the upper Welland River Watershed downstream of the HIA (Area 2). The eastern portion of Area 1 comprises lands consisting of a portion of the upper Twenty Mile Creek watershed. These substudy areas are identified on Figure 3A. Figures 3B to 3D provide additional detailed views of each of the substudy areas. The following presents various site characteristics of each sub-study area (based on NPCA 2011):

Area 1

- Location (relative to the HIA): upstream (to north and northwest) and serves as a potential surface water and sediment reference area;
- Approximate area: 5.8 square kilometres;
- Land use: predominately agricultural with some small areas of residential and industrial/commercial; and,

- Significant groundwater recharge area: predominately high groundwater vulnerability.

Area 2

- Location (relative to the HIA): west and predominantly in the upper Welland River watershed;
- Approximate area: 46.3 square kilometres;
- Land use: urban (commercial/ residential and industrial) to the east and southeast of the HIA. The remaining landuse in Area 2 is predominantly agricultural with occasional residential use and sporadic commercial use (sod farms, golf courses);
- Significant groundwater recharge area: predominately high groundwater vulnerability near the HIA and low to medium vulnerability in downstream areas;
- Natural resources: one (1) locally significant wetland (Welland River Headwater Tributaries Wetland Complex), one (1) provincial wetland (Glanford Station West Wetland), one (1) conservation area (Lake Niapenco Binbrook Conservation Area Wetland Complex); and,
- Other features: three (3) closed landfills.

3.2 Water Use in and Near the Study Area

3.2.1 Potable Use

3.2.1.1 Groundwater

The majority of the watershed study area is considered a Source Protection Area under the Niagara Peninsula Conservation Authority. The study area is both a significant groundwater recharge area and a high groundwater susceptibility area, due to hydraulic connection between surface and the aquifer used for potable purposes. Potable water is primarily obtained from groundwater in the study area. Domestic use groundwater wells and high density areas of domestic use wells are indicated on Figure 9, based on information obtained from the MOE Ontario Groundwater well record data. Due to the frequency of domestic wells in the study area, only wells immediately surrounding the HIA are identified. The closest domestic well record to FFTA-2 is approximately 205 m (10542381 – refer to Figure 8).

3.2.1.2 Surface Water

There are no drinking water intake protection zones in the upper Welland River (NPCA, 2011). No evidence for surface water use in the study area for drinking water purposes was identified.

3.2.1.3 *Municipal Supplied Water*

Drinking water is supplied to the immediate area around the HIA from the Woodward Avenue Water Treatment Plant located on Woodward Ave North in the City of Hamilton. A watermain runs south along Glancaster Rd from Twenty Rd, under runway 12-30 at the west portion of the HIA and proceeds to Airport Rd. The watermain continues parallel to the south HIA property boundary along Airport Rd to Upper James St and north on Homestead Dr / Upper James St to Twenty Rd. City of Hamilton (Dillon, 2011). The location of watermains in the area of the HIA are provided on Figure 8. Areas downstream of the HIA in the study area do not appear to be municipally serviced.

3.2.2 Recreational Use

The upper Welland River provides recreational opportunities consisting of boating and fishing. The Binbrook Conservation Area (Lake Niapenco) has a splash pad for children and beach. The risk assessment area should be considered capable of providing recreational opportunities for individuals in the area.

3.2.3 Agricultural/Commercial Use

Groundwater and Surface water taking of more than 50,000 litres per day is governed under the Ontario Water Resources Act (MOE 1990). A total of fourteen (14) permits to take water (PTTW) were identified in the study area (Figure 9). All are commercial/agricultural related permits, with the exception of two (2) permits. Commercial/agricultural use permits relate to sod farms, nursery and golf course operations. Ducks Unlimited is granted a permit to obtain water from Lake Niapenco for wildlife conservation purposes, and discharge from the water control dam at Lake Niapenco is also permitted. None of the PTTW apply to surface water taking from drainage features directly linked to the FFTAs, with the exception of those at Lake Niapenco. The closest PTTW to FFTA-1 or FFTA-2 is approximately 1.6 km (FFTA-1 to PTTW-10 - groundwater).

Two (2) wells used for agricultural purposes (livestock watering) are present at approximately 580 m and 1.1 m distant from FFTA-1. These wells are located generally hydraulically downgradient from the FFTA.

Piping extending from the Welland River inland was observed by SNC-Lavalin staff in June 2014. It is not known what purpose this piping served.

3.3 *Natural Resources in and Near the Study Area*

The Niagara River flows from Lake Erie to Lake Ontario and has over 200 hazardous waters sites including 33 major sources of toxic contamination to the river (EC, 2003). A binational area of concern (AOC) was established which extends the entire length of the Niagara River and fully includes the Welland River drainage basin. The 2003 remedial action plan indicated that most of the environmental issues on the Canadian side were associated with non-point sources including pesticide use, nutrient runoff, wetland and habitat loss, riparian zone impacts and health of the fisheries. The upper Welland River watershed makes-up approximately 40 percent of the Canadian Niagara River AOC.

The upper Welland River watershed is located in the Eastern Deciduous Forest Region, also known as the Carolinian forest. The Carolinian Forest is rich in ecological diversity; it makes up less than one percent of Canada's land mass but contains the greatest number of species compared to any of the other ecosystems in Canada. The upper Welland River watershed includes the Caisstor-Canborough Slough Forest, a Carolinian Canada Signature Site, and several provincially and locally significant Areas of Natural Scientific Interest (ANSI). The upper Welland River watershed area also includes nineteen (19) federally listed species at risk, twelve (12) provincially rare species, and numerous provincially significant wetland and natural areas (NPCA, 2011).

Land use in the study area is characterized as a mix of urban and agriculture usages. The urban areas include the portion of the City of Hamilton in the headwaters, the area around the HIA, and Binbrook further downstream outside of the study area. Agriculture commodity groups used in the City of Hamilton from locations surrounding the Welland River watershed include greenhouse and nursery products, animal production products, and oilseed and grain farming.

The majority of the land within the study area, most notably lands downstream of White Church Road, has been identified as protected countryside assigned as part of the Greenbelt Plan. The Greenbelt Plan has been prepared by the Ontario Ministry of Municipal Affairs and Housing (MMAH, 2005) which was designed to provide permanent protection of the agricultural land base and ecological features from encroaching urban environments. The Greenbelt plan, which covers the entire study area, outlines three (3) key policy areas for lands within Protective Countryside:

- Agricultural system is comprised of specialty crops, prime agricultural areas and rural areas;
- Natural system is comprised of Natural Heritage System, Water Resource System and key natural heritage features and key hydrologic features; and,
- Settlement areas are comprised of towns/villages and hamlets.

Also, the Binbrook conservation area and Lake Niapenco are located in the study area which offers recreational opportunities including fishing, boating, camping and a splash pad for children.

3.3.1 Biological Resources

3.3.1.1 *Aquatic Environment*

The Welland River is the largest tributary to the Niagara River Area of Concern. The Welland River watershed is a dense network of small tributaries that possess similar features to the main river channel. The Welland River flows from its headwaters located south-west of Hamilton in the Mount Hope and HIA area and covers a meandering course of 132 km until it discharges into the Queenston-Chippawa Power Canal. The flow in the Welland River is subject to extreme dry down periods during draught conditions with permanent flow limited to 5 spring fed tributaries and possibly the Welland River headwaters. For this reason, the NPCA constructed a dam on the river near Binbrook, creating Lake Niapenco, to augment low flow periods during draught conditions which the river could experience zero flow conditions.

3.3.1.1.1 Upper Welland River Headwaters

The majority of the aquatic habitat in the upper Welland River headwaters above Lake Niapenco consists of pools with only one riffle habitat identified by the MNR (MNR, 2008). The substrate consisted of soft loose silt. The lotic environment (flowing water environment) generally consists of two distinct seasonal changes. During the spring, the flow of the upper Welland River is high, with cool to moderate water temperatures and adequate mixing of nutrients. This habitat supports fish species that are intolerant to low dissolved oxygen, to high nutrients and to high temperatures. In the spring, when conditions are optimal, these types of fish are likely to have wide distributions in the upper Welland River. However, in the summer the flow of the upper Welland River slows to low flow conditions. In these conditions, there is little mixing of water and high water temperatures are common. During this time period these intolerant fish are limited to locations within the best habitat conditions which force fish into concentrated areas.

3.3.1.1.2 Binbrook Resevoir (Lake Niapenco)

Lake Niapenco is an artificial lake which covers roughly 174 hectares and spans 5.4 km. Lake Niapenco is exposed to seasonal draw downs of water levels and storage of spring runoff. The Ministry of the Environment (MOE) assessed fish for contaminants and the results forced the MOE to set human consumption limits due to elevated PAH and mercury levels, and more recently, PFOS. Water management of Lake Niapenco results in a destruction of prime fish habitat due to fluctuations in water level. Major rehabilitation project have been implemented along the shorelines to try and create prime fish habitat. Adult Pickerel have been stocked in the Lake in the hope that a natural producing population could be established; however, no juvenile pickerel have been identified in the lake to date. The drawdown of water continues to be a significant concern forcing the fish population into close confinement and the freezing of vegetation on the lake bottom. The dam serves as a barrier to aquatic organisms and prevents the upstream migration or downstream movement of fish. The bottom of the lake is comprised of predominately fine material consisting of clay and soft silt. Also, due to the changing water elevations, the shorelines are prone to flooding or encroachment allowing for the growth of vegetation along the lake and river banks.

3.3.1.2 *Fish Habitat and Communities*

Fish habitat has been delineated in a portion of the upper Welland River watershed by the NCPA. The classification of fish habitat falls into one of three categories based on the MNR stream classification data (NPCA, 2011):

- Type 1 – "critical habitat" is considered to be the most sensitive fish habitat and as a result requires the highest level of protection. This habitat included critical spawning and rearing areas, migrations routes, over-wintering areas, productive feeding areas and habitat occupied by sensitive species.
- Type 2 – "important habitat" is less sensitive than type 1 and requires a moderate level of protection. These areas include feeding areas for adult fish and unspecialized spawning habitat.
- Type 3 – "marginal habitat" is considered marginally or highly degraded and does not contribute directly to fish productivity such as channelized streams and artificially created watercourses.

None of the tributaries in the study area have been classified for fish habitat by the NPCA or MNR. A small number of streams and a small portion of the upper Welland River near the Hamilton Airport have been classified by Dillon- Aquafor Beech (2011), based on the classification system described above. The specific location within the investigation area is south of the Hamilton International Airport, north of White Church Road, to Airport Road and west to Butter Road. Many of the second order tributaries were classified as important Type 3 habitat and directly contribute to fish productivity and the third order tributaries were concluded to be marginal Type 3 fish habitat that indirectly contribute to fish habitat. The Welland River was identified as critical fish habitat for a warm water fish community type. Although only a small portion of the upper Welland River headwaters have been investigated for potential fish habitat, the MNR has conducted fish community surveys in the upper Welland River.

The Ontario Ministry of Natural Resources conducted fish community surveys from 2003 to 2007 (Yagi and Blott, 2008) and from 1997 to 2011 (Yagi and Blott, 2012). The Niagara River Watershed is divided into ten (10) aquatic resource areas (ARA) as a result of natural and anthropogenic influences. Two of the ARAs fall within the study area; Welland River Headwaters (the upper Welland River upstream of Lake Niapenco) and Lake Niapenco. The Welland River Headwaters ARA includes the main stem of the Welland River and its tributaries upstream of Lake Niapenco. When sampling was conducted in 2007 it was estimated that continuous habitat extended roughly 11 km upstream of Highway 6. The fish community survey revealed that the upper Welland River headwater fish community resembles that of the fish community downstream of Lake

Niapenco as opposed to the fish community in Lake Niapenco. In the upper Welland River headwaters, fish were collected at five (5) sampling locations by the MNR covering a 21 km upstream distance from Lake Niapenco. The following fish species were identified by the MNR in the upper Welland River upstream of Lake Niapenco:

- White Sucker;
- Grass Pickerel (species at risk);
- Central mudminnow;
- Black Bullhead;
- Yellow Bullhead;
- Brown Bullhead;
- Tadpole Madtom;
- Johnny Darter;
- Golden Shiner;
- Bluntnose Minnow;
- Green Sunfish;
- Pumpkinseed;
- Northern Pike;
- Largemouth Bass;
- White Crappie;
- Black Crappie;
- Yellow Perch; and,
- Common Carp.

Species identified by the MNR at sampling stations in the Binbrook Reservoir consisted of the following:

- White Sucker;
- Yellow Bullhead;
- Brown Bullhead;
- Channel Catfish;
- Golden Shiner;
- Emerald Shiner;
- Common Shiner;
- Spottail Shiner;
- Bluntnose Minnow;
- Rock Bass;

- Green Sunfish;
- Pumpkinseed;
- Bluegill;
- Northern Pike;
- Smallmouth Bass;
- Largemouth Bass;
- White Crappie;
- Black Crappie;
- Yellow Perch;
- Walleye; and,
- Common Carp.

Based on the dominance of warm water fish species and absence of cold water species, it is likely that the upper Welland River would be classified as a warm water fish community. It should be noted that Grass Pickerel is listed under Schedule 1 of the Federal Species at Risk Act and was identified in the upper Welland River during the MNR fish community assessment (Yagi and Blott, 2008). The Grass Pickerel requires specific habitat and in Niagara Region they can be found in wetland associated watercourses with organic rich sediments. All tributaries draining the HIA are considered habitat for Grass Pickerel. Grass Pickerel, if present in the risk assessment area, may occur on a seasonally variable basis.

3.3.1.3 *Benthic Invertebrate Community*

Benthic community structure is an important measure of the health of an aquatic environment. Benthic invertebrates play an import role in the cycling of nutrients in the aquatic food web and serve as a food source for many fish species. Benthic macro-invertebrate sampling has been conducted at surface water quality monitoring stations by the NCPA. Benthos typical of the Niagara Peninsula include species of clams, snails, leeches, worms and larval stages of dragonflies, stoneflies, caddisflies, mayflies and beetles. The benthic invertebrate samples were used to assess water quality using the BioMAP protocol. The NCPA states that sediment loading, lack of in-stream habitat and nutrient enrichment are primary causes for benthic community impairment. NPCA also report that glycol and storm water discharges from the Hamilton airport are having a negative impact on two of the benthic invertebrate stations. Dillon- Aquafor Beech (2011) repeated sampling at NPCA sampling stations and reported similar results to the NCPA.

3.3.1.4 *Terrestrial Habitat and Communities*

The Welland River watershed is located in the Eastern Deciduous Forest Region which comprises Carolinian forest. The Carolinian Life Zone is an ecosystem within the Eastern Deciduous Forest Region that consists of a complex network of cores and corridors that stretch from Toronto to Grand Bend extending to Lake Erie. The landscape surrounding the Welland River has been identified as a corridor which serves to connect to the system of core natural areas comprising the Carolinian Life Zone.

The upper Welland River watershed is rich in ecological diversity. It includes the Caisstor-Canborough Slough Forest, a Carolinian Canada Signature Site, and several provincially and locally significant Areas of Natural Scientific Interest. The Caistor-Canborough Slough Forest is one of 38 Carolinian Life Zones and is considered a natural heritage feature and as a provincial Area of Natural and Scientific Interest (ANSI) as well as a provincially significant wetland. The site is nearly 350 hectares in size and consists of one of the most extensive woodlot complexes remaining in the region serving as habitat for wildlife and as a source for over 20 streams. The Caistor-Canborough Slough Forest is a considerable distance downstream from Lake Niapenco but it is connected to the investigation area through an ecological corridor which extends the length of the Welland River. Pockets of land areas adjacent to the corridor are considered to be Meta Cores to the Carolinian forest.

Binbrook Conservation Area is part of the investigation area and hosts Niagara's largest inland lake; Lake Niapenco. The Lake supports a wide range of recreational activities including: fishing, controlled water fowl hunts, swimming area, nature trails and a splash pad for children.

3.3.1.5 *Species at Risk*

Federally listed Species at Risk identified or potentially present in the Upper Welland River Watershed are summarized below (NPCA, 2011 and NHIC).

Table II: Species at Risk

Listed Species at Risk in the Upper Welland River Watershed			
COSEWIC Status (Federal)	**COSSARO Status (Provincial)**	**Common Name**	**Scientific Name**
END	END-NR	American Chestnut	*Castanea dentata*
END	END	Butternut	*Juglans cinerea*
END	END	Flowering Dogwood	*Cornus florida*
END	END-R	Henslow's Sparrow	*Ammodramus henslowii*
END	SC	Five-lined Skink	*Eumeces fasciatus*
THR	THR	Blanding's Turtle	*Emydoidea blandingii*
THR	THR	Mapleleaf Mussel	*Quadrula quadrula*
SC	SC	Cerulean Warbler	*Dendroica cerulea*
SC	SC	Eastern Ribbonsnake	*Thamnophis sauritus*
SC	SC	Grass Pickerel	*Esox americanus*
SC	SC	Green Dragon	*Arisaema dracontium*
SC	SC	Milksnake	*Lampropeltis triangulum*
SC	SC	Northern Map Turtle	*Graptemys geographica*
SC	SC	Short-eared Owl	*Asio flammeus*

SC	SC	Woodland Vole	*Microtus pinetorum*
SC	SC	Yellow-breasted Chat	*Icteria virens*
THR	THR	Bobolink	*Dolichonyx oryzivorus*
NAR	SC	Southern Flying Squirrel	*Glaucomys volans*
SC	S3 (rare)	Snapping Turtle	*Chelydra serpentina serpentina*

Three bat species have been listed as endangered species in Ontario since the NPCA 2011 report. The little brown bat is listed as endangered under Ontario's Endangered Species Act and after an emergency species assessment in 2012, the tri-colored bat, northern bat and the little brown bat were all listed as federally endangered species by COSEWIC.

Provincially Rare Species identified or potentially present in the upper Welland River Watershed consist of the following:

- Bee-balm;
- Blue-tipped Dancer;
- Blunt-lobe Grapefern;
- Branching Bur-reed;
- Button-bush Dodder;
- Flaccid Sedge;
- Flat-stemmed Danthonia;
- Giant Swallowtail;
- Hairy Forked Chickweed;
- Halberd-leaved Tear-thumb;
- Hickory Hairstreak;
- Hirsute Sedge;
- Jefferson-Blue spotted Salamander;
- Lance-leaved Grapefern;
- Northern Ribbon Snake;
- Perfoliate Bellwort;
- Slender Sedge;
- Sharp-fruit Rush;
- Scheber's Wood Aster;
- Tufted Titmouse;

- Wax-leaved Meadow-rue;
- Weak Stellate Sedge; and,
- Wildennow's Sedge.

Regionally Rare Species identified or potentially present in the upper Welland River Watershed consist of the following:

- Dotted Water Meal;
- Downy Hawthorn;
- Giant Ragweed;
- Halberd-leaved Tearthumb;
- Marsh bellflower;
- Narrow-leaved Willow-herb;
- Pilewort;
- Purple-tinged Sedge;
- Rattlesnake Manna Grass;
- Rough Hair Grass;
- Sallow Sedge;
- Small's Spike-rush;
- Small-flowered Agrimony;
- Smooth Solomon's Seal;
- Sweet Ox-eye;
- Sweetfleaf;
- Tall Swamp Beggar-tricks;
- Water Pimpernel; and,
- Yellow Mandarin.

The location of species observations and fish habitat classifications are provided on Figure 8. Legend information is provided on Figure 2A.

3.4 Risk Assessment Approach

The risk assessment will be completed in the spirit of the Ontario provincial risk assessment framework established by O. Reg 153/04. Established methods for conducting RAs are available from other federal and alternate regulatory authorities and will also be employed in completion of the RA for the study area. The following sections present overall guidance for the completion of the RA, including:

- Risk Assessment Objectives;
- Study Area Management Goal;
- Key deviations from RA requirements presented in O.Reg. 153/04;
- Screening of Chemicals of Concern;
- General approach for human health risk assessment; and,
- General approach for ecological risk assessment.

3.4.1 Risk Assessment Objectives

The objectives of the risk assessment include the following:

- Determine the likelihood of adverse effects that could arise to human and ecological receptors from the presence of PFCs within the study area downstream of the Hamilton International Airport (HIA) property through various applicable exposure pathways;
- Develop site specific risk based media quality objectives protective of human health and the environment based on applicable federal and other guidance;
- Identify management areas which exceed acceptable risk based levels; and,
- Identify viable risk management and/or remedial options that could be used to meet site specific remediation objectives and their costs.

The level of RA detail will be detailed quantitative/Tier III. The deliverable at the completion of Stage 1 will be an interim detailed quantitative risk assessment, as the information required to complete the evaluation is consistent with a detailed quantitative assessment approach (e.g. measured *vs*. modelled concentration data and multiple lines of evidence, where available). The Stage 2 risk evaluation will incorporate any additional uncertainty reduction programs and will be a refined and final detailed quantitative risk assessment for the final study area.

3.4.2 Study Area Management Goal

The Ontario Ministry of Environment and Energy (MOEE, 1994) established a provincial surface water quality management goal, as a basis for the provincial water quality objectives that consists of ensuring “that the surface waters of the province are of a quality which is satisfactory for aquatic life and recreation” (MOEE, 1994 (Section 3.1). This goal is generally adopted as a study area management goal for the aquatic environment. A similar goal is adopted as a RA management goal for the terrestrial environment. The preliminary risk assessment area management goals are as follows:

- Ensure that soil, sediment, surface water and groundwater in the study area are of a quality which is satisfactory for ecological health, recreation and human health.

3.4.3 Key Deviations from O.Reg. 153/04

As discussed in previous sections, the risk assessment for PFC's detected downstream from HIA is to be conducted in the spirit of Ontario Ministry of the Environment (MOE) requirements, as per Ontario Regulation (O.Reg) 153/04. However, where appropriate, RA guidance from Canadian Federal government (i.e. Health Canada, Environment Canada/Federal Contaminated Sites Action Plan and the Canadian Council of Ministers of the Environment) and other regulatory agencies (i.e. the United States Environmental Protection Agency) should also be consulted. As previously noted, the RA is not being undertaken with the objective of obtaining a Record of Site Condition (RSC). Key deviations from risk assessment requirements, as presented in O.Reg. 153/04, include:

- The RA will not include the preparation and submission of an MOE pre-submission form (PSF) for comment on the proposed risk assessment approach. As such, mandatory requirements of a PSF presented in Schedule C, Part I, S.3 of O.Reg. 153/04 as amended will not be required. However, input obtained from stakeholder and technical group will be considered in the RA. Please refer to the engagement schedule (Section 5) for further details on the proposed consultation and engagement approach.
- The RA will generally be developed in accordance with the RA framework and methodologies provided in MOE guidance (i.e. MOE 2005, O.Reg. 153/04 as amended); however, the RA report may not be organized strictly based on the structure specified in Table 1 presented in Schedule C of O.Reg. 153/04. Additionally, the RA may not include all required appendices to be attached to the report; for example, a separate appendix that contains a summary of the Phase I and II site characterization findings;
- A separate appendix consisting of mandatory certification as presented in Schedule C, Part I, S.5 of O.Reg. 153/04 as amended will not be included in the RA;
- MOE acknowledgment of site specific standards will not be required as part of the RA, although MOE comments will be sought on these standards at the draft report stage;
- Additional record and document review and/or supplemental site investigations undertaken during Stage 1 and 2 will not formally constitute a Phase I and Phase II Environmental Site Assessment (ESA) as defined in Schedule D and E of O.Reg. 153/04 as amended. The spirit of the process and protocols as defined under the Phase I and Phase II ESA section of O.Reg 153/04 will be followed during site assessment works to support this RA; and,

- Soil sampling for the purpose of establishing background levels of PFCs, if undertaken as part of this assessment, will not follow sampling requirements stipulated in O.Reg 153/04.

3.4.4 Screening of Chemicals of Concern

The screening step of COC for RA involves comparing the relevant analytical results measured in the study area to standards/guidelines/criteria (referred herein to as "screening criteria") and/or background/reference concentrations applicable to the site. A summary of available screening criteria are provided in Appendix B. The list in not exhaustive, but provides values from Canadian, US EPA, the UK, Germany and Norway, in addition to peer reviewed literature values. COCs will be screened separately in the human health and ecological risk assessment utilizing human health and ecological risk-based screening criteria. Where screening criteria are not available for a specific PFC or applicable pathway, the analytical results should be compared to the corresponding background concentrations collected from the reference locations, if available. Background values will be confirmed from a supplemental investigation conducted during Stage 1.

The maximum concentration of each parameter should be chosen as the most appropriate concentration for chemical screening purposes. Chemicals with detectable concentrations or detection limits lower than or equal to corresponding screening levels and/or background concentrations are unlikely to represent a human health or ecological risk and need not be examined further. Conversely, an exceedance of the corresponding background concentrations/screening criteria does not necessarily mean that risks are unacceptable. Further assessment with the consideration of site-specific information if available should be examined to confirm whether negative impacts could occur.

3.4.4.1 *Data Quality Evaluation*

All available PFC analytical data should be considered for the purpose of conducting this proposed HHERA. Data will also be evaluated in accordance with minimum data requirements provided in *Guidance for Data Usability for Risk Assessment* (US EPA 1992 a, b). The requirements to ensure that data will be appropriate for risk assessment use include, but are not limited to the following:

- Data sources;
- Consistency of data collection methods;
- Analytical methods and detection limits;
- Variable monitoring data; and,
- Data quality indicators.

The consultant will be required to evaluate data quality within a separate section of the report, identify all data quality issues and comment on the acceptability of the data to be used in the risk assessment.

3.4.4.2 *Selection of Applicable Screening Criteria*

Screening criteria represent thresholds that are protective of ecological and human health under all plausible exposure scenarios, and applicable at the majority of situations encountered at a contaminated site. With respect to PFCs, no existing provincial human health and ecological standards and/or guidelines are available. However, Environment Canada (EC 2013) recently published draft Federal Environmental Quality Guidelines (FEQG) for PFOS in various media (refer to Appendix B) and Health Canada has developed health based drinking water guidance and screening values. Both the EC and HC guidelines/guidance and screening values may change in the future. A limited summary of available screening criteria are provided below.

Table III: Summary of Proposed Ecological Screening Criteria

PFC/Media	Criterion	Receptor	Reference	Comments
PFOS (Soil) PFOS (Soil)	1.3 mg/kg 0.9 mg/kg	Protection of aquatic life (Coarse Soil) Protection of aquatic life (Fine Soil)	Environment Canada, 2013 Environment Canada, 2013	Provisional advice only, but developed by a Canadian Regulatory source for the protection of aquatic life. There is uncertainty in the criteria based on the BCF used to derive the final values.
PFOS (Soil)	39 mg/kg	Screening benchmark (invertebrates)	Beach et al. 2006	Considered to be more appropriate for the evaluation of community level soil invertebrate impact compared to available predicted NOEC criterion
PFOS (Soil)	0.0106 mg/kg	Secondary effects value (mammals and birds consuming earthworms)	Merrington et al, 2009	Based on 2004 UK Environment Agency $PNEC_{oral}$ of 0.067 mg/kg ww in food. Selected based on limited availability of criteria applicable to consumers
PFOSA (Soil)	0.16 mg/kg	Predicted no effect concentration (earthworm)	NPCA, 2008	Only available regulatory criterion.
PFOS (Surface Water)	6 µg/L	Aquatic life protective value. Derived based	Environment Canada, 2013	Value may be over-conservative though for

		on a reasonably robust dataset using a SSD and EC5.		aquatic plant protection, based on MPCA (2013).
PFOS (Groundwater)	60 µg/L	Aquatic life protective value.	Environment Canada, 2013	Based on relevant guideline and only regulatory groundwater criterion of its kind available. Based on provisional aquatic life value adjusted for a 10 m transport distance.
PFOS (Fish Tissue)	8.3 mg/kg WW	Protective of fish.	Environment Canada, 2013	Only available regulatory criterion. Limitations may be present in the uptake model input value for the accumulation factor.
PFOS (Avian Diet)	8.2 µg/kg WW	Protective of avian receptors consuming aquatic biota	Environment Canada, 2013	Only available regulatory criterion.
PFOS (Mammal Diet)	4.6 µg/kg WW	Protective of mammalian receptors consuming aquatic biota	Environment Canada, 2013	Only available regulatory criterion.

Table IV: Summary of Proposed Human Health Screening Criteria

PFC/Media	Criterion	Receptor	Reference	Comments
PFOS (Soil)	0.7 mg/kg	Residential/Parkland (Toddler)	Health Canada, 2013	Provisional Screening level subject to change.
PFOA (Soil)	16 mg/kg	Residential (Child)	US EPA, 2009b	Based on subchronic RfD, child, 6 year exposure. Given uncertainty (subchronic TRV), the Consultant should determine if the screening criterion is appropriate.
PFOS (Drinking Water)	0.3 µg/L	Adult	Health Canada, 2012a	Drinking water guidance value and equivalent to MDH and UK HPA values.
PFOA (Drinking Water)	0.7 µg/L	Adult	Health Canada, 2012b	Drinking water guidance value and roughly equivalent (slightly higher) to US EPA and MDH values.
PFBS (Drinking Water)	15 µg/L	Adult	Health Canada, 2011	Drinking water guidance value
PFBA (Drinking Water)	30 µg/L	Adult	Health Canada, 2011	Drinking water

				guidance value
PFPeA (PFPA) (Drinking Water)	0.7 µg/L	Adult	Health Canada, 2011	Drinking water screening value based on PFOA. Consultant should determine if PFOA-PFPeA TEF can be assumed to be 1 prior to application.
PFHxA (Drinking Water)	0.7 µg/L	Adult	Health Canada, 2011	Drinking water screening value based on PFOA. Consultant should determine if PFOA-PFHxA TEF can be assumed to be 1 prior to application.
PFHpA (Drinking Water)	0.7 µg/L	Adult	Health Canada, 2011	Drinking water screening value based on PFOA. Consultant should determine if PFOA-PFHpA TEF can be assumed to be 1 prior to application.
PFNA (Drinking Water)	0.7 µg/L	Adult	Health Canada, 2011	Drinking water screening value based on PFOA. Consultant should determine if PFOA-PFNA TEF can be assumed to be 1 prior to application.
PFHxS (Drinking Water)	0.3 µg/L	Adult	Health Canada, 2011	Drinking water screening value based on PFOS. Consultant should determine if PFOS-PFHxS TEF can be assumed to be 1 prior to application.

The consultant undertaking the risk assessment will be required to provide written rationale for selection of appropriate screening criteria for each PFC. Human health drinking water criteria may be used as human health surface water screening criteria, assuming that recreational exposure is lower than that assumed in drinking water criteria development. In the absence of human health protective criteria for sediment, the consultant should consider application of soil criteria, recognizing the limits of such criteria (i.e. protection of food chain transfer and consumption of fish). Where no criteria are available, a detailed literature review and compilation of toxicity in support of developing site-specific screening criteria should be conducted. The derivation approach for site-specific screening criteria should be based on sound science, appropriate protocol/guidance and current best practices (i.e. MOE 2011, CCME 2006). For certain PFCs with no toxicity data available to allow for derivation of screening criteria, the exposure and toxicity assessment will not address these PFCs; however, discussion of risk assessment uncertainty should be completed.

3.4.4.3 *Site Specific Background Levels*

Where screening criteria are not available, or cannot be suitably derived for a specific PFC, PFC concentrations measured within the study area will be compared to the corresponding site-specific background concentrations in specific media collected from reference areas. The development of background levels must be based on a process which meets the spirit of the O.Reg. 153/04 risk assessment requirements, be scientifically defensible, statistically robust, and appropriate for the application in the proposed risk assessment. Further details are provided in Section 4.

3.4.5 **General Approach for Human Health Risk Assessment**

This section describes a general approach for completing the quantitative human health risk assessment (HHRA), in the spirit of provincial requirements, to determine the likelihood of adverse effects that could arise from the presence of PFCs to people interacting with the study area through various applicable exposure pathways.

The HHRA will be completed primarily under the provincial guidance of:

- Procedures for the Use of Risk Assessment under Part XV.1 of the Environmental Protection Act (MOE, 2005).

A list of resources for human health risk assessments is provided in Section 9.1 of the MOE (2005) guidance document. Additional relevant guidance to be considered for the HHRA includes, but is not limited to the following:

- Federal Contaminated Site Risk Assessment In Canada Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA) (Health Canada, 2010a);
- Federal Contaminated Site Risk Assessment In Canada Part V: Guidance on Detailed Quantitative Human Health Risk Assessment for Chemicals ($DQRA_{Chem}$) (Health Canada, 2010b);
- Federal Contaminated Site Risk Assessment in Canada: Supplemental Guidance on Human Health Risk Assessment for Country Foods ($HHRA_{Foods}$) (Health Canada. 2010c); and,
- Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) (US EPA, 2005).

The general methodology to be used for completing the HHRA involves calculating exposure doses for critical receptors and complete exposure pathways. The resultant doses are then multiplied by appropriate risk factors to estimate the resultant risks. This process requires the identification of potential receptors that are most likely to receive the greatest exposures and the identification of the potential exposure pathways by which the various receptors are exposed to contaminants under study. The proposed methodology and underlying assumptions to be considered in the HHRA are outlined in the following sections.

3.4.5.1 *General Requirements*

The HHRA report will be a stand-alone document and include all data necessary for a reviewer to evaluate the risk assessment. Example calculation including all intermediate stages of the quantitative evaluation up to and including the final site specific target level calculations must be provided in the HHRA. All inputs values, toxicity reference values (including extrapolations and incorporated uncertainty values if undertaken by the Consultant), assumptions and references in the report must be completely referenced in order that a third party review can be reasonably conducted.

The HHRA report will clearly describe any aspects of the assessment that deviated from the referenced protocols and guidance documents and should document all assumptions made by the Consultant.

3.4.5.2 *Problem Formulation*

The problem formation generally involves the following components:

- Completion of a human health conceptual site model (CSM) that describes the potential contamination problems to be assessed from a human exposure to PFCs and health risk perspective (MOE, 2005), including the identification of the release mechanisms and transport pathways, all on-site and off-site human receptors, and exposure points and routes; and,
- General statement regarding the HHRA objectives as defined in Section 3.2. of the MOE (2005) guidance document; and,
- Discussion of data quality

Key components of the problem formulation are discussed in the following sub-sections.

3.4.5.2.1 Micro-Environment/Exposure Unit Identification

Exposure units must be identified within the study area. The Consultant shall identify a final list of microenvironments following supplemental sampling program completion in order to conduct the RA based on this evaluation. The rationale behind separation of the study area into discrete exposure units, or evaluation of the site as one exposure unit, will need to be fully documented in the HHRA. A preliminary evaluation of the study area indicates there are two (2) general exposure units consisting of a) the upper Welland River and tributaries, and c) predominantly agricultural areas proximal to the Welland River and tributary exposure units.

Additional exposure units may be identified based on the results of the investigation programs completed during Stage 1 or Stage 2 of the RA.

3.4.5.2.2 Receptor Identification

The study area can be used by peoples of all ages who live within or frequent (from long to short periods of time) the study area for multiple purposes, the HHRA is considered to be undertaken to cover five age classes defined by MOE 2011b: infant (0-5 months); toddler (6 months to 4 years), child (5-11 year), teen (12-19 years) and adult (20 years and over).

For evaluation of risk related to potential non-carcinogenic effects, a toddler is considered the more highly exposed receptor, given their physical characteristics and behaviours (i.e. generally spend more time outdoor swimming or playing around the river than other age groups). The selection of this age group is proposed as the basis for evaluating non-carcinogenic risk in consideration that PFCs are not classified as carcinogenic to humans at this point in time. There is evidence for developmental effects (in laboratory mammals) resulting from PFOS and PFOA exposure. The consultant will need to evaluate the basis of the toxicity reference values used in the HHRA to determine the appropriate receptor and exposure term to conduct the evaluation.

3.4.5.2.3 Exposure Pathway Identification

The surface water downstream of the HIA is potentially used for recreational purposes such as swimming or fishing. Although water from the river is not generally considered as potable water source, accidental ingestion of water through various activities (i.e., swimming) is expected. Considering that residents or visitors may come into contact with sediments, water and fish through various exposure routes, the HHRA is proposed to examine applicable direct and indirect pathways of exposure:

A detailed rationale in support of the pathway elimination should be provided, i.e. using the intrinsic physical/chemical properties of the COC, the natural geology/ hydrology of the site, and/or the presence of a barrier.

3.4.5.2.4 Preliminary Human Health Conceptual Site Model

Recreational contact with surface water occurs in the study area and exposures through sportfish consumption are considered as complete exposure pathways. The latter pathway is currently managed through a consumption advisory for Lake Niapenco. Surface water may also be used as a livestock watering source if pastures have access to surface water in the Welland River and tributaries impacted by PFCs. Groundwater is utilized in part as a drinking water and livestock watering source in the study area. Current information indicates that domestic well water in the vicinity of the HIA meets the Health Canada drinking water guidance value concentration for PFOS, although additional PFCs will also have to be considered, in addition to the potential for future impact to domestic well water. The potential exposure pathways for human receptors include the following:

- Inhalation of PFCs in air (particulates only);
- Ingestion or dermal contact with PFCs in surface water;
- Ingestion, dermal contact of PFCs in groundwater;
- Ingestion, dermal contact, or inhalation of PFCs in sediments;
- Ingestion, dermal contact, or inhalation of PFCs in soils; and,
- Ingestion of food items (produce, country food and fish/game).

3.4.5.3 *Exposure Assessment*

The HHRA exposure assessment will identify the magnitude, frequency, duration and exposure routes of the COCs and generally include the identification of the following components in compliance with the provincial guidance (MOE 2005):

- All relevant on-site and off-site human receptors that could be affected by the COCs;
- Receptor characteristics that are clearly articulated in the HHRA; and,
- Identification of all potential exposure routes and pathways.

3.4.5.3.1 Receptor Characteristics

Human receptors of all ages who live (for long to short periods of time) adjacent to the river within the study area might come into contact with PFC through various impacted media, physical activity patterns. The following general protocol is proposed for use in order to obtain information (data) for exposure factors used in the exposure pathways analyzed*: Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario* (MOE 2011b) Health Canada *Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA)* (HC, 2010a) and *Compendium of Canadian Human Exposure Factors for Risk Assessment* (Richardson, 1997) in addition to the *Canadian Exposure Factors Handbook* (Richardson, 2013) are used as a primary source. In the absence of any Canadian data, *U.S. EPA Exposure Factors Handbook* (U.S. EPA, 2011) can be consulted. All characteristics will be thoroughly referenced and justified within the HHRA.

3.4.5.3.2 Exposure Pathway Analysis

This analysis is intended for identification of the exposure routes and pathways considered potentially complete or complete without risk management measures (MOE, 2005). An exposure pathway describes the mechanism through which a chemical may be contacted by a receptor. There must be a complete exposure pathway from the source of COPC in the environment (i.e., in soil, groundwater, or air) to human receptors in order for chemical intake to occur. A complete chemical exposure pathway consists of the following four basic components:

- A source and mechanism of chemical release to the environment;
- An environmental transport medium/mechanism;
- A point of contact (exposure point) for receptors with the COPC; and,
- A route of intake at the exposure point for the chemical into the receptor.

If one of these four elements is missing, then the exposure pathway can be considered incomplete and there is no intake (or potential health risks) associated with that pathway. The presence or absence of any of these elements depends on site-specific conditions

3.4.5.3.3 Exposure Estimates

The exposure assessment is aimed to estimate the potential exposure of the receptor to PFCs using a number of input parameter including, but not limited to the following:

- Exposure point concentration;
- Receptor body weight;
- Water consumption rate;
- Incidental ingestion rate;
- Dermal rate;
- Time activity patterns (i.e., time spent swimming); and,
- Chemical bioavailability.

To evaluate potential health risks, this HHRA is proposed to consider the following three exposure and toxicological effect endpoints, subject to exposure unit applicability.

- Acute effect: a non-carcinogenic change that occurs within a relatively short time (i.e., minutes, hours, days) following exposure to a chemical;
- Chronic and subchronic non-cancer effect: a non-carcinogenic change that occurs over a relatively long time (i.e., weeks, months, years) following repeated exposure or a single over-exposure to a substance; and,

- Chronic cancer effects: a carcinogenic change that is associated with a long-term exposure duration usually defined in years or life time.

Equations and model inputs used for each exposure pathways are generally obtained from the MOE guidance document (i.e., MOE 2011). Alternatively, guidance provided by Health Canada (2010a) and United States Environmental Protection Agency (i.e., US EPA 2005) can be consulted with some potential modifications appropriate to the current application. Where exposure estimates are conducted based on measured tissue concentrations, the consultant must ensure that the sample analytical data is representative of the exposure point concentration that the receptor would be exposed to. This consideration applies to fish tissue (whole organism tissue *v.s*. fillet fraction (skin on/skin off), etc.) but must also be considered for other tissues as well. The consultant will be required to justify the appropriateness of the sample, and how they were processed, for evaluating exposure.

3.4.5.4 *Toxicity Assessment*

A toxicity assessment determines toxicological endpoints (cancer or non-cancer) and establishes exposure doses below which adverse effects are unlikely to occur in sensitive receptors. Toxicity assessment is required for all COC including the following components:

- Document potential adverse effects (i.e. carcinogenic and non-carcinogenic) on human receptors associated with their exposure to those COCs with the consideration of toxicological end points (developmental) and time period of effect (acute/sub-chronic/chronic); and,
- Identify appropriate toxicity values with the consideration of presenting the relationship between the magnitude of exposure for different routes and the occurrence of adverse effects for the receptor and also analyzing all major sources of uncertainties.

3.4.5.4.1 Hazard Assessment

A detailed toxicological summary for each PFCs must be provided to support the selected TRVs.

3.4.5.4.2 Dose Response Assessment

The MOE has not published TRVs for PFCs. A limited number of TRVs, most notably for PFOS and PFOA are available from Health Canada, US EPA and European regulatory agencies. The consultant will be required to identify appropriate TRVs for PFCs and justify their use in the assessment. Primary TRV preference should be given to those available from agencies which have incorporated the following in developing TRVs (MOE 2005):

- A rigorous peer review mechanism by credible experts and multiple regulatory bodies/jurisdictions and/or academia;
- Ongoing review and updating of values on the basis of new studies and advances in science; and,
- Published and/or publish available TRV values, together with the basis for the value selection.

3.4.5.5 *Risk Characterization*

The final step in the risk assessment involves comparing the total estimated exposure doses to TRVs that were identified in the toxicity assessment. This risk characterization step also evaluates the relative contribution to total exposure of each individual exposure route, and media to the overall risk for human receptors. Risks for non-carcinogenic and carcinogenic are estimated separately using different estimation equations. The following subsection presents the general approach for quantitative interpretation of risks.

3.4.5.5.1 Quantitative Interpretation of Human Health Risks

Risks associated with individual non-carcinogenic effects are general evaluated using the ratio of estimated exposure doses to the corresponding TRVs. The ratio is expressed as Hazard Quotients (HQ) and calculated as follows:

$$HQ = \frac{\text{Exposure Level}}{\text{TRV}} \qquad \text{(Equation 2)}$$

where:

HQ = Hazard quotient (unitless);

Exposure Level = Estimated exposure dose (i.e., mg/kg/day); and

TRV = Toxicity reference value (i.e., mg/kg/day).

For a chemical with non-carcinogenic effects, it is often assumed that 20% of the total allowable intake is apportioned to any single source (i.e. water, sediment). In other words, exposures resulting in HQ values at or below 0.2 are generally considered acceptable. The consultant should identify the appropriate apportionment for PFCs based on their anticipated presence in the five main exposure media. Justification for selected apportionment must be provided in the Stage 1 report. The interpretation of risk must consider risk additivity for PFCs with similar modes of action/target organ systems. The consultant will be required to identify risk additivity support in the Stage 1.

3.4.5.6 *Risk Assessment Uncertainty*

Analysis of major sources of uncertainty associated with each phase of the risk assessment should be identified to ensure that the risk characterization would be both conservative and realistic. Where uncertainties are identified, commentary on approaches to reduce uncertainty, if possible, must be provided in the HHRA.

3.4.6 General Approach for Ecological Risk Assessment

Generally, the objective of an ecological risk assessment (ERA) is to estimate the possibility of adverse impacts to receptors as a result of PFC exposure within the study area. This section presents a general approach for completing a quantitative ERA in the spirit of the provincial requirements. As indicated in the *Procedures for the Use of Risk Assessment under Part XV.1 of the Environmental Protection Act.* (MOE 2005), the primary guidance for conducting an ERA in Ontario is the CCME document, entitled "*A Framework for Ecological Risk Assessment: General Guidance*" (CCME 1996) and "*A Framework for Ecological Risk Assessment: Technical Appendices*" (CCME 1997). In addition to the aforementioned guidance, a detailed list of useful resource literature on various aspects of ecological health risk assessments is also provided in Section 9.2 of the MOE 2005 guidance document. The following are, for example, generally considered applicable for conducting the ERA, as appropriate:

- Federal Contaminated Sites Actions Plan (FCSAP): Ecological Risk Assessment Guidance (FCSAP 2012);
- Federal Contaminated Sites Actions Plan (FCSAP), 2010. FCSAP Supplemental Guidance for Ecological Risk Assessment, Toxicity Test Selection and Interpretation. Module 1;
- Federal Contaminated Sites Actions Plan (FCSAP), 2010. FCSAP Supplemental Guidance for ERA: Toxicity Reference Values. Module 2;
- Federal Contaminated Sites Actions Plan (FCSAP), 2012. FCSAP Supplemental Guidance for ERA: Standardization of Wildlife Receptor Characteristics. Module 3;
- Federal Contaminated Sites Actions Plan (FCSAP), 2013. FCSAP Supplemental Guidance for ERA: Causality Assessment. Module 4;
- Federal Contaminated Sites Actions Plan (FCSAP), 2013. Ecological Risk Assessment Guidance. Module 5: Defining Background Conditions and Using Background Concentrations. Draft April 2013. (refer to final version if available during Stage 1 of the assessment)

- Canadian Council of Ministers of the Environment (CCME), 2015. Ecological Risk Assessment Guidance For Contaminated Sites. Draft issued March 2015. (refer to final version if available during Stage 1 of the assessment)
- British Columbia Ministry of the Environment (2008). Detailed Ecological Risk Assessment (DERA) in British Columbia, Technical Guidance. Science Advisory Board. September;
- United States Environmental Protection Agency (US EPA), 1998. Guidelines for Ecological Risk Assessment;
- Ontario Ministry of Environment (MOE), 2008. Guidelines for identifying, assessing and managing contaminated sediments in Ontario - an integrated approach;
- Chapman PM. 2011. Framework for Addressing and Managing Aquatic Contaminated Sites Under the Federal Contaminated Sites Action Plan (FCSAP). Golder Associates Ltd, Burnaby (BC); and,
- United States Environmental Protection Agency (US EPA), 1993. Wildlife Exposure Factors Handbook.

Based on the currency of the documents, FCSAP guidance should be considered to take precedence over CCME (1996, 1997) guidance if conflicting approaches are presented between the documents. The basic structure for conducting an ERA is similar to conducting the HHRA, with the exception that multiple lines of evidence are incorporated into the ERA strategy.

3.4.6.1 *Problem Formulation*

The problem formulation stage of the ERA follows a similar sequence as the DQHHRA problem formulation and consists of pathway identification, receptor Identification, exposure unit identification and hazard identification.

The assessment and measurement endpoints for this ERA are based on a management goal involving maintenance of terrestrial and aquatic ecological function of the site and restoration of ecological function in areas of unacceptable toxicity. The assessment endpoints for this ERA consist of the following:

- Reduced survival, growth and reproduction for non-threatened/endangered mammalian and avian populations exposed to PFCs over a chronic duration;
- Reduced survival, growth and reproduction for threatened/endangered mammalian and avian species exposed to PFCs over a chronic duration;
- Reduction in abundance and/or production of the soil invertebrate community due to exposure to PFCs;
- Reduced abundance of the terrestrial plant community due to exposure to PFCs; and,
- Reduced abundance and production of aquatic life communities related to PFC exposure.

Measures used to evaluate the assessment endpoints will be based on multiple lines of evidence. An assessment approach that involves a number of lines of evidence in order to evaluate risk recognizes that one line of evidence alone typically does not provide an acceptable degree of certainty regarding the final risk conclusion. Lines of evidence will consist of the following:

- Measures of exposure are based on measured media (soil, sediment, surface water, groundwater, tissue) concentrations of PFC and modeled food item (plant tissue, soil invertebrate tissue) and intake (i.e. as applicable to mammals and birds); and,
- Measurement of effect based on toxicity testing and on evaluation of exposure with respect to established toxicity benchmarks or toxicity reference values, in addition to modelled benchmarks.

Measures of exposure and effects lines of evidence program components are identified in Section 4. Key components of the problem formulation for an ERA are discussed in the following sub-sections:

3.4.6.1.1 Exposure Unit Identification

Similar to the HHRA, exposure units are identified generally based on habitats present in the study area. A preliminary exposure unit evaluation indicates that three general units are present consisting of a riparian, aquatic and terrestrial or upland habitat. Based on additional studies (i.e. species survey which may identify specific sub areas requiring assessment), additional exposure units may be identified.

3.4.6.1.2 Ecological Receptor Identification

A description of ecological communities within the study area will be prepared based on information contained in the previous investigation reports, general ecological information in Ontario regions and any observation reported during the site visits. Potential ecological receptors include the following:

- Terrestrial plants and invertebrates;
- Mammals, birds, reptiles, amphibians; and,
- Aquatic biota living in and adjacent to the Welland River (i.e., benthos, fish).

3.4.6.1.3 Exposure Pathway Identification

Ecological receptors of concern may be directly exposed to PFCs through direct contact or ingestion. Other potential pathways of exposure should be evaluated if they are considered significant for ecological receptors, or discounted and rationale for exclusion clearly provided.

3.4.6.1.4 Preliminary Conceptual Site Model

A Conceptual Site Model (CSM) provides a relationship between the characteristics of the site that result in complete exposure pathways between COCs and the receptors. The CSM incorporates the sources of COCs, processes that control COC fate and transport and the various routes of exposure to the COC. A significant number of species at risk are potentially present in the study area. A species survey will require completion as part of the RA in order evaluate if potentially present species occur in the study area. Based on the available information and assuming an FFTA source, the ecological CSMs are discussed generally as follows.

Ecological Conceptual Site Model – Aquatic Environment

PFC exposure to aquatic receptors may occur through interaction with PFC sorbed particulates and dissolved phase runoff to the upper Welland River tributaries, groundwater seepage to surface water of dissolved phase PFCs, downstream flow of dissolved phase PFCs in surface water and suspended sediment and uptake and trophic transfer of PFCs through food items. The aquatic environment consists of the lotic river and tributary system in the risk assessment area and an additional lentic area (Lake Niapenco) in the overall study area. Receptors consist of broad receptor groups and individuals requiring higher degrees of protection, such as species at risk. The preliminary list of aquatic food web receptors are considered to consist of:

- Benthic macro-invertebrate community with special consideration for the Mapleleaf Mussel;
- Macrophyte community;
- Plankton community;
- Fish communities, with individual consideration for Grass Pickerel;
- Amphibians and reptiles, with individual consideration for the Snapping Turtle, Northern Map Turtle and Jefferson Salamander (breeding);
- Avian herbivores, omnivores and piscivores; and,
- Mammalian herbivores, omnivores and piscivores.

Ecological Conceptual Site Model – Terrestrial Environment

The terrestrial environment consists of both semi-aquatic shoreline areas, such as the riparian zone, and upland areas defined as locations above the high water level in the study area. PFC exposure to terrestrial receptors in shoreline areas may occur through interaction with the aquatic environment or through exposure to PFCs in periodically inundated areas. In this situation, exposure may occur through contact with PFC sorbed particulates (e.g. sediment) and dissolved phase PFCs in surface water, groundwater seepage contact or exposure through food ingestion. In upland areas, receptors may be exposed through interaction with groundwater or soil. It is anticipated that the upland RA area will be smaller than the shoreline RA area, although data is not presently available to evaluate the limits of the upland area. Receptors consist of broad receptor groups and individuals requiring higher degrees of protection, such as species at risk. The preliminary list of riparian zone terrestrial food web receptors are considered to consist of:

- Terrestrial invertebrate community;
- Plant community with special consideration to species listed in Section 4.2.1.5;
- Amphibians and reptiles, with individual consideration for the Jefferson Salamander;
- Avian herbivores, omnivores and carnivores with special consideration for the Tufted Titmouse; and,
- Mammalian herbivores, omnivores and carnivores.

The preliminary list of upland terrestrial food web receptors are considered to consist of:

- Terrestrial invertebrate community;
- Plant community with special consideration to species listed in Section 4.2.1.5;
- Amphibians and reptiles, with individual consideration for the Jefferson Salamander, milksnake and Northern Ribbon Snake;
- Avian herbivores, omnivores and carnivores with special consideration for Yellow Breasted Chat and Bobolink; and,
- Mammalian herbivores, omnivores and carnivores with special consideration for the Woodland Vole.

3.4.6.2 *Exposure Assessment*

Ecological receptors are generally grouped at the community level and an ERA is usually conducted for all species in the community, considering the time-consuming and large cost associated with evaluations of each individual species.

3.4.6.2.1 Receptor Characterization

Receptor characterization in an ERA would address (1) multiple ecological receptors, (2) potential exposure pathways and (3) potential environmental impacts. The potential receptors on and off-site might be evaluated as valued ecosystem components (VECs). The CCME 1996 document, entitled "*A framework for Ecological Risk Assessment: General Guidance*" provides the following guidance for identification of VECs:

- Are important to human populations;
- Have economic and/or social significance;
- Have intrinsic ecological significance; and/or,

- Serve as a baseline from which impacts of development can be evaluated, including changes in management or regulatory policies.

3.4.6.2.2 Exposure Pathway Analysis

This step is aimed to identify exposure routes and pathways that are considered to be complete or potentially complete without risk management measures. Eliminations of any pathways which can be anticipated based on chemical properties and site geology from the assessment will require justification in the form of pathway-specific site assessment evidence. A detailed analysis of requirements can be found in MOE 2005, but generally include the following components: (1) exposure pathways of concern according to the ecological conceptual site model, (2) sources of all potential releases, (3) potential receiving media, (4) physical fate and transport properties of the chemicals of concern, (5) exposure points, and (6) exposure routes.

3.4.6.2.3 Endpoint Assessments and Measures

Assessment endpoints are generally indicated as the ecological resources that are to be protected which consist of an ecological entity and a characteristic of the entity that is important to protect (US EPA 1997). Risks to assessment endpoints are evaluated using measure of effects (i.e. toxicity results), measure of exposure (i.e. chemical concentration in selected media) and/or measures of ecosystem and receptor characteristics (US EPA 1998). More specifically, the following endpoint measures will be considered for different ecological receptors:

- No Observed Adverse Effect Level (NOAEL) or Lowest Observed Adverse Effect Levels (LOAEL) toxicity reference values, if available, for mammalian and avian receptors. Preference should be given to the use of effects concentration percentile toxicity reference values (TRVs) which are relevant to the endpoints requiring protection in the ERA; and,
- Community level protection (i.e., LC_{50} and EC_{50}) or LOAEL based on higher levels of biological organization for terrestrial invertebrates, plants, and aquatic biota. Alternate percentile effects levels may be applied in the ERA with appropriate justification (i.e. based on land use or communities requiring protection).

3.4.6.2.4 Exposure Estimates

Exposure estimates refer to the quantification of the exposure to the receptors using the calculation of intake, uptake rate or delivered target dose for each potentially complete exposure pathway which include the following components (MOE 2005):

- Exposure concentration;

- Contact rate; and,
- Total time of exposure.

Where exposure estimates are conducted based on measured tissue concentrations, the consultant must ensure that the sample analytical data is representative of the exposure point concentration that the ecological receptor would be exposed to. The consultant will be required to justify the appropriateness of the samples, and how they were processed, for evaluating exposure.

3.4.6.3 *Hazard Assessment*

A toxicity assessment determines toxicological endpoints and establishes exposure doses below which adverse effects are unlikely to occur in sensitive receptors. In the absence of provincially accepted TRVs for PCFs, an literature search should be conducted, as described in Section 4 of this report.

3.4.6.4 *Risk Characterization*

The potential risks of COC posed to each ecological receptors is evaluated using a hazard quotient (HQ) which is determined by the ratio of total exposure estimates and the appropriate toxicity reference value presented in respectively, as shown in the following equation:

$$HQ = \frac{\text{Exposure Level}}{\text{TRV}} \qquad \text{(Equation 3)}$$

where:

HQ = Hazard quotient;

Exposure Level = Estimated exposure dose; and,

TRV = Toxicity reference value (same unit as Exposure Level).

For each receptor and COC, exposures resulting in HQ values at or below one (1) are generally considered acceptable. The magnitude of possible risk estimations and also their associated uncertainties should be evaluated.

It is anticipated that the estimation of potential risk in the ERA will be based on a weight of evidence evaluation where alternate lines of evidence will be considered in the final risk conclusion.

3.4.7 Risk Management

The results of the final detailed quantitative RA will be used to recommend whether risk management measures are required to protect the human receptors and natural environment. Should risk management be recommended, appropriate risk management options will be identified in the final detailed quantitative risk assessment report provided at the end of Stage 2.

4 IMPLEMENTATION OF SITE INVESTIGATION AND RISK ASSESSMENT

4.1 Staging of Tasks

Tasks will be completed in two (2) stages (see Table V below).

- Stage 1 represents background review, identification of information such as screening criteria and toxicity reference value, arranging access to properties and completion of an interim detailed quantitative risk assessment. The interim detailed quantitative risk assessment will include recommendations and cost estimates for data gap/risk assessment uncertainty reduction program items to be evaluated in Stage 2.
- Stage 2 represents a final detailed quantitative risk assessment undertaken based on a gap and uncertainty reduction assessment, which is anticipated to consist of refinements to programs completed in Stage 1. The results will be used to recommend whether risk management measures are required to protect human receptors and the natural environment in the final risk assessment area. Should risk management be recommended, potential appropriate risk management options will be identified in the final report including cost and schedule estimates for implementation. Tasks to be completed at each stage are further described in the following sub-sections.

Table V: Staging of Tasks

Task	Stage	Rationale
Identify Screening Criteria, Toxicity Reference Values and Transfer Factors	1	Complete as an initial stage of work in order to identify potential risk assessment limitations.
Species and Ecological Resource Survey (Preliminary)	1	Results will be used to refine the VEC list and exposure units in the risk assessment area (Figure 1B) for the ERA.
Sediment Toxicity Evaluation	1	Results will be used as one line of evidence to identify areas of sediment impairment within the study area.
Benthic Community Structure Evaluation	1	Results will be used as a second line of evidence to identify areas of sediment impairment within the study area.
Surface Water Toxicity Testing	1	Results will be used as a line of evidence to identify the presence of, or areas of, surface water impairment within the study area.
Tissue Residue Analysis	1	Results will be used as a line of evidence to identify if significant uptake is present (comparison to limited tissue residue guidelines) and provide data for exposure point concentrations to be used in the RA.
Soil and	1	Results will be compared to available human health and ecological guidelines in order to

Groundwater Quality Investigation		evaluate Stage 2 delineation requirements if necessary. The investigation will focus on the HIA property boundary to evaluate offsite migration of PFCs
Reporting	1 – Interim Detailed Quantitative Risk Evaluation and Data Gaps	The Stage 1 report will consist of reporting on all aspects of Stage 1 investigations, and provide an interim detailed quantitative risk assessment. Stage 1 reporting will provide an identification of additional sampling requirements for Stage 2 investigations based on data gaps identified within the interim detailed quantitative risk assessment report.
Supplemental Investigations	2	Depending on the results of Stage 1, additional supplemental investigations may be required to address risk assessment uncertainties or refine study area limits. Potential supplemental investigations are described below.
Species and Ecological Resource Survey		Breeding bird survey (if required), bat survey (if required) and additional plant community survey in order to refine receptor list for the detailed quantitative risk assessment.
Refined Sediment Assessment		Additional sediment chemistry, benthic community and toxicity evaluation may be required, depending on risk assessment data gaps (i.e. unclear linkage between effects and PFC concentrations) identified in Stage 1.
Refined Surface Water Assessment		Additional surface chemistry and toxicity evaluation may be required, depending on the risk assessment data gaps (i.e. unclear linkage between effects and PFC concentrations).
Additional Tissue Analysis		Additional samples may be required if multiple exposure units require evaluation based on separate exposure point concentrations.
Soil and Groundwater Quality Investigation		If required based on Stage 1 investigations, offsite soil and groundwater quality will be evaluated to identify exposure point concentrations and extents of impact necessary for fate and transport modeling.
Reporting	2 – Detailed Quantitative Risk Assessment	The Stage 2 report will consist of reporting on all aspects of Stage 2 investigations, and provide a detailed quantitative risk evaluation.

4.2 Chemical Screening Criteria and Toxicity Reference Values for PFCs

Human health benchmarks for tissue (fish consumption), soil contact and water ingestion are available for a limited number of PFCs (refer to Appendix B). A summary of available screening criteria is provided below.

Table VII: Summary of Available Human Health Screening Criteria

PFC	Drinking Water	Soil Contact	Inhalation (Particulate)	Sediment Contact	Fish Consumption	Produce/Game Consumption
PFBA	X	X				
PFPeA	X					
PFHxA	X	X				
PFHPA	X	X				
PFOA	X	X				
PFNA	X	X				
PFDA	X	X				
PFUnA	X	X				
PFDoA	X	X				
PFBS	X	X				
PFHxS	X	X				
PFOS	X	X			X	
PFOSA	X	X				

Note: and "x" in a cell indicates at least one screening criterion is available. The risk assessor will be required to confirm if the criterion is suitable for screening purpose.

Human health screening criteria for potential exposure pathways will require identification, where possible. This, at a minimum, will require toxicity reference value identification and criteria calculation.

Ecological benchmarks for tissue (fish and dietary), aquatic life (freshwater), soil (to protect aquatic life from eroded material) and groundwater (migration to surface water) are available for a limited number of PFCs (refer to Appendix B). A summary of available screening criteria is provided below.

Table VIII: Summary of Available Ecological Screening Criteria

PFC	Surface Water	Fish Tissue	Tissue Residue	Sediment	Groundwater	Soil
PFBA						
PFPeA						
PFHxA						
PFHPA						
PFOA				X[1]		
PFNA						
PFDA						
PFUnA						

PFDoA						
PFBS						
PFHxS						
PFOS	X	X	X	X[1]	X	X
PFOSA						X

Note: an "x" in a cell indicates at least one screening criterion is available. The risk assessor will be required to confirm if the criterion is suitable for screening purpose. [1]- Marine sediment.

Literature data exists that allows for identification of ecological soil criteria for PFBS and PFOA, and a chronic duration surface water criteria for PFOA. With the exception of limited marine sediment criteria, freshwater sediment criteria are not available. Transfer factors to be used in an initial screening level evaluation will be identified, and gaps based on inadequate definition of transfer factors for analytes of interest will be identified. There is considerable uncertainty in uptake or transfer modeling based on limited literature uptake factors, therefore a direct measure of tissue residues is preferred. As with the limitations of the human health screening criteria, toxicity reference value identification, justification and criteria calculation, where possible will be required.

4.3 Species and Ecological Resource Survey

A number of potential species at risk may be present in the study area, although sighting records are restricted to a limited number of actual species and records may not coincide with the risk assessment area. A species and ecological resource evaluation will be conducted to identify valued ecosystem components to be evaluated in the ERA and to provide data to compare site characteristics relative to reference conditions. The scope of work for Stage 2 species surveys will be defined at the end of Stage 1, dependent on the findings at Stage 1. The Stage 1 survey is specified in this document.

4.3.1 **Stage 1 Survey Requirements**

This evaluation would include a field survey conducted under the direction of a qualified biologist to identify the presence and spatial distribution of resources (e.g., plants communities) and receptors (wildlife) within the terrestrial and riparian exposure units of the risk assessment area as defined on Figure 10 and Figure 11. Identification of listed aquatic species would also be completed through literature review and direct observation, where possible. Results of the investigation would then be used to inform the problem formulation and exposure assessment. It is assumed that the survey would be conducted in the upland area immediately adjacent to the HIA and riparian and aquatic areas along tributaries draining the FFTA locations, in addition to the upper Welland River downstream of the confluence of these tributaries with higher order water bodies and at reference stations.

It is anticipated that multiple surveys will be required to complete a habitat and receptor survey if additional information is required following Stage 1. The preliminary Stage 1 survey would focus on habitat assessment and species identification based on field/desktop and communications with relevant authorities. The Stage 1 surveys will be limited to 3 m into the surrounding terrestrial area from the wetted bank limits of the tributaries being evaluated. Later surveys (Stage 2), if required, would be conducted to complete breeding and crepuscular bird surveys, bat survey, salamander survey (e.g. Jeffersons Salamander) and additional vegetation surveys to target different flowering times and may extend further into the terrestrial portions of the risk assessment area. Stage 2 surveys, if required, will be identified by the consultant in the Stage 1 Interim Detailed Quantitative Risk Assessment Report.

The implication of species and vegetation communities observed must be verified against the SARA Public Registry, Ontario Regulation 230/08 Species at Risk in Ontario (SARO) List, the Natural Heritage Information Centre's (NHIC) Biodiversity Explorer. Additional resources, such as Oldham (2010), Oldham and Brinker (2009), Bakowsky (1996), NPC (2006-2009) and additional resources available through the Hamilton Naturalists Club should also be consulted. All provincial species to be identified include species at risk (SARO list) in addition to NHIC S1 to S3 ranked components. Species of regional conservation concern may be identified from the additional resources listed above (e.g. NPC 2006-2009).

The intent of the Stage 1 field program is to provide exposure point concentration data for the Interim Detailed Quantitative Risk Assessment and provide species and habitat information necessary for receptor identification and endpoint and goal identification in the risk assessment. Stage 1 will also provide data necessary to complete a weight-of-evidence based ERA and allow for comparison of site data against reference conditions. Based on the outcome of Stage 1, additional surveys designed to evaluate alternate lines of evidence may be required at Stage 2. The need to evaluate additional lines of evidence to refine the risk assessment will be identified in the Stage 1 Interim Detailed Quantitative Risk Assessment by the consultant. Need will be driven by risk estimate uncertainty reduction or data gap closure requirements in order to complete an informed evaluation risk.

4.3.1.1 *Vegetation*

Classification, mapping and evaluation of vegetation communities within the study area will be completed following the nomenclature identified in the Ecological Land Classification for Southern Ontario (Lee et al., 1998). Certain vascular plant species may be identifiable only for limited periods of time within a year. The timing of surveys for specific vascular plants (known or suspected at risk plants which may occur at the site) should be identified in Stage 1 of the risk assessment. The vascular plant survey will result in a listing of vascular plant species (common and scientific name), including regional/provincial/federal status, which are observed on the site. An indication of the relative abundance and areal extent (in map form with orthophoto base) of each species on the site will also be provided. GPS coordinates for locations of rare species will be recorded.

4.3.1.2 *Birds*

A survey of breeding birds will be carried out within the site limits following the Ontario Breeding Bird Atlas (OBBA, 2001) procedures, including both point count and incidental observations. Representative stations consisting of different habitats within the site should be identified in Stage 1 and targeted for point count surveys (Stage 1 and potentially Stage 2). Species review conducted in Stage 1 should also identify if the use of tape-playback will be required in Stage 2 to identify species which do not self-advertise. Point locations should be separated by in excess of 100 m to avoid count duplication. The risk assessment area consists of two general habitat types consisting of agricultural and isolated forest habitat. For estimation purposes, one (1) forest habitat station and four (4) agricultural habitat stations will be evaluated in Stage 1 (Figure 11). Field personnel conducting the study must be experienced with song identification.

4.3.1.3 *Small Mammals*

A list of mammals which may occur at the site and vicinity must be compiled from sources such as the Atlas of the Mammals of Ontario (Dobbyn, 1994), the NHIC, SARA and Species at Risk in Ontario range mapping as part of Stage 1. MNR (2000) provides additional information on the habitat preferences and habits of mammals in Ontario. Incidental mammal observations (i.e., sightings, tracks, scats, dens, etc.) and habitat must be recorded during each field visit. A small mammal survey completed in Stage 1 will include a live capture program, in part to assist with tissue collection and exposure point concentration identification requirements of the interim detailed quantitative risk assessment. Small mammals, such as mice, voles and shrews will represent tissue sampling target species. Thirteen (13) stations will be evaluated along the species and habitat survey route (Figure 11). Observations of habitat types present at the site and surroundings should be combined with local species occurrence information to evaluate potentially present species.

At Stage 1, the mammal survey will focus on species identification and tissue collection. Tissue would be retained from reference locations and a subset of site sample locations. Site samples should be obtained along an exposure gradient to avoid biasing tissue data from a restricted number of locations. Reference station tissue will be required to evaluate if site prey food concentrations of PFCs differ statistically from that of reference conditions. Site sample locations will be situated within 3 m of the Stage 1 species and habitat survey route (Figure 11). Weights and species of individual specimens will be recorded. Captured specimens would be temporarily marked and live-released on site if sampling occurs over more than one trap set period. A care and handling plan and a scientific collection permit will likely be required to complete this work. The timeframes for permit approval vary. Permit application by the consultant will be required within 2 weeks of contract award.

Stage 2 evaluations may consist of small mammal catch per unit effort (CPUE) surveys in order to indirectly evaluate small mammal abundance differences between the site and reference locations. More rigorous biological LOE such as capture of animals for histological and biochemical investigations biomarkers for exposure or effect), determination of abundance and diversity by more intensive demographic techniques and evaluation of breeding success (nest examinations) could also be conducted in Stage 2 if justified by the consultant in the Stage 1 report.

4.3.1.4 *Herpetofauna*

A list of herpetofauna that may be present at the site must be compiled in Stage 1 from available information including Oldham and Weller (2000) and Ontario Nature (2013), in addition to NHIC, SARA and Species at Risk in Ontario range mapping. Field staff should also record all other fauna observed or incidentally identified at the site along the species and habitat survey route (Figure 11). Seasonal limits in Stage 1 will not permit a detailed herpetofauna survey. If a more detailed survey is required in Stage 2, justification will be provided in the Stage 1 Interim Detailed Quantitative Risk Assessment report.

For consideration in Stage 1 when planning the single Stage 1 and potential Stage 2 field visits, it should be kept in mind that amphibian surveys may need to take place three times in one year to coincide with peak breeding time periods. Field staff conducting the amphibian survey must be able to identify all expected species at the site by sound. Peak breeding activity is temperature dependent; therefore field visits should be coordinated with expected weather conditions. Salamander presence/absence may be conducted as part of a walkover visual survey, preferably on a wet or rainy spring night during the first amphibian survey timeperiod. Egg masses may also be observed during a site walkover. Visual surveys for turtles should include looking for basking individuals in spring or early fall. Snake surveys may be most feasibly conducted in the early spring to mid-summer to observe basking individuals, although site walkovers at other times of the year should include opportunistic searches. A number of these multi-year visits will not be accommodated in the Stage 1 timeframe, although sufficient information may be obtained in Stage 1 such that additional surveys would not be considered required based on the additional value they may provide to the risk assessment.

4.3.1.5 *Fish/Benthic Organisms*

Available fish habitat and community information must be evaluated in Stage 1 to determine the requirements for a fish community and habitat survey. Preliminary information is provided in this workplan. A preliminary survey will be completed in Stage 1. At a minimum, habitat and community information data will be collected during completion of other field work tasks (incidental observations during terrestrial evaluations and tissue or sediment sampling programs). Aquatic surveys must follow Stanfield (2013), with appropriate modification for the current work. At Stage 1, each survey location (benthos) will be a minimum of 10 m in length at the sediment sample stations identified on Figure 11, although may require adjustment based on tributary characteristics and requirements to standardize sampling between locations to avoid bias on abundance and density measurements. An Ontario Ministry of Environment scientific collector permit is required for all fish sampling and a federal Species at Risk Act (SARA) permit is required if a SARA-listed species is present or a provincial ESA permit is required if an ESA-listed species is anticipated to be collected. Benthic surveys should be completed following the Ontario Benthic Biomonitoring Network protocols. Based on the size of the watercourses in the study area, it is considered feasible to conduct benthos sampling by traveling kick and sweep-transect method. Site assessment should include evaluation for the presence and identification of mussels, which may occur below the sediment surface and may not be obvious from visual examination while conducting a benthic sampling program. Mussels have been observed in upper portions of the Welland River watershed, although not at the site, based on limited historical evaluation (Morris et al., 2012). At Stage 1, fish surveys will be conducted by incidental observation and trapping. Trap locations will be in the vicinity of the small mammal survey locations identified on Figure 11. If more exhaustive methods (i.e. electrofishing) are considered required, recommendations/scheduling and cost estimates will be provided by the consultant in the Stage 1 report. All tributaries draining the HIA are considered habitat for Grass Pickerel and the species use of the tributaries may be seasonally dependent. The consultant should refer to the *Protocol for the Detection of Fish Species at Risk in Ontario Great Lakes Area (OGLA)* for guidance when conducting a fish survey.

If a more detailed survey is required in Stage 2, communities and habitats should be assessed at the most appropriate times for evaluating various species over the course of a year.

4.4 Sediment Toxicity

Laboratory sediment toxicity testing will be completed in Stage 1 to provide a line of evidence to evaluate potential risk posed by sediment exposure to aquatic life. Freshwater sediment criteria are not available for PFCs, therefore a measure of effects based on established toxicity based benchmarks is not possible. FCSAP ERA guidance, draft CCME ERA guidance and the Framework for Addressing and Managing Aquatic Contaminated Sites (Chapman, 2011) provide guidance on the acceptable level of effects.

Sediment toxicity testing will be completed according to the following Environment Canada and MOE test methods:

- Environment Canada, 1997. Biological Test Method. Test for Survival and Growth in Sediment Using Larvae of Freshwater Midges (*Chironomus tentans* or *Chironomus riparius*). EPS 1/RM/32, December 1997; and,
- Environment Canada, 2013. Biological Test Method: Test for Survival and Growth in Sediment and Water Using the Freshwater Amphipod *Hyalella azteca*. EPS 1/RM/33 Second Edition - January 2013; and,
- Bedard, D., A. Hayton and D. Persaud. 1992. MOE Laboratory Sediment Biological Testing Protocol, Ontario Ministry of the Environment, Toronto, Ontario. 23 p. Fathead Minnow 21-day survival and bioaccumulation whole sediment toxicity test (chronic lethal/sublethal test).

Reference site samples will be subjected to toxicity testing in addition to site samples in order to provide a basis for effects comparison. Sediment physical-chemical properties will require characterization in order to allow for identification of potential confounding factors (i.e. differences in nutrient levels potentially due to agricultural runoff that may affect the results of toxicity testing). Sediment will be characterized for the following physical-chemical parameters:

- Grainsize (sieve+hydrometer);
- Nitrate;
- Nitrite;
- TKN;
- Ammonia;
- Organochlorine pesticides;
- Metals (including sodium and phosphorous);
- Glycol;
- Total Organic Carbon; and,
- PFCs.

Four (4) reference site locations (REF-1, REF-2, REF-3, REF-4) and eight (8) risk assessment area sample locations (SITE-1 through SITE-8) will be subjected to toxicity testing in Stage 1. Samples for toxicity testing will also be collected from WT-1, WT-2, WT-3, WT-5 and MOE LAKE NIAPENCO OUTLET, WR-2, WR-3, WR-4, WR-5, SITE-9, OFFSITE 1 and OFFSITE 2. A number of these latter locations are being sampled for initial chemistry confirmation purposes. If confirmation chemical analysis indicates that additional analysis is not required (i.e. the reference site is considered unsuitable or the risk assessment area will not be expanded), then additional data will not be obtained at any one or all of these locations. The sediment sample depth will be limited to the depth where the majority of biological activity occurs. Generally this depth consists of the upper 10 cm of surficial sediment (e.g. MOE, 2008, although please note that Bedard et al (1992) indicates 5 cm depth). Samples collected for toxicity testing will be appropriately stored pending a decision to proceed with toxicity testing from the contracting authority, or delegate. Chemical analysis must be complete before a decision to proceed with additional analysis can be granted; therefore in order to avoid sample hold-time issues, chemical analysis must be initiated promptly. Toxicity test sample hold times are typically four (4) to six (6) weeks, but must be confirmed by the consultant prior to sampling. The consultant must also confirm with the toxicity test laboratory the number of samples in an analysis block that the lab can accept and if sufficient test organisms will be available at the time of test initiation. The consultant will review the chemistry data immediately upon receipt of results and identify if the risk assessment area interpretation is consistent with the limits identified in the Workplan. The consultant will provide a recommendation regarding their re-interpretation of the risk assessment area limits and recommend which additional stations and associated analysis on-hold should proceed. Sample stations are identified on Figure 10 and Figure 11. Table 1 provides a breakdown of sampling and analysis requirements at each station. Table 6 provides the coordinates for each sample station. Pesticide analysis should focus on compounds commonly in current use in agricultural areas and include herbicides as opposed to analysis of legacy compounds (i.e. DDT) which may be present at such a low level as to pose no appreciable direct toxicity. Pesticide/herbicide analysis should consider both phosphate and chlorine compounds.

Each sample location will be subsampled three (3) times, unless analytical methods require additional subsampling. Each subsample collected from REF-1, REF-2, REF-3, REF-4, and SITE-1 through SITE-8 will be submitted for chemical analysis. A single subsample (not consisting of a composite) of the three subsamples collected from each of WT-1, WT-2, WT-3, WT-5 and MOE LAKE NIAPENCO OUTLET, WR-2, WR-3, WR-4, WR-5, SITE-9, OFFSITE 1 and OFFSITE 2 will be submitted for chemical analysis with additional samples suitably stored by the consultant in the event additional characterization is required. If toxicity/benthic community structure analysis is required at the locations where a single chemistry sample was submitted, the additional chemistry subsamples from each of the associated stations will also be submitted for analysis. The reference site sampling strategy regarding subsampling and analysis of REF-1 through REF-4 meets or exceeds the minimum reference site characterization requirements identified in FCSAP (2013 section 2.3). Additional potential reference station data (WR series and WT-1 through WT-3 data) may also be used if considered appropriate although the requirement to analyze subsamples from these locations will be dependent upon whether a difference can be adequately detected based on the REF series data, whether these stations are considered suitable to characterize reference conditions, such as differences in natural variables such as substrate conditions, or the presence of impacts which are considered elevated to a degree that the data is not considered representative of reference conditions.

Samples for submitted for toxicity texting will consist of one sample per station, as the analytical method will include subsampling. The single sample may be either a composite of samples submitted for chemical analysis or reflect a single subsample. The choice of either approach must be justified by the consultant to identify that the approach will not limit the interpretation of effects or the identification of factors (e.g. chemical stressors) resulting in effects. If a single subsample is selected for toxicity testing, the consultant must consider the range in chemical concentrations present at the sampling station and identify whether the potential bias in toxicity results will be appropriate to meet ERA objectives. In situations where the method requires the subsamples to be collected in the field, the consultant will collect the required subsamples. Prior to commencing field work, the consultant must identify analytical method requirements to determine whether field subsampling for toxicity analysis, and the number of required subsamples, is required in order to avoid repeat field visits. The location of all samples collected as part of this work (including surface water, tissue, etc.) must be recorded in Universal Transverse Mercator coordinates with a global positioning system. The ellipsoid that the coordinate applies to and the zone must also be recorded with the coordinates.

Reference sites will include tributary locations downstream from the HIA in order to sample similar stream order locations as situated immediately downstream of the HIA in the risk assessment area. It is imperative that substrate conditions at the reference sites closely match, as feasibly possible, subject site locations in order to minimize natural factors that may confound toxicity test result interpretation. The consultant may have to modify the final sample location from the coordinates provided in Table 6 as a result. If a sample location is modified, the consultant must ensure that all samples which are intended to be co-located samples (e.g. surface water, benthic community structure analysis samples, chemistry, etc.) are also relocated to the modified sample position.

The consultant will be required to evaluate if a chemical stressor or natural variable controls changes in laboratory toxicity test response. The consultant must exercise judgment in the field in order to best match reference sample locations to risk assessment area sample stations in order to reduce confounding factors which may limit the ability to test for these relationships. If the outcome of Stage 1 indicates that additional sampling and toxicity testing is required, the consultant will identify the rationale for additional work, cost and schedule estimates in the Stage 1 Interim Detailed Quantitative Risk Assessment report.

4.5 Benthic Community Structure

The objective of the assessment will be to characterize the benthic community structure within the study areas and to identify if a gradient in community structure is present which may correlate with sediment PFC concentrations. Reference sites will be characterized to provide a basis for comparison of community structure downstream of the HIA. Benthic community structure will be evaluated as a direct measure of effects, and will represent a second line of evidence to evaluate sediment quality. In conjunction with laboratory sediment toxicity testing, benthic community structure will be used to provide a weight of evidence conclusion regarding sediment impairment at each sampling location and the risk assessment area. Correlation of impaired community structure with PFC concentrations will be required areas part of the analysis.

Stage 1 sample locations will be coincident with sediment sample stations (Figure 10 and Figure 11). Analysis requirements are generally summarized in Table 1. Sample collection methods must be consistent between each station in order that results are comparable. In addition to enumeration of benthic macro-invertebrates to the lowest feasible taxonomic level (minimum of Family level is the objective) in each sample, the following additional sample parameters will require collection:

- Sediment grain size (sieve and hydrometer);
- Total organic carbon;
- Water depth;
- Sediment pH and redox (field measured);
- Current velocity;
- Secchi depth;
- Current velocity;
- PFC's; and,
- Water temperature, dissolved oxygen, pH (above the sediment water interface).

In addition to the above, potential analytes which may contribute to community degradation, and unrelated to PFCs will also be characterized in each sample to evaluate if an impact is potentially related to a non-PFC stressor. These potential analytes of interest consist of:

- Nitrate;
- Nitrite;
- Glycols;
- Organochlorine pesticides;
- Metals (including sodium and phosphorous);
- TKN; and,

- Ammonia.

Four (4) reference site locations (REF-1, REF-2, REF-3, and REF-4) and eight (8) risk assessment area sample locations (SITE-1 through SITE-8) will be subjected to benthic community analysis in Stage 1. Samples for benthic community analysis will also be collected from WT-1, WT-2, WT-3, WT-5 and MOE LAKE NIAPENCO OUTLET, WR-2, WR-3, WR-4, WR-5, SITE-9, OFFSITE 1 and OFFSITE 2. As indicated in the previous section, a number of these latter locations are being sampled for initial chemistry confirmation purposes. If confirmation chemical analysis indicates that additional analysis is not required (i.e. the reference site is considered unsuitable or the risk assessment area will not be expanded), then benthic community structure data will not be obtained at any one or all of these locations. Samples must be co-located with sediment toxicity and chemical analysis sample locations to allow for an evaluation of inter-relationships. Samples collected for benthic community analysis will be appropriately preserved by the consultant and stored pending decision to proceed with benthic community analysis from the contracting authority, or delegate. Samples must be stored by the consultant until project completion, which includes Stage 2 if undertaken. Chemical analysis must be complete before a decision to proceed with additional analysis can be granted. The consultant will review the chemistry data immediately upon receipt of results and identify if the risk assessment area interpretation is consistent with the limits identified in the Workplan. The consultant will provide a recommendation regarding their re-interpretation of the risk assessment area limits and recommend which additional stations and associated analysis on-hold should proceed. Sample stations are identified on Figure 10 and Figure 11. Table 6 provides the location for each sampling station. Depending on sampling approach, it is recognized that a a sample may be obtained from a reach (e.g. kick net sampling) rather than is restricted location (e.g. clamshell dredge sampling). Whichever sampling approach is employed by the consultant, the consultant must ensure that the approach allows for evaluation of inter-relationships between other data (chemistry, toxicity, etc) collected as part of this program without contributing excessive uncertainty in the analysis.

Each sample location will be subsampled three (3) times. Each subsample will be submitted for chemical analysis. Please note, for stations which are subjected to other testing such as toxicity which also require chemical analysis, equivalent analytical requirements will not be additive. For example, if a station requires benthic community analysis and toxicity testing and both require chemical analysis in triplicate, then the chemical analysis shall not be conducted six fold. The anticipated reference stations consist of REF-1 through REF-4. Additional potential reference station data (WR series and WT-1 through WT-3 data) may also be used if considered necessary to identify whether a difference can be adequately detected based on the REF series data.

Data will be analyzed through a multimetric approach. Identification and enumeration data will be used to evaluate benthic community structure in terms of measures such as richness (number of species per sample), density (number of organisms per area), abundance (number of organisms, evenness (Simpson's Evenness) and diversity (Simpson's Diversity – Shannon-Weiner Diversity). The sample similarity to reference conditions will be evaluated, based on suitable statistical approaches. The consultant will be required to evaluate if a chemical stressor or natural variable controls changes in community structure. If the outcome of Stage 1 indicates that additional sampling is required, the consultant will identify the rationale for additional work, cost and schedule estimates in the Stage 1 Interim Detailed Quantitative Risk Assessment report.

4.5.1 Subsampling Requirements

Sample station subsampling in triplicate for chemical analysis and benthic community structure evaluation has been indicated as a requirement above. Subsampling is required to understand with and between group variance and accurately describe each station with the aid of metrics to be used in the data evaluation. Subsampling has not been identified for toxicity test samples since the analytical method includes subsampling. Various recommendations on minimum subsampling requirements exist. The requirement for triplicate analysis is based on Jones et al., 2005 and EC, 2012c (section 4.4.2) recommendations for bioassessments where background information required to evaluate sampling effort required to achieve a sufficient degree of statistical is not available. As part of the Stage 1 report, the consultant will be required to evaluate statistical power based on the subsample data collected in Stage 1 and recommend whether additional subsampling will be required as part of Stage 2 investigations (if undertaken). This requirement applies to all data and is not restricted to benthic community structure data. Statistical power should not be below 0.80 (1-β), although level of sampling effort to achieve a desirable level of power (ideally 0.95) shall be identified by the consultant during Stage 1 draft reporting.

4.6 Surface Water Toxicity Testing

Laboratory surface water toxicity testing is recommended to be undertaken to provide a line of evidence to evaluate potential risk posed by surface water exposure to aquatic life. Freshwater aquatic life criteria are unavailable for a number of PFCs, therefore a measure of effects based on established toxicity based benchmarks is not fully possible, with the notable exception of PFOS.

Surface water toxicity testing is proposed to evaluate toxicity to alga, plants (macrophytes), fish (Fathead minnow) and invertebrates according to the following Environment Canada test methods:

- *Lemna minor* 7-day growth toxicity test, based on the protocol "Biological Test Method: Test Method for Measuring the Inhibition of Growth Using the Freshwater Macrophyte, *Lemna minor*", Report EPS 1/RM/37, Second Edition (January 2007)
- *Pseudokirchneriella subcapitata* Growth Inhibition Test using a Freshwater Algae. Report EPS 1/RM/25, 2nd edition (March 2007).

- *Ceriodaphnia dubia* 3-brood reproduction and survival toxicity test, based upon the protocol "Biological Test Method: Test of Reproduction and Survival Using the Cladoceran *Ceriodaphnia dubia*", Report EPS 1/RM/21, Second Edition (February 2007).
- Fathead minnow 7-day toxicity test, according to the protocol "Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows", Environmental Protection Series, Ottawa, ON, Report EPS1/RM/22, Second Edition (February 2011).

In Stage 1, toxicity testing will not identify No Observed Effect Concentrations (NOEC) or Lowest Observed Effect Concentrations (LOEC). NOEC and LOEC determination will only be completed if PFCs are identified as potential toxicants, as supported through analysis completed by the consultant in Stage 1. It is anticipated that if NOEC or LOEC determination is required, this will be undertaken in Stage 2 if justified by the consultant. Surface water chemistry will require characterization for analytes of interest, in addition to potential toxicants that may negatively impair endpoint response. These analytes consist of:

- Nitrate;
- Nitrite;
- Glycols;
- BOD;
- Organochlorine pesticides;
- Metals (including sodium and phosphorous);
- Ammonia; and,
- PFCs.

Four (4) reference site locations (REF-1, REF-2, REF-3, REF-4) and eight (8) risk assessment area sample locations (SITE-1 through SITE-8) will be subjected to surface water toxicity analysis in Stage 1. Samples for analysis will also be collected from WT-1, WT-2, WT-3, WT-5 and MOE LAKE NIAPENCO OUTLET, WR-2, WR-3, WR-4, WR-5 and SITE-9 for surface water toxicity analysis. Sample stations are identified on Figure 10 and Figure 11. For locations outside the risk assessment area limits (WT-1, WT-2, WT-3, WT-5 and MOE LAKE NIAPENCO OUTLET, WR-2, WR-3, WR-4, WR-5 and SITE-9 which is located inside the risk assessment area), samples will be collected for surface water chemistry analysis (including required field measurements) only. Pesticide analysis should focus on compounds commonly in current use in agricultural areas and include herbicides as opposed to analysis of legacy compounds (i.e. DDT) which may be present at such a low level as to pose no appreciable direct toxicity. Pesticide/herbicide analysis should consider both phosphate and chlorine compounds. The hold time for surface water toxicity test analysis does not permit chemical analysis followed by toxicity testing once the chemical analytical data is received. A second field visit will be required to complete additional surface water sampling at any location where chemical analysis indicates additional testing is required to complete the Stage 1 assessment. Sampling during the additional field visit will include recharacterization of surface water chemistry. Initial chemical analysis must be complete before a decision to proceed with a second field visit can be granted by the contracting authority, or delegate. The consultant will review the chemistry data immediately upon receipt of results and identify if the risk assessment area interpretation is consistent with the limits identified in the Workplan. The consultant will provide a recommendation regarding their re-interpretation of the risk assessment area limits and recommend which additional stations should be the subject of the additional field visit. Based on analytical turnaround time and time required to evaluate analytical data, this recommendation will be provided by the consultant within 1.5 months of submission of surface water samples to the chemical analytical laboratory during the first field visit. Watercourse flow measurements will be collected at each sample station and the consultant will identify the watercourse volumetric flow rate at the time of sampling. This will require cross sectional stream measurements. Toxicity response and chemistry will be evaluated to identify if a causal relationship between PFC concentrations and toxicity is apparent. If the outcome of Stage 1 indicates that additional sampling and toxicity testing is required, the consultant will identify the rationale for additional work, cost and schedule estimates in the Stage 1 Interim Detailed Quantitative Risk Assessment report. If a Toxicity Identification Evaluation (TIE) associated with any media is considered required by the consultant in Stage 2, the consultant will identify in the potential uncertainty associated with the TIE analysis, in additional to rationale, costs and schedule in the Stage 1 Interim Detailed Quantitative Risk Assessment report. The evaluation of uncertainties must consider the compound groups and individual compounds evaluated in a TIE analysis and whether PFC toxicity can be separated from toxicity associated other parameters.

4.7 Tissue Residue Analysis

Tissue residue analysis is anticipated to be required in order to complete a detailed ecological risk assessment and to assist in biomagnification risk evaluation. Media to food item uptake factors are not available for the majority PFC analytes, or are based on limited available studies. It is anticipated that the result of the Stage 1 Transfer Factor Review task will identify gaps in the available information and provide recommendations to complete screening level uptake modeling.

Tissue residue analysis may include as a minimum:

Aquatic food web:

- Aquatic plants;
- Fish; and,

- Aquatic Invertebrates.

Terrestrial food web:

- Plants;
- Soil invertebrates; and,
- Small mammals.

Additional tissue classes (e.g. aquatic emergent insects) may require evaluation depending on the final ERA receptor list (e.g. receptors whose feeding strategy involves aerial food capture). The Stage 1 tissue sampling program will consist of analysis of a minimum of twenty (20) samples of each tissue class (fish, aquatic invertebrate, etc.). Samples must be collected from a gradient in the risk assessment area. To assist in evaluating risk relative to background, tissue samples will be collected at each of four (4) reference locations (REF-1 through REF-4) identified on Figure 10. The species composition, physical measurements and pathology observations for sample materials must be recorded. Sample stations for fish collection are identified on Figure 11. Depending on capture success, in excess of ten (10) locations will require sampling (thirteen are noted on the figure) to obtain a minimum of twenty (20) samples. Justification for fish tissue samples retained for analysis must take into account species relevance to the HHRA and ERA and include consideration of site fidelity. Plant tissue will be collected along the species and habitat survey route. Plant tissue collected should represent potential food items for species present and should also represent a consistent species type or species mix (including proportions) between sampling locations to allow for comparison of tissue chemistry between locations. Aquatic invertebrate tissue will be collected at each sediment sample station and four (4) additional stations (Figure 11). Small mammal and soil invertebrate sampling stations will consist of small mammal survey location (Figure 11) with samples retained from a subset of stations across the full survey route. If the outcome of Stage 1 indicates that additional tissue analysis is required, the consultant will identify the rationale for additional work, cost and schedule estimates in the Stage 1 Interim Detailed Quantitative Risk Assessment report.

4.8 Groundwater and Soil Quality

Groundwater quality in the vicinity of the HIA has been evaluated to a limited degree by HPHS (2011a, 2011b), consisting of private domestic well and irrigation pond sampling. The soil conditions in the study areas have not been historically evaluated. A staged soil and groundwater investigation is proposed to be undertaken consisting of the following:

- HIA Property boundary investigation (Stage 1); and,
- Investigation of areas outside the HIA (Stage 2, if required).

At Stage 1, property boundary sampling will be conducted where necessary to determine and evaluate concentrations of PFCs discharging the HIA property. Two (2) groundwater monitoring and sampling events will be conducted in Stage 1 and will be separated by approximately a 3 month timeperiod minimum. Elevated concentrations of PFCs exist in groundwater in the vicinity of FFTA-2 at the HIA. Lower concentrations of PFC were present in the area of FFTA-1. The potential risks from elevated levels of PFCs in groundwater must be evaluated. Acceptable levels will consist of risk based benchmarks (where available). The evaluation at Stage 2 will consist of site investigations for delineation purposes, possible domestic well sampling and background soil and groundwater investigations if necessary. The need for these additional assessments will be evaluated based on the results of the Stage 1 property boundary evaluation.

The objectives of the Stage 1 soil and groundwater investigation are to:

- Install groundwater monitoring wells at the HIA property boundary based on locations selected at the completion of Stage 1. Install a network of groundwater monitoring wells to assess and identify PFCs concentrations in groundwater.

Sample soils at the HIA property boundary locations will provide an indication of potential offsite soil PFC concentrations. If the outcome of Stage 1 indicates that additional assessment is required, the consultant will identify the rationale for additional work, cost and schedule estimates in the Stage 1 Interim Detailed Quantitative Risk Assessment report.

In an effort to delineate the PFC impacts in groundwater, an anticipated network of six (6) multilevel well installations at each FFTA area along the property boundary of HIA (total of twelve (12) installations in the area of each FFTA, or a total of 24 installations overall) are identified (Figure 11). Prior to any intrusive work, the consultant will be required to locate public and private utilities in the work area. Wells will be installed as multilevel installations in co-located boreholes (i.e. multiple wells are not to be installed in the same borehole). Installation depths will generally be dependent on shallow groundwater surface elevation. The intent is for multilevel well installation is to define changes in PFC concentrations at a location with depth in order to assist in interpretation of risks to domestic well impairment. Soil samples will be collected for analysis from each borehole pair, logged for stratigraphy and inspected for evidence of impacts. Samples will be submitted for analysis from a surface depth range applicable to plant uptake, dust generation and direct contact by ecological receptors and specific human receptors (e.g. within 0 to 1.5 mbgs), in addition to at least one sample below the surface soil range and within the saturated zone. Equipment used and sampling methods will take into account cross-contamination considerations indicated previously in the Sample Handling and Collection section (see section 3.2.2). The drilling contractor will be pre-consulted by the consultant to determine if lubricants used on the equipment may contain fluorinated compounds. Field activities will be conducted according to CCME (2012), unless more stringent procedures (e.g. procedures pertaining to minimization cross contamination) are considered applicable to the PFC assessment.

All excess drill cuttings will be placed in labelled drums and temporarily stored pending waste characterization analyses.

Upon completion of drilling, each borehole will be instrumented with a single monitoring well. Well screen interval lengths should be minimized to avoid integrating groundwater quality over a significant vertical distance, masking variation by connecting zones of differing head or transmissivity, or cross connecting aquifers. The consultant must follow recommendations in CCME (2012) unless site specific or chemical specific considerations justify deviation from federal guidance. Any deviation will require documentation of the rationale in the Stage 1 report. The borehole annulus monitoring well screen intervals will be backfilled with clean coarse silica sand and sealed with bentonite. All monitoring wells will be completed with either flush mount or monument protective casings, depending on property owner requirements regarding above grade installations at the airport.

Following installation, monitoring wells will be developed by installing dedicated low density polyethylene tubing and inertial foot valves and by purging a minimum three (3) well volumes of water in a manner that avoids dewatering of the well screen (CCME, 2012). A surveyor will be retained to survey the elevations and locations of the newly installed monitoring wells relative to a geodetic datum. Monitoring well installations shall conform to O.Reg. 903 requirements. The twenty four (24) newly installed wells will be sampled for PFCs with equipment suitable to minimize positive bias that may be created by entrained sediment in a sample. Purge water generated during monitoring well development and sampling will be disposed of off-site by a licensed contractor under a HWIN number, per the administrative requirements stated in section 4.9.5. Teflon tubing, materials with Teflon parts and Teflon greases or o-rings shall not be used in installation and dedicated equipment, monitoring equipment or sample collection equipment.

Prior to groundwater sampling, it will be confirmed that representative formation groundwater conditions are achieved based on field measurement stability (temperature, pH, turbidity and conductivity). Field readings will be recorded and included in the Stage 1 report. Groundwater samples will be collected using equipment that minimizes bias due to entrained sediment, preferably low flow methods or suitable alternative methods. Each groundwater sample will be analysed for PFCs. Duplicate frequency will be 1:10 and one (1) blank sample will be analysed for PFCs. An auger rinsate blank and a groundwater level indicator rinsate blank will be analysed to confirm appropriate decontamination procedures were followed. A total of twenty-nine (29) groundwater samples will be analysed for PFCs in Stage 1. Soil sample analysis will include a duplicate frequency of 1:10. A total of twenty-six (26) soil samples will be analysed for PFCs, consisting of twenty four (24) soil samples and two (2) duplicate samples.

If the soil and groundwater investigation identifies property boundary PFC concentrations are below acceptable criteria or risk limits, the consultant must conduct suitable modelling in the Stage 1 report to identify if a risk may be present in the future due to PFC transport. The consultant will be required to support all fate and transport input values and assumptions in the risk assessment, in addition to the selection of modelling time.

4.9 Site Investigation Sampling and Analytical Protocol

4.9.1 Analytical Program

PFC compounds that would be quantified as part of this program are listed in Table VI. The analytical laboratory selected must have the appropriate certification with the Canadian Association for Laboratory Accreditation (CALA).

The proposed lab program will include verification that the selected analytical methods will have minimum detection limits that are less than the applicable environmental quality criteria on which the numerical comparison will be based and low enough that background levels can reasonably be quantified. In instances where the laboratory detection limits have been raised and/or elevated above the applicable guidelines, discussion/rationale must be provided in the report to support these results. Where possible, the laboratory should be engaged as soon as possible to determine if the sample can be re-analyzed to meet the agreed upon guidelines or to provide rationale for the elevated detection limit.

Table IX: PFC Analyte List

Analyte	Acronym
Carboxylic Acids	
Perfluorobutanoate	PFBA
Perfluoropentanoate	PFPeA
Perfluorohexanoate	PFHxA
Perfluoroheptanoate	PFHpA
Perfluorooctanoate	PFOA
Perfluorononanoate	PFNA
Perfluorodecanoate	PFDA
Perfluoroundecanoate	PFUnA
Perfluorododecanoate	PFDoA
Sulphonic Acids	
Perfluorobutanesulfonate	PFBS
Perfluorohexanesulfonate	PFHxS
Perfluorooctanesulfonate	PFOS
Perfluorooctane sulfonamide	PFOSA

Analytical requirements identified in Section 4 of this Workplan are summarized in Table 1 through Table 5 provided following the text of this document. Analysis locations are provided on Figures 4A, 4B, 5, 6, 10 and Figure 11 and coordinates are provided in Table 6.

4.9.2 Sample Collection and Handling

The ubiquitous presence of PFCs and their extremely low detection limit (1 ng/L in the case of liquids) result in stringent quality assurance measures that need to be incorporated by field staff. To reduce the risk of sample contamination, certain sample collection and handling procedures for PFCs have been outlined by Transport Canada (2012) for field staff to follow. These procedures require field personnel to:

- Avoid all sources of Teflon, including sticky labels and adhesive tape during sample collection and storage;
- Avoid wearing jackets and other outer clothing that is new or that has not been washed a number of times (e.g. 6 times);
- Avoid use of paper bags and bringing food on site in any paper packaging, aluminum foil, coated papers and coated textiles. Hard plastic food containers should be used. Food prepared in a frying pan should not be brought to site as the non-stick coating of frying surfaces is composed of fluorinated materials. Snacks and meals should not be eaten in the field vehicle or in the immediate vicinity of a sampling location;
- Water resistant, water proof or stain-treated clothing will not be worn during the field program. Field clothing to be worn on site will be restricted to natural fibers, such as cotton. Field clothing will be laundered with minimal use of soap, no fabric softener or scented products and after they have been cleaned, the clothing should be rinsed again with water before drying. Preferably, field gear should be made of cotton, old and well laundered. Old laundered outerware, but which has had a durable water repellency spray applied shall not be worn. The use of new clothing while sampling or sample handling will be avoided. Gore-Tex™ consists of a PFC membrane and is prohibited from the site;
- To avoid plastic coating or glue materials waterproof field books, plastic clip boards, binders or spiral hard cover notebooks will not acceptable. Field notes should be recorded on loose paper on an aluminum clip board;
- Most safety footwear are made from leather and synthetic fibres that have been treated to provide some degree of waterproofing/increased durability and represent a source of trace PFCs. For health and safety of field personnel, footwear must be maintained. Contact with footwear should be made while wearing gloves which will properly disposed of prior to beginning field activities;
- The field vehicle seats may be treated with stain resistant products by the manufacturer. The seats of the vehicle shall be covered with a well laundered cotton blanket for the duration of the field program in order to avoid direct contact between field clothing and the seats of the vehicle;
- Field personnel will not use shampoo, conditioner, body gel, cosmetic or hand cream as part of their personal cleaning/showering routing on the day of a sampling event, as these products may contain surfactants and represent a potential source of PFCs. It is strongly recommended that field personnel

shower as per normal routine the night before and then rinse with water only on the morning of the sampling event. Use of a bar of soap is acceptable but it should not contain moisturizing lotions;

- Moisturizers, cosmetics and dental floss may contain PFCs and shall not be used throughout the duration of the field program, either on or offsite. Sunscreen and insect repellent also cannot be used; and,
- For washroom breaks, field personnel will remove themselves from the immediate vicinity of the sampling location and then remove gloves. Field personnel should wash as normal with extra time for rinsing with water after soap use. When finished washing, the use of an air dryer is preferred and the use of paper towel for drying should be avoided.

4.9.3 Quality Assurance and Quality Control

A specific QA/QC plan should be implemented for every component of the project to ensure that products and services are of sound technical and scientific quality, satisfy contract requirements and are sufficiently well standardized and documented to ensure Transport Canada's needs are met. Most importantly, the QA/QC program should ensure that all products and services are supported by a record of origin and evolution. The QA/QC program should include:

a) Documentation Procedures - These ensure that information is collected and recorded in a systematic and logical manner. These procedures specify field notes, interview and photograph requirements, and documentation of historical information. Once collected, project information is stored in separate paper and electronic files with unique identifying numbers;

b) Sample Handling, Custody and Analysis – Specific field and laboratory procedures are followed to minimize and quantify impacts introduced during sample collection, handling, shipping and analysis. Analyses are conducted by laboratories accredited by the Canadian Association for Laboratory Accreditation, as amended.

c) Sampling protocols include proper containers, preservation, storage and holding times according to contaminant characteristics, minimizing sample handling; use of QA/QC samples; use of dedicated non-contaminating sampling equipment; use of sample specific identification and labeling procedures; and using Chain of Custody records.

d) Field QA/QC samples include blind field duplicates, replicates, field and trip blanks. Laboratory QA/QC samples include duplicates, method blanks, surrogate, matrix spikes and reference material. Overall, these samples allow evaluation of the accuracy, precision and reproducibility of analytical results and detection and identification of potential, unintended sample contamination.

e) Prescribed Protocols - Relevant guidelines and standards from regulatory and other sources should be followed for most routine procedures. Typically these should meet or exceed those specified in CSA Z768-01, O.Reg 153/04 and the MOE Guidance for Sampling and Analyses at Contaminated Sites in Ontario; and,

f) Reviews of Deliverables - Prior to release to the client, all deliverables should undergo an extensive review for technical accuracy and product quality, including a review of components listed in the scope of work.

4.9.4 Health and Safety Plan

Prior to conducting a site visit or implementing the field program a Health and Safety program should be established in accordance with all applicable codes/regulations. The Health and Safety program shall ensure the health and safety of all its employees, sub-contractors, and others at the site. The program will outline potential hazard incidents, the codes/regulations to be met, rules of behavior, protective equipment, and clothing to be provided, security features to be established, responsible individuals and all related matters. The project consultant shall be responsible for making all employees and others at the site aware of any potential contamination and for ensuring the health and safety of all personnel at the site. The plan shall always be with the project consultant while working on the site. The plan must be submitted to the project authority a minimum of three (3) days in advance of conducting the field work and a plan is required for each site visited if multiple sites are subject to site visitation.

4.9.5 Administrative Requirements

In support of the RA implementation, administrative requirements are anticipated to include the following:

- Private property access: site access agreements with landowners must be negotiated and granted prior to conducting field work (site visit, sampling);
- Well record(s); any wells installed on the HIA property or at offsite locations as part of this work will require cluster tagging and well record filing with the Ontario Ministry of the Environment;
- Waste disposal - Water: Groundwater generated as waste during monitoring well development will require manifesting for offsite disposal under Ontario Regulation 347. The most prevalent applicable waste class is typically selected for waste manifesting purposes. A waste class specific to PFCs does not exist under Ontario Regulation 347, therefore, as the property is not TC property, waste classification (and hazardous waste information system registration) should be completed with concurrence of the site owner. Where the sole applicable contaminant is PFCs (i.e. samples from outside any other contaminant plume that may be present at the HIA), the MOE may be consulted to identify an appropriate waste class;

- Waste disposal - Soil: Soil generated as waste during borehole installation activities will require appropriate testing according to Ontario Regulation 347 prior to disposal. The waste hauler will need to be consulted to determine analytical requirements specific to their disposal situation.
- Species at Risk Handling or Collection: If trapping is required to identify the presence of a species at risk in the risk assessment area, an Endangered Species Act (ESA) - Protection or Recovery Permit will be required from the Ontario Ministry of Natural Resources.
- Small Mammal Trapping - A care and handling plan (if specimens are live caught and released) and scientific collection permit will be required, unless the requirement is waived by the local Ministry of Natural Resources.
- Fish Tissue Collection – A scientific collection permit should be obtained from the Ontario Ministry of Natural Resources. Although samples may be obtained using traditional angling methods under a provincial fishing licence, more efficient means (netting, trapping, electrofishing) will require a collection permit. The License to Collect Fish for Scientific Purposes is provided in Section 36.1 of the Ontario Fishery Regulations (OFR) which also identifies the appropriate local authority for license request submission. This license is issued under Section 34.1(1) of the Fish Licensing Regulations under the Fish and Wildlife Conservation Act. A permit may be required under the provincial ESA or the federal Species at Risk Act (SARA), if the sampling locations are in areas where a listed species at risk may be captured. The local Ontario Ministry of Natural Resources and Department of Fisheries and Oceans offices should be contacted regarding potential for species at risk encounter and sampling approach. If the sampling activity is anticipated to cause an unacceptable level of harm (e.g. netting vs. electrofishing) to the population of a listed species, it is possible that a permit will not be issued and alternative sampling locations or methods may be required.

A work permit or other approvals is not required to sample sediment and surface water within the river and tributaries of the study area, as long as these waterbodies can be accessed by boat without requiring private landside property access, as has been confirmed with the NPCA.

4.10 Optimum Timing of Field Program Tasks

A number of field program activities are anticipated in Stage 1 and potentially in Stage 2. Certain tasks are considered to be unrestricted in terms of optimum timeperiods of the year to complete the task, whereas other tasks are constrained by limitations imposed by the objective of the task. For example, monitoring well installation can be completed at anytime of the year and the limitations on task completion are dictated mainly based on schedule requirements. Benthic macroinvertebrate sampling though is ideally completed at a specific time of the year. Optimum timeperiods for field program tasks are described below.

4.10.1 Species and Ecological Resource Survey

4.10.1.1 *Vascular Plants*

The vascular plant survey must be conducted during the growing season when species (including potentially present rare species) are most likely visible based on the occurrence of diagnostic features. The study area should be surveyed multiple times during a growing season to observe early and late season plants. A minimum of two growing season visits (e.g. spring and summer) will be required, unless additional visits are required to evaluate early or late-blooming rare species occurrences. For schedule identification purposes, optimal survey time periods are early June and mid July.

4.10.1.2 *Breeding Birds*

A survey of breeding birds should be carried out between May 24 and July 10 and require a minimum of two site visits separated by at least two weeks during the breeding season. The optimum time to complete the first visit is within the first three weeks of June.

4.10.1.3 *Mammals*

There is no one timeperiod that is preferable to complete a mammal survey. Small mammal capture efficiency tends to increase following the breeding season and populations peak during the late summer and early fall. Stage 1 surveys completed for tissue collection and presence/absence evaluation should be conducted at this timeperiod. At Stage 2, as part of a weight of evidence risk assessment if necessary, it is possible that surveys will be completed to assess relative abundance. Abundance surveys, if required, should be completed twice between May to October, with one survey completed during the spring breeding period and a follow-up survey completed in the fall after the breeding season.

4.10.1.4 *Herpetofauna*

Amphibian surveys may need to take place up to three times in one year to coincide with peak breeding time periods for different amphibians. The three (3) surveys should be conducted at least fifteen (15) days apart. For scheduling purposes, it is assumed that the first survey would be conducted in the last half of April (April 15-30), the second in the last half of May (May 15-30) and the final survey in the last half of June (June 15-30). Surveys are started a half-hour after sunset. Salamander presence/absence may be conducted during the first amphibian survey timeperiod. Visual surveys for snakes and turtles may be best completed on warm days in spring (mid-April to mid-June). It is anticipated that a survey of this detail will only be conducted at Stage 2 if required.

4.10.1.5 *Fish and Benthos*

The upper reaches of some tributaries at the site could be ephemeral. Fish community assessments should be conducted in May or early June in order to document if fish are present at a time when water is also most likely to be present at all locations. Surveys should include the ability to observe mussels, which are ideally conducted during summer low flow conditions (generally August to early September) with sufficient period of timing following a rain event to coincide with minimal turbidity. The optimum timing for benthos evaluation is discussed below.

4.10.2 **Benthic Community Structure Evaluation**

Although sampling can be conducted during any season or timeperiod, late summer or early fall sampling is generally considered ideal to characterize benthic macro-invertebrate structure (EC, 2012a; BC MOE, 2006) based on a relatively high biomass, advanced lifestage and low flow conditions occurring at this timeperiod of the year. The optimum timeperiod is from Late August to October. Alternative feasible timeperiods extend from May through November. In consideration that benthic macro invertebrate sampling may be conducted in both Stage 1 and Stage 2, a single equivalent seasonal timeperiod must be targeted otherwise pooling of sample data will not be possible.

4.10.3 **Sediment Toxicity Evaluation**

Sample collection for sediment toxicity analysis is conducted concurrently with surface water and benthic macro- invertebrate sampling. There are no seasonal limitations related to sediment sampling, therefore scheduling will be dictated by benthic macro-invertebrate sampling requirements.

4.10.4 **Tissue Collection**

It is anticipated that tissue collection will be conducted concurrently with other sampling and assessment activities. Limitations on timing may be imposed by seasonal feeding strategies that minimize exposure at certain times of the year or the lack of availability of tissue during certain seasons. In general, tissue sampling should be avoided during the winter.

4.10.5 **Soil and Groundwater Quality Evaluation**

Soil and groundwater sampling may be conducted at anytime of the year.

4.11 General Sampling Requirements

Samples will be collected from multiple properties, many of which do not have a common owner. Samples submitted for analysis must be separated by chain of custody that applies to each property. Samples collected from two or more separate properties must not be submitted under one chain of custody unless the property owner is common between the sample locations. Analytical results reported by the laboratories shall be requested, by the consultant, to be reported on a certificate of approval sample block basis. If the laboratory provides data interpretation that requires compilation of results from multiple properties, this shall be reported separately from the raw analytical data. This requirement applies to all samples collected and analyzed as part of section 4 of this workplan (i.e. soil, groundwater, sediment, surface water, tissue, etc.).

In the event that any of the confirmed sampling/survey location becomes inaccessible for any reason, the consultant will notify PWGSC as soon as possible of the circumstances, and propose a suitable alternate location that satisfies the intent of the original location and ensures delivery of the required risk assessment in either of Stage 1 and Stage 2. PWGSC/TC will be responsible for arranging access permission from private landowners with support from the Consultant, if and as required, prior to the consultant proceeding with sampling at the proposed alternate location. RA schedule and/or deliverable implications would be reviewed and agreed upon between PWGSC and the consultant.

5 STAKEHOLDER AND AGENCY ENGAGEMENT

The lands comprising the study area consist of properties which are not under ownership by Transport Canada. In keeping with the spirit of Ontario Regulation 153/04 (as amended), where a wider area of abatement may be considered to apply, a stakeholder engagement component is included in the RA process for the site. The objectives of the stakeholder engagement process are as follows:

- Public stakeholders will be identified and communication will be initiated on a select basis with the purpose of informing potentially affected parties on the work being undertaken; and,
- Agency stakeholders will be identified and invited to participate in the RA process through provision of technical input.

In the Ontario Regulation 153/04 (as amended) record of site condition (RSC) process, the primary regulatory agency stakeholder is the Ontario Ministry of Environment, although local levels of government provide limited input during the RSC process (i.e. acceptance of risk based standards applying to a site rather than adoption of generic potable water standards). Other agencies may be contacted for supporting information during the RSC process, but are not typically active participants in the process. In the interest of conducting the planned RA in the spirit of Ontario Regulation 153/04 (as amended), the primary agency stakeholder will be the Ontario Ministry of Environment. Additional federal scientific support agencies will also be consulted by Transport Canada to provide guidance during the RA process.

In support of RA implementation, a proposed list of public stakeholders and governmental agencies and types of engagement are discussed in the following sections, primarily based on selected criteria consisting of the following:

- Identification of the study area proposed within the scope of this work program: Immediate surroundings of the HIA and a portion of the upper Welland River watershed;
- Identification of primary uses of the study area: a mix of urban and agriculture with a number of natural use features;
- Identification of groups (or individuals) who use the study area and/or have a vested interest in the study area; and,
- Identification of key watershed management objectives: water resources, fish and aquatic habitat, natural heritage resources and recreation.

5.1 Public Stakeholders

It is anticipated that the following public stakeholders may be included in the consultation process:

- Property owners (and possibly tenants) of property within the risk assessment area or those who may be directly affected by study implementation. This may include commercial and residential owners and developers;
- Non-governmental organizations (specifically the Niagara Peninsula Conservation Authority);
- First Nations with a direct interest in the study area. First Nations may consist of Mississaugas of the New Credit First Nation and the Six Nations of the Grand River Territory First Nation although collection of data on the location covered by treaty rights and traditional land use issues would be required.
- Farming groups (specifically the Hamilton-Wentworth Federation of Agriculture and Local 351 (Brant, Hamilton, Halton) of the National Farmers Union). A significant percentage of farmland in Hamilton are rental properties and communication with the landowner as opposed to the tenant may be required initially; and,
- Municipalities in the affected study area (City of Hamilton).

No resident associations have been identified in the study area, therefore notification of groups is not considered required. The progress of activities related the presence of PFCs in the upper Welland River has been periodically reported by the Hamilton Spectator. It is proposed that general public updates may be made through public notice to the Hamilton Spectator.

5.1.1 Level of Public Engagement

Two levels of public stakeholder engagement are identified. These two levels of engagement relate to a) general information release and b) more detailed information release to key public stakeholders. Key public stakeholders are considered to be represented by members of the public who own or oversee property in the study area, specifically in locations where PFCs are identified to exceed applicable guidelines. A preliminary list of key public stakeholders is provided above in section 5.1. Once a key list of public stakeholders is finalized by the consultant in Stage 1, in discussion with the technical stakeholder group, these key stakeholders will be notified by mailout regarding a source for general information, such as website hosted and maintained by the risk assessment consultant. Information provided on the website would consist of an outline of the issue and notification of general approach anticipated for dealing with the issue. At the close of reporting for each stage of work, results pertaining to individual properties will be provided to affected property owners who have granted access to allow the work to proceed.

General information regarding the status and progress of work may be made to the public through public notice to a local news agency (i.e. Hamilton Spectator).

5.1.2 Timing of Public Engagement

Property owners of proposed sampling locations have been notified of the project in the process of requesting property access. Timing and nature of additional communications to public stakeholders will include: 1) general mailout to public stakeholders regarding general source of information (referenced in 5.1.1) following initiation of Stage 1; 2) finalization of Stage 1; 3) finalization of Stage 2.General information releases are planned to take place at major milestones consisting of finalization of Stage 1 and finalization of Stage 2.

5.2 Key Governmental Agencies

A number of governmental stakeholders may have regulatory interest in the study area. A preliminary list includes the following:

- Environment Canada (EC);
- Ontario Ministry of the Environment (MOE); and,
- Department of Fisheries and Oceans Canada (DFO).

These key governmental agencies are considered to have a vested interest in the risk assessment process due to the regulatory role they play. The regulatory interest and relationship to the RA process for each of the key governmental agencies is summarized below.

Table X: Summary of Key Governmental Agency Association to the Project

Governmental Agency	Regulatory Association	Relationship to RA Project
Environment Canada	Provisions of Fisheries Act may apply	Administers the pollution control provisions of the Fisheries Act
Ontario Ministry of Environment	Aspects of the Ontario Environmental Protection Act may apply	Administers the Ontario Environmental Protection Act
Department of Fisheries and Oceans	Provisions of Fisheries Act may apply	Overall responsibility regarding the Fisheries Act

A number of additional agencies are considered to represent key technical stakeholders. Key technical stakeholders are considered to consist of representatives from organizations who do not necessarily have a vested interest in the site, but may have expertise in the process of conducting risk assessment. This includes Federal Contaminated Sites Action Plan expert support agencies.

5.2.1 Level of Governmental Engagement

Governmental agency representatives will be involved in the RA process at two levels. The two levels will consist of a) technical advisory committee (major support role) and b) issue-specific consultation (minor support role). It is anticipated that the following are agencies will be asked to participate as technical advisory committee agencies providing a major support role to Transport Canada (proponent), Public Works and Government Services Canada (proponent's project manager), and the RA consultant

- Ontario Ministry of the Environment (MOE);
- Environment Canada (EC);
- Health Canada (HC); and,
- Department of Fisheries and Oceans Canada (DFO).

Members of the technical advisory committee will be involved in RA project development by providing input on assessment approach and outcomes, and reviewing of draft reports and deliverables. The technical advisory committee may also be asked for support on various public consultation activities and communications to be led by Transport Canada with support from the RA consultant. Formal technical stakeholder meetings would typically be conducted at a closed door type meeting and minutes made available.

Other government agencies may be directly approached for their expertise on subject-specific issues on an as required basis during the implementation of the RA, and therefore will have a minor support role. These agencies may include the following:

- Ontario Ministry of Natural Resources (MNR); and,
- City of Hamilton (Hamilton Public Health).

5.2.2 Timing of Governmental Engagement

All key governmental agency representatives will be identified and notified at the initiation of Stage 1. Updates to technical advisory committee members will take place primarily by email on a semi-monthly basis. Technical committee members will provide input as follows:

- Prior to initiation of Stage 2 work (review and input on workplan and study design to meet workplan stage objectives); and,
- At the draft reporting stage (review and input regarding work execution, outcomes, conclusions and recommendations).

Other supporting agencies will be engaged as required for issues relating to their mandate, and will also be updated at the end of each stage.

6 TIMING AND DELIVERABLES

Supplemental investigation task components of the RA are identified in Section 4. A summary of task purpose, deliverables and timing, is provided below. It is proposed that all deliverables would be reviewed by the technical stakeholder advisory committee.

Table XI: Summary of Task Purpose, Timing and Deliverables

Task	Deliverable	Timing	Purpose
Identify Screening Criteria, Toxicity Reference Values, Transfer Factors and Gaps	Letter report outlining selected criteria, derivation approach for criteria which are not adopted from established criteria and supporting information. Identify gaps related to pathway characterization, media characterized and receptor uncertainties. Identify recommendations to address uncertainties and gaps. Identify Stage 2 Workplan details.	Conclusion of Stage 1	Identify screening criteria and provide initial indication of limitations of the risk assessment (PFC which cannot be evaluated). Gaps to be identified and gap program, if feasible identified in the report.
Species and Ecological Resource Survey	Field work methodology, results and identification of species/key communities observed and location.	Stage 1 Stage 2 (if required)	Refine VEC list requiring ERA evaluation, identify microenvironments that may require consideration in the ERA.
Sediment Toxicity Evaluation	Field work methodology, results and interpretation of sampling locations displaying adverse effects correlated to PFCs.	Stage 1 Stage 2 (if required)	Identify extent of sediment impact based on toxicity in the absence of established sediment toxicity benchmarks. Provides a direct (laboratory) measure of effects.
Benthic Community Structure Evaluation	Field work methodology, results and interpretation of which sampling locations displaying adverse effects correlated to PFCs.	Stage 1 Stage 2 (if required)	Identify extent of sediment impact based on community structure in the absence of established sediment toxicity benchmarks. Provides a direct (field) measure of effects.
Surface Water Toxicity Testing	Field work methodology, results and interpretation of which sampling locations displaying adverse effects correlated to PFCs.	Stage 1 Stage 2 (if required)	Identify presence/extent of surface impact based on toxicity in the absence of established surface water quality benchmarks. Provides a direct (laboratory) measure of effects.
Tissue Residue Analysis	Field work methodology and results in addition to conclusions with respect to tissue residue guidelines	Stage 1 Stage 2 (if required)	Identify tissue exposure point concentrations for human and ecological receptors.
Property Boundary Soil and Groundwater Quality Investigation	Field work methodology, results and compare to screening criteria.	Stage 1	Identification of potential for risk to nearby domestic wells and receiving surface water bodies. Identification of potential risk to receptors interacting with soil.

Interim Detailed Quantitative Risk Assessment Report	Reporting of all Stage 1 site investigations, completion of a detailed quantitative risk assessment based on available information and information obtained in Stage 1. Identification of costs, schedule and justification and plan for data gap and risk assessment uncertainty reduction programs in Stage 2.	Conclusion of Stage 1	Identify risk assessment outcome, gaps and uncertainties and how additional Stage 2 work can be completed to refine the risk assessment.
Final Detailed Quantitative Risk Assessment Report	Reporting of all Stage 2 site investigations, completion of a final detailed quantitative risk assessment based on all available information. Identification of risk management selection approach, costs, schedule and plan for risk management.	Conclusion of Stage 2	Identify the final detailed quantitative risk assessment analysis and conclusions and risk management plan to address potentially unacceptable risks associated with historical FFTA operation.

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8 NOTICE TO READER

This report has been prepared and the work referred to in this report have been undertaken by SNC-Lavalin Inc., Environment & Water (SNC-Lavalin) for the exclusive use of Public Works and Government Services Canada (the Client), who has been party to the development of the scope of work and understands its limitations. The methodology, findings, conclusions and recommendations in this report are based solely upon the scope of work and subject to the time and budgetary considerations described in the proposal and/or contract pursuant to which this report was issued. Any use, reliance on, or decision made by a third party based on this report is the sole responsibility of such third party. SNC-Lavalin accepts no liability or responsibility for any damages that may be suffered or incurred by any third party as a result of the use of, reliance on, or any decision made based on this report.

The findings, conclusions and recommendations in this report (i) have been developed in a manner consistent with the level of skill normally exercised by professionals currently practicing under similar conditions in the area, and (ii) reflect SNC-Lavalin's best judgment based on information available at the time of preparation of this report. No other warranties, either expressed or implied, are made as to the professional services provided under the terms of our original contract and included in this report. The findings and conclusions contained in this report are valid only as of the date of this report and may be based, in part, upon information provided by others. If any of the information is inaccurate, new information is discovered, site conditions change or applicable standards are amended, modifications to this report may be necessary. The results of this assessment should in no way be construed as a warranty that the subject site is free from any and all contamination.

Any soil and rock descriptions in this report and associated logs have been made with the intent of providing general information on the subsurface conditions of the site. This information should not be used as geotechnical data for any purpose unless specifically addressed in the text of this report. Groundwater conditions described in this report refer only to those observed at the location and time of observation noted in the report.

This report must be read as a whole, as sections taken out of context may be misleading. If discrepancies occur between the preliminary (draft) and final version of this report, it is the final version that takes precedence. Nothing in this report is intended to constitute or provide a legal opinion.

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Senior Risk Assessor

Encld.

TABLES

TABLE 1 **Stage 1 Analytical Requirements - Sediment**
Upper Welland River Watershed
Mount Hope, Ontario

Sample Station	Location	Section Reference	Media	Analytical Suite	Parameters Grainsize (sieve+hydrometer)	BOD	Organochlorine Pesticides	Nitrate	Nitrite	TKN	Ammonia	Metals (incl. Na, P	Glycols	TOC	PFC	*C.riparius* (tox)	*H.azteca* (tox)	*P.promelas* (tox)	Field Water depth	Field pH/Redox	Field Velocity	Field Secchi depth	Field T, DO, pH	Benthic Invertebrate Enumuration	Note
Site 1	Site sample (main tributary group)	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location is one of the open triangle locations on Figure 11
Site 2	Site sample (main tributary group)	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location is one of the open triangle locations on Figure 11
Site 3	Site sample (main tributary group)	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location is one of the open triangle locations on Figure 11
Site 4	Site sample (main tributary group)	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location is one of the open triangle locations on Figure 11
Site 5	Site sample (main tributary group)	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location is one of the open triangle locations on Figure 11
Site 6	Site sample (main tributary group)	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location is one of the open triangle locations on Figure 11
Site 7	Site sample (main tributary group)	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location is one of the open triangle locations on Figure 11
Site 8	Site sample (main tributary group)	4.4 - see note	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location is one of the open triangle locations on Figure 11
Site 9	Site sample	4.7	Sediment												x[1]										Identified as "+" on Figure 11
Offsite 1	Offsite sample	4.7	Sediment												x[1]										Identified as "+" on Figure 11 immediately south of the HIA property
Offsite 2	Offsite sample	4.7	Sediment												x[1]										Identified as "+" on Figure 11 immediately south of the HIA property
Ref 1	Offsite sample	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location on figure 10. Intended as a reference station
Ref 2	Offsite sample	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location on figure 10. Intended as a reference station
Ref 3	Offsite sample	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location on figure 10. Intended as a reference station
Ref 4	Offsite sample	4.4/4.5	Sediment	Note 4	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Sample location on figure 10. Intended as a reference station
WT-5	Downstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	WT-5 identified on Figure 6. Toxicity analysis held pending chemistry results
WT-1	Downstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Figure 6. Toxicity analysis held pending chem results
WT-2	Downstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Figure 6. Toxicity analysis held pending chem results
WT-3	Downstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Figure 6. Toxicity analysis held pending chem results
MOE LAKE NIAPENCO	Downstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x		Figure 6. Toxicity analysis held pending chem results
WR-2	Upstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Figure 4A, Figure 4B
WR-3	Upstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Figure 4A, Figure 4B
WR-4	Upstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Figure 4A, Figure 4B
WR-5	Upstream of site	4.4/4.5	Sediment	Note 3	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[1]	x[3]	x[3]	x[3]	x	x	x	x	x	x[1]	Figure 4A, Figure 4B
Chemistry duplicates			Sediment		x[2]	x[2]	x[2]	x[2]	x[2]	x[2]	x[2]	x[2]	x[2]	x[2]	x[2]										Duplicates for above samples

Notes

1 Sample locations are subsampled and triplicates are submitted for analysis.
2 1:10 sample submission frequency.
3 Subsample per method requirements.
4 All analysis conducted concurrently.
5 Final analytical suite dependednt on chemistry results. Refer to Workplan.

TABLE 2 **Stage 1 Analytical Requirements - Surface Water**
Upper Welland River Watershed
Mount Hope, Ontario

Sample Station	Location	Section Reference	Media	BOD	Organochlorine Pesticides	Nitrate	Nitrite	TKN	Ammonia	Metals (incl. Na, F	Glycols	TOC	PFC	*L. Minor*	*P.subcapitata*	*C.dubia*	*P.promelas*	Note
Site 1	Site sample (main tributary group)	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location is one of the open triangle locations on Figure 11
Site 2	Site sample (main tributary group)	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location is one of the open triangle locations on Figure 11
Site 3	Site sample (main tributary group)	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location is one of the open triangle locations on Figure 11
Site 4	Site sample (main tributary group)	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location is one of the open triangle locations on Figure 11
Site 5	Site sample (main tributary group)	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location is one of the open triangle locations on Figure 11
Site 6	Site sample (main tributary group)	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location is one of the open triangle locations on Figure 11
Site 7	Site sample (main tributary group)	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location is one of the open triangle locations on Figure 11
Site 8	Site sample (main tributary group)	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location is one of the open triangle locations on Figure 11
WT-5	Downstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	WT-5 identified on Figure 6. Toxicity analysis held pending chem results
WT-1	Downstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Figure 6. Toxicity analysis held pending chem results
WT-2	Downstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Figure 6. Toxicity analysis held pending chem results
WT-3	Downstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Figure 6. Toxicity analysis held pending chem results
MOE LAKE NIAPENCO	Downstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Figure 6. Toxicity analysis held pending chem results
WR-2	Upstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Refer to Figure 4A and Figure 4B.
WR-3	Upstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Refer to Figure 4A and Figure 4B.
WR-4	Upstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Refer to Figure 4A and Figure 4B.
WR-5	Upstream of site	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Refer to Figure 4A and Figure 4B.
Site 9	Site sample	4.7	Surface Water										x					Identified as "+" on Figure 11
Offsite 1	Offsite sample	4.7	Surface Water										x					Identified as "+" on Figure 11 immediately south of the HIA property
Offsite 2	Offsite sample	4.7	Surface Water										x					Identified as "+" on Figure 11 immediately south of the HIA property
Ref 1	Offsite sample	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location on figure 10. Intended as a reference station
Ref 2	Offsite sample	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location on figure 10. Intended as a reference station
Ref 3	Offsite sample	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location on figure 10. Intended as a reference station
Ref 4	Offsite sample	4.6	Surface Water	x	x	x	x		x	x	x		x	x	x	x	x	Sample location on figure 10. Intended as a reference station
Chemistry duplicates			Surface Water	x^2	x^2	x^2	x^2		x^2	x^2	x^2		x^2					Duplicates for above samples

Notes

2 1:10 sample submission frequency

TABLE 3 **Stage 1 Analytical Requirements - Tissue**
Upper Welland River Watershed
Mount Hope, Ontario

Sample Station	Location	Section Reference	Media	PFC	Moisture	Note
Site/Ref	Site and Reference	4.8	Aquatic Plant Tissue	X[3]	X[3]	A gradient sampling approach in the site area on Figure 11. Specific sample locations are not identified on Figure 11. Refer to legend (Figure 2A) for general sample locations along the the gradient.
Site/Ref	Site and Reference	4.8	Fish Tissue	X[3]	X[3]	A gradient sampling approach in the site area on Figure 11. Specific sample locations are not identified on Figure 11. Refer to legend (Figure 2A) for general sample locations along the the gradient.
Site/Ref	Site and Reference	4.8	Aquatic Invertebrate Tissue	X[3]	X[3]	A gradient sampling approach in the site area on Figure 11. Specific sample locations are not identified on Figure 11. Refer to legend (Figure 2A) for general sample locations along the the gradient.
Site/Ref	Site and Reference	4.8	Terrestrial Plant Tissue	X[3]	X[3]	A gradient sampling approach in the site area on Figure 11. Specific sample locations are not identified on Figure 11. Refer to legend (Figure 2A) for general sample locations along the the gradient.
Site/Ref	Site and Reference	4.8	Soil Invertebrate Tissue	X[3]	X[3]	A gradient sampling approach in the site area on Figure 11. Specific sample locations are not identified on Figure 11. Refer to legend (Figure 2A) for general sample locations along the the gradient.
Site/Ref	Site and Reference	4.8	Small Mammal	X[3]	X[3]	A gradient sampling approach in the site area on Figure 11. Specific sample locations are not identified on Figure 11. Refer to legend (Figure 2A) for general sample locations along the the gradient.
Chemistry duplicates				x[2]	x[2]	

Notes

2 1:10 sample submission frequency
3 Total of 20 samples, a portion of which must be obtained at refernce stations. Multiple samples may be obtained from a single station. The workplan specifies that a gradient sampling approach for the risk assessment area.

TABLE 4 **Stage 1 Analytical Requirements - Groundwater**
Upper Welland River Watershed
Mount Hope, Ontario

Sample Station	Location	Section Reference	Media	PFC	Note
MW/BH 1A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 1B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 2A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 2B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 3A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 3B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 4A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 4B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 5A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 5B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 6A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 6B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 7A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 7B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 8A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 8B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 9A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 9B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 10A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 10B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 11A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 11B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 12A	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
MW/BH 12B	HIA Boundary	4.9	Groundwater	x	Figure 11. Note - this well is part of a multilevel installation. There are two sampling events
Chemistry duplicates			Groundwater	x[2]	

Notes

2 1:10 sample submission frequency

TABLE 5 **Stage 1 Analytical Requirements - Soil**
Upper Welland River Watershed
Mount Hope, Ontario

Sample Station	Location	Section Reference	Media	PFC	Note
MW/BH 1A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 1B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 2A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 2B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 3A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 3B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 4A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 4B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 5A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 5B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 6A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 6B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 7A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 7B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 8A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 8B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 9A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 9B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 10A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 10B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 11A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 11B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
MW/BH 12A	HIA Boundary	4.9	Surface Soil	x	Sample location identified on Figure 11
MW/BH 12B	HIA Boundary	4.9	Subsurface soil	x	Sample location identified on Figure 11
Chemistry duplicates			Soil	x[2]	

Notes

2 1:10 sample submission frequency

TABLE 6 **Stage 1 Sampling Locations**
Upper Welland River Watershed
Mount Hope, Ontario

Sample Station	Position[2]	Sampling requirement	Access[1]		Address	Location	Pin	Property Owner	Street Address
			Aquatic	Terrestrial					
WR-2	585467.99 E 4782376.5 N	Surface water, Sediment, Invertebrate sampling	Access by road and/or boat, and no requirement for terrestrial crossing of private property	NA	Roadway Right of Way	South side of Book Road East in drainage ditch	170820036	The Town of Ancaster	
WR-3	584870.85 E 4782226.73 N	Surface water, Sediment, Invertebrate sampling	Access by road and/or boat, and no requirement for terrestrial crossing of private property	NA	Roadway Right of Way	South side of Book Road East in drainage ditch flowing to pond on private property	174130052	The Town of Ancaster	
WR-4	584533.65 E 4782157.67 N	Surface water, Sediment, Invertebrate sampling	Access by road and/or boat, and no requirement for terrestrial crossing of private property	NA	Roadway Right of Way	North side of Book Road East at drainage structure entrance	174130052	The Town of Ancaster	
WR-5	584291.37 E 4782091.32 N	Surface water, Sediment, Invertebrate sampling	Access by road and/or boat, and no requirement for terrestrial crossing of private property	NA	Roadway Right of Way	North side of Book Road East at drainage structure entrance	174130052	The Town of Ancaster	
MOE Lake Niapenco	595559.99 E 4772526.89 N	Surface water, Sediment, Invertebrate sampling	Access by road and/or boat, and no requirement for terrestrial crossing of private property	NA	If not accessed from water or roadway right-of-way, then access from land through 4339 Harrison Road.	East side of Harrison Road in main channel Sampling may be completed at public roadway right-of-way.	173830144	R.M. Hamilton-Wentworth	
WT-1	590350.98 E 4774245.42 N	Surface water, Sediment, Invertebrate sampling	Access by road and/or boat, and no requirement for terrestrial crossing of private property	NA	Not applicable	Confluence of two tributaries which enter the Welland River Most convenient access is by small boat.	173920133	Gurdev Buttar & Balinder Buttar	6303 Chippewa Rd E
WT-2	590761.14 E 4773703.38 N	Surface water, Sediment, Invertebrate sampling	Access by road and/or boat, and no requirement for terrestrial crossing of private property	NA	5020 Tyenside Road (Roll number 251890271063200) if not accessed by boat	Tributary entering Welland River. Sample collected upstream of embayment to obtain representative tributary sample. Boat access, otherwise provate property access required If private property access is required, then access through property at 5020 Tyenside Road (Roll number 251890271063200)	173920047	Allan Douglas MacLean & Marilyn Elaine MacLean & Kathleen Lynn Smith	4427 Miles Rd
WT-3	589260.35 E 4774486.02 N	Surface water, Sediment, Invertebrate sampling	Access by road and/or boat, and no requirement for terrestrial crossing of private property	NA	Public Trail Access	Tributary sample on west side of Chippewa Trail. Access from public trail. Trail has Roll number 251890271032400	173920109	The Hamilton & Port Dover Railway Company	
WT-5	586419.52 E 4777509.55 N	Surface water, Sediment, Invertebrate sampling	Access through private property, or by boat starting at White Church Road. Parking for boat access is difficult based on roadway shoulder conditions. Multiple pull throughs required if accessing by boat.	NA	Glanford Concession 6, Lot 3. **9485 White Church Road**. Roll 251890261001200	Welland River main channel. Access by boat with several pull throughs, or from private property located at 9485 White Church Road.	174010011	Hedwig Auguste Pearce, Ronald James Pearce, Randolph Joseph Pearce	9425 White Church Road W
Site 1	586015.81 E 4779428.88 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Access by road.	Site 1 is located on the City ROW, although requirement for terrestrial crossing of private property (9879 Airport Road) to undertake survey and capture/collect tissues.	Roadway Right of Way Surveys will require access to adjacent private property.	Drainage feature at north side of Airport Road East. Location is in the public road right of way, but survey will require accessing south property at 9879 Airport Road.	173990216	City of Hamilton	
Site 2	585644.53 E 4778984.27 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Access by road through private property	requirement for terrestrial crossing of private property located at Roll # 251890251022020 to undertake survey and capture/collect animal tissues	Glanford Concession 5, Lot 1. Roll 251890251022020 Address not locatec	Drainage feature north of Hwy 6. Private property.	174000937	City of Hamilton	9910 White Church Road
Site 3	585432.97 E 4778467.71 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Access by road initially and only partial access by boat. Land access through Roll # 251890251000200 required.	Requirement for terrestrial crossing of private property at Roll # 251890251000200 to undertake survey and capture/collect animal tissues	Glanford Concession 5, Lot 1. Roll 251890251000200 Address not locatec	Confluence of two tributaries north of White Church Road West. Private property access through Roll # 251890251000200 required.	174000310	Paul Hill & Anthony Rizzuto	
Site 4	585580.54 E 4778178.24 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Access by road and/or boat	Requirement for terrestrial crossing of private property to undertake survey and capture/collect animal tissues. Survey route upstream of Site 4 to Site 3 is on the same property as Site 4. Immediately downstream of Site 4 is a small private property (9760 White Church Road), followed by 9630 White Church Road.	Glanford Concession 6, Lot 1. Address and Roll number not located.	North side of White Church Road West. Shoreline potentially at public roadway right-of-way	174000782	Paul Hill & Anthony Rizzuto	
Site 5	585819.91 E 4777979.19 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Accessible boat for sw and sed samples from White Church Road, although road shoulders may not allow for convenient parking.	Requirement for terrestrial crossing of private property to undertake survey and capture/collect tissues and samples. Survey route to the south of Site 6 and Site 5 requires access through private property at 9727 White Church Road.	Glanford Concession 6, Lot 2, **9727 White Church Road**, Roll 251890261001000	Main channel feature south of White Church Road West. Private property access through 9727 White Church Road required.	174010007	Gary Rousseau	9727 White Church Road
Site 6	585748.47 E 4778277.38 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Inacessible directly by road and/or boat for sw and sed samples. Access 9630 White Church Road and property at Roll #251890251000200 (no address). Accessing initailly from White church road will require an initial main channel crossing. If this is not convenient, a walk from the east through 9630 White Church Road will be required. There appears to be a small bridge near Site 4 which likely represents the most convenien terrstrial crossing.	Requirement for terrestrial crossing of private property to undertake survey and capture/collect tissues and samples. Survey route to the north towards Site 7 requires access through private properties at 9630 White Church Road and property at Roll #251890251000200 (no address).	Glanford Concession 5, Lot 2. **9630 White Church Road West**, Roll 251890251021800	North of White Church Road West. Private property access required, either through 9630 White Church Road, or property at Roll #251890251000200 (no address).	174000175	Catherine Charlotte Isbister	9630 White Church Road

Notes

1 Access approvals will be finalized by a contractor retained by PWGSC. Property access must not be undertaken unless approvals are in place prior to physically accessing the property. The contractor completing Stage 1 work must ensure that the sampling locations being accessed are those properties at which agreements or consents have been finalized.

2 Positions provided in UTM coordinates, Zone 17, ellipsoid WGS84

NA Not applicable

HIA Hamilton International Airport

TABLE 6 (cont'd) **Stage 1 Sampling Locations**
Upper Welland River Watershed
Mount Hope, Ontario

Sample Station	Position[2]	Sampling requirement	Access[1]		Address	Location	Pin	Property Owner	Street Address
			Aquatic	Terrestrial					
Site 7	585954.40 E 4778868.73 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Access by road.	Access by road for sw and sed samples; requirement for terrestrial crossing of private property (9705 Airport Road, owned by the City of Hamilton) to undertake survey and capture/collect animal tissues.	Glanford Concession 5, Lot 2. **9705 Airport Road**, Roll 251890251000800 Sample can be obtained on public road right-of-way.	North of Hwy 6, private property access required, although a sample can be obtained at the culvert entrance on the public road right-of-way. Surveys will require access to the private property.	174000301	City of Hamilton	9705 Airport
Site 8	586445.92 E 4779302.8 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Access by road.	Access by road and/or boat for sw and sed samples; requirement for terrestrial crossing of private property (9705 Airport Road, owned by the City of Hamilton) to undertake survey and capture/collect animal tissues.	Roadway Right of Way Surveys will require access to adjacent private property.	Drainage feature at north side of Airport Road East. Location does not appear to require private property access, although surveys to the south will require accessing private property	173990216	City of Hamilton	
Site 9	585650.88 E 4779928.43 N	Collection of Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals)	Access by road.	Access by road for sw and sed samples.	Roadway Right of Way.	Small tributary entering drainage ditch on east side of Glancaster Road. Location does not appear to require private property access.	173990313	City of Hamilton	
Offsite 1	586885.55 E 4779174.38 N	Surface water, Sediment	Access by road and/or boat, and no requirement for terrestrial crossing of private property.	Access by road and/or boat, therefore, no requirement for terrestrial crossing of private property (close to public road).	Roadway Right of Way.	Drainage feature at south side of Airport Road East and west of Centre Road. Location does not appear to require private property access.	173990216	City of Hamilton	
Offsite 2	587212.67 E 4779078.74N	Surface water, Sediment	Access by road and/or boat, and no requirement for terrestrial crossing of private property	Access by road and/or boat, therefore, no requirement for terrestrial crossing of private property (close to public road)	Roadway Right of Way.	Drainage feature at south side of Airport Road East and west of Centre Road east of main airport entrance. Location does not appear to require private property access.	173990291	Canadian Warplane Heritage	
REF 1	587489.44 E 4776463.47 N	Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals).	Park on Hwy 6 and enter by foot to collect samples on 9090 Chippewa Road.	Requirement for terrestrial crossing onto private property (9090 Chippewa Road) to undertake sampling.	Glanford Concession 6, Lot 5. **9090 Chippewa Road West**, Roll 251890261007400	Drainage feature on west side of Hwy 6 which discharges to the Welland River. Private property access required.	174010046	Frank Wallace Love, Helen Winnifred Love	9090 Chippewa Road
REF 2	584462.52 E 4779999.06 N	Surface water, Sed, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals).	Acessible by road, then by foot.	No requirement for terrestrial crossing of private property to undertake survey and capture/collect animal tissues if all surveys completed in the right of way. If sampling locations in the right of way are not suitable, access to private property at Roll # 251814042060200 will be required.	Roadway Right of Way.	Tributary discharging at culvert south of Butter Road East and west of Hwy 6. Location does not appear to require private property access.	174030119	Her Majesty the Queen of Ontario	
REF 3	591763.39 E 4780179.49 N	Collection of Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals).	Access by road and/or boat	Requirement for terrestrial crossing of private property (Roll 251890233002000, Miles Road) to undertake survey and capture/collect tissues.	Glanford Concession 3, Lot 11. Roll 251890233002000, Miles Road (no address).	Twenty Mile Creek main channel. Meander bend accessed to the east of Miles Road approximately 280 m south of Dickenson Road East. Property address not identified. Potentially private property.	173890002	The Roman Catholic Episcopal Corporation of the Diocese of Hamilton	
REF 4	586184.49 E 4777688.84 N	Collection of Surface water, Sediment, Tissue (aquatic/terrestrial vegetation, aquatic/terrestrial invertebrate, fish, mammals).	Access by road (then foot) and/or boat for sw and sed samples;	requirement for terrestrial crossing of private property (9485 White Church Road) to undertake survey and capture/collect animal tissues. Crossing by land from 9485 White Church Road will also require crossing the Welland River channel to access the sample site.	Glanford Concession 6, Lot 3. **9485 White Church Road**. Roll 251890261001200	Small tributary entering Welland River. Private property access required.	174010011	Hedwig Auguste Pearce, Ronald James Pearce, Randolph Joseph Pearce	9425 White Church Road W
MW/BH-1A/B	586098.87 E 4780080.23 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 1. Roll number 251890231032200.	West HIA property boundary.	173990206	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-2A/B	586056.40 E 4779943.31 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 1. Roll number 251890231032200.	West HIA property boundary.	173990206	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-3A/B	586002.19 E 4779769.25 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 1. Roll number 251890231032200.	West HIA property boundary.	173990206	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-4A/B	585965.41 E 4779642.65 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 1. Roll number 251890231032200.	West HIA property boundary.	173990206	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-5A/B	585911.15 E 4779466.41 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 1. Roll number 251890231032200.	Southwest HIA property boundary.	173990216	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-6A/B	586024.55 E 4779432.50 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 1. Roll number 251890231032200.	South HIA property boundary.	173990216	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-7A/B	586172.53 E 4779386.74 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 2. Roll number 251890231032200.	South HIA property boundary.	173990216	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-8A/B	586366.81 E 4779327.23 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 2. Roll number 251890231032200.	South HIA property boundary.	173990216	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-9A/B	586527.67 E 4779282.25 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 2. Roll number 251890231032200.	South HIA property boundary.	173990216	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-10A/B	586742.49 E 4779215.18 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 3. Roll number 251890231032200.	South HIA property boundary.	173990216	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-11A/B	586896.74 E 4779172.05 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 3. Roll number 251890231032200.	South HIA property boundary.	173990216	Tradeport (Leasee) and/or City of Hamilton (Leaser)	
MW/BH-12A/B	587024.41 E 4779134.59 N	Collection of groundwater, soil	NA	Access required (pending approval from the HIA owner and/or leasee).	Glanford Concession 4, Lot 3. Roll number 251890231032200.	South HIA property boundary.	173990216	Tradeport (Leasee) and/or City of Hamilton (Leaser)	

Notes

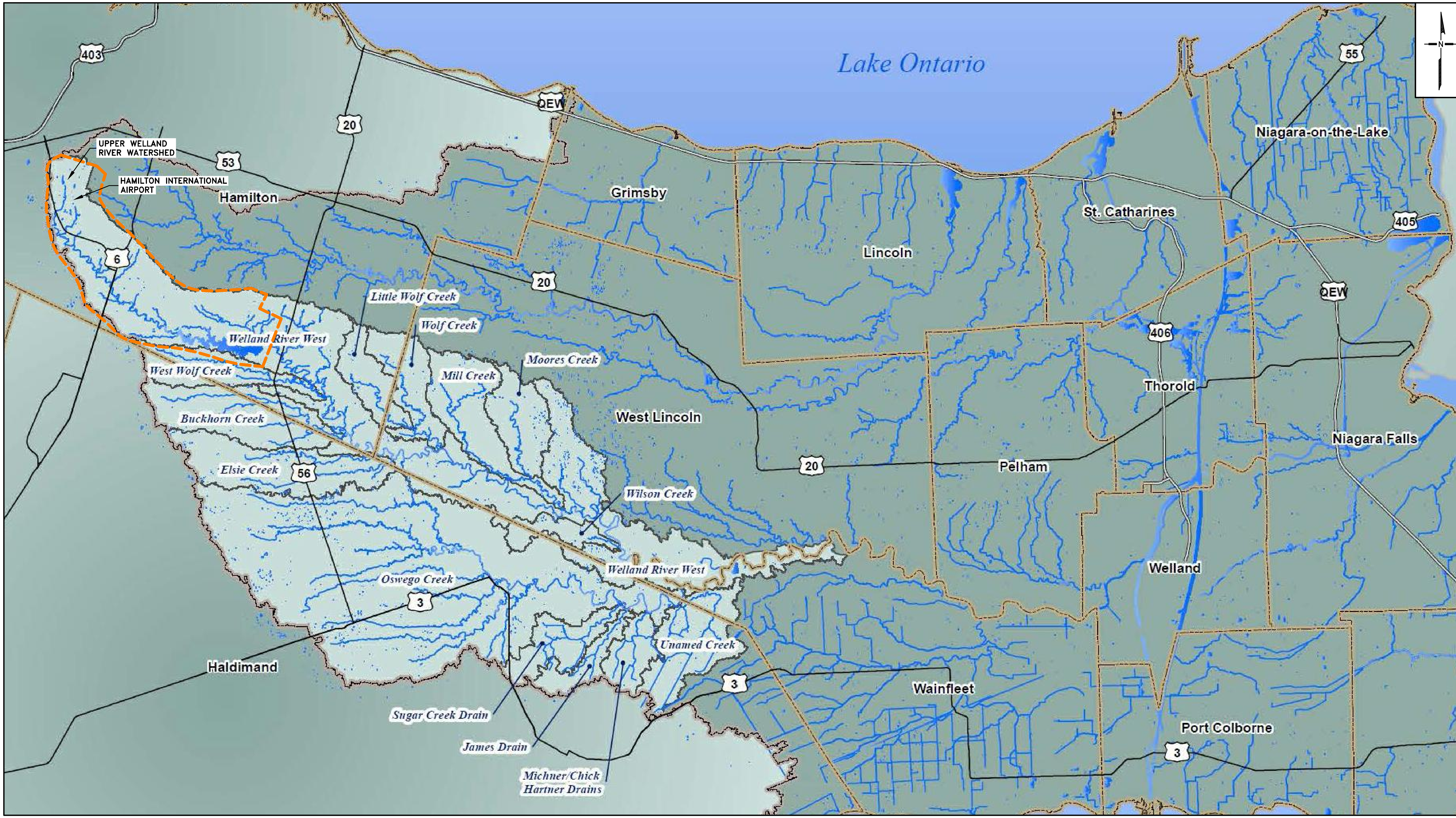
1 Access approvals will be finalized by a contractor retained by PWGSC. Property access must not be undertaken unless approvals are in place prior to physically accessing the property. The contractor completing Stage 1 work must ensure that the sampling locations being accessed are those properties at which agreements or consents have been finalized.

2 Positions provided in UTM coordinates, Zone 17, ellipsoid WGS84

NA Not applicable

HIA Hamilton International Airport

FIGURES



NOTE(S):
1. SCALE AND SITE INFRASTRUCTURE LOCATIONS ARE APPROXIMATE
2. INFORMATION ON THIS FIGURE MAY BE LOST IF IT IS PRINTED, PHOTOCOPIED OR FAXED IN OTHER THAN ITS ORIGINAL SIZE AND COLOURS
3. 'km' : KILOMETRES

SOURCE(S):
1. NIAGARA PENINSULA CONSERVATION AUTHORITY, UPPER WELLAND RIVER WATERSHED PLAN, MARCH 2011

LEGEND
STUDY AREA LIMITS

SNC·LAVALIN

Client/Location:	PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO
Title:	GENERAL LOCATION OF STUDY AREA
Project No:	616807
Filename:	007F1A_616807
Date:	DECEMBER 2014
Dwg No:	FIGURE 1A
Drawn:	AG
Verified:	DT
Project Manager:	DT

PAGE FORMAT: 11x17

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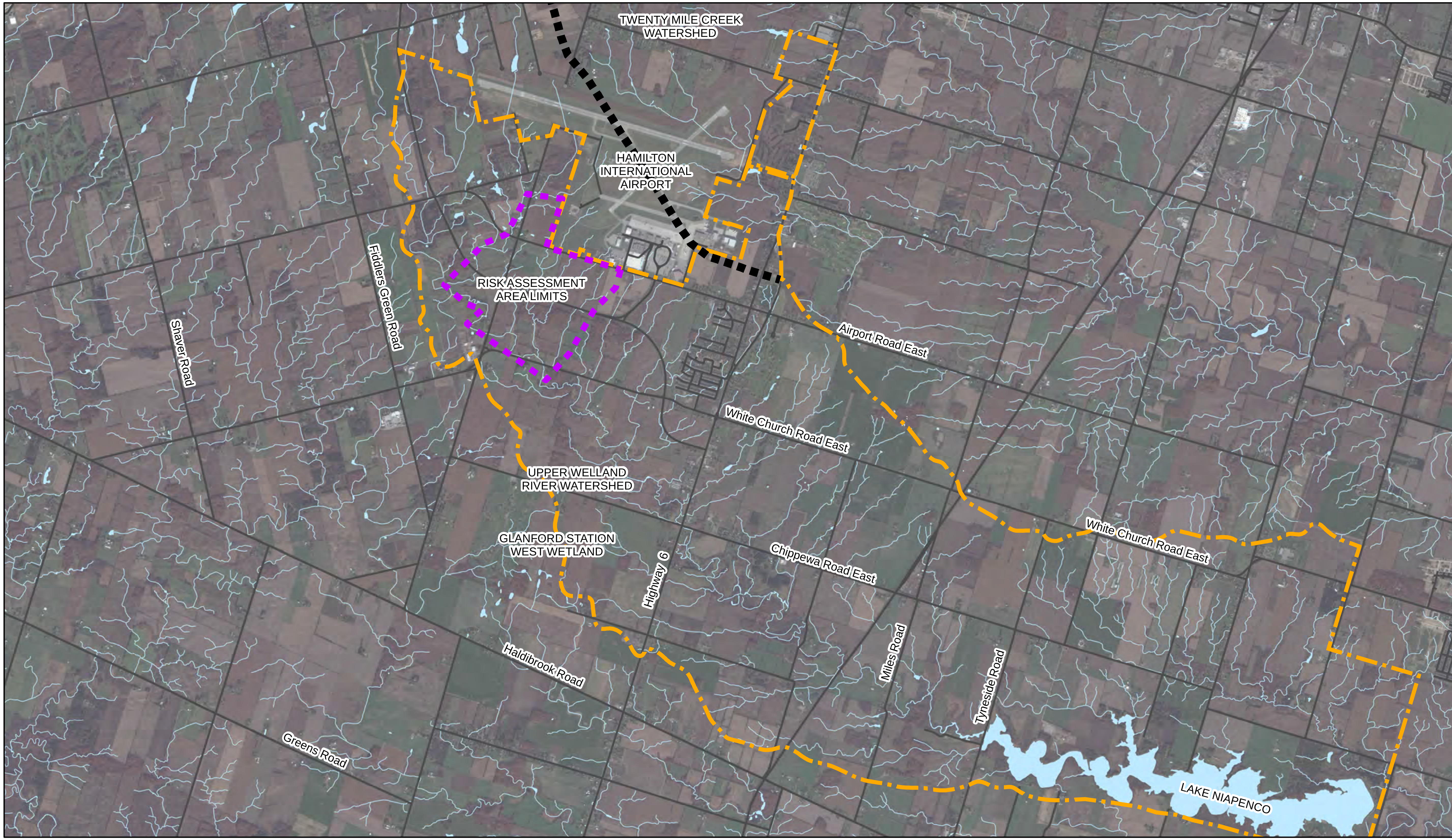

NOTE(S):
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3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

SNC · LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: RISK ASSESSMENT AREA LIMITS	
Project No: 616807	Filename: 007F1B_616807	Date: DECEMBER 2014	Drawing No: FIGURE 1B
Drawn: AG	Verified: DT	Project Manager: DT	

FILENAME: D:\Projects\616807 - Hamilton PFC\4.0 Execution\4.7.3 CAD_GIS\007\007F1B_616807.mxd

HPH SAMPLING LOCATIONS
(JUNE 2011)

- Surface Water
- Water Well

MOE SAMPLING LOCATIONS
(MARCH 2012)

- Sediment Sample
- Surface Water and Sediment

SPECIES AT RISK

- Snapping Turtle
- Milksnake
- Yellow Breasted Chat
- Jefferson Salamander
- Northern Map Turtle
- Bobolink

CLOSED LANDFILLS

- Hamilton Waste Landfill Location (Closed)

CAROLINIAN ZONES

- Corridor Connections
- Meta Core

FISH HABITATS

- Critical Fish Habitat
- Marginal Fish Habitat
- Indirect Fish Habitat

ADDITIONAL INFORMATION

- Binbrook Conservation Area
- Permits to Take Water (PTTW)
- Existing Watermain
- Domestic Use Well Areas

- Ministry of the Environment Water Well Record Location
- Proposed Property Boundary Borehole/ Monitoring Well Location
- Proposed Reference Sample Location
- Risk Assessment Area Limits
- Proposed Borehole/Monitoring Well
- Small Mammal and Fish Survey Locations
- Sediment, Surface Water, Benthos, Toxicity Sample Locations
- Bird Survey Stations
- Additional Aquatic Invertebrate Sample Station
- Species (vegetation, birds, mammals, herpetofauna, fish) Observation and Habitat Survey Route
- Surface Water and Sediment Sampling Location (Chemistry)

SNC·LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: LEGEND	
Project No: 616807	Filename: 007F2A_616807	Date: JULY 2015	Drawing No: FIGURE 2A
Drawn: AG	Verified: DT	Project Manager: DT	

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NOTE(S):
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3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

N

0 162.5 325 650 Meters

SNC·LAVALIN

Client/Location:	PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO			Title:	HISTORICAL INVESTIGATION LOCATIONS (ALL CHEMICALS OF POTENTIAL CONCERN)		
Project No:	616807	Filename:	007F2B_616807	Date:	JULY 2015	Drawing No:	FIGURE 2B
Drawn:	AG	Verified:	DT	Project Manager:	DT		

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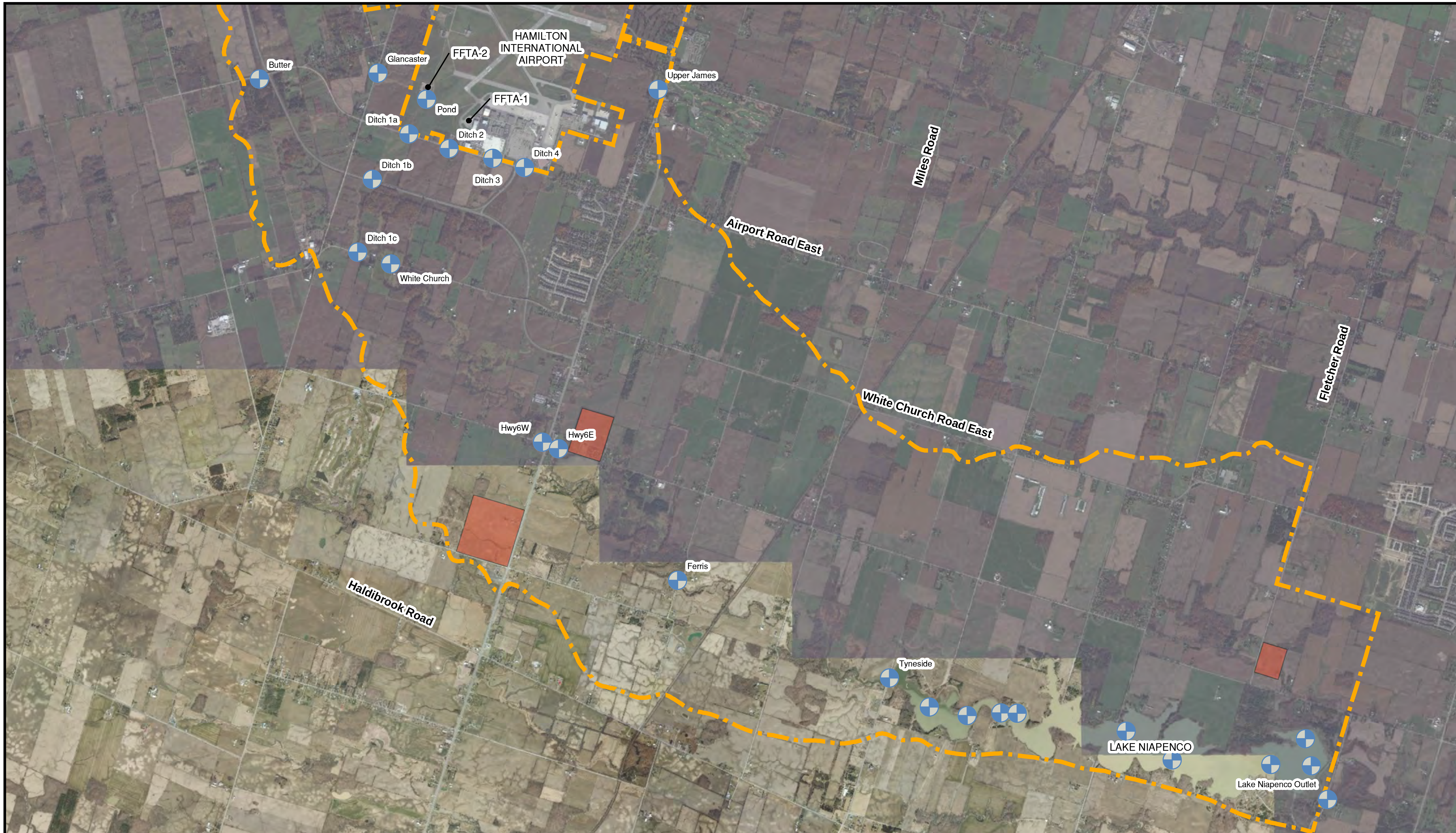

NOTE(S):
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2. INFORMATION ON THIS FIGURE MAY BE LOST IF PHOTOCOPIED OR FAXED
3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

N

0 500 1,000 2,000 Meters

SNC · LAVALIN

Client/Location:		Title:	
PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		HISTORICAL INVESTIGATION LOCATIONS (ALL CHEMICALS OF POTENTIAL CONCERN)	
Project No: 616807	Filename: 007F2C_616807	Date: JULY 2015	Drawing No: FIGURE 2C
Drawn: AG	Verified: DT	Project Manager: DT	

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NOTE(S):
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3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

N

0 155 310 620 Meters

SNC · LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: HISTORICAL INVESTIGATION LOCATIONS (ALL CHEMICALS OF POTENTIAL CONCERN)	
Project No: 616807	Filename: 007F2D_617203	Date: JULY 2015	Drawing No: FIGURE 2D
Drawn: AG	Verified: DT	Project Manager: DT	

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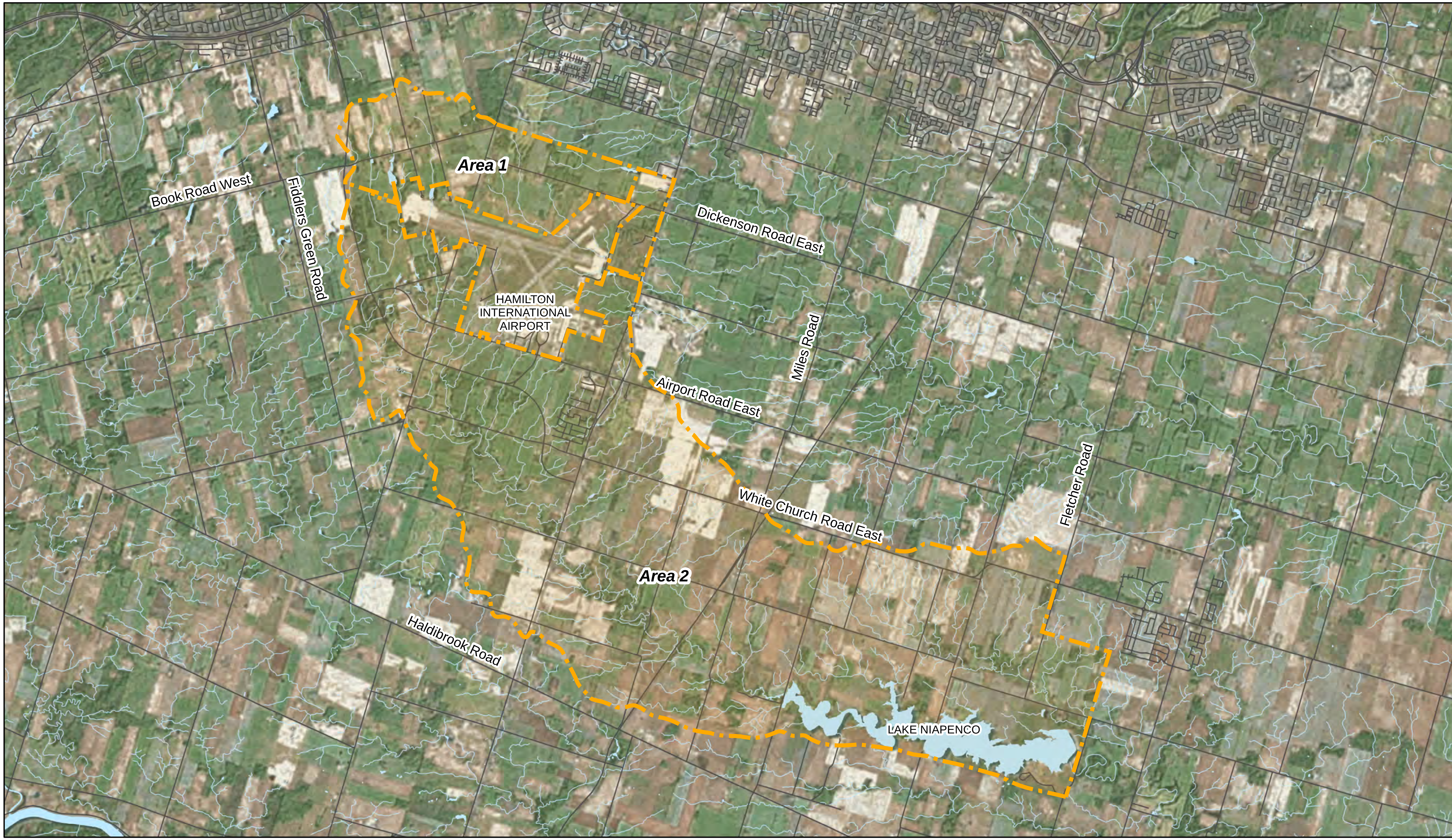

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3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

N

0 750 1,500 3,000 Meters

SNC · LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: PROPOSED STUDY AREA - PORTION OF THE UPPER WELLAND RIVER WATERSHED AND SURROUNDINGS	
Project No: 616807	Filename: 007F3A_616807	Date: DECEMBER 2014	Drawing No: FIGURE 3A
Drawn: AG	Verified: DT	Project Manager: DT	

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NOTE(S):
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3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

N

0 170 340 680 Meters

SNC · LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: PROPOSED STUDY AREA: SUB-STUDY AREA 1	
Project No: 616807	Filename: 007F3B_616807	Date: DECEMBER 2014	Drawing No: FIGURE 3B
Drawn: AG	Verified: DT	Project Manager: DT	

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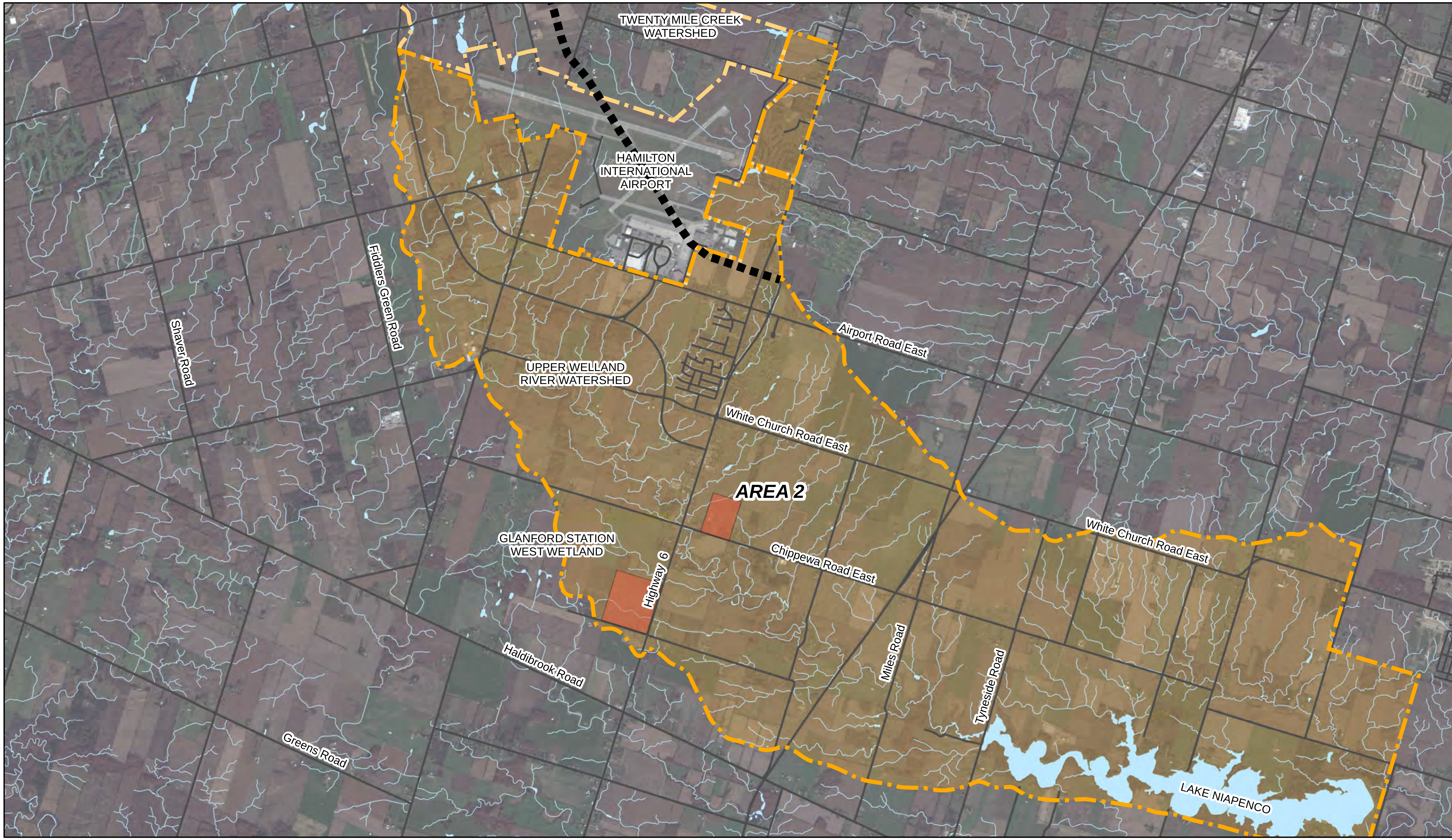

NOTE(S):
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3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

N

0 550 1,100 2,200 Meters

SNC · LAVALIN

Client/Location:		Title:	
PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		PROPOSED STUDY AREA: SUB-STUDY AREA 2	
Project No: 616807	Filename: 007F3C_616807	Date: DECEMBER 2014	Drawing No: FIGURE 3C
Drawn: AG	Verified: DT	Project Manager: DT	

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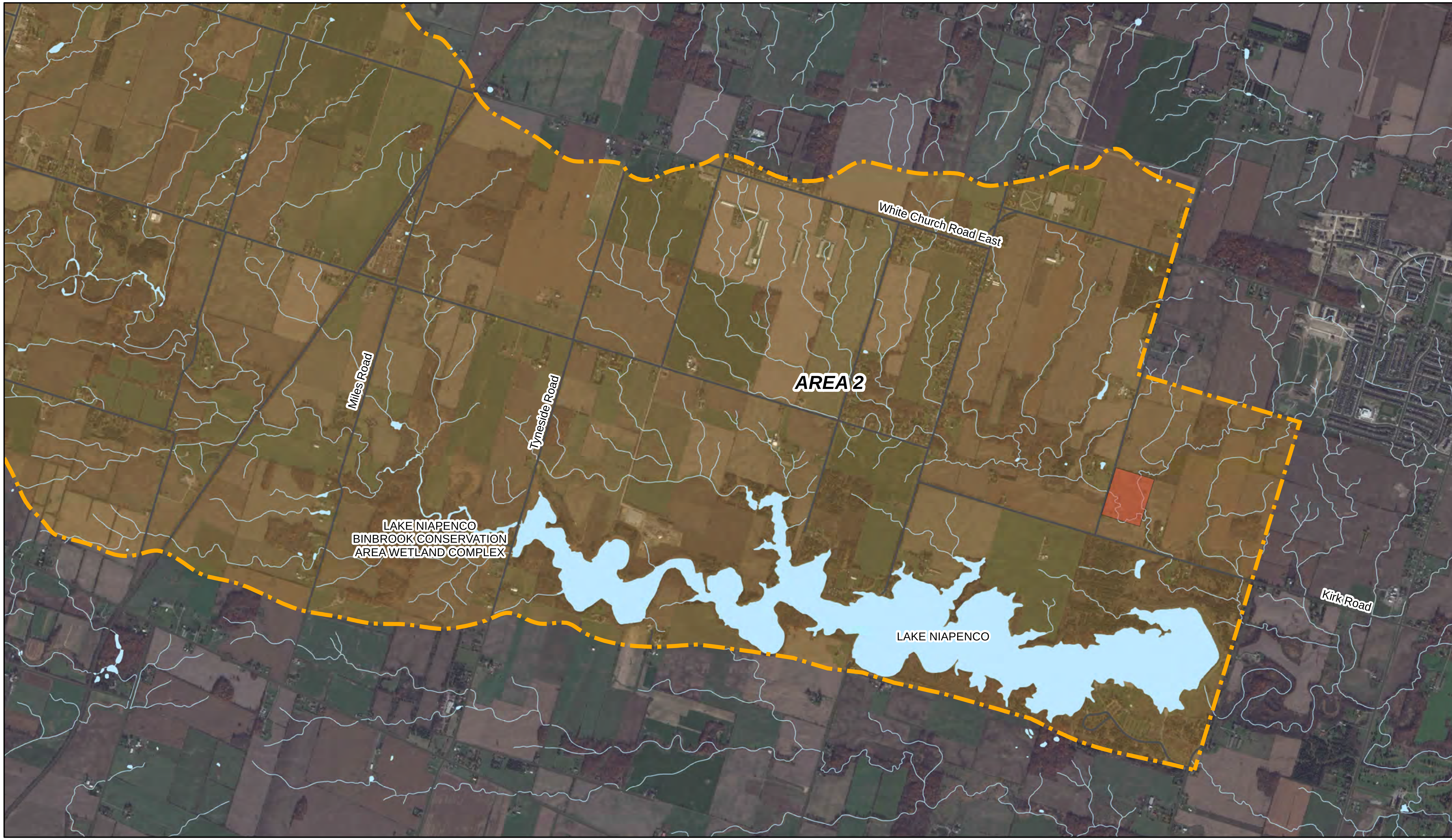

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3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

N

0 315 630 1,260 Meters

SNC • LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: PROPOSED STUDY AREA: SUB-STUDY AREA 2 (LAKE NIAPENCO)	
Project No: 616807	Filename: 007F3D_616807	Date: DECEMBER 2014	Drawing No: FIGURE 3D
Drawn: AG	Verified: DT	Project Manager: DT	

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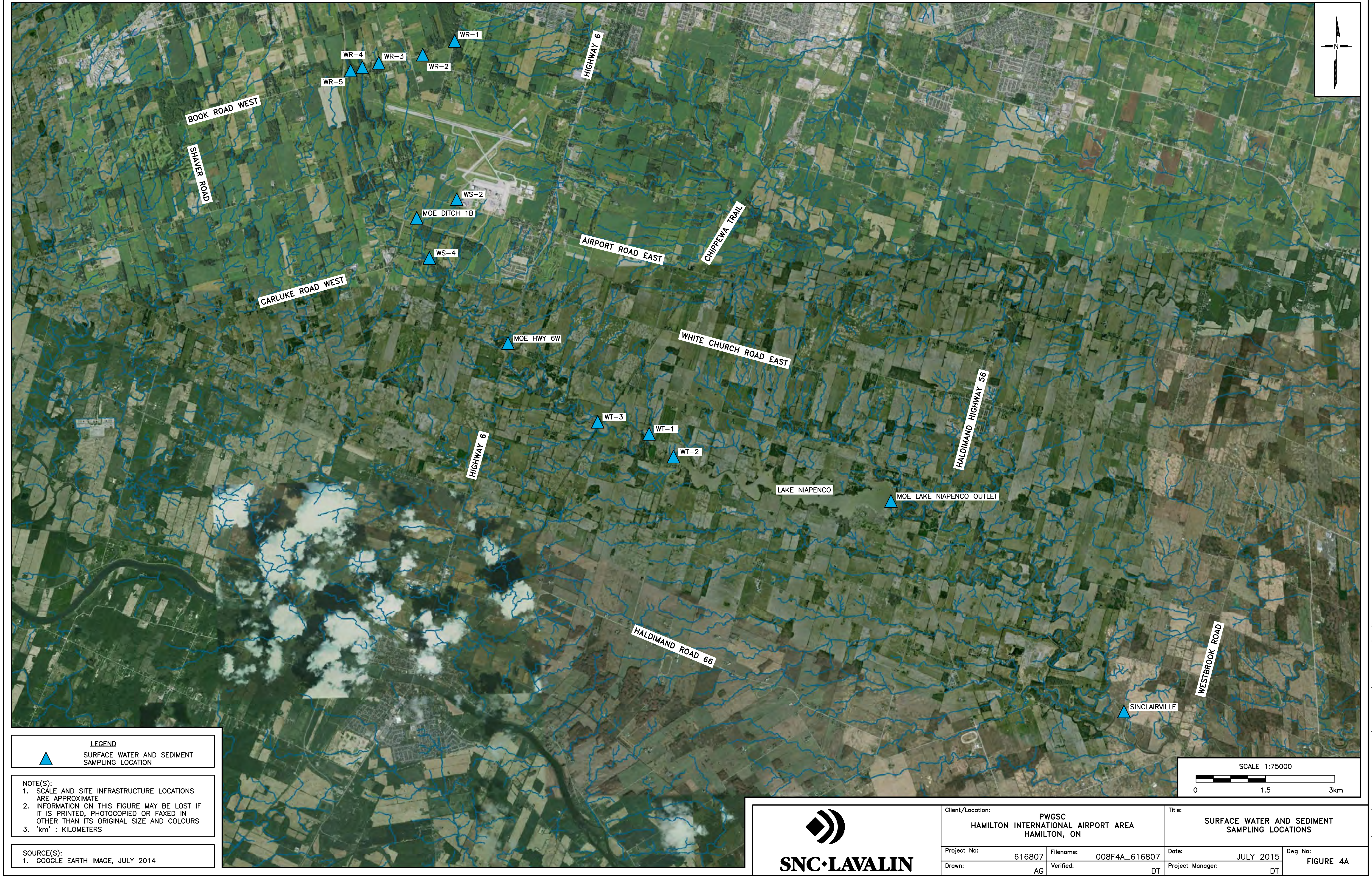

LEGEND

▲ SURFACE WATER AND SEDIMENT SAMPLING LOCATION

NOTE(S):
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3. 'km' : KILOMETERS

SOURCE(S):
1. GOOGLE EARTH IMAGE, JULY 2014

SNC·LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ON		Title: SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS	
Project No: 616807	Filename: 008F4A_616807	Date: JULY 2015	Dwg No: FIGURE 4A
Drawn: AG	Verified: DT	Project Manager: DT	

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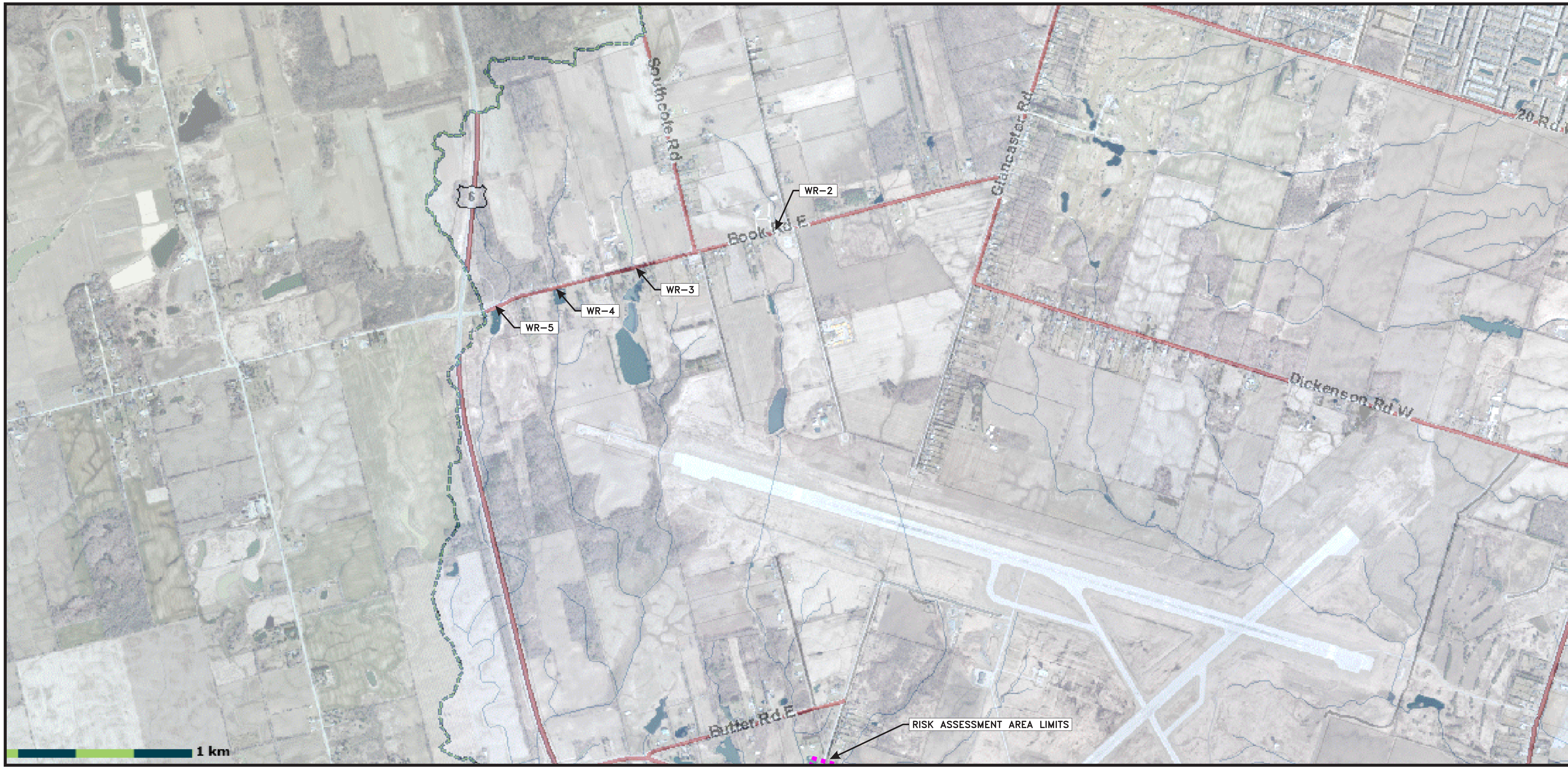

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3. 'km' : KILOMETRES

SOURCE(S):
1. NIAGARA PENINSULA CONSERVATION AUTHORITY, AIR PHOTO & TOPOGRAPHIC MAP, 2012

SNC·LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: SAMPLING LOCATIONS	
Project No: 616807	Filename: 008F4B_616807	Date: JULY 2015	Dwg No: FIGURE 4B
Drawn/Design: AG/DM	Verified: DT	Project Manager: DT	

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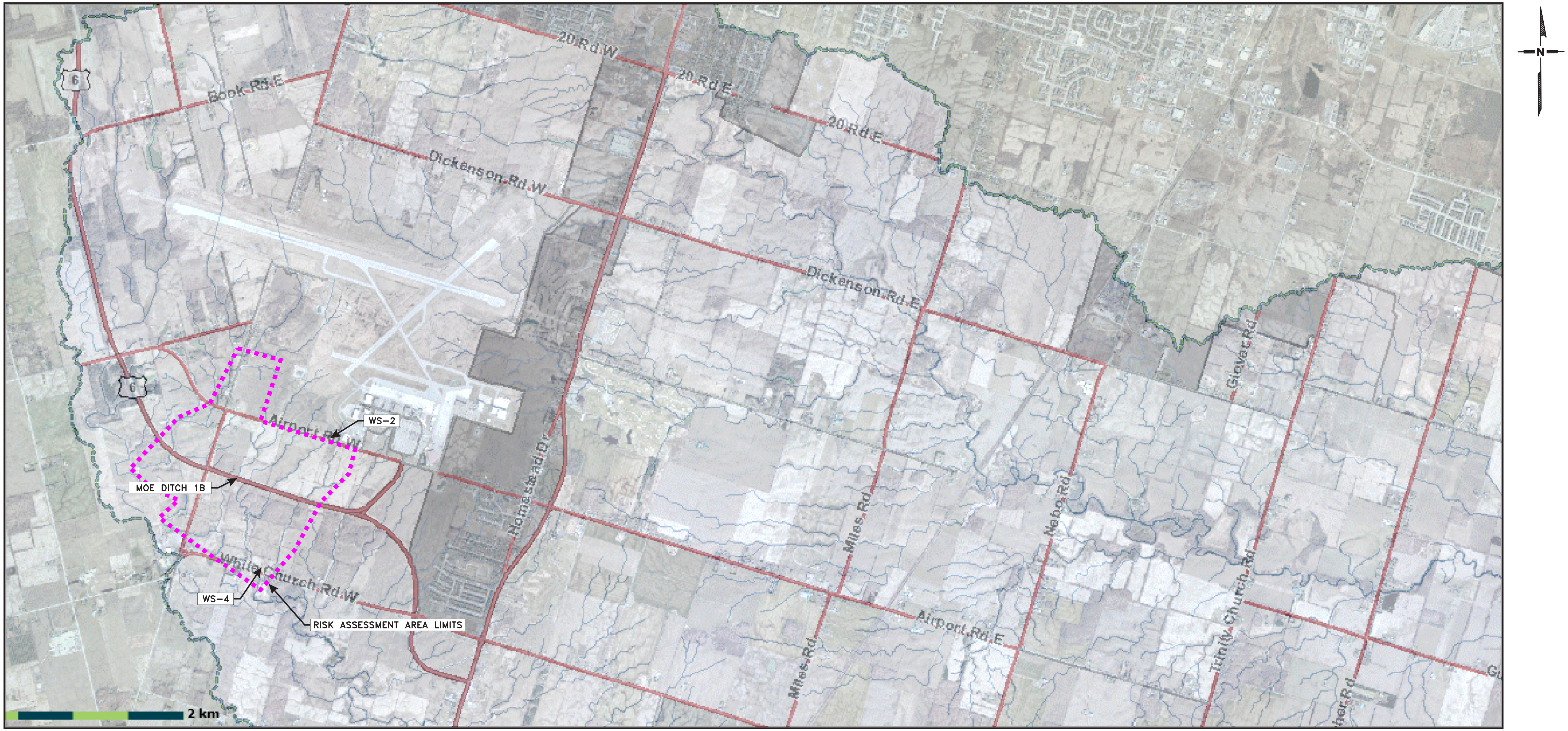

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SOURCE(S):
1. NIAGARA PENINSULA CONSERVATION AUTHORITY, AIR PHOTO & TOPOGRAPHIC MAP, 2012

SNC·LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: SAMPLING LOCATIONS	
Project No: 616807	Filename: 008F05_616807	Date: JULY 2015	Dwg No: FIGURE 5
Drawn/Design: AG/EM	Verified: DT	Project Manager: DT	

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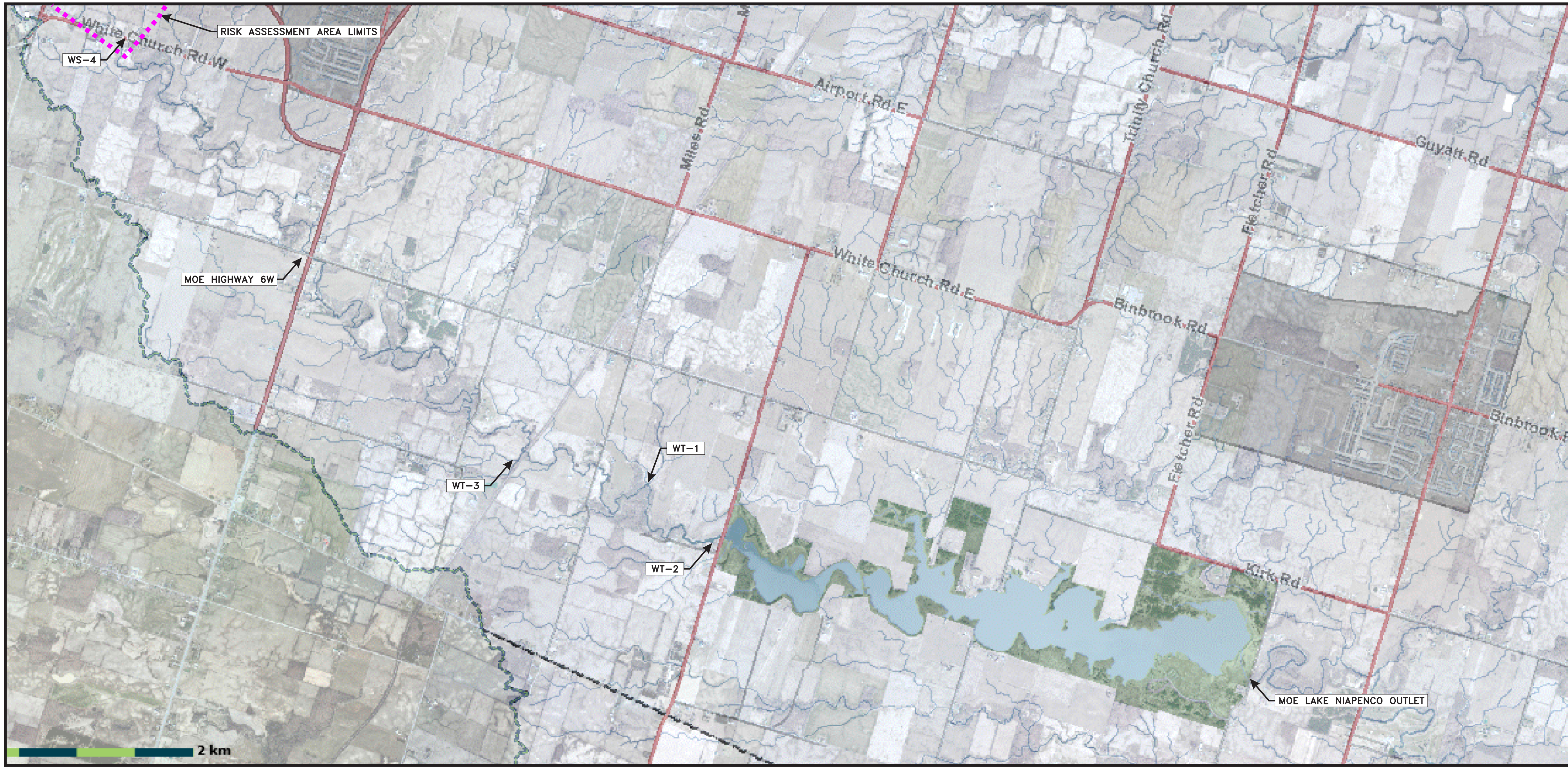

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SOURCE(S):
1. NIAGARA PENINSULA CONSERVATION AUTHORITY, AIR PHOTO & TOPOGRAPHIC MAP, 2012

SNC·LAVALIN

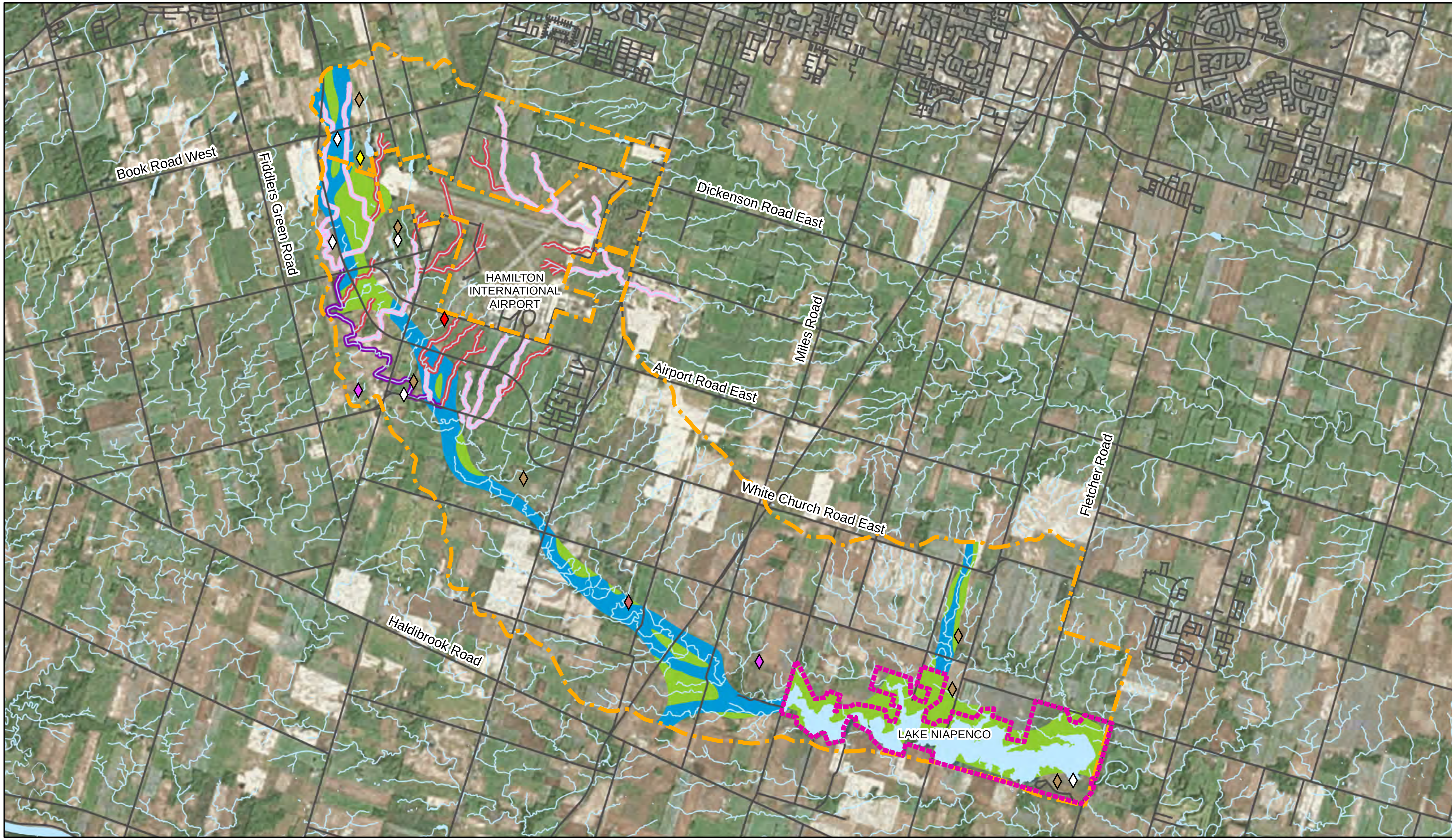
Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: SAMPLING LOCATIONS	
Project No: 616807	Filename: 008F06_616807	Date: JULY 2015	Dwg No: FIGURE 6
Drawn/Design: AG/EM	Verified: DT	Project Manager: DT	

PAGE FORMAT: 11x17

Figure 8 and Figure 9 – Location Summary

Figure 8 – Well Identifier, Use, Installation Date, Depth, Diameter and Construction
10542381-Domestic 2003 – 120' – 6' steel
10485410-Domestic 1971 – 55' – 36' concrete
10489135-Domestic 1989 – 53' – 36' concrete
10485830-Domestic 1973 – 50' – 36' concrete
10486260-Domestic 1974 – 60' – 36' concrete
10484112-Domestic 1968 – 49' – 36' concrete
10488934-Domestic 1989 – 43'? – 24' steel
10481379-Domestic 1955 – 123' – 6" steel
10479146-Livestock 1958 – 85' - 155' – 6" steel
10487630-Domestic 1981 – 30' - 36" concrete
11327424-Domestic 2005 – 16 m
10487327-Domestic 1979 – 55' – 36' concrete
10481457-Livestock 1954 – 158' – 6" steel
10481461-Domestic 1953 – 109' – steel (no apparent structure)
10487575-Domestic 1980 – 82' – steel

Figure 9 – Permit Identifier, Figure Identifier, Use, Source and End Use
5458-85KQP2 - PTTW-2 – Commercial Irrigation – Groundwater – Golf Course
6230-6PFRE9 - PTTW-3 –Commercial Irrigation – Groundwater – Golf Course
1272-88882B - PTTW-4 – Agricultural – Groundwater and Surface Water – Sod Farm
0130-85EHGE - PTTW-5 – Commercial – Groundwater – Golf Course
0130-85EHGE - PTTW-6 – Commercial (irrigation) – Groundwater – Golf Course
0130-85EHGE - PTTW-7 – Commercial (irrigation) – Groundwater – Golf Course
1272-88852B - PTTW-8 – Agricultural – Surface and Groundwater – Sod Farm
03-P-2409 - PTTW-9 – Agricultural – Groundwater – Sod Farm
6614-8FMKC2 - PTTW-10 – Other – Agricultural – Groundwater – Nursery
1272-88852B - PTTW-1 – Agricultural – Surface and Groundwater – Sod Farm
1272-88882B - PTTW-11 – Agricultural – Surface and Groundwater – Sod Farm
1228-6AK53M - PTTW-12 – Agricultural – Groundwater – Sod Farm
2105-8JQPM2 - PTTW-13 – Agricultural – Groundwater – Field and Pasture crops
2640-6G8GLX - PTTW-14 – Recreational – Surface Water – Ducks Unlimited



NOTE(S):
1. SCALE, SITE INFRASTRUCTURE AND SAMPLE LOCATIONS ARE APPROXIMATE
2. INFORMATION ON THIS FIGURE MAY BE LOST IF PHOTOCOPIED OR FAXED
3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

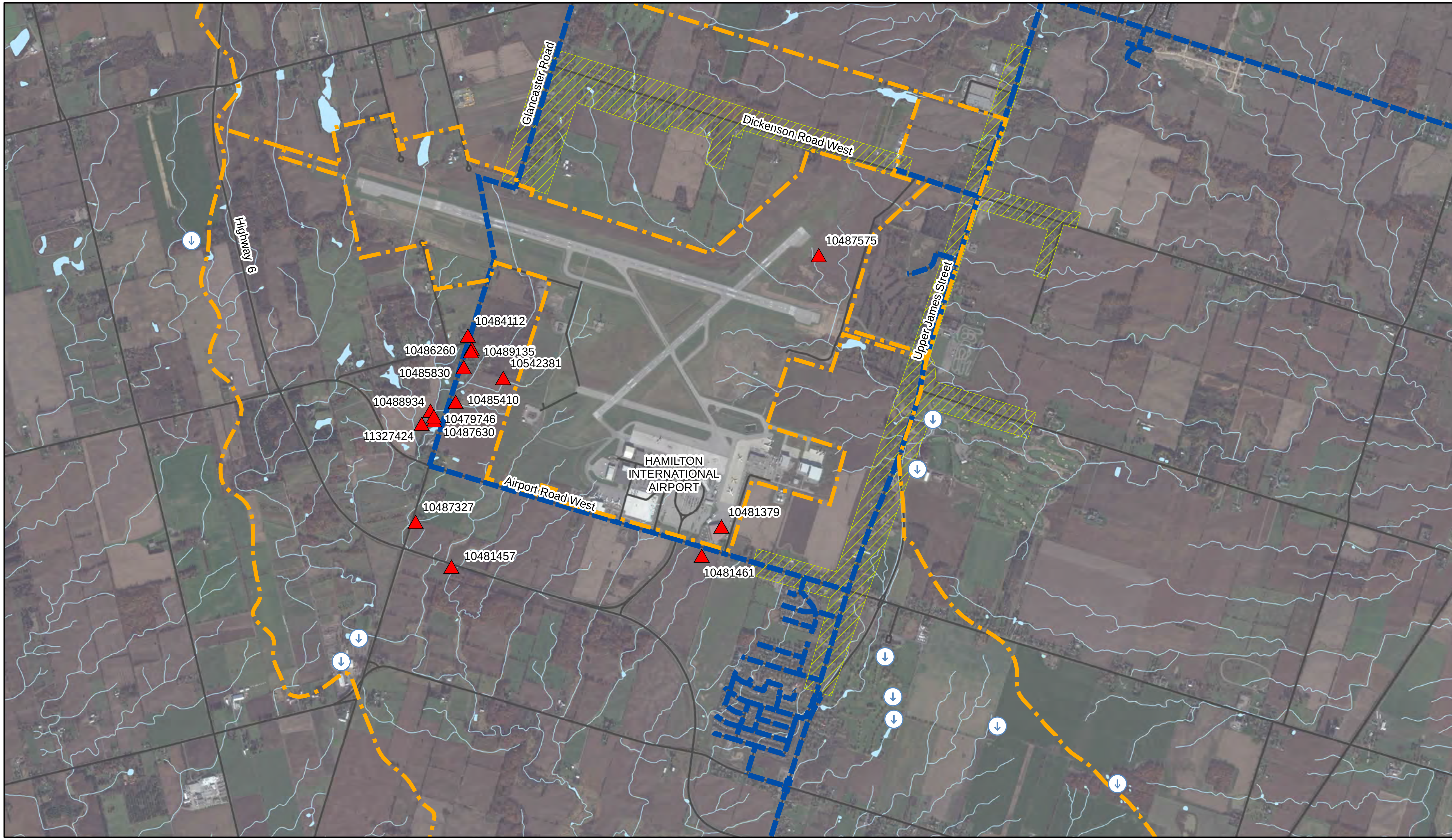
N

0 700 1,400 2,800 Meters

SNC·LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: BIOLOGICAL RESOURCES	
Project No: 616807	Filename: 001F07_616807	Date: DECEMBER 2014	Drawing No: FIGURE 7
Drawn: AG	Verified: DT	Project Manager: DT	

FILENAME: D:\Projects\616807 - Hamilton PFC\4.0 Execution\4.7.3 CAD_GIS\007\007F07_616807.mxd



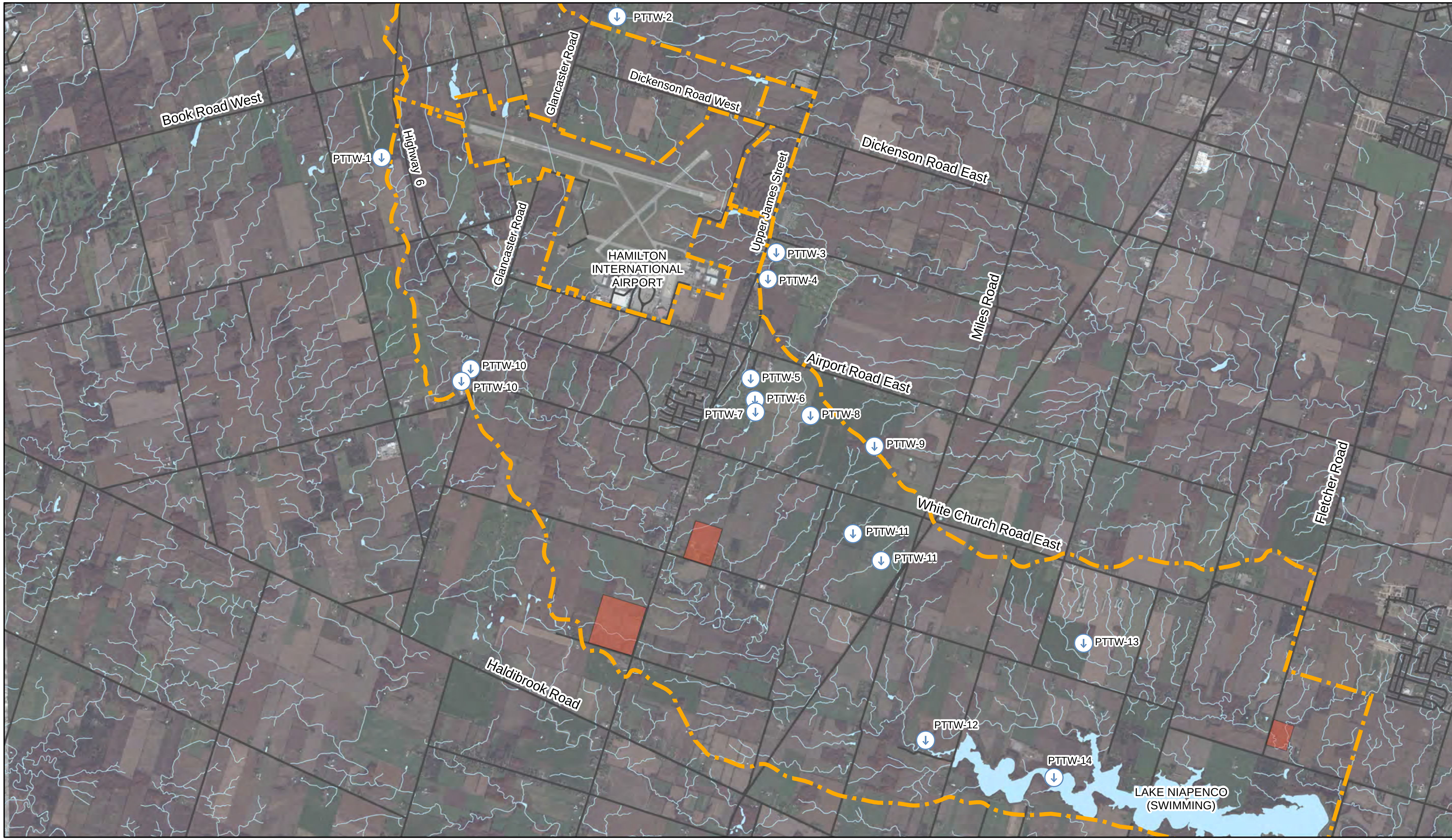
NOTE(S):
1. SCALE, SITE INFRASTRUCTURE AND SAMPLE LOCATIONS ARE APPROXIMATE
2. INFORMATION ON THIS FIGURE MAY BE LOST IF PHOTOCOPIED OR FAXED
3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

SNC·LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: STUDY AREA WATER USE	
Project No: 616807	Filename: 001F08_616807	Date: DECEMBER 2014	Drawing No: FIGURE 8
Drawn: AG	Verified: DT	Project Manager: DT	

FILENAME: D:\Projects\616807 - Hamilton PFC\4.0 Execution\4.7.3 CAD_GIS\007\007F08_616807.mxd



NOTE(S):
1. SCALE, SITE INFRASTRUCTURE AND SAMPLE LOCATIONS ARE APPROXIMATE
2. INFORMATION ON THIS FIGURE MAY BE LOST IF PHOTOCOPIED OR FAXED
3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

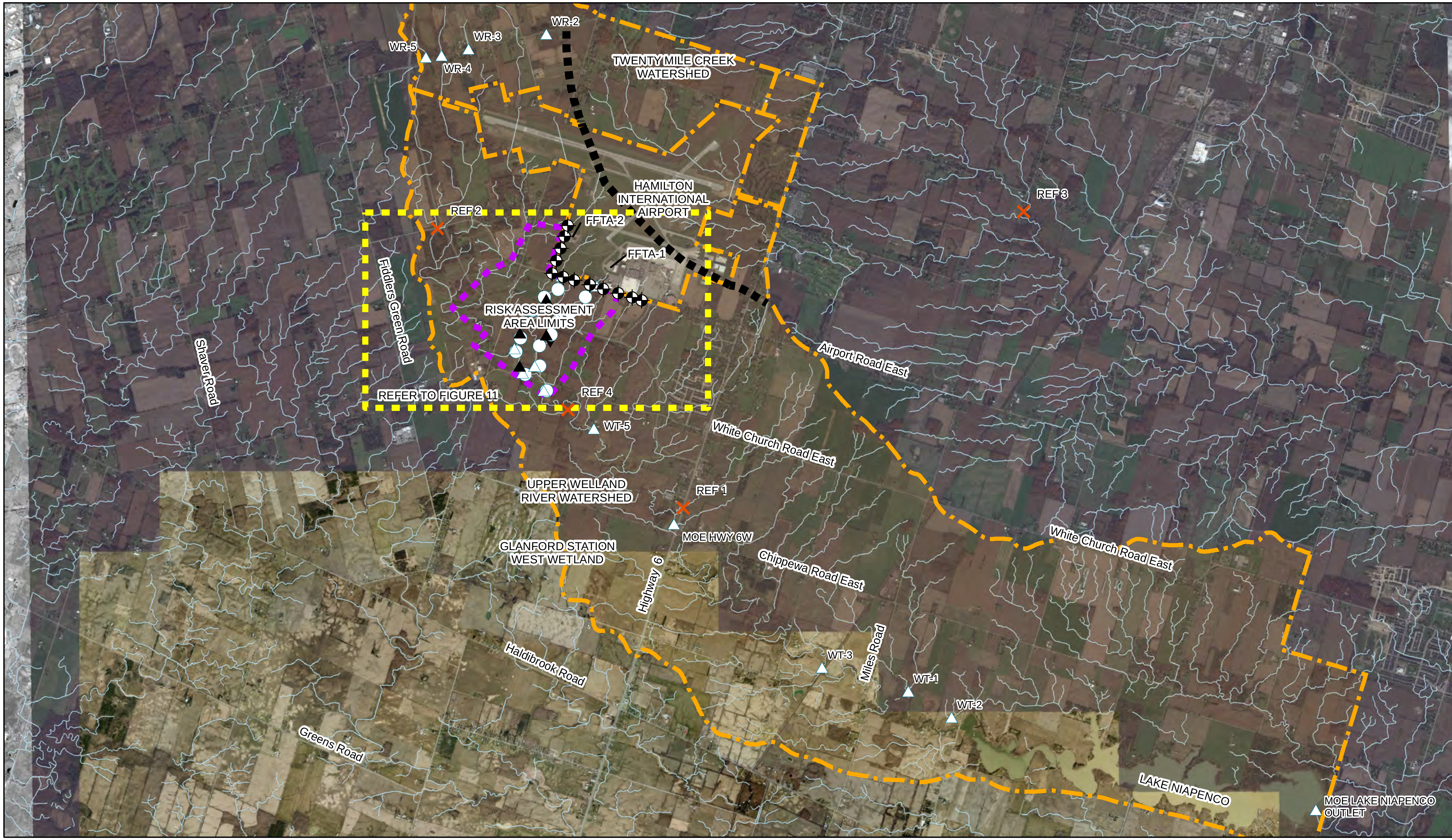
N

0 550 1,100 2,200 Meters

SNC • LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		Title: STUDY AREA WATER USE	
Project No: 616807	Filename: 001F09_616807	Date: DECEMBER 2014	Drawing No: FIGURE 9
Drawn: AG	Verified: DT	Project Manager: DT	

FILENAME: D:\Projects\616807 - Hamilton PFC\4.0 Execution\4.7.3 CAD_GIS\007\007F09_616807.mxd



NOTE(S):
1. SCALE, SITE INFRASTRUCTURE AND SAMPLE LOCATIONS ARE APPROXIMATE
2. INFORMATION ON THIS FIGURE MAY BE LOST IF PHOTOCOPIED OR FAXED
3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

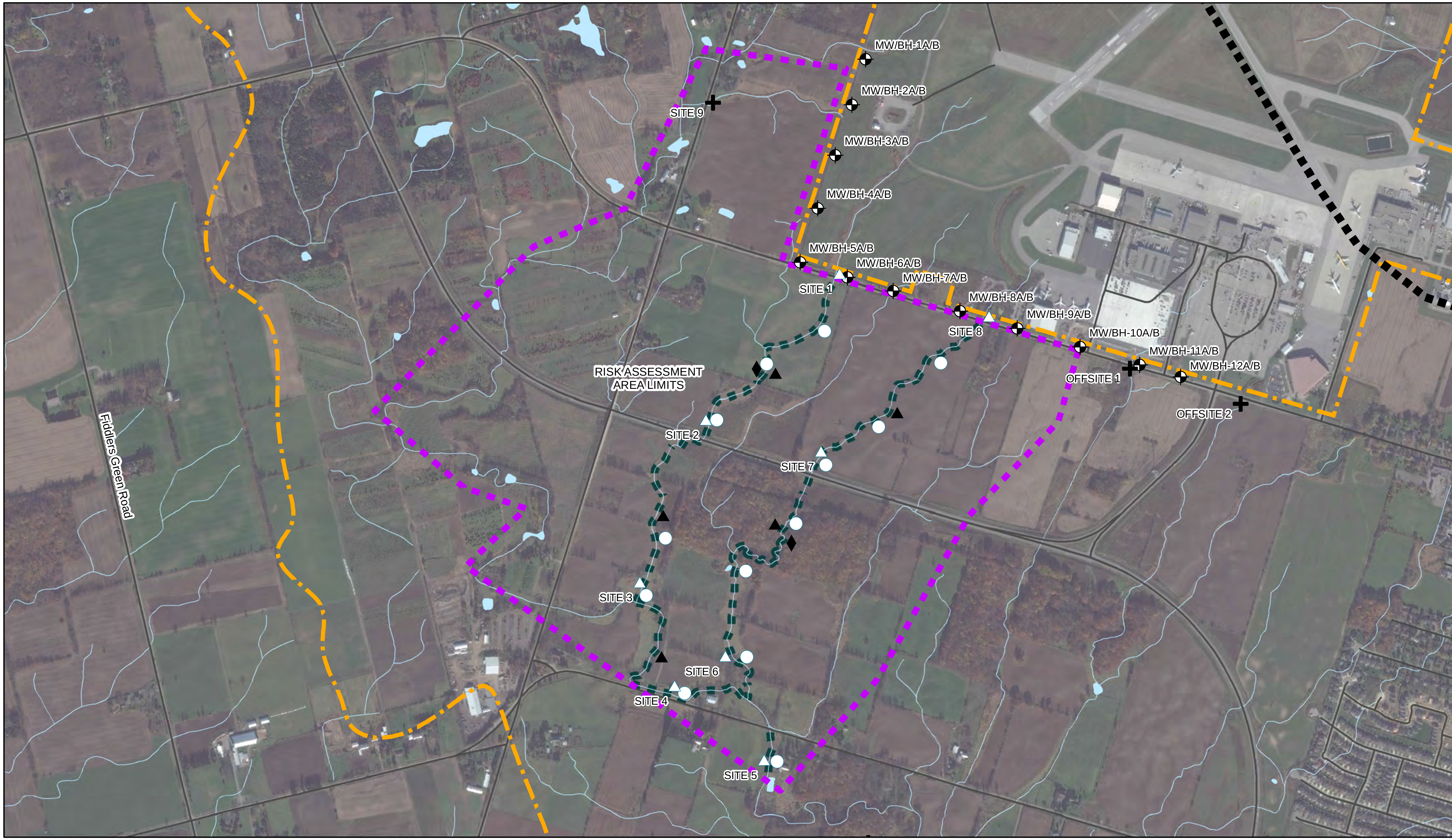
N

0 550 1,100 2,200 Meters

SNC · LAVALIN

Client/Location: PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO				Title: STAGE 1 INVESTIGATION LOCATIONS	
Project No: 616807	Filename: 007F10_616807			Date: APRIL 2015	Drawing No: FIGURE 10
Drawn: AG	Verified: DT			Project Manager: DT	

FILENAME: D:\Projects\616807 - Hamilton PFC\4.0 Execution\4.7.3 CAD_GIS\007\007F10_616807.mxd



NOTE(S):
1. SCALE, SITE INFRASTRUCTURE AND SAMPLE LOCATIONS ARE APPROXIMATE
2. INFORMATION ON THIS FIGURE MAY BE LOST IF PHOTOCOPIED OR FAXED
3. 'm' : METRES

LEGEND
PLEASE REFER TO FIGURE 2A

N

0 130 260 520 Meters

SNC · LAVALIN

Client/Location:		Title:	
PWGSC HAMILTON INTERNATIONAL AIRPORT AREA HAMILTON, ONTARIO		STAGE 1 INVESTIGATION LOCATIONS	
Project No: 616807	Filename: 007F11_616807	Date: DECEMBER 2014	Drawing No: FIGURE 11
Drawn: AG	Verified: DT	Project Manager: DT	

FILENAME: D:\Projects\616807 - Hamilton PFC\4.0 Execution\4.7.3 CAD_GIS\007\007F11_616807.mxd

APPENDIX A

Review of Background Documents

Historical Document Review

City of Hamilton, 2005. Information Report: Status Report on City's Closed Landfills.

The City of Hamilton is responsible for monitoring and maintaining twelve (12) closed landfill sites. Eleven (11) sites were used as municipal landfill sites and closed by 1980 while the twelfth site was used for disposal of construction and inert-type waste up until approximately 2000. Since closure of these sites, various monitoring and remediation measures were implemented by the former municipalities and Region of Hamilton-Wentworth. The report outlined methodologies used; costs incurred (including future capital operating dollars recommended); and external/internal conditions of each site.

Decommissioning Consulting Services Limited. 1992. Geophysical Survey Report, Hamilton Airport Fire Training Area.

A Geophysical survey of the Hamilton International Airport (HIA) Fire Fighter Training Area (FFTA) was conducted by DCS in 1992. Twelve linear trends were observed which could be related to the presence of buried services and roadside ditches. One area (Zone C2) displayed an anomaly that could be related to fill or contamination. The report proposed borehole locations and gas monitors to further investigate. Another area (Zone C3) displayed an anomaly that was likely related to drainage. Vapour monitoring was proposed for this area.

Decommissioning Consulting Services Limited. 1995. Surface and Groundwater Monitoring Program at the Hamilton Airport Fire Training Area.

DCS conducted surface and groundwater characterization in 1993. The report details the implementation of a surface water sampling and laboratory testing program, identification of surface water or groundwater contaminants beneath and in the vicinity of the FFTA, identification of exceedances, collection of climatic information, and observation of a typical fire training activity.

Chlorinated organic compounds of 1,2-dichlorobenzene, 1,4-dichlorobenzene and vinyl chloride were found at detectable levels in surface water samples. Further sampling of the aqueous film forming foam used in fire training activities was not able to determine the potential contribution of the foam with respect to chlorinated compounds in the mock-up and retention pond. It was determined that the foam is a major contributor to nitrogen levels in the mock-up and retention pond. It was suggested that a possible source of the chlorinated compounds identified is their production as a result of ignition of gasoline in the presence of the chlorine ion, typically found in surface waters.

It was determined that the risk to the environment generated from contaminants from the fire training area is not through the groundwater pathway. Volatile organics were determined to be not a concern with regard to surface water downgradient of the HIA FFTA. It was determined that risk to the environment from contaminants generated from the fire training exercises is through surface water. However, in comparison to background surface water quality, the impacts are insignificant.

Observations made during the fire training sessions indicate that the containment dyke may have partially deteriorated to the point where it is no longer providing an adequate barrier. It was suggested that the retention pond be expanded to enhance its treatment functions. Further testing for 1,2- and 1,4-dichlorobenzene and vinyl chloride was recommended.

Exp, 2011. Initial Subsurface Investigation – Perfluorooctane Sulfonate (PFOS) and Perfluoroctanoate (PFOA), Former Fire Training Facility.

Exp conducted an initial subsurface investigation to determine the presence or absence of PFOS and PFOA within the soil, groundwater, surface water and sediment. Based on water quality results, the Ontario Ministry of Environment (MOE) has identified HIA as the primary source of PFOS.

Exp recommended additional boreholes and groundwater monitoring wells be completed on-site to further delineate PFOS and PFOA concentration. It was recommended that a bench scale study using Nanozox be undertaken to determine the concentrations of ozone required to treat groundwater. In addition, the remainder of the FFTA site should be capped to prevent infiltration or surface water flow on site. Remedial activities should be undertaken in a phased approach beginning with the bench scale and pilot studies to determine if the technologies will address the PFOS and PFOA contamination. Remediation program will focus on the FFTA and pond area to address the source of contamination.

Golder Associated Ltd, 1997. Remedial Action Plan. Hamilton International Airport, Mount Hope, Ontario.

TradePort International planned to complete specific remedial activities (based on the Remedial Action Plan written by XCG) including removal of Underground Storage Tanks (USTs), remediation of impacted soils associated with the USTs, removal of buried demolition waste, remediation of impacted soils, backfilling and compaction of all remedial excavations, removal of asbestos containing material and submission of an application for a certificate of approval for a paint booth exhaust system. Golder was contracted by TradePort to provide technical consulting and project administration. This report outlined the scope of work to conduct the previously listed remedial activities.

Ontario Ministry of Environment, 2011 and 2012. PFOS in the Welland River and Lake Niapenco.

The purpose of this project was to further evaluate the potential sources and distribution of perfluorooctane sulfonate (PFOS) within the Welland River and Lake Niapenco. The field work was conducted in 2011 which involved two phases. Water and sediment samples within tributaries of the Welland River and at the outlet of Lake Niapenco (Phase 1) were collected to ascertain concentrations of PFOS in the Welland River. The second phase of sampling (Phase 2) was conducted at Lake Niapenco, specifically to provide a benchmark of PFOS concentrations within the reservoir for water and sediment.

Water quality results indicated that the highest PFOS concentration was observed in the HIA pond and decreased further downstream. The same trend was also observed for sediment concentrations. PFOS concentrations in the sediments of Lake Niapenco were marginally higher in front of the weir compared to below. No definitive trends were observed with specific depths of samples. Concentrations did increase slightly from the older to newer sediment deposits.

In general, the sampling program indicates that no measurable water or sediment contributions from the closed Glanford Landfill site were observed. The HIA was suspected as a source of PFOS and impact to aquatic organisms at and in vicinity of the HIA would be expected. The report also indicated that the existing PFOS contaminated sediment within the Welland River should be considered a potential source of PFOS.

S.R. de Solla, A.O. De Silva, R.J. Letcher, 2012 Highly Elevated Levels of Perfluorooctane Sulfonate and Other Perfluorinated acids Found in Biota and Surface Water Downstream of An International Airport, Hamilton, Ontario, Canada. Environment International 39 (2012) 19–26.

Per- and Poly-fluorinated compounds (PFCs) are a broad class of substances, they can be categorized as perfluoroalkyl acids (PFAAs), perfluorinated carboxylic acids (PFCAs), and perfluorinated sulfonic acids (PFSAs). PFCAs and PFSAs are persistent and bioaccumulative, specifically, perfluorooctane sulfonate (PFOS).

Snapping turtles were sampled throughout southern Ontario. PFOS was found in high concentrations in snapping turtle plasma in Lake Niapenco, but no PFOA was detected. Concentrations of PFOS in snapping turtles were 40-120 times higher in Lake Niapenco compared to other sample sites. It was determined that the sites downstream of the airport had relatively high PFOS concentrations and the sites in the upper Welland River also had relatively high concentrations of other PFCs. Sites closest to the airport displayed the highest concentrations of PFAAs.

Stormwater management practices have not been sufficient to prevent contamination to the Welland River. Aqueous film forming foam (AFFF) may not be the only source of PFCs in Lake Niapenco. Other airport activities may be contributing to the contamination. Further monitoring of terminal PFAAs in the

Welland River and Lake Niapenco was recommended to determine if the elevated levels are the result of historical activities or continued release.

Transport Canada Civil Engineering Safety and Technical Services, 1991, Edited 1995. Fire Training Area AK-70-05.

The Fire Training Area is comprised of an aircraft mockup, a burn area, a containment basin, an effluent handling system, a fuel system, and a maneuvering surface. The foaming agent used during training is a mixture of glycol and water with various surfactants and stabilizers. The main concern with AFFF is the major potential environmental impact to biochemical oxygen demand to surface waters. In addition, potassium bicarbonate is used as a dry chemical fire fighting agent. Liquid effluent from fire training areas cannot be released to the environment without treatment and must be contained.

The report indicated that several factors should be considered when examining options for a new fire training area. These factors include proximity to trees and brush, soil topography and soil characteristics, access to a service road, surrounding communities and land use, as well as prevailing wind directions. Site preference should be given to locations with access to utilities (water, power, etc.). The report recommended that an impermeable membrane be installed for the containment basin (several options available).

XCG Consultants, Ltd., 1996. Baseline Study Summary Report, Environmental Baseline Study, Hamilton Airport, Mount Hope, Ontario.

In 1996, XCG Environmental (XCG) conducted an Environmental Baseline Study (EBS) consisting of a Site Environmental Audit, Field Investigations, and Remedial Options Evaluation. The objective of the EBS was to summarize non-compliance issues and areas of environmental concern as well as evaluate remedial options to address the non-compliance issues and areas of concern.

The study found that pond sediment samples taken exceeded the Ontario Ministry of Environment and Energy (MOEE) Table E Guidelines for chromium, copper, lead, nickel, and zinc. Storm sewer samples were collected and found that exceedances of BOD, aluminum, cobalt, copper, iron, lead, phosphorus, vanadium and zinc were the same as background levels. Soil on-site was found to have exceeded MOEE Table B Criteria for concentrations of TPH, BTEX, pyrene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, beryllium, and lead. All soil results were found to have negligible risk to public health. In addition, small amounts of asbestos containing material were distributed throughout buried demolition waste onsite.

Some non-compliance issues included failure to monitor stormwater run-off from the fire training area or the maintenance garage/fire hall and boneyard areas for compliance with the CCME CWQG or the MOEE

PWQO. The automatic stormwater sampling device was not in operation from April to December, 1995 and the method of sample preparation was not consistent with the Airport Water Quality Manual.

XCG Consultants, 1996. Remedial Action Plan, Environmental Baseline Study, Hamilton Airport, Mount Hope, Ontario.

In 1996, XCG Environment completed a Remedial Action Plan (RAP) for Hamilton Airport as part of an Environmental Baseline Study. This RAP summarized the proposed remedial actions for issues that were identified in the Environmental Baseline Study.

The RAP recommended the removal of out-of-service USTs and sampling for BTEX and TPH concentrations for each excavation. Furthermore, it was recommended that contaminated soil containing asbestos, hydrocarbons, and/or metals be excavated and disposed of at an appropriate facility. After excavation, soil should be sampled to ensure the remaining soil meets target objectives and clean granular fill should be used to backfill the excavation sites.

XCG Consultants, Ltd., 1996. Detailed Investigation Report Environmental Baseline Study Hamilton Airport, Mount Hope, Ontario.

XCG conducted an Environmental Baseline Study. This report outlined the field investigation portion. The field investigation objective was to determine the degree of contamination of the airport environment.

Twenty areas within the airport were identified as areas of potential environmental concern; additional sampling was conducted at these locations. The field investigation involved stormwater sampling for BOD_5, phenols, metals, oil and grease, and nitrite as N. Soil and groundwater sampling was conducted for metals, TPH, PAHs, VOCs, PCBs, BTEX, lead, and asbestos.

The stormwater sampling program found exceedances of phenols, BOD, aluminum, copper, iron, lead, phosphorus, and zinc, but this was consistent with stormwater flowing onto the airport property and therefore not a concern for impact on the quality of stormwater. Surficial soil sampling found impacted soil exceeding the MOEE Table B Criterion for lead. Test pit samples exceeded MOEE Table B Criteria or the CCME Criteria for pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and dibenzo(a,h)anthracene. Methane levels were monitored at the former landfill area and were determined to not be approaching explosive levels. Soil sampling identified MOEE Table B Criterion exceedances for toluene and TPH.

Soil in the Fire Training Area was sampled for BTEX and TPH, and groundwater was sampled for VOCs and TPH; no exceedances were detected. Based on this, it was determined that the soil and groundwater in the area southwest of the Fire Training Area had not been impacted. The investigation determined that there were sixteen areas of potential concern. These areas included the Airport Boneyard, Active and

Out-of-Service USTs, Trenches in Hangars #1 and #2, buried demolition waste, and the former coal storage area.

XCG Environmental Services Inc., 1996. Field Screening Report, Environmental Baseline Study Hamilton Airport, Mount Hope, Ontario.

XCG conducted an Environmental Baseline Study. This report outlined the field screening portion. The field screening objective was to determine if there was any soil and/or groundwater contamination in each of the areas of environmental concern and to determine an appropriate scope of work for additional subsurface investigations.

Seventeen areas of potential concern were examined by conducting shallow soil vapour testing, borehole drilling, test pit excavation, groundwater sampling, stormwater sampling, shallow/surficial soil sampling, sediment sampling, tank precision leak testing and geophysical investigations.

Samples were compared to one or more criteria, including (but not limited to) the CCME Interim Canadian Environmental Quality Criteria for Contaminated sites, Ontario Drinking Water Objectives, and the Region of Hamilton-Wentworth Sewer Use By-Law. Surface water samples contained exceedances of oil and grease, phenols, BOD_5, and nitrite as N. Stormwater samples contained exceedances for aluminum, boron, cobalt, copper, iron, and phosphorus. Pond sediment samples contained exceedances for chromium, copper, lead, nickel, and zinc. No PCBs were detected in any of the sediment samples. The airport boneyard was found to have soil pH value that exceeded the applicable criteria, however, this was determined to be common on other sites in the area, and therefore did not provide evidence of a significant impact on the quality of soil. It was determined that due to buried waste material in the former landfill site, exceedances of TPH, pyrene, benzo(a)pyrene, and dibenzo(a,h)anthracene were detected. The former UST areas northeast of Hangar 2 and 3 both contain soils exceeding applicable guidelines for BTEX and/or TPH. Sediment samples from trenches of Hangars 1, 2 and 5 resulted in exceedances of oil and grease, cadmium, lead, and zinc.

Of the original 23 areas of concern, all were subsequently classified into the following: areas not of concern (10 areas), areas of quantified concern (1 area), and areas of unquantified potential concern (12 areas).

XCG Environmental Services Inc., 1996. Phase I Environmental Baseline Study Final Audit Report, Volumes 1, 2, 3.

Transport Canada commissioned XCG to complete an Environmental Baseline Study in support of the proposed transfer of ownership of the Airport to a new local entity. The objectives of the EBS were to identify where existing operations at the airport were not in compliance with applicable guidelines, determine the degree of contamination, and establish a Proposed Remedial Action Plan. This report summarizes the Site Environmental Audit.

The audit team reviewed the management systems, including, waste management practices, storm and wastewater control, spill and emergency procedures, management of PCBs, as well as historical use of waste disposal areas. A list of hazardous materials and designated substances was developed. Substances of potential concern were identified as asbestos, lead, mercury, PCBs, oils, lubricants, and ozone depleting substances.

Concentrations of antifreeze (glycol) from the airport had been identified as a pollution source in the Binbrook Reservoir by the Niagara Peninsula Conservation Authority. However, improvements in glycol management improved the quality of tributary water. An agreement with the Regional Municipality of Hamilton-Wentworth allowed for exceedances of sewer use by-law criteria for BOD and glycol. Failure to monitor stormwater run-off from the fire training area or the maintenance garage/fire hall and boneyard areas were identified as a non-compliance issue. Several oil/water separators onsite were found to be not in compliance with regulations and procedures. Proper storage and disposal of waste products (oil, solvents, antifreeze) was found to be not in compliance at several locations onsite due to lack of secondary containment and labeling. Failure to maintain an up to date PCB-containing equipment inventory was identified as an area of non-compliance.

A number of other public websites and documents related to environmental management at HIA and public health concern were also reviewed for information, including the following. No summary was provided in this appendix.

- Hamilton Public Health Services (HPHS), 2011a. Public Health Concerns Regarding Perfluorooctane sulfonic acid (PFOS) in Lake Niapenco and Propylene Glycol in the Headwater Creeks of the Upper Welland River (Airport Area). April 27, 2011;
- Hamilton Public Health Services (HPHS), 2011b. Hamilton Public Health Services Update Regarding PFOS & Glycols. June 13, 2011. Summary of Reviewed Documents;
- J.C. Munro Hamilton International Airport, Environmental Management. Accessed January 12, 2014;
- Transport Canada. Canadian Aviation Regulations (CARs). Accessed January 12, 2014.

APPENDIX B

Summary of Environmental Screening Criteria

Existing Soil Quality Criteria - Ecological

Soil criteria were identified for PFOS and PFOSA.

PFOS

The following PFOS criteria, intended to be protective of terrestrial ecological receptors, have been identified:

Summary of Existing/Proposed Soil Criteria for PFOS

Criterion (mg/kg)	Type	Reference	Comments
1.3 0.9	Protection of aquatic life (Coarse Soil) Protection of aquatic life (Fine Soil)	Environment Canada, 2013 Environment Canada, 2013	Provisional advice and not intended for use at Federal sites
1.5	Screening benchmark (plants)	Beach et al. 2006	Based on lowest observed effect (<3.91 mg/kg ww) divided by a UF of 3 and converted to dw.
39	Screening benchmark (invertebrates)	Beach et al. 2006	Based on earthworm NOEC of 77 mg/kg and a UF of 2
0.1	Predicted no effect concentration (earthworm)	NPCA, 2008	Based on earthworm NOEC multiplied by TGD recommended UF of 0.01.
0.021 mg/kg-d	ADI for Level 4 Avian Predators (birds)	Beach et al. 2006	Based on quail ADI and UF of 36.
1.3	Site specific terrestrial ecological receptor criteria	SLR	Lettuce NOEC of <3.9 divided by a UF of 3
0.046	Predicted no effect concentration (plant – dry weight soil based)	Merrington et al, 2009	2004 UK Environment Agency PNEC based on toxicity data adjusted by factor of 100
0.373	Predicted no effect concentration (earthworm – dry weight soil based)	Brooke et al, 2004	LC50 (acute) adjusted by a factor of 1000.
0.0106	Secondary effects value (mammals and birds consuming earthworms)	Merrington et al, 2009	Based on 2004 UK Environment Agency PNECoral of 0.067 mg/kg ww in food

PFOSA

The following PFOSA criteria, intended to be terrestrial receptors, have been identified:

Criterion (mg/kg)	Type	Reference	Comments
0.16	Predicted no effect concentration (earthworm)	NPCA, 2008	Based on earthworm NOEC multiplied by TGD recommended UF of 0.01.

Existing Surface Water Quality Criteria – Ecological

PFC	Criterion	Reference	Comment
PFOS	6 µg/L	Environment Canada, 2013	Provisional value based on 5th percentile freshwater species sensitivity distribution
PFOS	170 µg/L 0.014 µg/L 19 µg/L 300 µg/L	MPCA, 2013. Mississippi River – Site Specific, Pool 2. MPCA, 2013. Mississippi River – Site Specific, Pool 2. MPCA, 2007a (2013) MPCA, 2007a (2013)	Final Acute Value, salmonid/Non-salmonid. Chronic Standard, salmonid/Non-salmonid. Chronic criterion – aquatic organisms – uncertain if amphibian protective. Chronic criterion – aquatic plants
PFOS	13,500 µg/L	Hazelton et al., 2012	Lowest acute EC50 (valve closure) – larval Black sandshell
PFOA	3520 µg/L	Yang et al., 2013	Stated to be a continuous chronic concentration
PFOA	1705 µg/L 23,900 µg/L	MPCA, 2007b MPCA, 2007b	Continuous chronic (invertebrate) – Lake Calhoun Final Plant Value – (milfoil) NOEC
PFOA	161,000 µg/L	Hazelton et al., 2012	Lowest acute EC50 (valve closure) – larval

			Black sandshell

Existing Groundwater Quality Criteria - Ecological

PFC	Criterion	Reference	Comment
PFOS	60 µg/L	Environment Canada, 2013	Provisional value based on 5th percentile freshwater species sensitivity distribution adjusted for 10 m transport.

Existing Sediment Quality Criteria – Ecological Health

PFC	Criterion	Reference	Comment
PFOS			
PFOS	0.0017 mg/kg	KFD, 2012 (Norway)	EQSsed, Annual average EQS. Marine.
PFOA			
PFOA	0.0027 mg/kg	KFD, 2012 (Norway)	EQSsed, Annual average EQS. Marine.

Existing Soil Quality Criteria – Human Health

PFC	Criterion	Reference	Comment
PFOS			
PFOS	0.7 mg/kg (Residential/Parkland) 1 mg/kg (commercial) 5 mg/kg (Industrial)	Environment Canada, 2013 Environment Canada, 2013 Environment Canada, 2013	Interim Advice – Provisional Screening Level Interim Advice – Provisional Screening Level Interim Advice – Provisional Screening Level
PFOS	6 mg/kg	US EPA, 2009a	Based on subchronic RfD, child, 6 year exposure (residential)
PFOS	0.53	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFOA			
PFOA	16 mg/kg	US EPA, 2009a	Based on subchronic RfD, child, 6 year exposure (residential)
PFOA	0.24	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.

PFUnA			
PFUnA	0.27	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFPA			
PFPA	1.5	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFHxA			
PFHxA	1.5	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFDoA			
PFDoA	0.26	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFDA			
PFDA	0.33	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFDS			
PFDS	0.27	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFHxS			
PFHxS	1.5	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFBA			
PFBA	58	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFBS			
PFBS	26	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFHpA			
PFHpA	0.53	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.
PFNA			
PFNA	0.26	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.

PFOSA			
PFOSA	0.05	TCEQ, 2014	Residential combined PCL, 0.5 acre source. Alternate values also available. Target HQ used by TCEQ is 1.

Existing Water Quality Criteria – Human Health (Drinking Water and Tissue Consumption)

PFC	Criterion	Reference	Comment
PFOS			
PFOS	0.3 µg/L	Health Canada, 2012a (FCSAP, 2013)	Drinking water guidance value – does not represent a final drinking water guideline.
PFOS	0.3 µg/L	MDH, 2009a	Drinking water health risk limit HRL – Chronic. Developmental effects; Liver system; Thyroid
PFOS	0.3 µg/L	UK HPA, 2007	Maximum acceptable drinking water concentration. 10 kg one year old child. 10% TDI.
PFOS	67 µg/L 100 µg/L 300 µg/L	UK HPA, 2012 UK HPA, 2012 UK HPA, 2012	Bottle fed babies. Acute effects. Drinking water. One year old children. Acute effects. Drinking water. Adult, Acute effects. Drinking water.
PFOS	0.2 µg/L	US EPA, 2009b	10 kg child, 1 L/day, allocation factor=0.2
PFOS	0.2 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFOS + PFOA			
PFOS+PFOA	0.3 µg/L	TWK, 2006	Lifelong exposure
PFOA			
PFOA	0.7 µg/L	Health Canada, 2012b	Drinking water guidance value – does not represent a final established drinking water guideline.
PFOA	10 µg/L	UK HPA, 2007	Maximum acceptable drinking water concentration. 5 kg infant. 50% TDI.
PFOA	0.4 µg/L	US EPA, 2009	Provisional Health Advisory level. 10 kg child, 1 L/day, allocation factor=0.2
PFOA	1 µg/L	NCDENP, 2008	Interim Maximum Allowable Level. Adult , 2L/day and 0.2 allocation factor
PFOA	0.04 µg/L	NJ DEP, 2007	Intended to protect for lifetime exposure, normally defined as 70 years
PFOA	0.3 µg/L	MDH, 2009b	Drinking water health risk limit HRL – Chronic. Development effects; Liver system; Immune system.
PFOA	0.098 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL.

			Alternate values also available. Target HQ used by TCEQ is 1.
PFOA	0.61 µg/L 1.62 µg/L	MPCA, 2007b (Lake Calhoun) MPCA, 2007b (Lake Calhoun)	Continuous Chronic salmonid/non-salmonid – protective of human consumption of tissue Continuous Chronic non-salmonid– protective of human consumption of tissue
PFBS			
PFBS	15 µg/L	Health Canada, 2011	Drinking water guidance value – does not represent a final established drinking water guideline.
PFBS	7 µg/L 9 µg/L	MDH, 2011a MDH, 2011a	Drinking water health risk limit HRL – Chronic. Blood system; Liver system; Kidney system. Drinking water health risk limit HRL – Subchronic. Blood system; Liver system; Kidney system.
PFBS	3 µg/L	Wilhelm et al., 2010	Provisional Health Related Indication Value (HRIV) – lifelong exposure
PFBS	10 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFBA			
PFBA	30 µg/L	Health Canada, 2011	Drinking water guidance value – does not represent a final established drinking water guideline.
PFBA	7 µg/L 7 µg/L 7 µg/L	MDH, 2011b MDH, 2011b MDH, 2011b	Drinking water health risk limit HRL – Chronic (set at short term value). Liver system; Thyroid (Endocrine mediated effect) Drinking water health risk limit HRL – Subchronic (set at short term value). Liver system; Thyroid (Endocrine mediated effect) Drinking water health risk limit HRL – Subchronic (set at short term value). Liver system; Thyroid (Endocrine mediated effect)
PFBA	23 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFBA	7 µg/L	Wilhelm et al., 2010	Provisional Health Related Indication Value

			(HRIV) – lifelong exposure
PFPA or PFPeA			
PFPeA (PFPA)	0.7 µg/L	Health Canada, 2011	Drinking water screening value based on PFOA– does not represent a final established drinking water guideline.
PFPA (PFPeA)	3 µg/L	Wilhelm et al., 2010	Provisional Health Related Indication Value (HRIV) – lifelong exposure
PFPA	0.56 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFHxA			
PFHxA	0.7 µg/L	Health Canada, 2011	Drinking water screening value based on PFOA– does not represent a final established drinking water guideline.
PFHxA	1 µg/L	Wilhelm et al., 2010	Provisional Health Related Indication Value (HRIV) – lifelong exposure
PFHxA	0.56 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFHpA			
PFHpA	0.7 µg/L	Health Canada, 2011	Drinking water screening value based on PFOA– does not represent a final established drinking water guideline.
PFHpA	0.3 µg/L	Wilhelm et al., 2010	Provisional Health Related Indication Value (HRIV) – lifelong exposure
PFHpA	0.2 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFNA			
PFNA	0.7 µg/L	Health Canada, 2011	Drinking water screening value based on PFOA– does not represent a final established drinking water guideline.
PFNA	0.02 µg/L	NJDEP, 2014 (DRAFT)	Chronic drinking water (groundwater) exposure. Based on available animal/human toxicokinetic data, used to extrapolate PFNA intake to increased PFNA in blood serum of 0.085 (ng/kg/day)/(ng/L) which corresponds to a blood serum:drinking water ratio of 200:1 for humans.
PFNA	0.098 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFPS			

PFPS	1 µg/L	Wilhelm et al., 2010	Provisional Health Related Indication Value (HRIV) – lifelong exposure
PFHxS			
PFHxS	0.3 µg/L	Health Canada, 2011	Drinking water screening value based on PFOS – does not represent a final established drinking water guideline.
PFHxS	0.3 µg/L	Wilhelm et al., 2010	Provisional Health Related Indication Value (HRIV) – lifelong exposure
PFHxS	0.56 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFHpS			
PFHpS	0.3 µg/L	Wilhelm et al., 2010	Provisional Health Related Indication Value (HRIV) – lifelong exposure
PFOSA			
PFOSA	0.098 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFDoA			
PFDoA	0.098 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFUnA			
PFUnA	0.098 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.
PFDA			
PFDA	0.12 µg/L	TCEQ, 2014	Residential groundwater ingestion PCL. Alternate values also available. Target HQ used by TCEQ is 1.

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APPENDIX C

Surface Water and Sediment PFC Data
June 2014

Analytical Data Tables

TABLE 1 SURFACE WATER ANALYTICAL RESULTS
Perfluorinated Compounds
Upper Welland River Watershed
Hamilton International Airport, Mount Hope, Ontario

SNC-Lavalin Sample No.	RDL	Units	Ecological Criteria	Human Health Criteria	WR-2	WR-3	WR-4	WR-5	WS-2	WS-99 Duplicate of WS-2
Laboratory Sample No.	na	na	na		*L21535-15*	*L21535-18 i*	*L21535-14*	*L21535-20 i*	*L21535-16*	*L21535-11 N*
Sampling Date	na	na	na		*31-May-14*	*31-May-14*	*31-May-14*	*31-May-14*	*1-Jun-14*	*1-Jun-14*
Monitoring Well No.	na	na	na		*WR-2*	*WR-3*	*WR-4*	*WR-5*	*WS-2*	*WS-2*
PFCs										
PFBA	1.1	ng/L	nc	30000 [2]	3.55	11.9	3.52	3.18	63.5	57.9
PFPeA	1.4	ng/L	nc	700 [3]	< 4.93	< 2.26	3.93	< 1.4	216	272
PFHxA	1.2	ng/L	nc	700 [3]	3.08	2.36	3.57	< 1.17	215	191
PFHpA	1.0	ng/L	nc	700 [3]	1.58	< 2.49	< 0.989	< 0.986	121	115
PFOA	1.24	ng/L	nc	700 [2]	1.63	2.11	< 0.989	< 1.24	115	116
PFNA	0.1	ng/L	nc	700 [3]	< 1.03	< 0.987	< 0.989	< 0.986	17.4	17.6
PFDA	0.99	ng/L	nc	nc	< 1.03	< 0.987	< 0.989	< 0.986	2.73	3.58
PFUnA	0.99	ng/L	nc	nc	< 1.03	< 0.987	< 0.989	< 0.986	1.1	< 1.16
PFDoA	0.99	ng/L	nc	nc	< 1.03	< 0.987	< 0.989	< 0.986	< 0.99	< 1.16
PFBS	2.0	ng/L	nc	15000 [2]	< 2.8	< 1.97	< 1.98	< 1.97	28.9	35.5
PFHxS	2.0	ng/L	nc	300 [3]	< 2.06	< 1.97	< 1.98	< 1.97	**389**	**415**
PFOS	1.97	ng/L	6000 [1]	300 [2]	< 2.06	< 1.97	< 1.98	< 1.97	**369**	**383**
PFOSA	0.986	ng/L	nc	nc	< 1.03	< 0.987	< 0.989	< 0.986	< 0.99	< 1.16

ng/L nanograms per litre
RDL Reportable Detection Limit unless noted
nc no criteria
< less than RDL
\- not analysed
BOLD Exceeds Human Health Criteria
Italics Exceeds Ecological Criteria
[1] Federal Environment Quality Guidelines for PFOS (EC, 2013)
[2] Health-based Drinking Water Guidance Value (Health Canada, 2012a and 2012b)
[3] Health-based Drinking Water Screening Value (Health Canada, 2011)

TABLE 1 SURFACE WATER ANALYTICAL RESULTS
Perfluorinated Compounds
Upper Welland River Watershed
Hamilton International Airport, Mount Hope, Ontario

SNC-Lavalin Sample No.	**RDL**	**Units**	**Ecological Criteria**	**Human Health Criteria**	**WS-4**	**MOE DITCH 1b**	**MOE HWY 6W**	**WT-1**	**WT-2**	**WT-3**	**MOE LAKE NIAPENCO**	**Sinclairville**
Laboratory Sample No.	na	na	na		*L21535-12 N*	*L21535-17*	*L21535-19*	*L21535-22*	*L21535-9 N*	*L21535-8 N*	*L21535-13 N*	*L21535-26*
Sampling Date	na	na	na		*1-Jun-14*	*1-Jun-14*	*31-May-14*	*3-Jun-14*	*3-Jun-14*	*4-Jun-14*	*31-May-14*	*4-Jun-14*
Monitoring Well No.	na	na	na		*WS-4*	*MOE DITCH 1b*	*MOE HWY 6W*	*WT-1*	*WT-2*	*WT-3*	*MOE LAKE NIAPENCO*	*Sinclairville*
PFCs												
PFBA	1.1	ng/L	nc	30000 [2]	16.9	356	35.1	10.8	10.9	8.82	12	12.9
PFPeA	1.4	ng/L	nc	700 [3]	87.3	**1630**	101	< 8.26	20.4	14.3	27.9	21.1
PFHxA	1.2	ng/L	nc	700 [3]	44.3	**1230**	71.2	12.9	12.3	4.44	23.1	21.1
PFHpA	1.0	ng/L	nc	700 [3]	27.9	424	39.4	4.3	15.8	< 1.14	16.1	11.4
PFOA	1.24	ng/L	nc	700 [2]	14.9	379	28.4	5.71	49.4	2.33	16.7	18.8
PFNA	0.1	ng/L	nc	700 [3]	2.85	101	9.84	< 1.02	2.28	< 1.14	2.37	2.32
PFDA	0.99	ng/L	nc	nc	< 0.975	< 9.37	< 0.997	< 1.01	< 1	< 1.14	< 0.957	< 0.998
PFUnA	0.99	ng/L	nc	nc	< 0.975	< 9.37	< 0.997	< 1.01	< 1	< 1.14	< 0.957	< 0.998
PFDoA	0.99	ng/L	nc	nc	< 0.975	< 9.37	< 0.997	< 1.01	< 1	< 1.14	< 0.957	< 0.998
PFBS	2.0	ng/L	nc	15000 [2]	4.44	125	6.96	< 2.03	3.41	7.52	2.42	3.27
PFHxS	2.0	ng/L	nc	300 [3]	58.9	**1810**	103	< 2.11	< 2.01	< 2.28	28.6	22.4
PFOS	1.97	ng/L	6000 [1]	300 [2]	101	**4290**	289	< 2.03	232	< 2.28	74.4	71.6
PFOSA	0.986	ng/L	nc	nc	< 0.975	< 9.37	< 0.997	< 1.01	2.91	< 1.14	< 0.957	1.04

ng/L nanograms per litre
RDL Reportable Detection Limit unless noted
nc no criteria
< less than RDL
\- not analysed
BOLD Exceeds Human Health Criteria
Italics Exceeds Ecological Criteria
[1] Federal Environment Quality Guidelines for PFOS (EC, 2013)
[2] Health-based Drinking Water Guidance Value (Health Canada, 2012a and 2012b)
[3] Health-based Drinking Water Screening Value (Health Canada, 2011)

TABLE 2 **SEDIMENT ANALYTICAL RESULTS**
Perfluorinated Compounds
Upper Welland River Watershed
Hamilton International Airport, Mount Hope, Ontario

SNC-Lavalin Sample No.	RDL	Units	Ecological Criteria	Human Health Criteria[1]	WR-2	WR-3	WR-4	WR-5	MOE DITCH 1b
Laboratory Sample No.	na	na	na	na	*L21537-3 N*	*L21537-4 N*	*L21537-6 N*	*L21537-9 N*	*L21537-8 N*
Sampling Date	na	na	na	na	*31-May-14*	*31-May-14*	*31-May-14*	*31-May-14*	*1-Jun-14*
Monitoring Well No.	na	na	na	na	*WR-2*	*WR-3*	*WR-4*	*WR-5*	*MOE DITCH 1b*
PFCs									
PFBA	0.089	ng/g	nc	nc	<0.188	<0.0995	<0.108	<0.139	0.415
PFPeA	0.089	ng/g	nc	nc	<0.188	<0.0995	<0.0993	<0.11	1.82
PFHxA	0.089	ng/g	nc	nc	<0.188	<0.0995	<0.0907	<0.109	1.29
PFHpA	0.089	ng/g	nc	nc	<0.188	<0.0995	<0.0907	<0.109	0.53
PFOA	0.089	ng/g	nc	nc	<0.188	<0.0995	<0.0907	<0.109	0.941
PFNA	0.089	ng/g	nc	nc	<0.188	<0.0995	<0.0907	<0.109	0.802
PFDA	0.089	ng/g	nc	nc	0.213	0.112	<0.0907	<0.109	0.184
PFUnA	0.089	ng/g	nc	nc	<0.188	<0.0995	<0.0907	<0.109	0.197
PFDoA	0.093	ng/g	nc	nc	<0.188	<0.146	<0.0907	<0.109	<0.189
PFBS	0.178	ng/g	nc	nc	<0.377	<0.199	<0.181	<0.218	<0.202
PFHxS	0.178	ng/g	nc	nc	<0.377	<0.199	<0.181	<0.218	3.79
PFOS	0.186	ng/g	nc	700	10.5	<0.327	<0.181	<0.218	124
PFOSA	0.089	ng/g	nc	nc	<0.188	0.138	<0.0907	<0.109	0.319

ng/g nanograms per gram expressed on a dry weight basis
RDL Reportable Detection Limit unless noted otherwise
nc no criteria
< less than RDL
- not analysed
1 In the absence of sediment quality guidelines protective of human health, soil guidelines applicable to a residential/parkland landuse have been applied to evaluate sediment quality. Guidelines represent "provisional screening levels" available from Environment Canada (EC), 2013. Interim advice to Federal Custodian Departments for the Management of Federal Contaminated Sites Containing Perfluorooctane Sulfonate (PFOS). Version 1.2, October 1, 2013
BOLD Exceeds Human Health Soil Quality Guideline

TABLE 2 SEDIMENT ANALYTICAL RESULTS
Perfluorinated Compounds
Upper Welland River Watershed
Hamilton International Airport, Mount Hope, Ontario

SNC-Lavalin Sample No.	RDL	Units	Ecological Criteria	Human Health Criteria[1]	WS-2	WS-99 Duplicate of WS-2	WS-4	MOE HWY 6W	WT-1	WT-2	WT-3
Laboratory Sample No.	na	na	na	na	*L21537-2 N*	*L21537-7 N*	*L21537-1 N*	*L21537-5 N*	*L21537-12 N*	*L21537-13 N*	*L21537-14 N*
Sampling Date	na	na	na	na	*1-Jun-14*	*1-Jun-14*	*1-Jun-14*	*31-May-14*	*3-Jun-14*	*3-Jun-14*	*4-Jun-14*
Monitoring Well No.	na	na	na	na	*WS-2*	*WS-2*	*WS-4*	*MOE HWY 6W*	*WT-1*	*WT-2*	*WT-3*
PFCs											
PFBA	0.089	ng/g	nc	nc	<0.101	<0.093	<0.109	<0.0932	<0.102	<0.0993	<0.0971
PFPeA	0.089	ng/g	nc	nc	0.214	0.186	0.199	<0.0932	<0.102	0.314	<0.0971
PFHxA	0.089	ng/g	nc	nc	0.138	0.124	<0.109	<0.0932	<0.102	<0.0993	<0.0971
PFHpA	0.089	ng/g	nc	nc	<0.101	<0.093	<0.109	<0.0932	<0.102	0.116	<0.0971
PFOA	0.089	ng/g	nc	nc	0.116	0.138	<0.109	<0.0932	0.215	0.551	0.34
PFNA	0.089	ng/g	nc	nc	<0.101	<0.093	0.134	<0.0932	0.121	0.208	0.179
PFDA	0.089	ng/g	nc	nc	0.116	0.0957	0.125	<0.0932	<0.102	0.192	0.147
PFUnA	0.089	ng/g	nc	nc	<0.101	<0.093	0.25	<0.0932	<0.102	<0.0993	0.153
PFDoA	0.093	ng/g	nc	nc	-	<0.093	<0.109	<0.0932	<0.102	<0.0993	0.124
PFBS	0.178	ng/g	nc	nc	<0.202	<0186	<0.218	<0.186	<0.203	<0.199	<0.194
PFHxS	0.178	ng/g	nc	nc	0.486	0.278	0.408	<0.186	<0.203	<0.199	<0.194
PFOS	0.186	ng/g	nc	700	3.84	2.86	14	2.6	1.15	28	1.05
PFOSA	0.089	ng/g	nc	nc	<0.101	<0.093	<0.109	<0.0932	<0.102	0.82	<0.0971

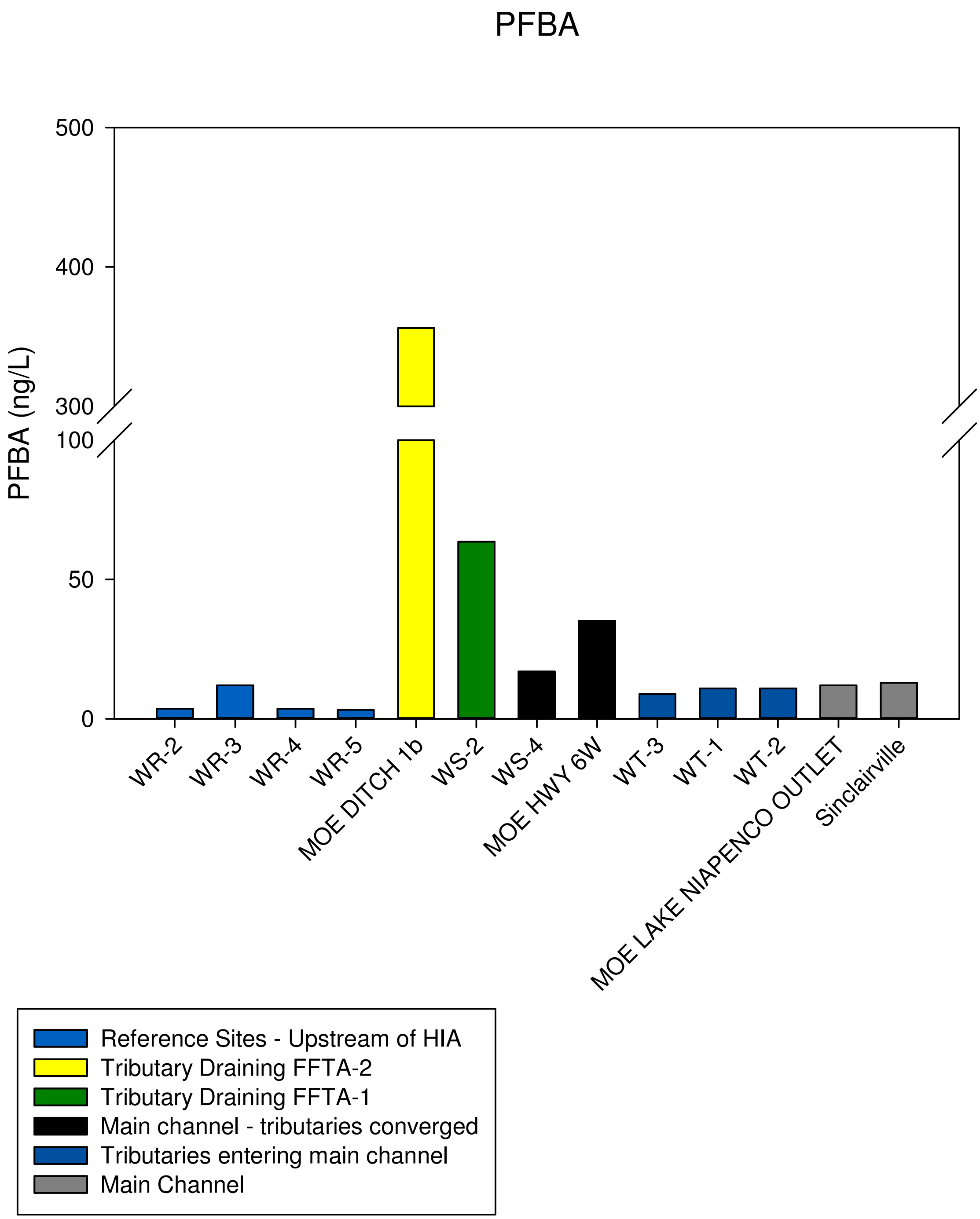
ng/g nanograms per gram expressed on a dry weight basis
RDL Reportable Detection Limit unless noted otherwise
nc no criteria
< less than RDL
- not analysed
1 In the absence of sediment quality guidelines protective of human health, soil guidelines applicable to a residential/parkland landuse have been applied to evaluate sediment quality. Guidelines represent "provisional screening levels" available from Environment Canada (EC), 2013. Interim advice to Federal Custodian Departments for the Management of Federal Contaminated Sites Containing Perfluorooctane Sulfonate (PFOS). Version 1.2, October 1, 2013
BOLD Exceeds Human Health Soil Quality Guideline

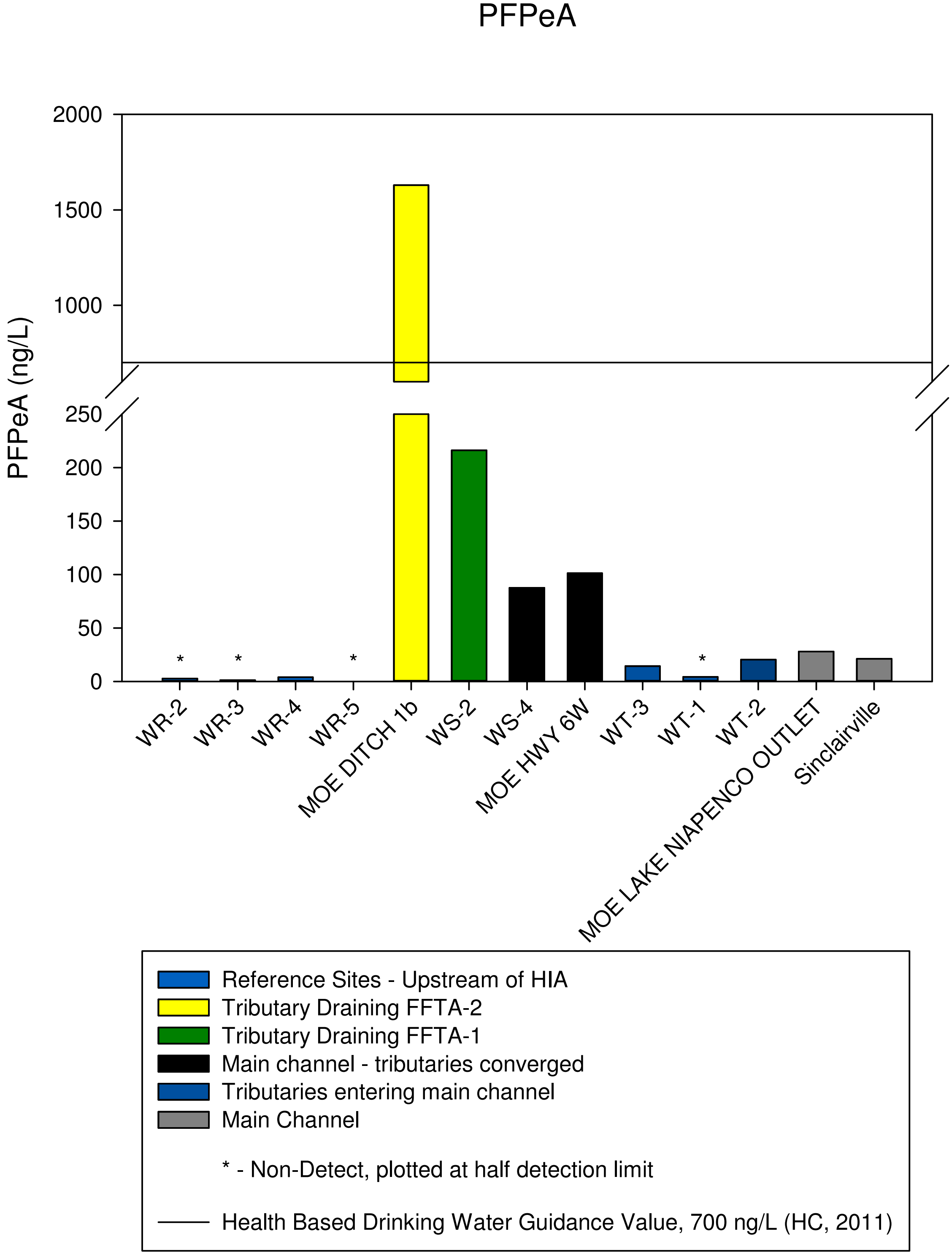
TABLE 2 SEDIMENT ANALYTICAL RESULTS
Perfluorinated Compounds
Upper Welland River Watershed
Hamilton International Airport, Mount Hope, Ontario

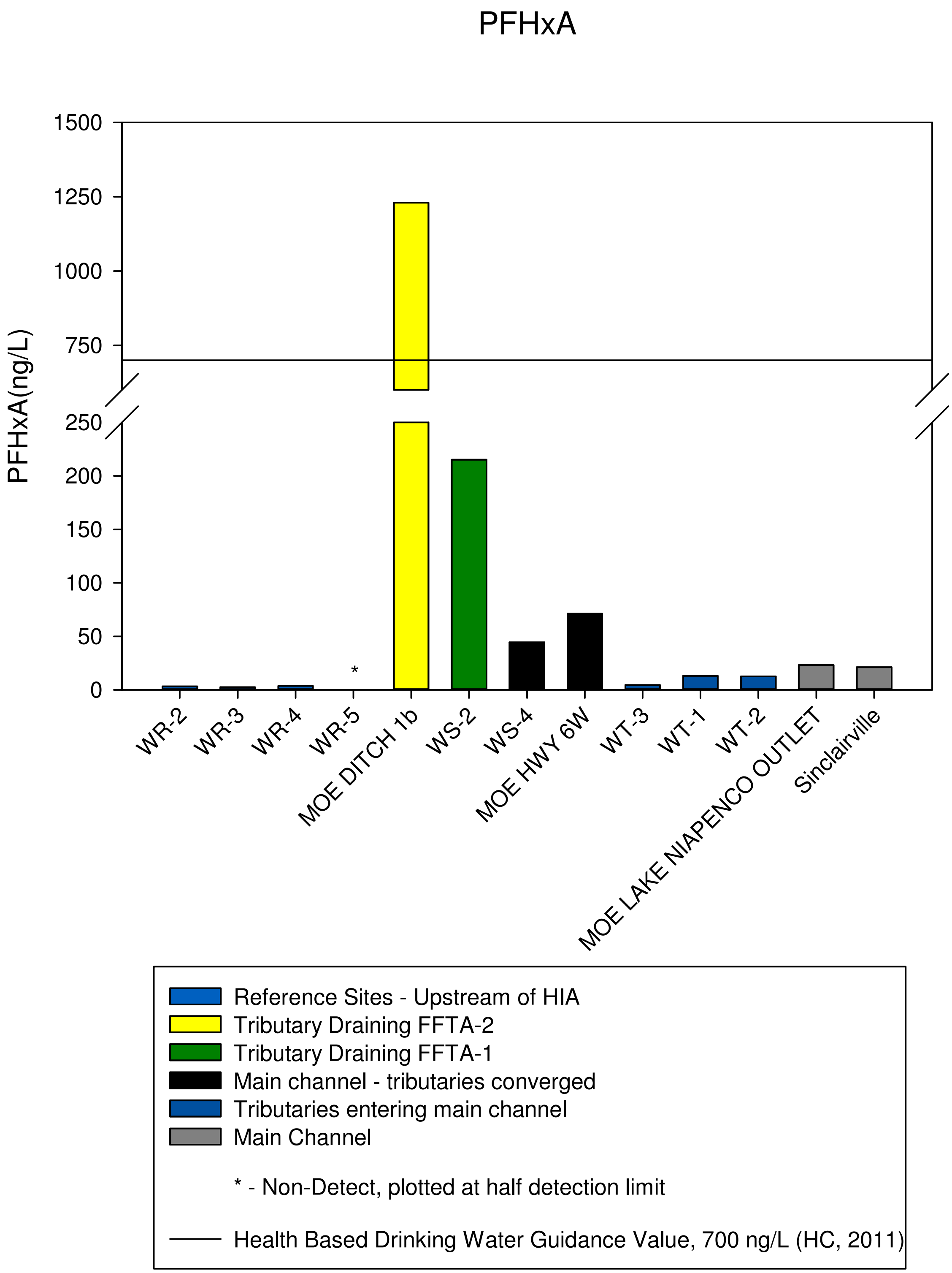
SNC-Lavalin Sample No.	**RDL**	**Units**	**Ecological Criteria**	**Human Health Criteria[1]**	**MOE LAKE NIAPENCO**	**Sinclairville**
Laboratory Sample No.	na	na	na	na	*L21537-10 N*	*L21537-15 N*
Sampling Date	na	na	na	na	*31-May-14*	*4-Jun-14*
Monitoring Well No.	na	na	na	na	*MOE LAKE NIAPENCO*	*Sinclairville*
PFCs						
PFBA	0.089	ng/g	nc	nc	<0.0912	<0.0955
PFPeA	0.089	ng/g	nc	nc	0.221	<0.0955
PFHxA	0.089	ng/g	nc	nc	0.127	<0.0955
PFHpA	0.089	ng/g	nc	nc	0.138	<0.0955
PFOA	0.089	ng/g	nc	nc	0.209	<0.0955
PFNA	0.089	ng/g	nc	nc	0.164	<0.0955
PFDA	0.089	ng/g	nc	nc	0.0997	<0.0955
PFUnA	0.089	ng/g	nc	nc	0.146	<0.0955
PFDoA	0.093	ng/g	nc	nc	<0.0912	<0.0955
PFBS	0.178	ng/g	nc	nc	<0.182	<0.191
PFHxS	0.178	ng/g	nc	nc	<0.182	<0.191
PFOS	0.186	ng/g	nc	700	11.7	2.68
PFOSA	0.089	ng/g	nc	nc	<0.0912	<0.0955

ng/g nanograms per gram expressed on a dry weight basis
RDL Reportable Detection Limit unless noted otherwise
nc no criteria
< less than RDL
- not analysed
1 In the absence of sediment quality guidelines protective of human health, soil guidelines applicable to a residential/parkland landuse have been applied to evaluate sediment quality. Guidelines represent "provisional screening levels" available from Environment Canada (EC), 2013. Interim advice to Federal Custodian Departments for the Management of Federal Contaminated Sites Containing Perfluorooctane Sulfonate (PFOS). Version 1.2, October 1, 2013
BOLD Exceeds Human Health Soil Quality Guideline

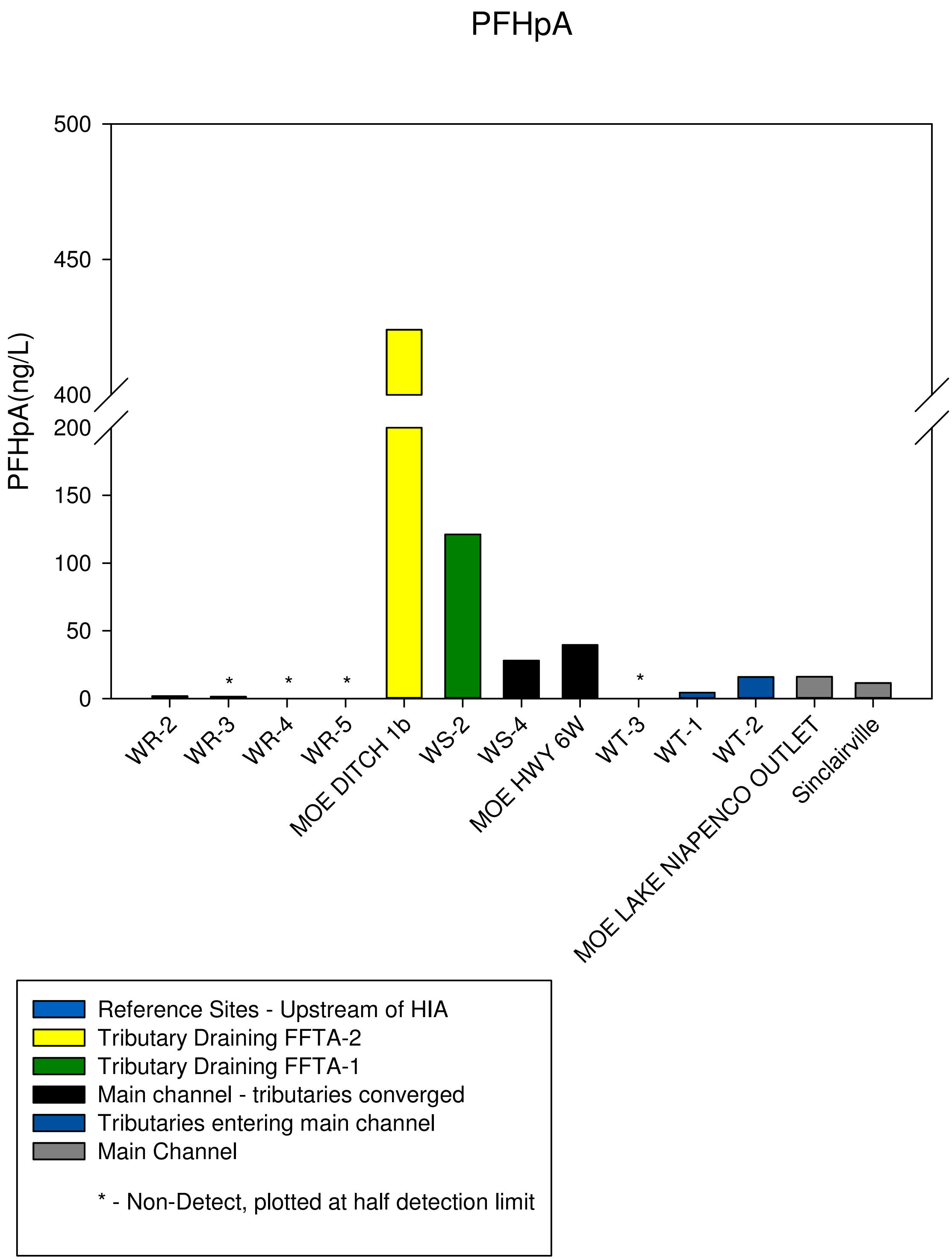
Surface Water PFC Concentration Bar charts


PFBA
PFBA (ng/L)
500
400
300
100
50
0
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel


PFPeA
PFPeA (ng/L)
2000
1500
1000
250
200
150
100
50
0
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit
Health Based Drinking Water Guidance Value, 700 ng/L (HC, 2011)

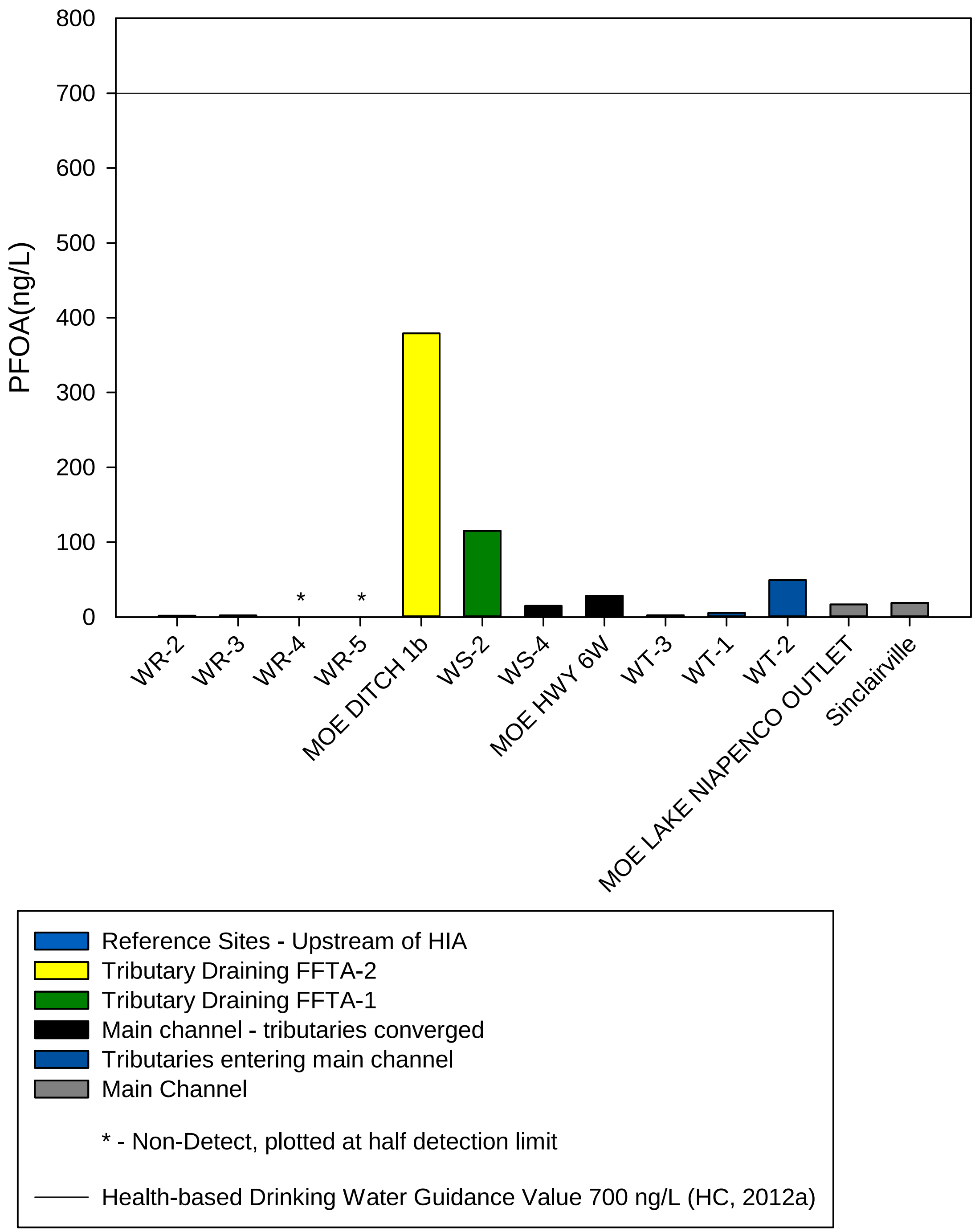


PFHxA
PFHxA(ng/L)
1500
1250
1000
750
250
200
150
100
50
0
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit
Health Based Drinking Water Guidance Value, 700 ng/L (HC, 2011)

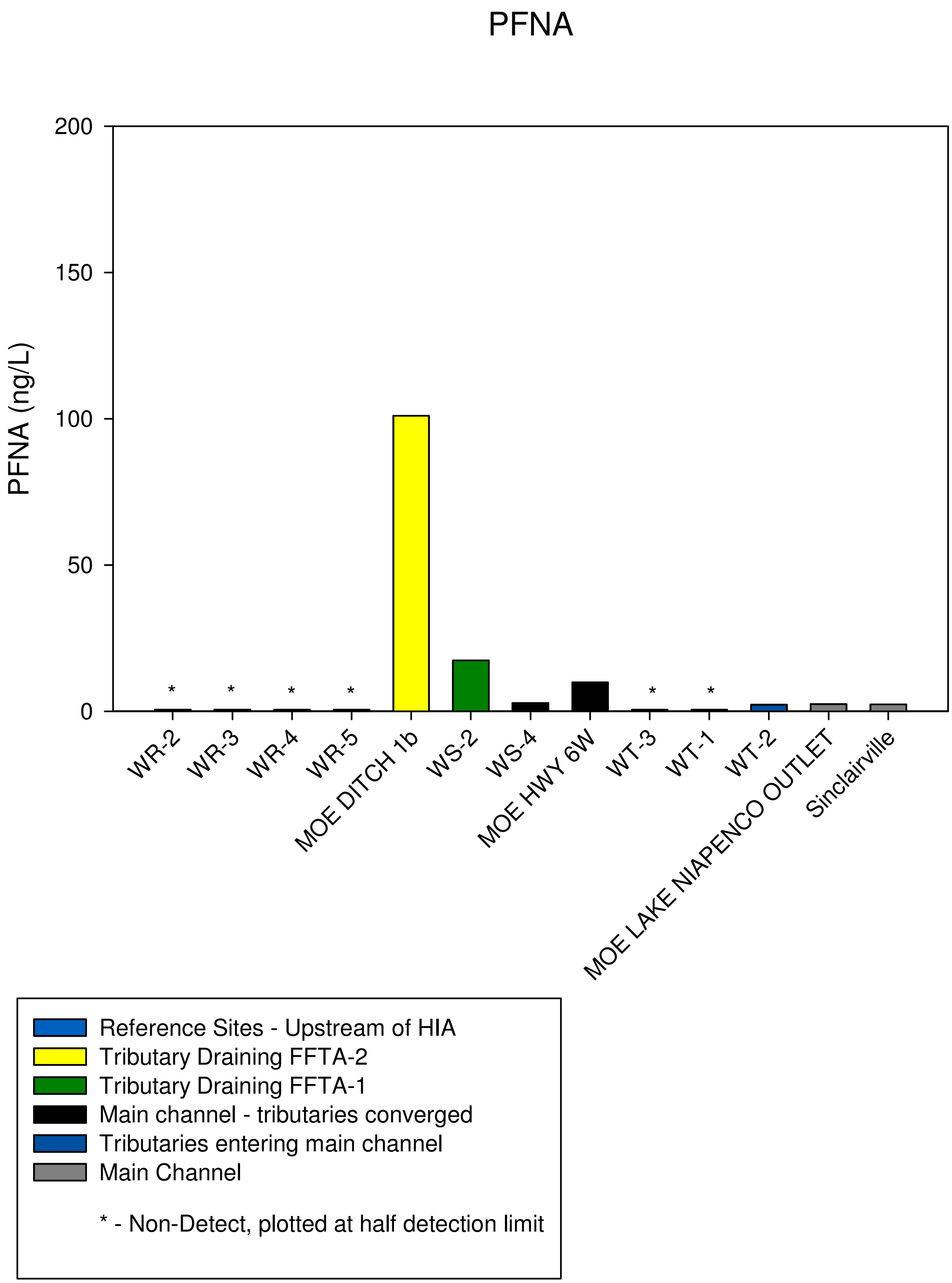


PFHpA
PFHpA(ng/L)
500
450
400
200
150
100
50
0
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
*
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

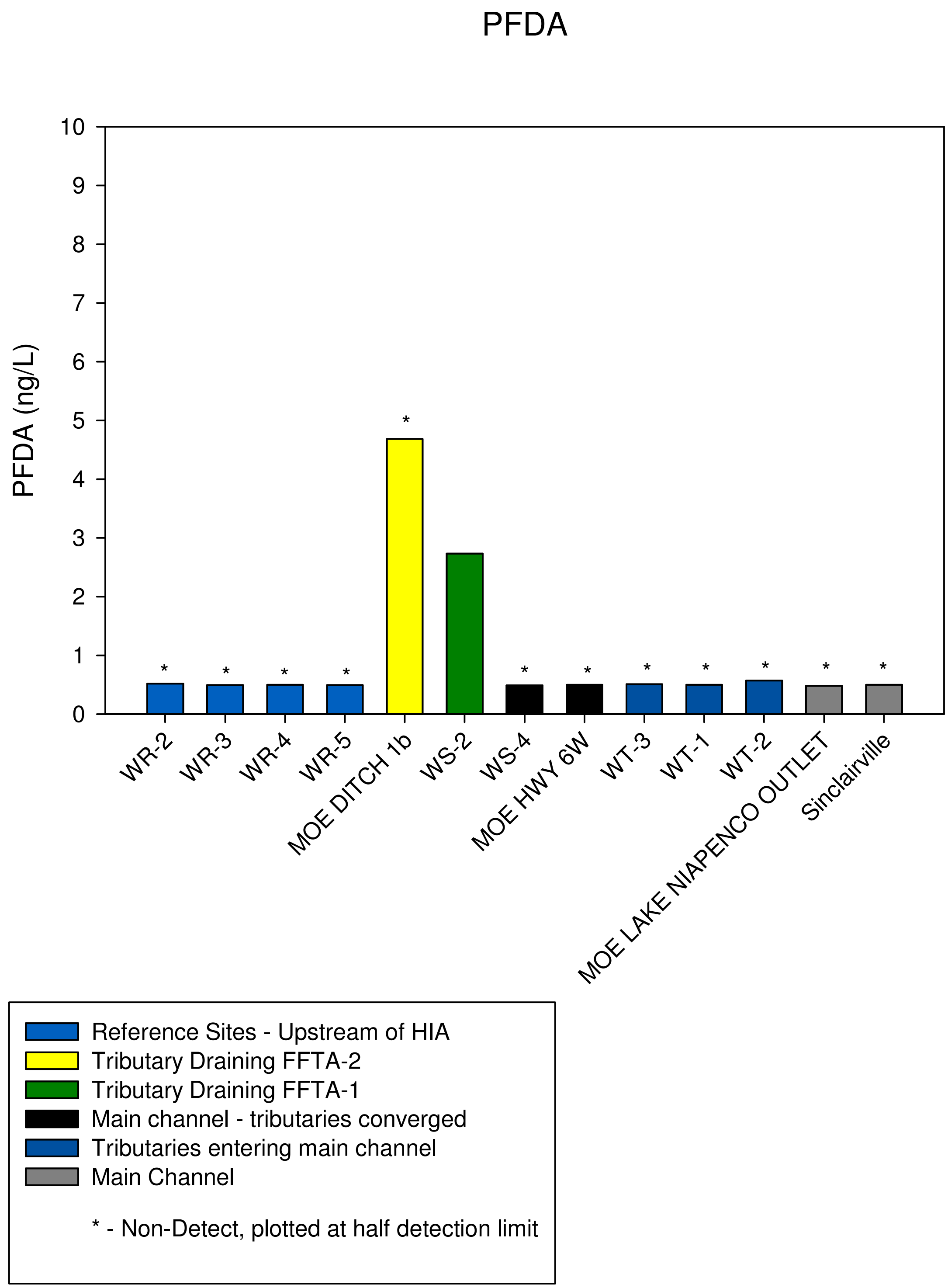
PFOA

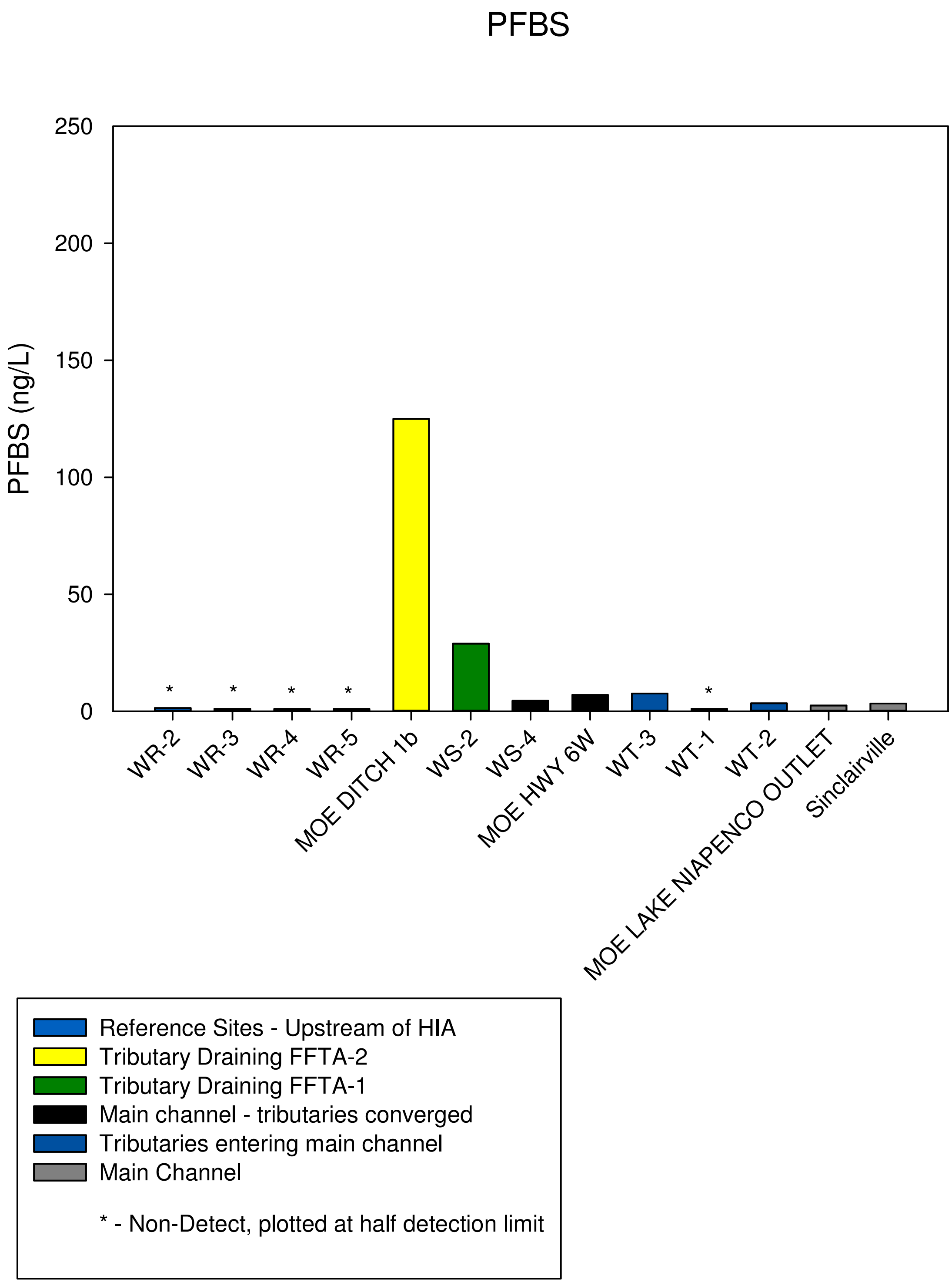


PFOA(ng/L)
800
700
600
500
400
300
200
100
0
*
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit
Health-based Drinking Water Guidance Value 700 ng/L (HC, 2012a)

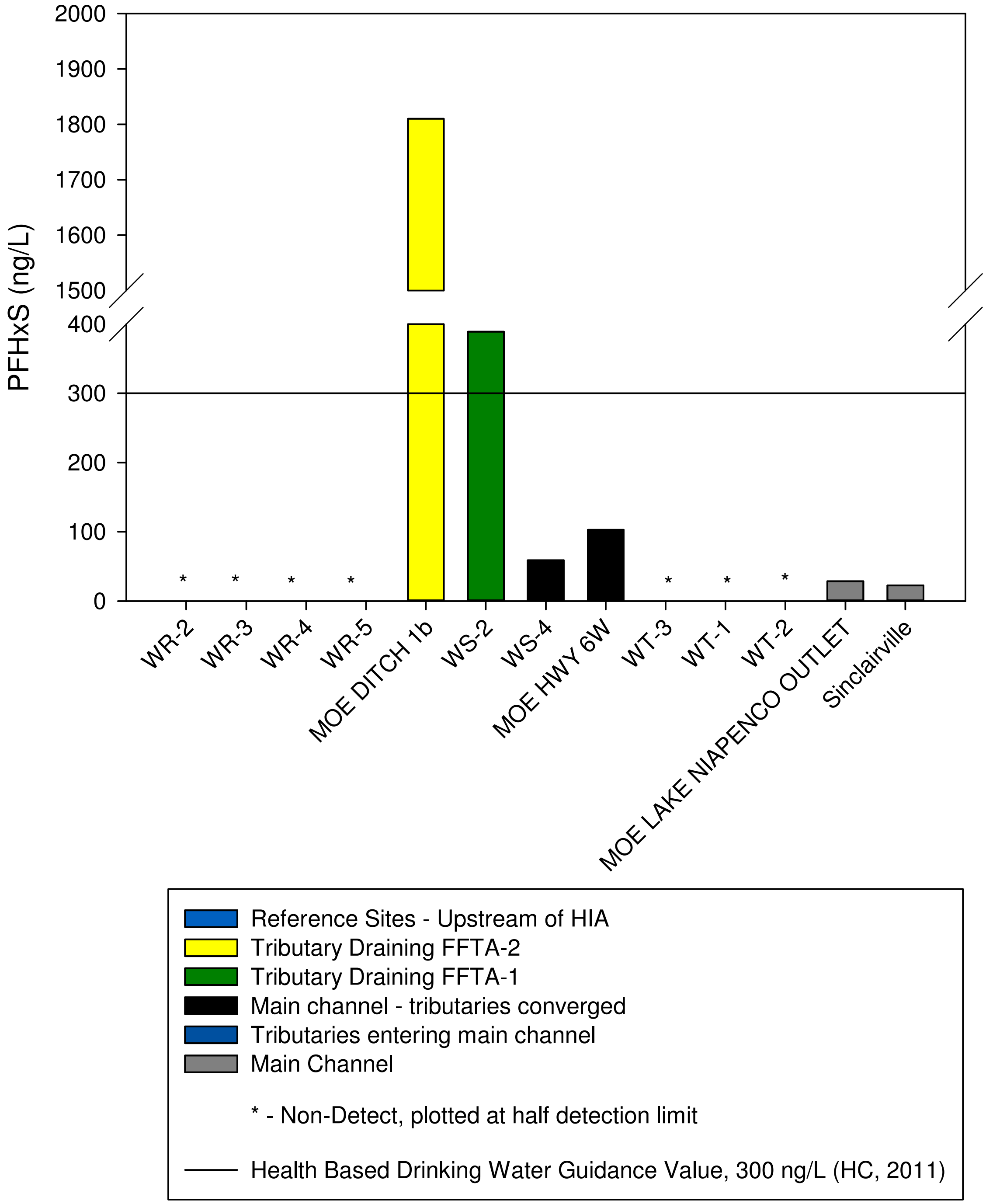


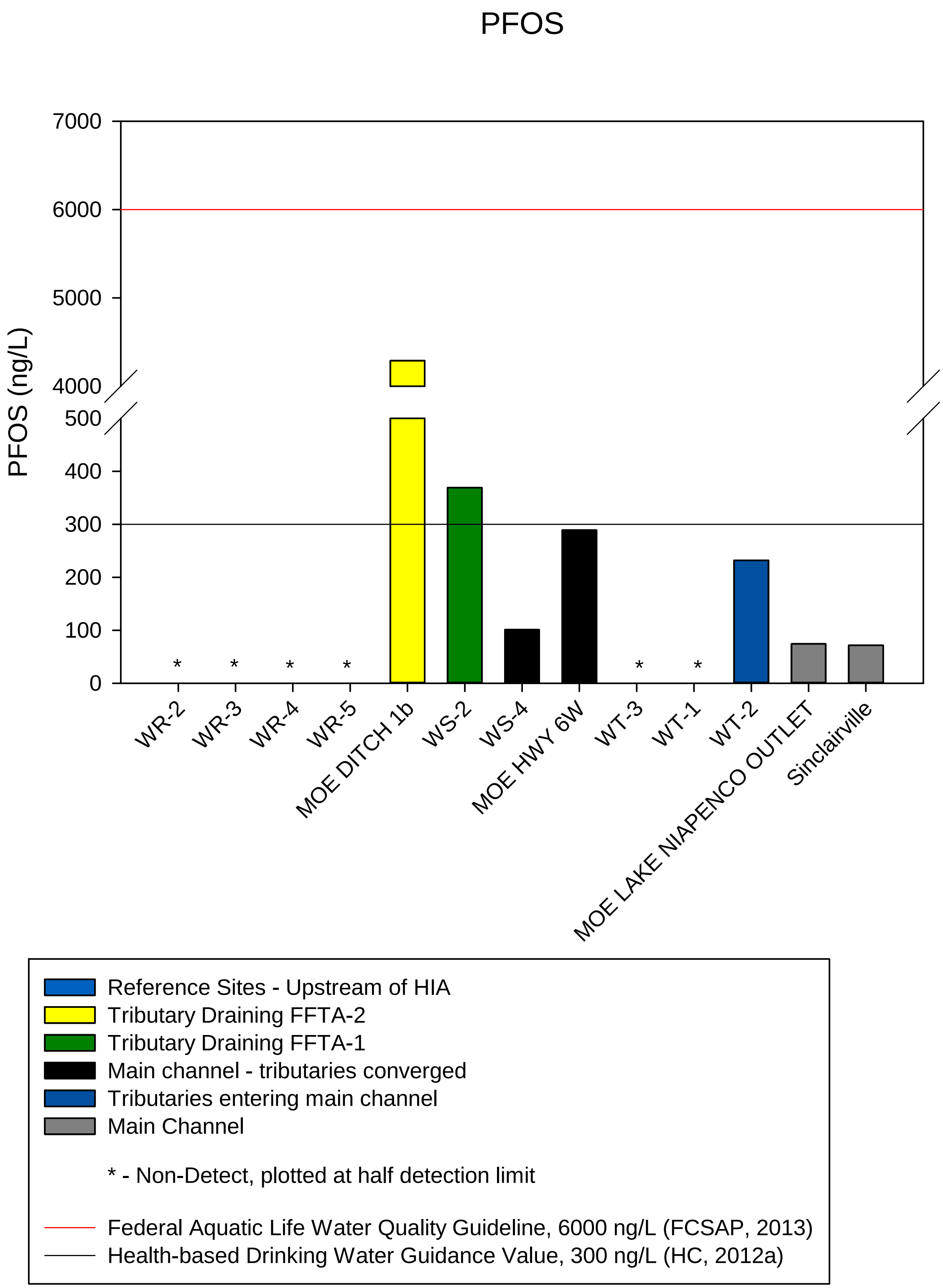
PFNA
PFNA (ng/L)
200
150
100
50
0
*
*
*
*
*
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit


PFDA
PFDA (ng/L)
0
1
2
3
4
5
6
7
8
9
10
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

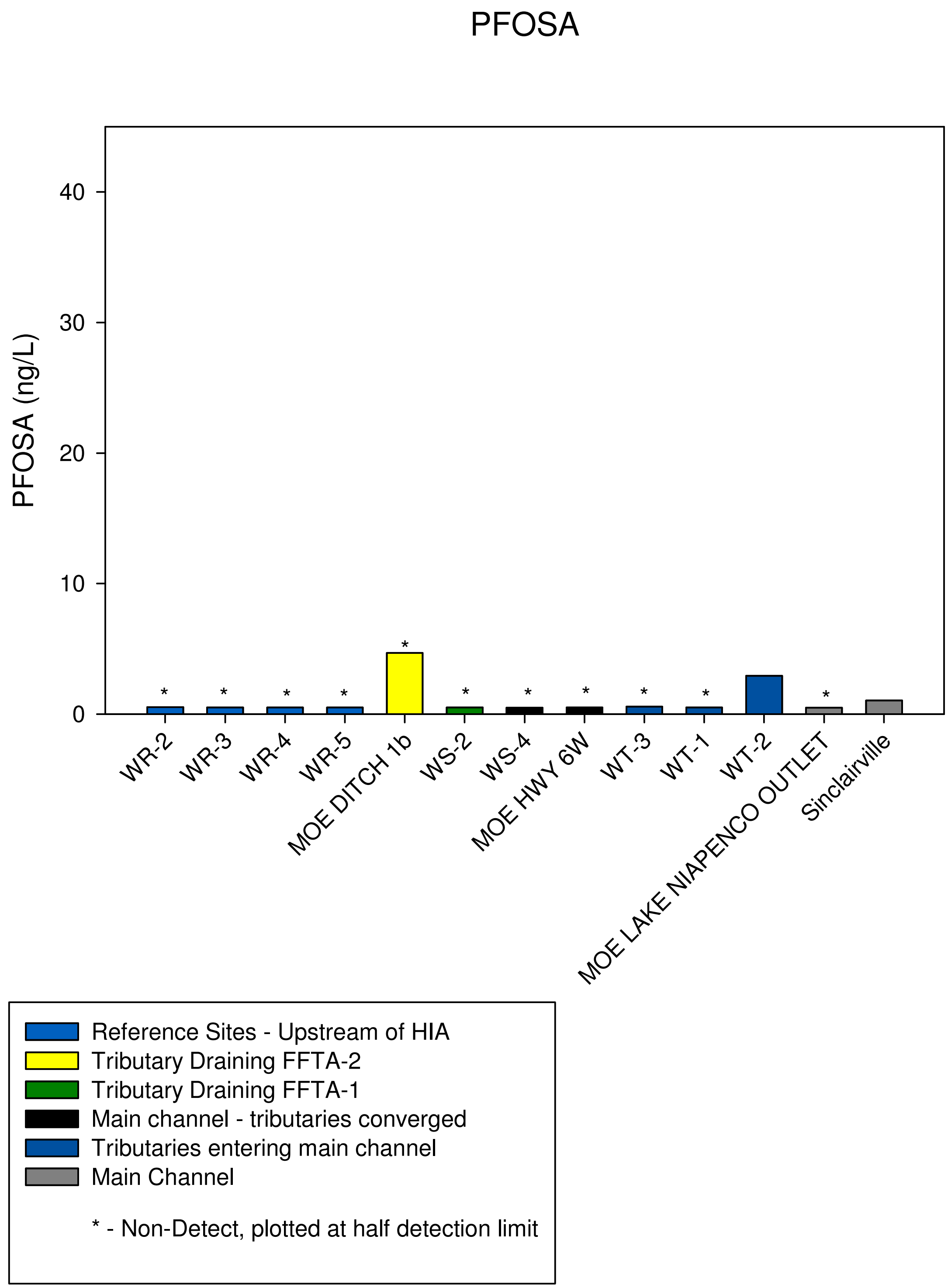

PFBS
PFBS (ng/L)
250
200
150
100
50
0
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

PFHxS


PFHxS (ng/L)
2000
1900
1800
1700
1600
1500
400
300
200
100
0
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit
Health Based Drinking Water Guidance Value, 300 ng/L (HC, 2011)

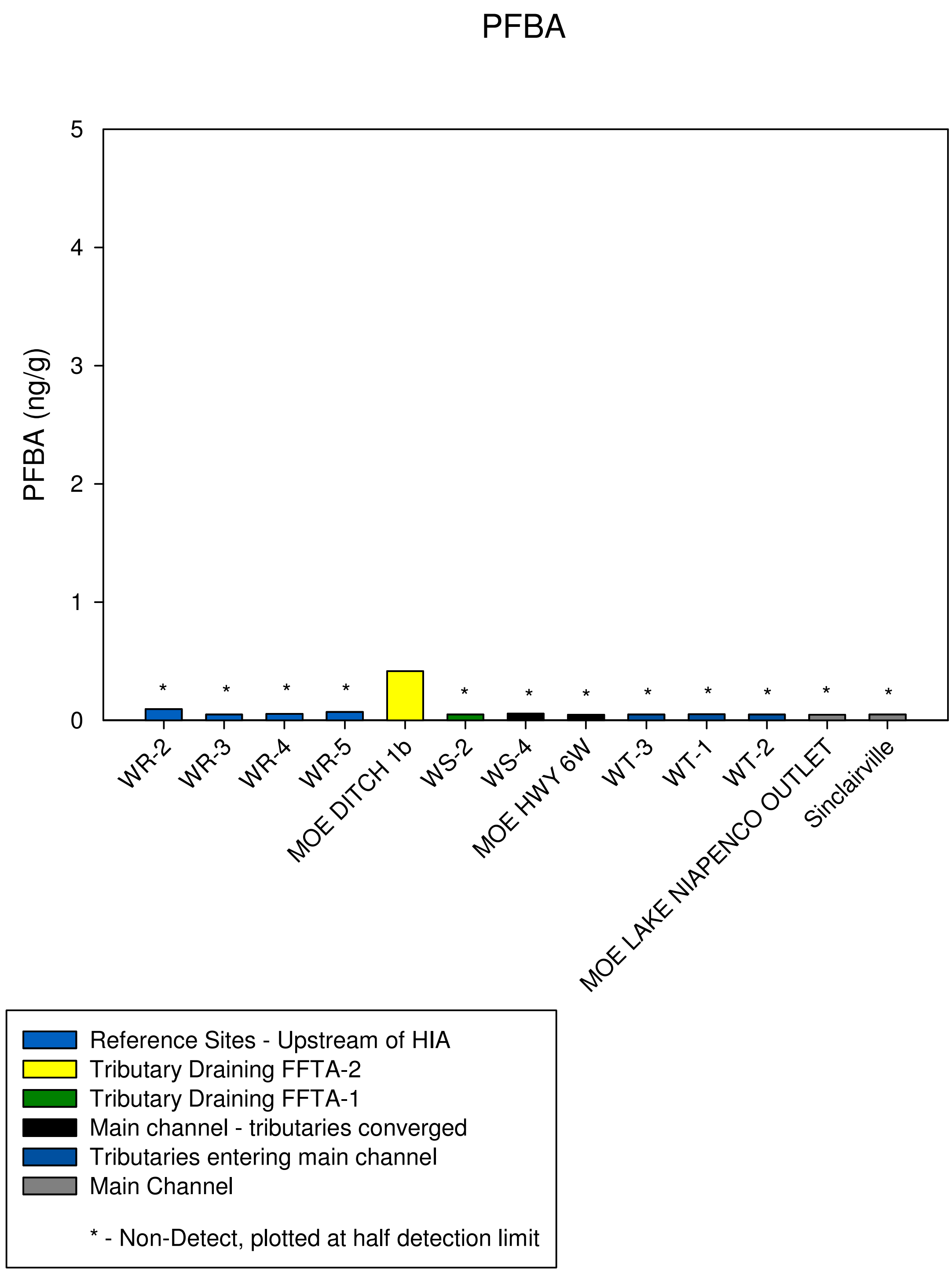


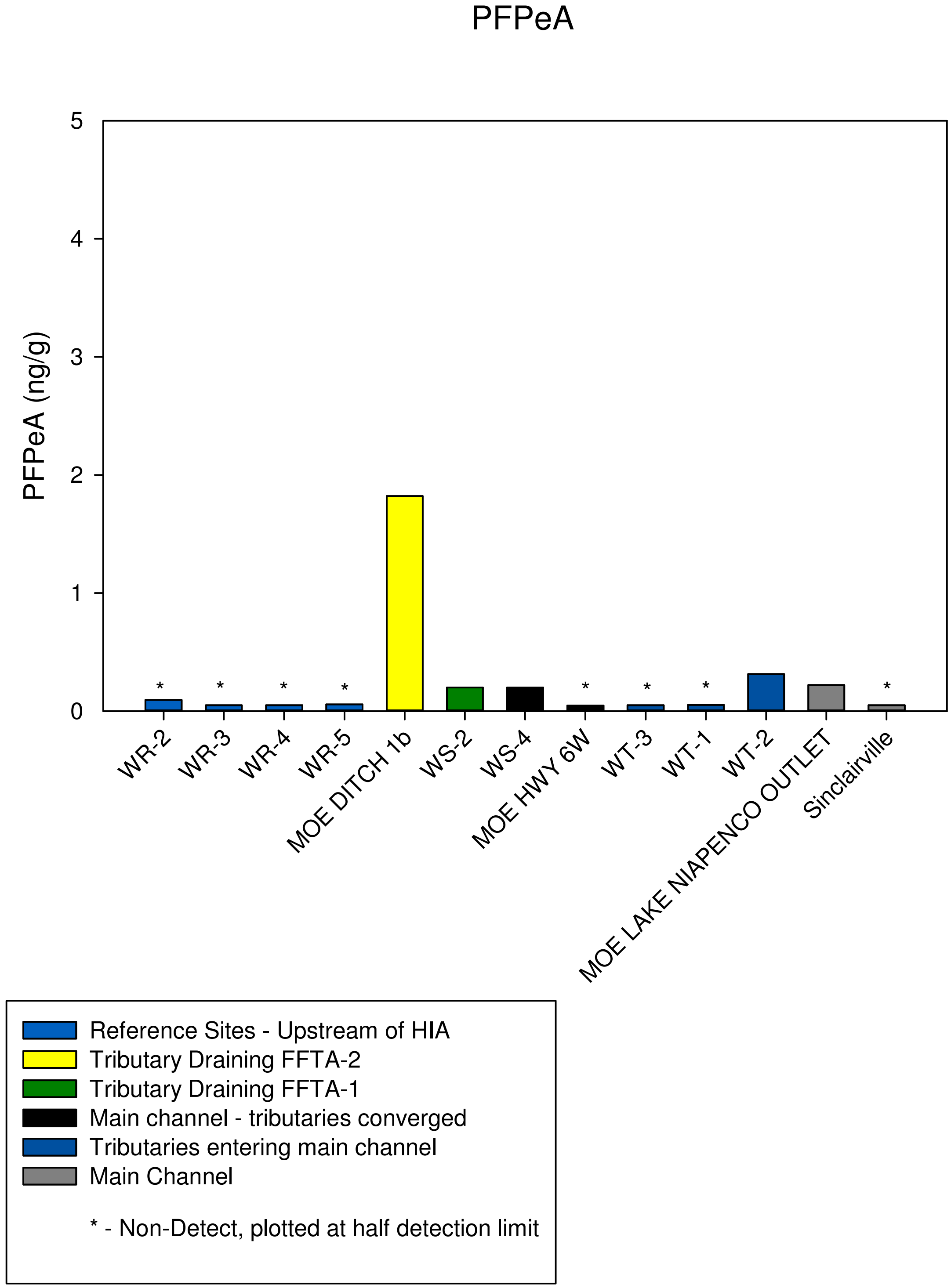
PFOS
PFOS (ng/L)
7000
6000
5000
4000
500
400
300
200
100
0
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit
Federal Aquatic Life Water Quality Guideline, 6000 ng/L (FCSAP, 2013)
Health-based Drinking Water Guidance Value, 300 ng/L (HC, 2012a)



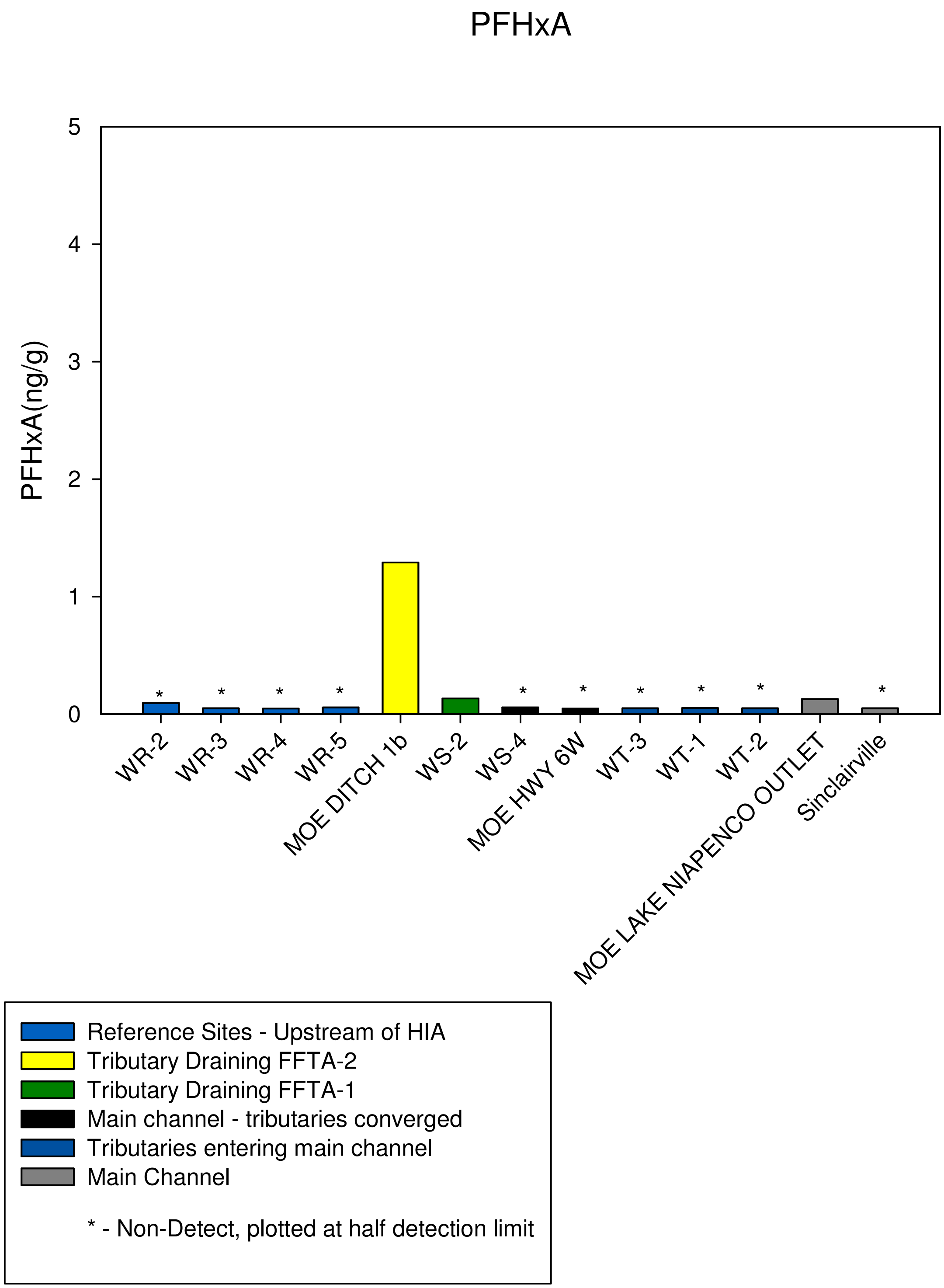
PFOSA
PFOSA (ng/L)
0
10
20
30
40
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

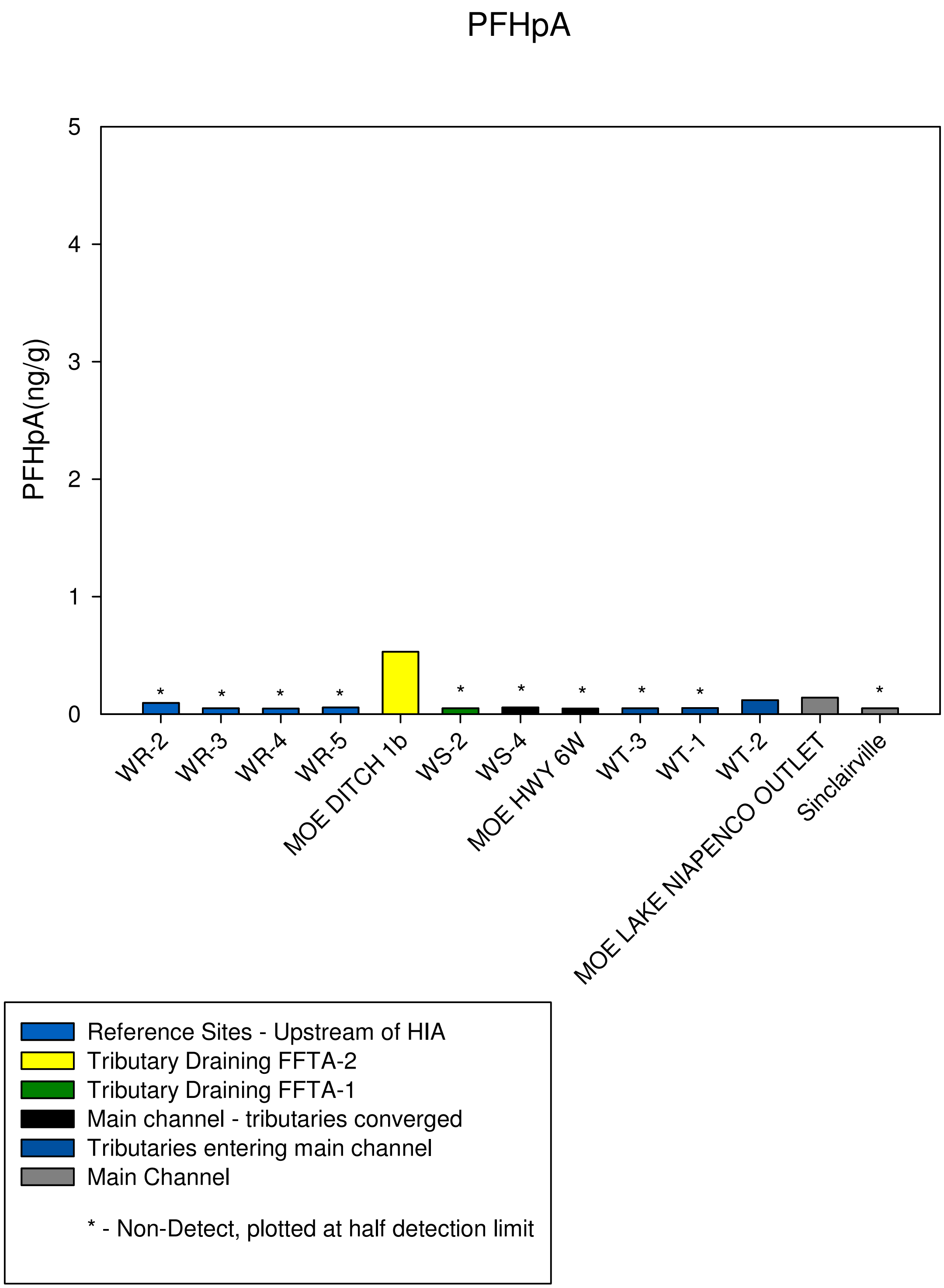
Sediment PFC Concentration Bar Charts


PFBA
PFBA (ng/g)
0
1
2
3
4
5
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

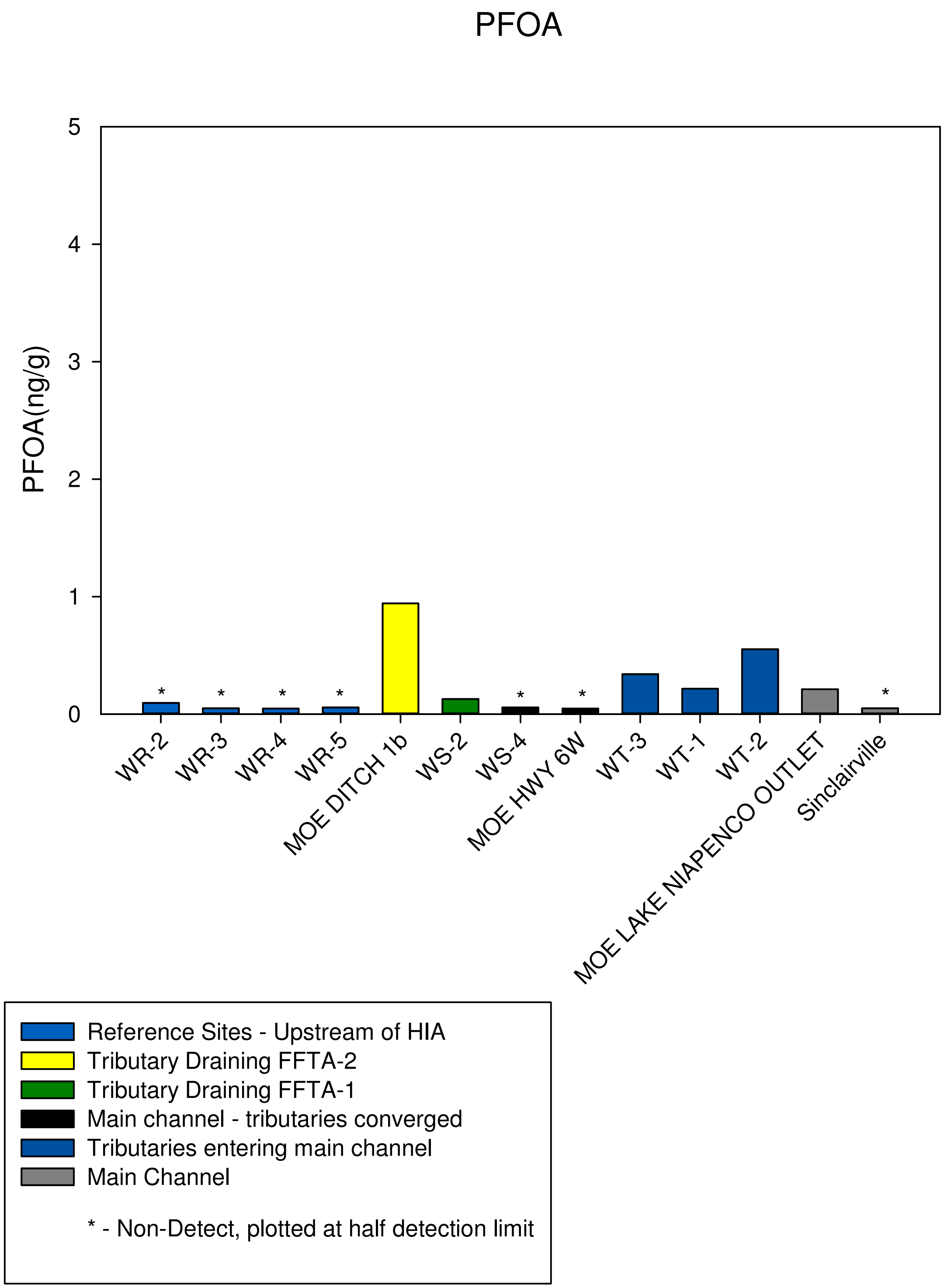


PFPeA
PFPeA (ng/g)
0
1
2
3
4
5
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

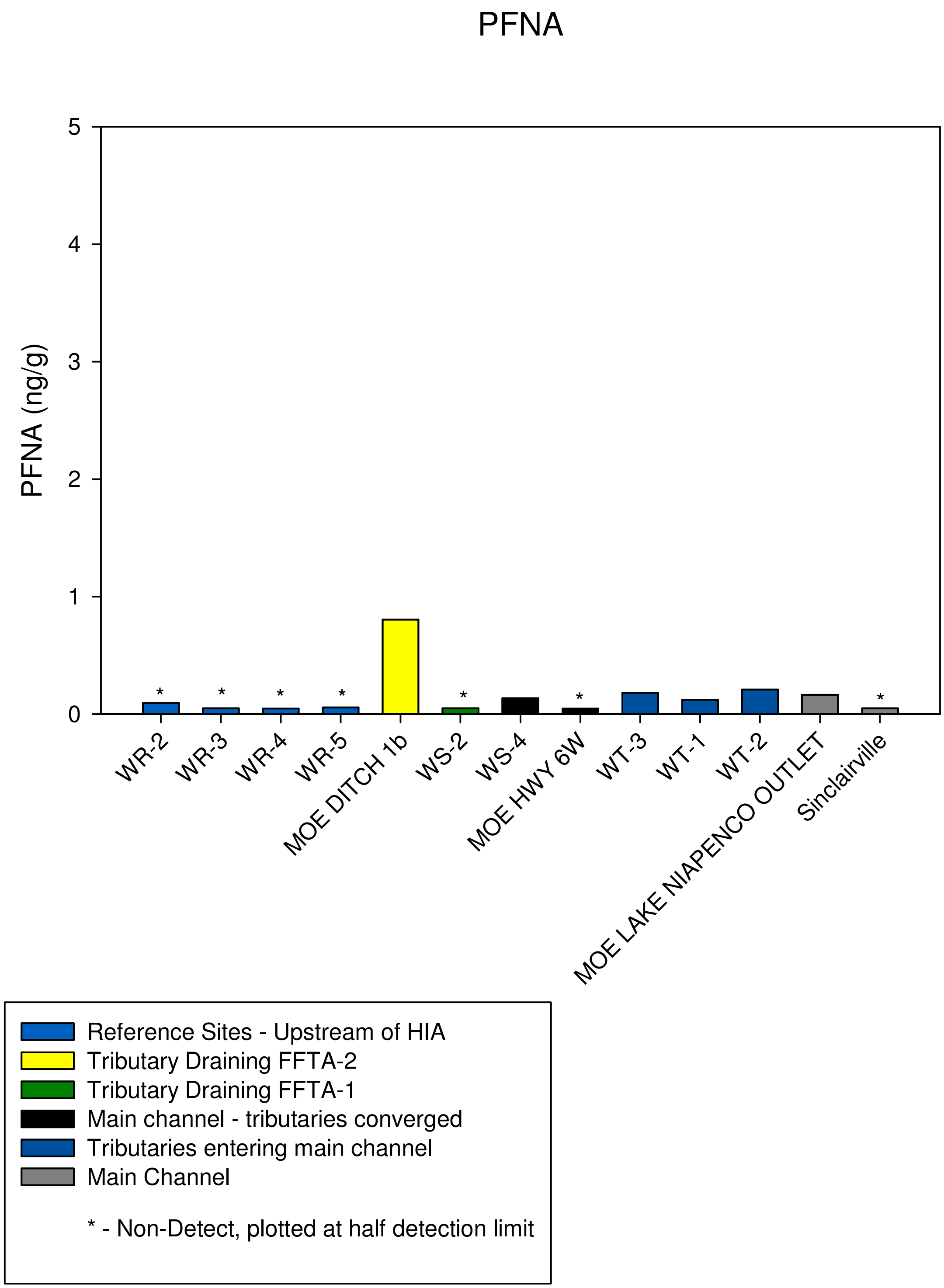

PFHxA
PFHxA(ng/g)
0
1
2
3
4
5
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

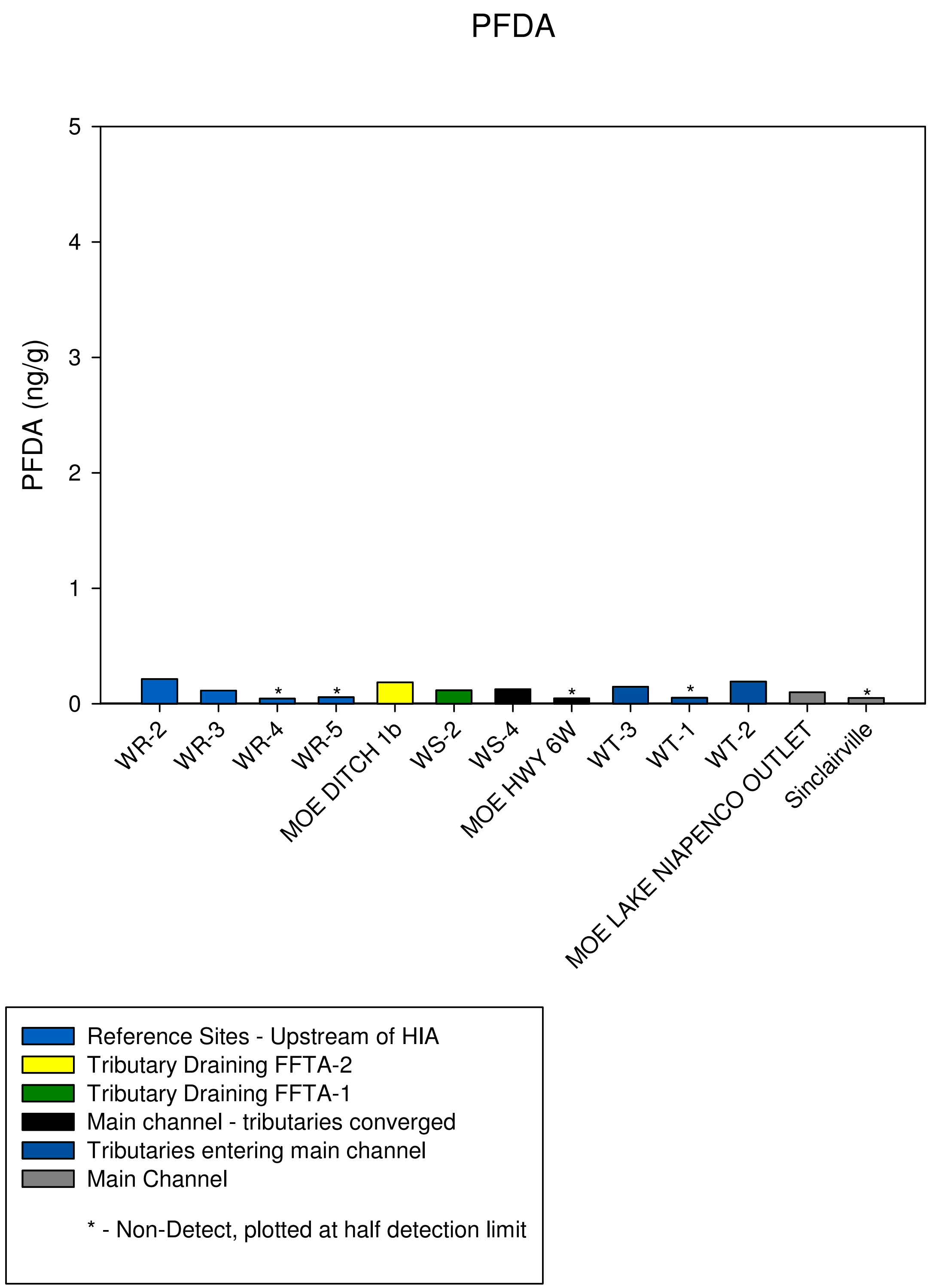


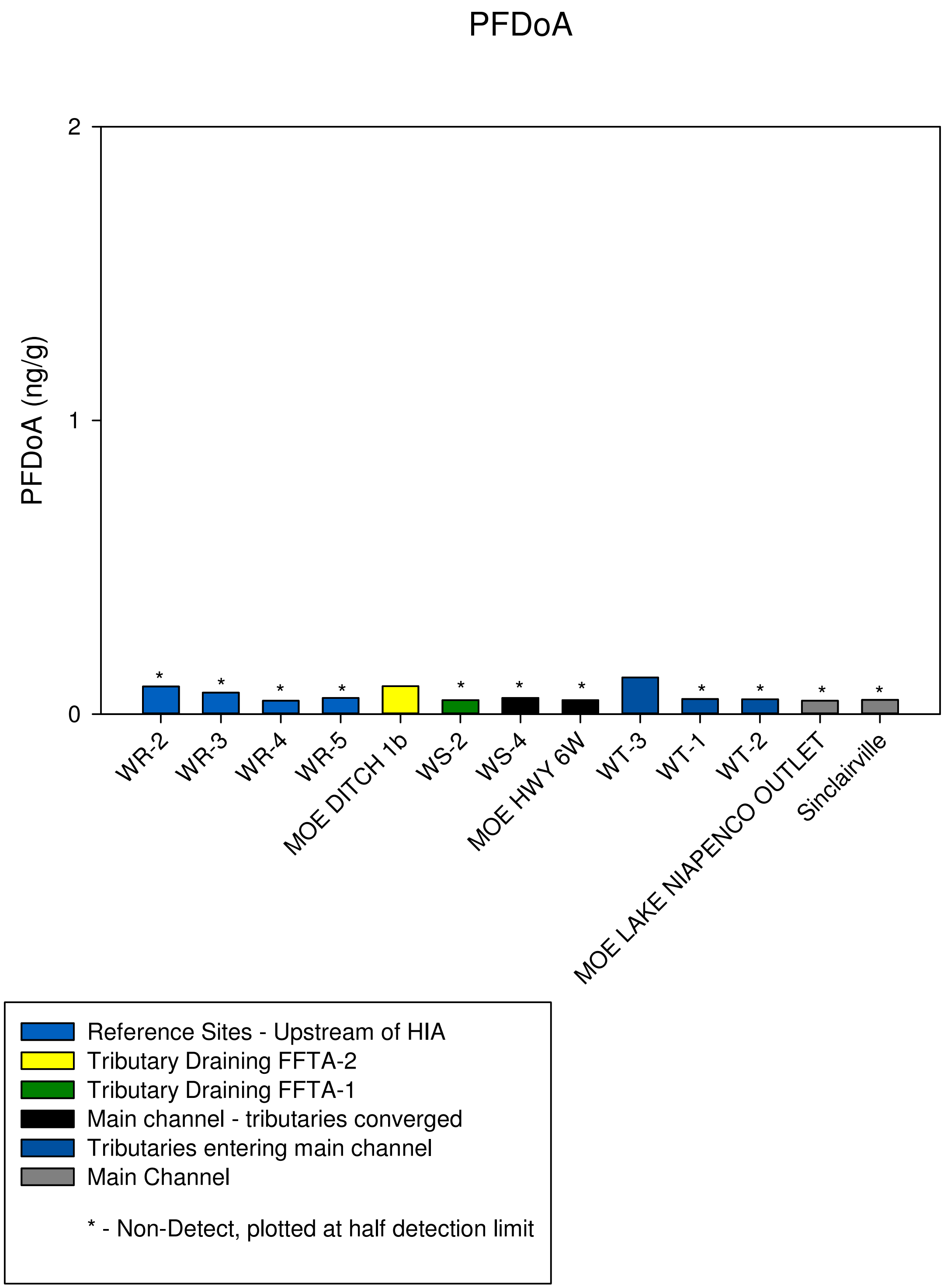
PFHpA
PFHpA(ng/g)
0
1
2
3
4
5
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit



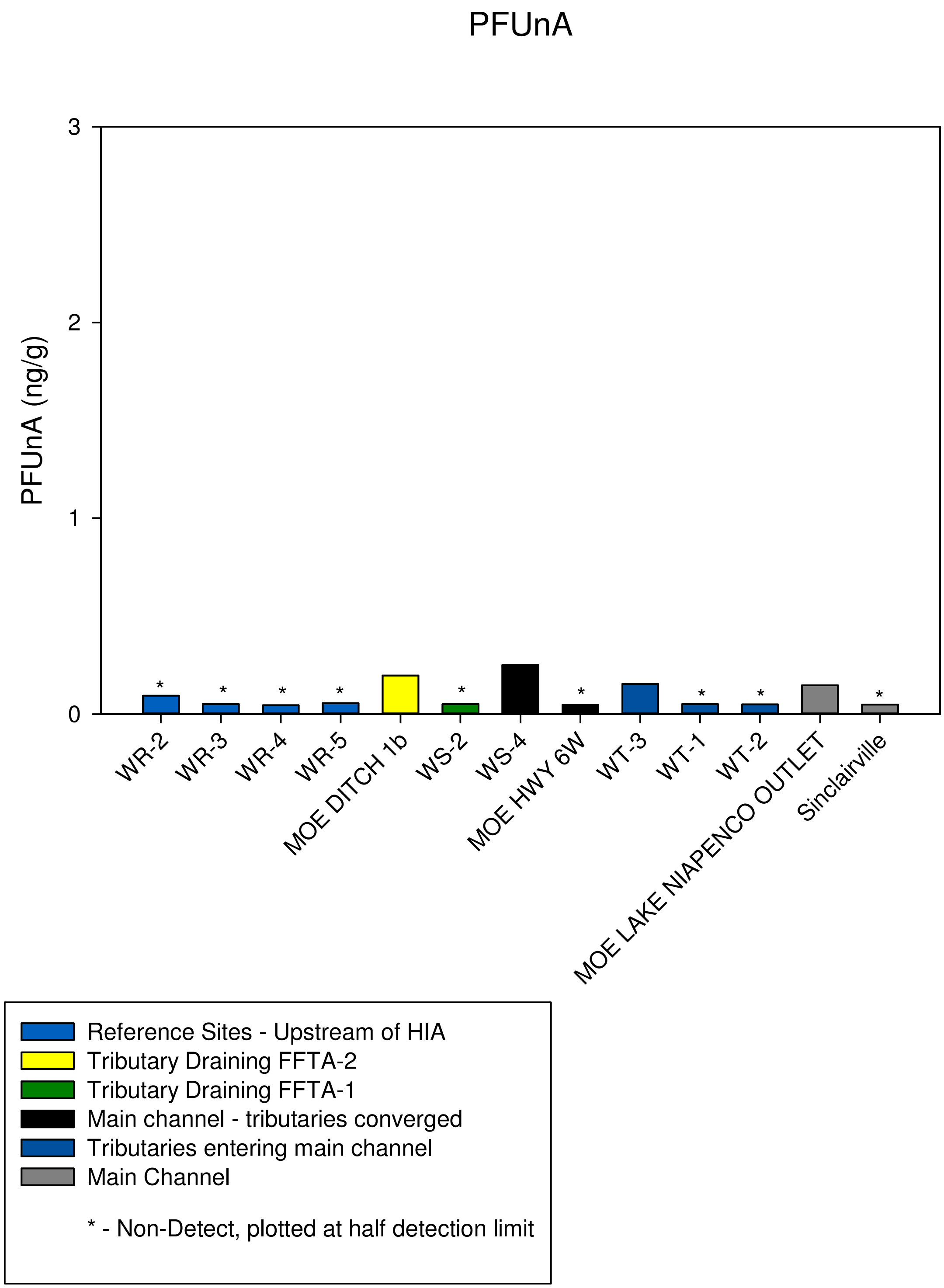
PFOA
PFOA(ng/g)
0
1
2
3
4
5
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit


PFNA
PFNA (ng/g)
0
1
2
3
4
5
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

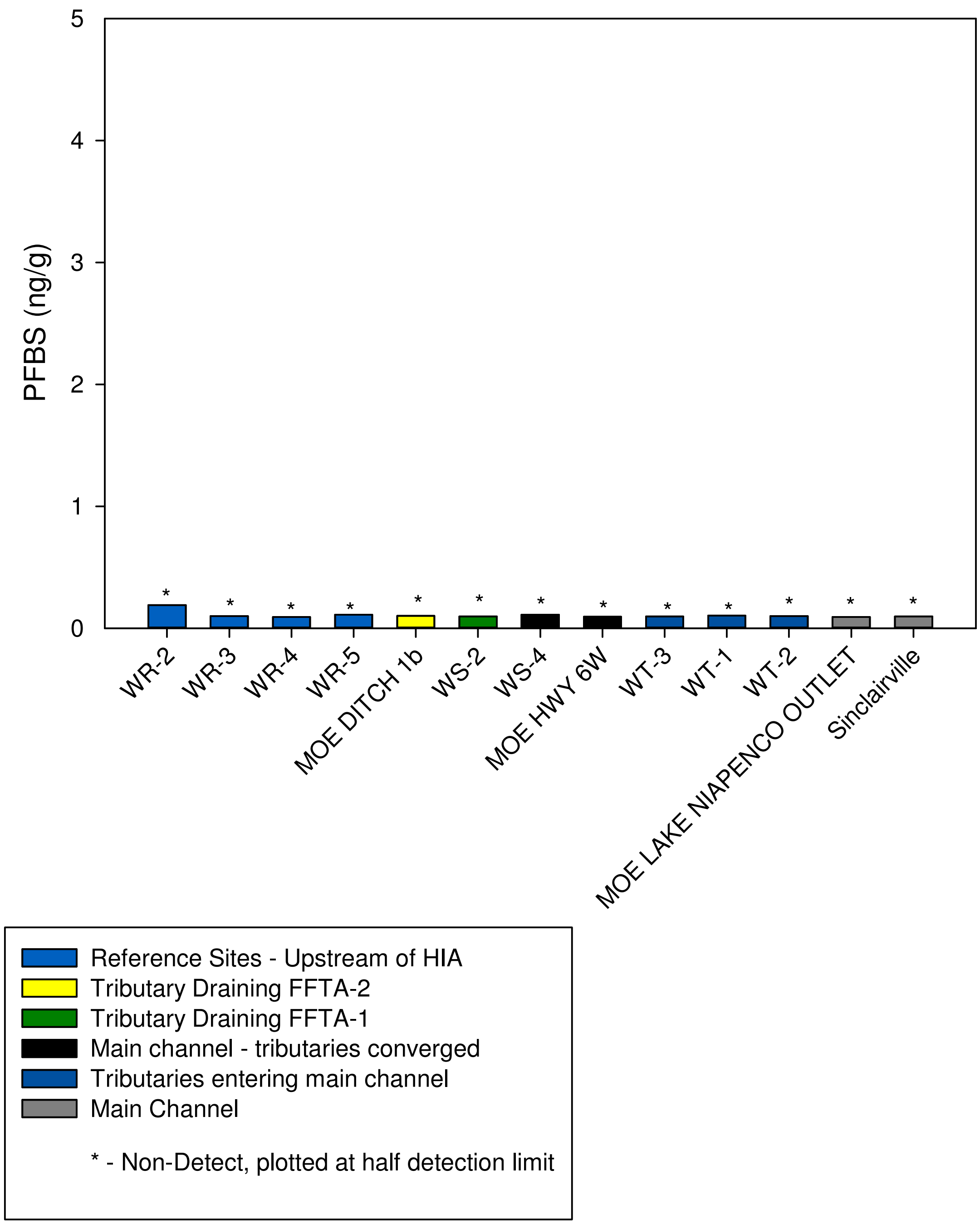

PFDA
PFDA (ng/g)
0
1
2
3
4
5
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

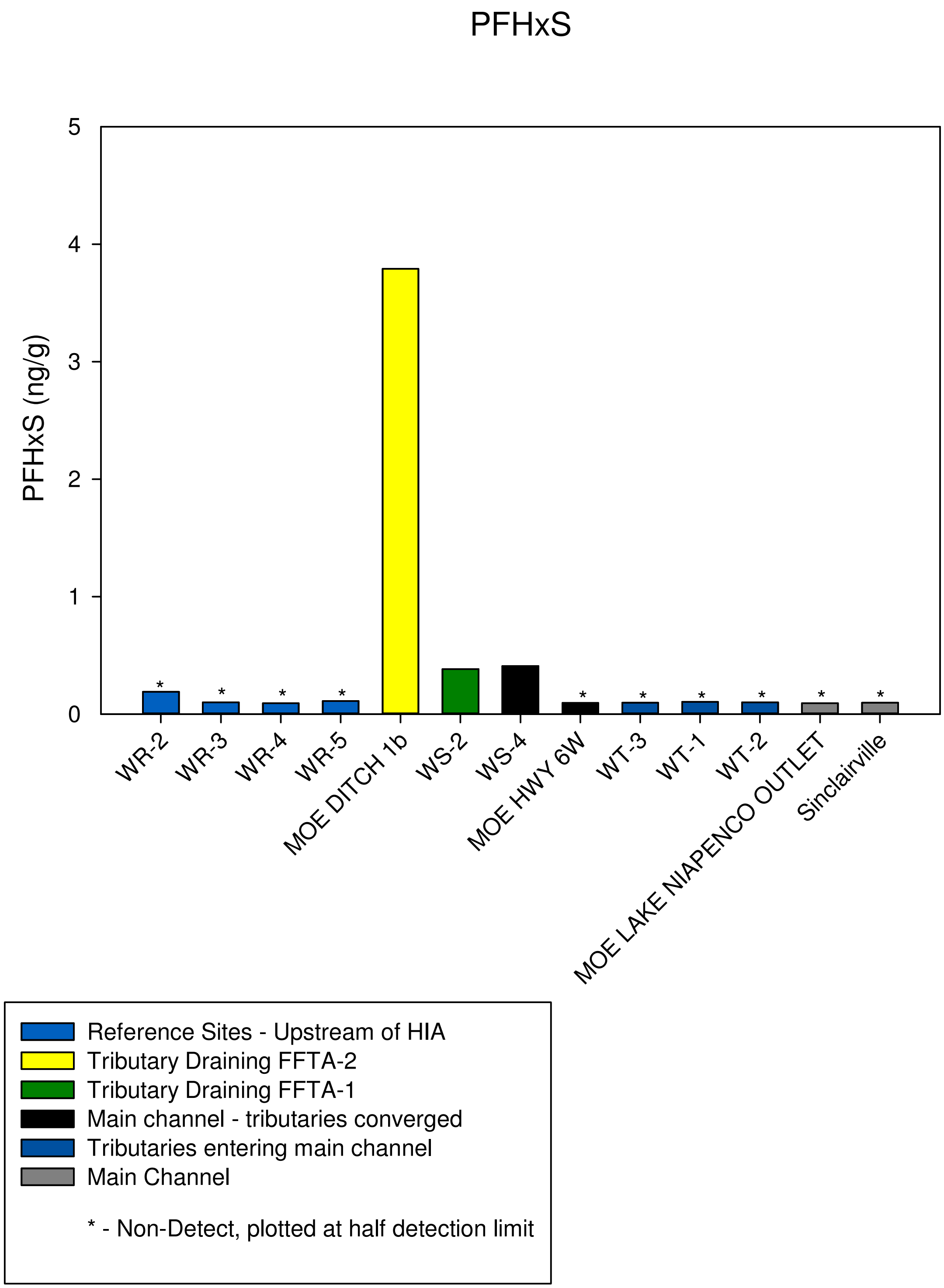


PFDoA
PFDoA (ng/g)
0
1
2
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit


PFUnA
PFUnA (ng/g)
0
1
2
3
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit

PFBS


PFBS (ng/g)
0
1
2
3
4
5
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit


PFHxS
PFHxS (ng/g)
0
1
2
3
4
5
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
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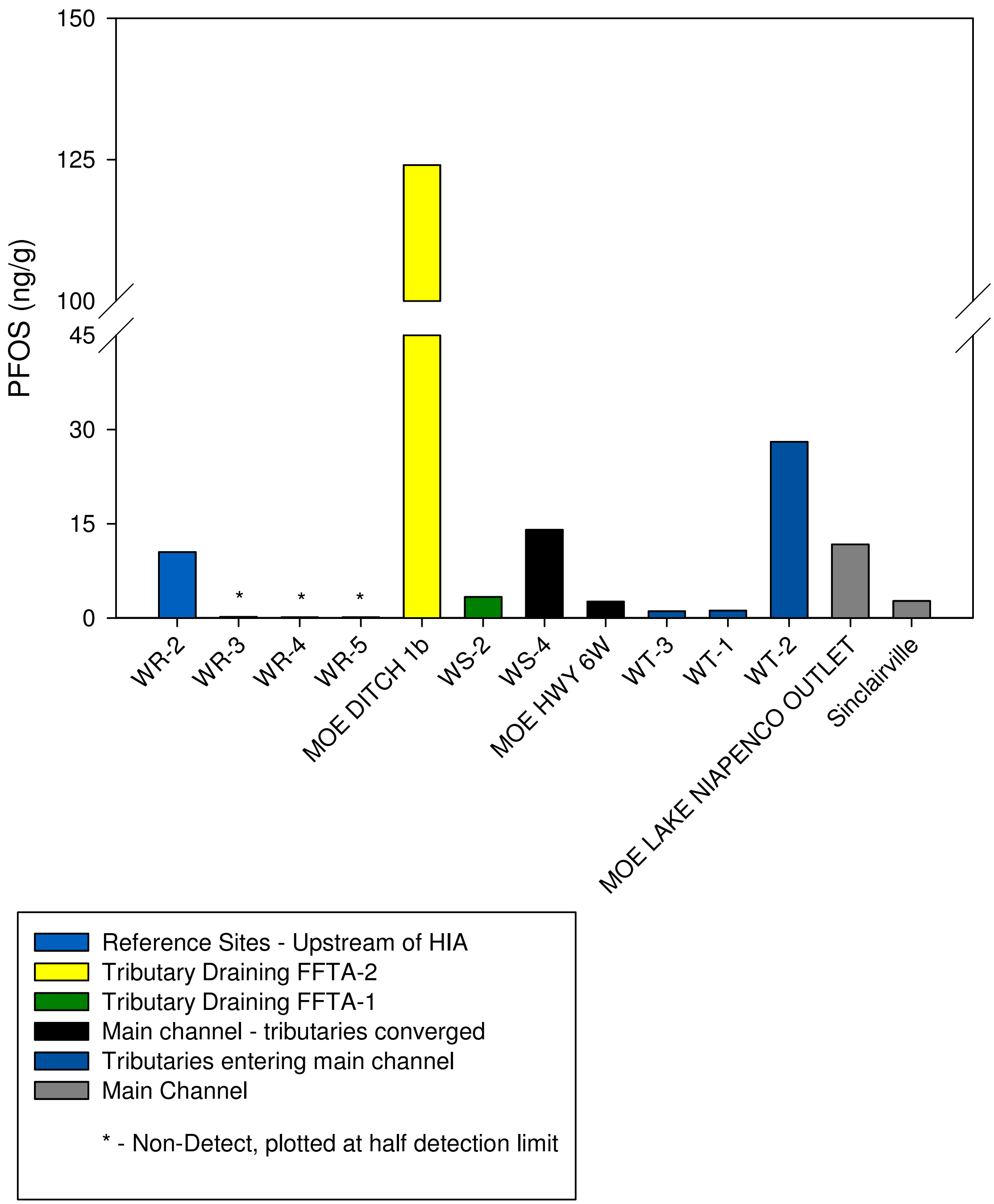
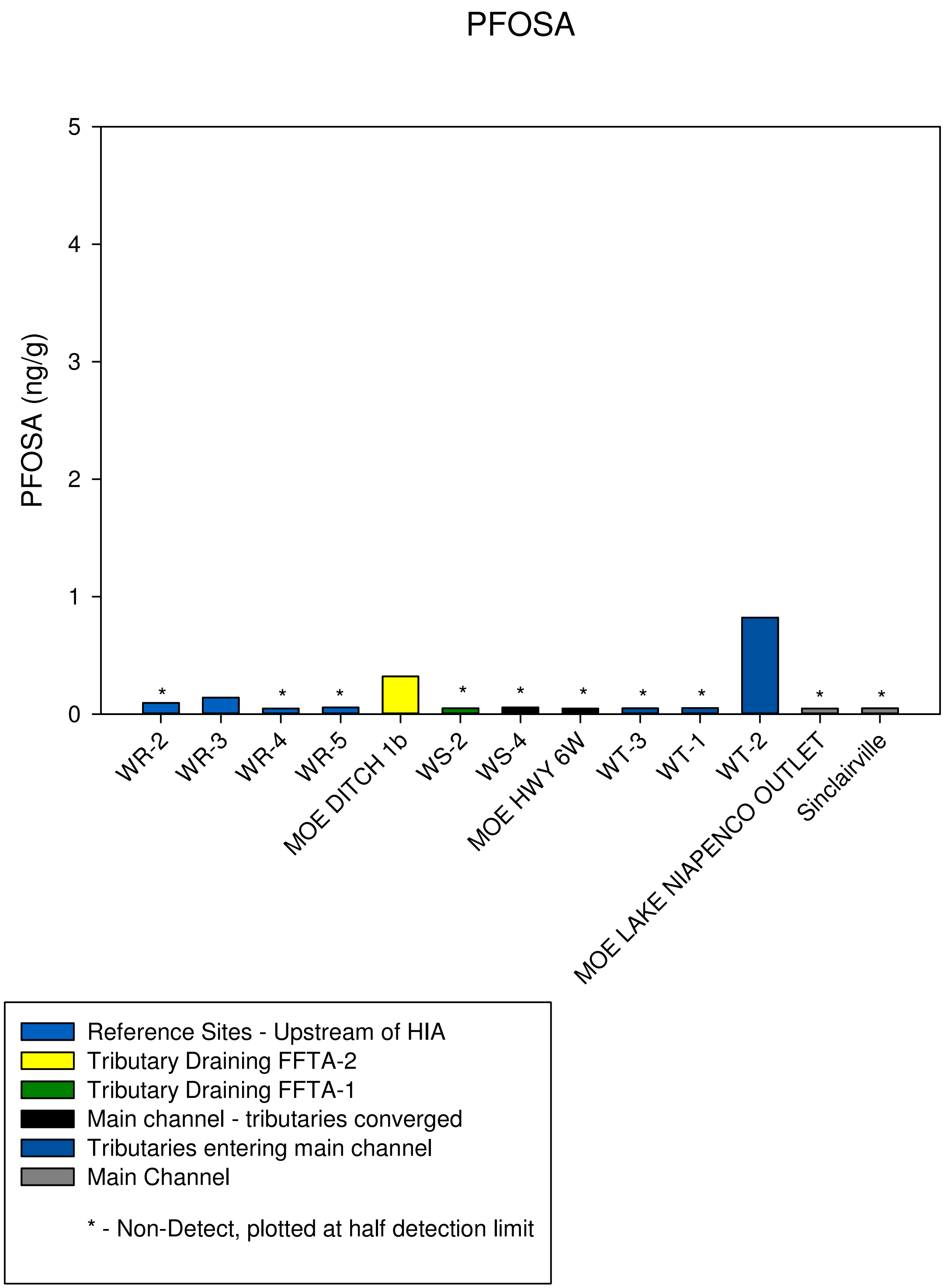
PFOS


PFOS (ng/g)
150
125
100
45
30
15
0
*
*
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
Sinclairville
Reference Sites - Upstream of HIA
Tributary Draining FFTA-2
Tributary Draining FFTA-1
Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit



PFOSA
PFOSA (ng/g)
0
1
2
3
4
5
*
*
*
*
*
*
*
*
*
*
*
WR-2
WR-3
WR-4
WR-5
MOE DITCH 1b
WS-2
WS-4
MOE HWY 6W
WT-3
WT-1
WT-2
MOE LAKE NIAPENCO OUTLET
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Main channel - tributaries converged
Tributaries entering main channel
Main Channel
* - Non-Detect, plotted at half detection limit


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