APPENDIX I
U.S. and Canadian Field Study Programs Investigating the Ecological Effects of Chemicals of Emerging Concern in the Great Lakes

1. Early Warning System to Identify the Effects of New Contaminants

In 2009, the USFWS initiated an early warning system to identify the effects of new contaminants (steroids, hormones, deodorizers, herbicides, disinfectants, and prescription and non-prescription drugs) in the Great Lakes environment. The objectives of the early warning system were to:

- Measure the concentration of emerging contaminants in natural resources located in the Great Lakes.
- Evaluate the toxicity of emerging contaminants to fish and wildlife resources.
- Relate environmental concentrations of emerging contaminants to toxicity values and effects to fish and wildlife resources.
- Evaluate the source, pathway, and effects of these contaminants to fish and wildlife resources (e.g., bioaccumulation through the foodweb).
- Recommend controls/regulations or resource management actions to prevent or reduce adverse impacts to fish and wildlife resources in the future.
- Collaborate with other federal agencies involved in the program (USEPA, NOAA, and USGS) to coordinate research to ensure efficient and effective use of funding.
- Establish a bibliographic database resulting from the literature search.
- Establish a database for collecting pilot project and future study information that is GIS-based.

Effects investigated included endocrine disruption, immune system/disease resistance, cancer/neoplasia, numerous physiological and pathological effects, and behavior. In 2010, USFWS conducted literature and database searches to identify concentrations of CEC, locations, and available toxicity information. Pilot projects were launched in the fall of 2010 at five locations in the Great Lakes: Duluth/Superior Harbor, Milwaukee, Detroit River, Swan Creek (Maumee Area of Concern) in Toledo, and Rochester, New York. Some sites overlap with US Legacy Act work (e.g., in the Duluth/Superior Harbor). A reference or background site was also included to differentiate effects of emerging contaminants from effects of legacy contaminants. In 2011, sampling will be repeated at the sites sampled in the fall of 2010, and the Ashtabula River will be added as a study site. USFWS will develop and maintain a database of study results, and trend analysis will be performed as the data allow. At the time of this report, preliminary results were not yet available.

2. Birds as Indicators of Contaminant Exposure in the Great Lakes

The USGS uses tree swallows and colonial waterbird species (cormorants, herons, and gulls) as indicators of contaminant exposure and potential effects in the Great Lakes. This project evaluates contaminant exposure across the Great Lakes and trends through time at Areas of Concern (AOCs), monitors remedy effectiveness, and quantifies contaminant effects. CEC such as polybrominated flame retardants (PBDEs), non-PBDE flame retardants, and perfluorinated compounds (PFCs) are being analyzed in addition to legacy contaminants (PCBs, dioxins and furans, and mercury). The uptake of bacteriostats and nonylphenols are being evaluated at selected sites. Standard study measurements include effect endpoints, such as reproductive success and physiological and genetic responses. Physiological and genetic responses include ethoxyresorufin-O-deethlyase (EROD) activity, oxidative stress, hematology, hormone analysis, immune responses, and DNA damage.

In 2010, the avian sampling effort included previously un-sampled areas in southern Lake Michigan, the south shore of Lake Superior, and eight AOCs. Some previously sampled areas were re-sampled, including Green Bay, Duluth, and Sheboygan, to begin to assess temporal trends. Four pilot study sites were sampled in collaboration with USFWS and NOAA: Detroit River, MI; Milwaukee, WI; Duluth, MN; and Maumee Bay area, Toledo, OH. Additionally, swallow boxes were erected at six more locations (including two AOCs), and sampling will begin at those sites in 2011.

Sampling at 20 study sites was completed by July 2010. Over 2,000 samples were collected and submitted to various analytical and biological laboratories. At the time of this report, some preliminary chemical results were available. Evaluation of effects endpoints will begin when the analytical chemistry data become available.

3. Expanded Mussel Watch Program

Founded in 1986, the NOAA Mussel Watch Program was designed to monitor the status and trends of local chemical contamination of US coastal waters, including the Great Lakes. The Mussel Watch Program began monitoring the Great Lakes in 1992, within a few years of the introduction of the invasive zebra mussels. Zebra and quagga mussels (*Dreissena* species), both invasive species, are collected annually from sites in the Great Lakes, and sediment sampling occurs every 10 years. In 2010, NOAA enhanced the traditional Mussel Watch Program to include monitoring of CEC and assessment of bioeffects in mussels and sediment of the Great Lakes. In addition to the analysis of newly collected samples, archived program samples allow for retrospective analysis of new chemical analytes.

Monitoring sites in the Enhanced Mussel Watch Program include Great Lakes AOCs and Mussel Watch Program sites. Traditional program measurements include trace elements, pesticides, PAHs, industrial chemicals, and butyltins. Enhanced analyses include sediment toxicity, concentrations of flame retardants and current use pesticides, and benthic (sediment) organism characterization. Ancillary measurements include reproductive stage characterization, bacteria characterization, and parasite, pathology, and disease intensity characterization. Collection of samples and analyses (contaminant concentrations, toxicity, histopathology, and gonadal index) began in the fall of 2009. At the time of this report, some preliminary results (traditional

chemistry, PBDE concentrations, histopathology, and benthic organism characterization) were available, but a complete data set for the Great Lakes was not available. For more information, see http://ccma.nos.noaa.gov/stressors/pollution/nsandt/greatlakes09/.

4. Canada's Environmental Effects Monitoring Program (EEM)

Canada's Environmental Effects Monitoring (EEM) Program, originally developed for the pulp and paper sector in 1990, has been incorporated into the metal mining industry and municipal waste water treatment plants. Through the Fisheries Act, Canada has authority to protect fish, fish habitat, and human use of fisheries resources. The EEM Program assesses the adequacy of effluent regulations by undertaking aquatic effects monitoring at all locations where effluent is discharged to the aquatic receiving environment. The program conducts iterative scientific evaluations of effects of effluent on fish, fish habitat, and the use of fisheries resources in a 2 to 6 year sequence of monitoring and interpretation phases. The program uses an adult fish survey to evaluate protection of fish, a benthic invertebrate community survey as a surrogate for fish habitat, a fish tissue and tainting survey to evaluate use of the fisheries resource, and integrated assessments of effects (McMaster 2010). Key effect endpoints are relative gonad weight, liver weight, condition, and growth. Additional endpoints examined include:

- Gonad development, egg size, fecundity, and expression of secondary sexual characteristics.
- Measurement of circulating vitellogenin, reproductive steroid hormone levels and thyroid hormones.
- Determination of steroid and thyroid biosynthetic capacity.
- Liver mixed-function oxidase.
- Histology of endocrine and other tissues (gonads, thyroid, liver).
- Liver tumors, deformities and other abnormalities.
- Binding of liver and SPMD extracts to endocrine receptors.

Industry is responsible for developing study designs, conducting field work, and preparing final reports. Environment Canada reviews study designs and results, updates government guidance documents, ensures national consistency, and conducts supporting research (McMaster 2010). For more information, see http://www.ec.gc.ca/esee-eem/?CFID=399245&CFTOKEN=44077959.

5. Great Lakes Nearshore Index Stations Network:

The Great Lakes Nearshore Index Station Network provides information on long-term and large scale-changes in water quality conditions by periodically monitoring a standardized suite of indicators at a standardized network of 60 stations throughout the Great Lakes Basin. Stations are either located in areas where background conditions for a lake sub-area prevail (index stations), or in locations where there is a natural integration of the stressors from a larger area (reference stations). Such areas include the delta zones of rivers, depositional zones in embayments and zones where prevailing water circulation

patterns focus stressors. The information gained on major trends in environmental conditions is used to evaluate management programs and to identify the onset of anomalous patterns or conditions. A lake-by-lake cycle is used with Lake Ontario and Lake Erie and their connecting channels sampled on a three year cycle. Lake Huron/Georgian Bay, Lake Superior and the Lake Huron North Channel are sampled on a six-year cycle. Between 10 and 18 locations are sampled each year, depending upon the lake and connecting channel under investigation.

Water quality is monitored for basic nutrients, ions and chlorophyll a in the spring, summer and fall. Chemical concentrations of persistent and biaccumulative contaminants, both legacy and current-use, are measured in surficial sediment and suspended sediment during the summer survey period. Summer sampling is also undertaken for benthic invertebrate enumeration and taxonomy as a biological indicator of trophic status and general environmental conditions. Thermal and optical profiles of the water column and physical characterization of the lake bottom are also observed as a measure of habitat integrity. Standard MOE sampling and analytical methodologies are employed to enable comparisons with historical and ongoing data collections elsewhere in the ministry.

6. Young of the Year (YOY) monitoring

To identify areas of concern and monitor contaminant trends over time, the Ontario Ministry of the Environment initiated a contaminant surveillance program using forage fish as biomonitors in the nearshore waters of the Great Lakes in 1975. Forage fish are used to assess temporal trends in contaminant levels in nearshore waters, determine the spatial extent of pollution throughout the Great Lakes, identify sources of contamination and assess the effectiveness of pollution control. They are ideal biomonitors because of their restricted home range, known exposure period and their key role in the food chain. Forage fish provide an important link in assessing contaminant transfer to higher trophic levels such as fish eating birds and wildlife.

Contaminant concentrations are compared to tissue residue benchmarks (IJC, CCME, NYSDEC), which are based on mammalian and avian studies and are set as guidelines for the protection of wildlife consumers of aquatic biota. Site-specific risk assessment must be performed to determine the actual risk to wildlife consumers of the forage fish since the guideline is based on conservative assumptions. The findings of this program have been widely reported in scientific papers, MOE greenbacks, reports and technical memos for the regions. The data is also used by Conservation Authorities and other agencies in watershed report cards, State of the Great Lakes Reports and Remedial Action Plan (RAP) reports.

7. Sportfish Monitoring

In 1976, the Sport Fish Contaminant Monitoring Program began measuring persistent contaminants in sport fish from Ontario waterbodies. This program has grown into one of the most comprehensive of its kind in North America, monitoring more than 1950 locations from the Canadian waters of the Great Lakes and selected inland lakes and rivers. Currently, the program monitors fish samples for many compounds, including mercury, PCBs, dioxins/furans and organochlorine pesticides, as well as emerging contaminants such as perfluorinated compounds

and polybrominated biphenyl ethers. The Ontario Ministry of Natural Resources collects the majority of samples, followed by program staff and Conservation Authorities, Consultants and Ontario Universities. The data is used to provide consumption advice for sport fish based on health protection guidelines developed by Health Canada. Consumption advisories are published biennially in the "Guide to Eating Ontario Sport Fish" (www.ontario.ca/fishguide). The data are also used to evaluate the success of remedial measures and to track long-term trends in fish contaminant levels.

8. Niagara River Biomonitoring

Since 1983 the Ontario Ministry of the Environment has monitored the concentrations of contaminants in caged mussel (*Elliptio complanata*) tissue and bottom sediments at sites in the Niagara River. The emphasis of the program since its inception has been to determine the presence/absence of contaminants at various sampling locations along the Niagara River (i.e., problem site identification), documenting the state of toxic substance contamination in biota. Significant differences in contaminant tissue concentrations between survey years within a site, and spatially between sites, suggested that the data could also be used to document the effectiveness of remedial actions implemented at identified sources along the river and, accordingly, has become a key component of the Niagara River Toxic Management Plan.

Over the past 26 years, the program has selectively monitored 62 sites on the Canadian and U.S. sides of the river for the presence of toxic chemicals (e.g., Mirex, PCBs, chlorinated benezenes, organochlorinated pesticides, dioxins and furans and PAHs). Stations are located at the head and mouth of the river, in tributaries and downstream of storm sewers, industrial outfalls and hazardous waste sites. Between 1983 and 1997, surveys were conducted every two years. More recently, they have been scheduled every three years. Typically, at least 30 stations have been monitored on each survey.