Recommendations for Actions to Address Priority Issues Relating to Toxic Substances in the Georgia Basin

April 2010
(Revised)

Final Report
of
the British Columbia Toxics Work Group
for the
Puget Sound/Georgia Basin International Task Force

OCEAN
COORDINATING
COMMITTEE

Recommendations for Actions to Address Priority Issues Relating to Toxic Substances in the Georgia Basin

Final Report of the British Columbia Toxics Work Group for the Puget Sound/Georgia Basin International Task Force

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DISCLAIMER

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Abstract

The Puget Sound/Georgia Basin International Task Force (PS/GB ITF) was formed by the British Columbia/Washington Environmental Cooperation Council (ECC) (created as a result of a signed agreement between the Province of British Columbia and the State of Washington) to jointly address concerns in the environment of the Puget Sound and Strait of Georgia. A Marine Science Panel of environmental experts from the United States and Canada was formed to develop recommendations on priority issues for the shared waters of Puget Sound and the Strait of Georgia. One of the priority issues identified by the Marine Science Panel was the control of toxic waste discharges. At the request of the PS/GB ITF, the British Columbia Toxics Work Group (BCTWG) (formerly called the Canadian Toxics Work Group) was formed and this multi-agency group was charged with identifying priority toxics-related issues within the Georgia Basin; making recommendations for future research, monitoring, and management actions; and developing an action plan for addressing the highest priority toxics-related issues in the Georgia Basin.

This report includes recommendations with respect to research, monitoring, and management actions needed to address priority substances of concern in the Georgia Basin. It also summarizes the process used by the BCTWG in identifying these priorities substances and in developing these recommendations. The recommendations focus on the highest priority substances or substance groups, as identified by BCTWG member agencies in 2005. However, the PS/GB ITF was disbanded before the BCTWG was able to complete its Terms of Reference. Although a draft of the report had been provided to the PS/GB ITF, a final report was not formally presented to the PS/GB ITF and its publication was put on hold. However, due to the valuable information and recommendations contained in the report, the decision was made to update and distribute this report and to make it available as a planning tool for future work on environmental contaminants in the Georgia Basin. In 2009, the report was reviewed by past member agencies of the BCTWG and the updated information on toxics-related projects and activities provided by these agencies was incorporated into a revised report. There was some concern that the recommendations in the report, which were developed by consensus based on information available to the BCTWG in 2005, would now be outdated. However, the 2009 review by member agenies confirmed that both the priorities and recommendations identified in the report are still current and, for this reason, few changes were made to the original priorities and recommendations identified in the 2005 draft report. It is important to note, however, that the BCTWG viewed the toxics action plan for the Georgia Basin as a living product and recognized that the priorities will change over time as new and emerging issues are identified.

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List of Acronyms and Abbreviations

Acronym/Abbreviation	Meaning
µg/L	micrograms per litre
µg/m^3	micrograms per cubic metre
ABS	acrylonitrile-butadiene-styrene
ACA	ammoniacal copper arsenate
ACQ	alkaline copper quaternary
ACZA	ammoniacal copper zinc arsen2ate
AET	apparent effects threshold
Ag	silver
ARD	acid rock drainage
AMPA	aminomethylphosphonic acid
AOX	adsorbable organic halides
AP	alkylphenol
APF	Agricultural Policy Framework
APnEOs	alkylphenol polyethoxylates
BBP	butylbenzyl phthalate
BC	British Columbia
BCF	bioconcentration factor
BC MAL	BC Ministry of Agriculture and Lands
BC MOE	BC Ministry of Environment
BCTWG	British Columbia Toxics Work Group (of the PS/GB ITF)
BC MOH	BC Ministry of Health
BCWQC	BC Water Quality Criteria
BDE	brominated diphenyl ether
BIEAP	Burrard Inlet Environmental Action Plan
B-IBI	benthic index of biotic integrity
BMPs	Best Management Practices
BOD	biological oxygen demand
CABIN	Canadian Aquatic Biomonitoring Network
CCA	copper chromium arsenate
CCME	Canadian Council of Ministers of the Environment
Cd	cadmium
CDPEs	chlorinated diphenyl ethers
CEAA	*Canadian Environmental Assessment Act*
CEPA	*Canadian Environmental Protection Act*
CFIA	Canadian Food Inspection Agency
CMN	Community Mapping Network
CPPA	Canadian Pulp and Paper Association
Cr	chromium
CRD	Capital Regional District
CSMWG	Contaminated Sites Management Working Group
CSO	combined sewer overflow

List of Acronyms and Abbreviations

Acronym/Abbreviation	Meaning
CWS	Canadian Wildlife Service
CWSs	Canada-Wide Standards
DAP	diallyl phthalate
DBDE	decabromodiphenyl ether (commercial PBDE mixture)
DBP	di-n-butyl phthalate
DBT	dibutyltin
DDAC	didecyldimethylammonium chloride
DDD	2,2-bis(p-chlorophenyl)-1,1dichloroethane
DDE	1,1-dichloro-2,2-bis(p-chlorophenyl)-ethene
DDT	2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane
DEHP	bis(2-ethylhexyl)phthalate or di(2-ethylhexyl)phthalate
DEP	diethyl phthalate
DHAA	dehydroabietic acid
DIBP	diisobutyl phthalate
DIDP	diisodecyl phthalate
DFO	Department of Fisheries and Oceans (or Fisheries and Oceans Canada)
DMP	dimethyl phthalate
DnOP	di-n-octyl phthalate
Dw	dry weight
EC	Environment Canada
EC_{50}	median effect concentration (concentration at which 50% of the exposed organisms show a specific effect)
ECC	Environmental Cooperation Council
EDCs	endocrine-disrupting compounds
EEM	environmental effects monitoring
EFP	Environmental Farm Planning
EMA	*Environmental Management Act*
ENGOs	Environmental Non-Government Organizations
EPA	Environmental Protection Agency (United States)
EROD	ethoxyresorufin O-deethylase
FA	*Fisheries Act*
FCSAAP	Federal Contaminated Sites Accelerated Action Plan
FCSAP	Federal Contaminated Sites Action Plan
FCSI	Federal Contaminated Sites Inventory
FOCs	fluorinated organic compounds
FPTCC	Federal/Provincial Toxic Chemicals Committee
FRAP	Fraser River Action Plan
FREMP	Fraser River Estuary Management Program
G	gram
GB	Georgia Basin
GBAP	Georgia Basin Action Plan
GBEI	Georgia Basin Ecosystem Initiative
GIS	geographic information system
GPP	Groundwater Protection Program

List of Acronyms and Abbreviations

Acronym/Abbreviation	Meaning
GVRD	Greater Vancouver Regional District
HC	Health Canada
HCB	hexachlorobenzene
HCH	hexachlorocyclohexane
Hg	mercury
HMW	high molecular weight
HpCDD	heptachlorodibenzodioxin
HxCDD	hexachlorodibenzodioxin
IMO	International Maritime Organization
IOS	Institute of Ocean Sciences (of DFO)
IPBC	3-iodo-2-propynyl butyl carbamate
IPM	Integrated Pest Management
IPMA	*Integrated Pest Management Act*
ISMPs	Integrated Stormwater Management Plans
ISQG	Interim Sediment Quality Guideline
Kg	kilograms
Km	kilometres
K_{ow}	octanol/water partition coefficient
LC_{50}	the lowest concentration of a contaminant that will kill 50% of the test organisms (median lethal concentration)
LMW	low molecular weight
LOEC	lowest-observed-effects-concentration
LOEL	lowest-observed-effect-level
LWMPs	Liquid Waste Management Plans
M	metres
MATC	maximum-acceptable-toxicant-concentration
MBT	monobutyltin
MFO	mixed function oxidases
mg/L	milligrams per litre
MMT	methylcyclopentadienyl manganese tricarbonyl
Mn	manganese
MOU	Memorandum of Understanding
MTBE	methyl tertiary-butyl ether
NAP	National Action Plan
ND	non-detectable or not detected
ng/L	nanograms per litre
Ni	nickel
NOAA	National Oceanic and Atmospheric Administration
NOEC	no-observed-effect-concentration
NP	nonylphenol

List of Acronyms and Abbreviations

Acronym/Abbreviation	Meaning
NPnEO	nonylphenol ethoxylates
NPRI	National Pollutant Release Inventory
NPS	non-point source
NWRI	National Water Research Institute (of EC)
OBDE	octabromodiphenyl ether (commercial PBDE mixture)
OC	organochlorine
OCDD	octachlorodibenzodioxin
OCP	Official Community Plan
P	phosphorus
P2	pollution prevention
PAHs	polycyclic aromatic hydrocarbons
PBDEs	polybrominated diphenyl ethers
P-B-T	persistent-bioaccumulative-toxic
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzodioxins
PCDFs	polychlorinated dibenzofurans
PCNs	polychlorinated naphthalenes
PCP	pentachlorophenol
PCPA	*Pest Control Products Act*
PeBDE	pentabromodiphenyl ether (commercial PBDE mixture)
PEL	probable effects level
PESC	Pacific Environmental Science Centre (EC laboratory)
PFAs	perfluorinated acids
PFOA	perfluoroalkyl sulfonic acid
PFOS	perfluorooctane sulfonate
pg/L	picograms per litre
pg/m^3	picograms per cubic metre
PMRA	Pest Management Regulatory Agency
POPs	persistent organic pollutants
PPCPs	pharmaceuticals and personal care products
PPER	*Pulp and Paper Effluent Regulations* (under the *Fisheries Act*)
Ppq	parts per quadrillion
PS/GB ITF	Puget Sound/Georgia Basin International Task Force
PSL	Priority Substances List (CEPA)
PVC	polyvinyl chloride
QACs	quaternary ammonium compounds
QA/QC	quality assurance/quality control
RSCP	Regional Source Control Program (of CRD)
SETAC	Society of Environmental Toxicology and Chemistry
SFU	Simon Fraser University
SHWP	Stormwater, Harbours and Watersheds Program (of CRD)
SLRAs	Screening Level Risk Assessments (CEPA)
SOP	Strategic Options Process (CEPA)
SORs	Strategic Options Reports (CEPA)

List of Acronyms and Abbreviations

Acronym/Abbreviation	Meaning
SPMDs	semi-permeable membrane devices
SPMEs	solid phase microextraction fibers
T	tonnes
t/yr	tonnes per year
TBT	tributyltin
TCDD	tetrachlorodibenzodioxin
TCDF	tetrachlorodibenzofuran
TCMTB	2-(thiocyanomethylthio)benzothiazole
TEL	threshold effects level
TEQ	toxic equivalence; toxic equivalency; or toxic equivalents
TIA	total impervious area
TOC	total organic carbon
TRD	Technical Recommendations Document
TSMP	Toxic Substances Management Policy
TSS	total suspended solids
UBC	University of British Columbia
UK	United Kingdom
UV	ultraviolet
US	United States
VEHEAP	Victoria and Esquimalt Harbours Environmental Action Plan
WW	wet weight
WMA	*Waste Management Act*
WWTP	wastewater treatment plant

Executive Summary

Background

The purpose of this report is to identify priority issues and data gaps relating to toxic substances in the Georgia Basin and to make recommendations for addressing these issues. This report was prepared by the British Columbia Toxics Work Group (BCTWG) (formerly called the Canadian Toxics Work Group) at the request of the Puget Sound/Georgia Basin International Task Force (PS/GB ITF). This request stemmed from recommendations made to the British Columbia (BC)/Washington Environmental Cooperation Council (ECC) by a Marine Science Panel of environmental experts from the United States and Canada, who identified toxic waste discharges as one of several issues which needed to be addressed to protect the shared waters of Puget Sound and Georgia Basin (also referred to as the Salish Sea). Several work groups were formed in Washington State[1] and in British Columbia for the purpose of developing action plans to address these issues.

The BCTWG was a multi-agency group (refer to Appendix 2 for a list of members) which was formed to prepare an action plan to address priority issues relating to toxic substances in the Georgia Basin. To accomplish this goal, the BCTWG identified priority toxic substances and related issues within the Georgia Basin, evaluated existing information, and developed recommendations for future research, monitoring and management actions. This report summarizes the findings and recommendations of the BCTWG and, under the requirements of the Terms of Reference, was to be presented to the the PS/GB ITF. However, the PS/GB ITF was disbanded prior to the finalization of this report. Although progress reports on the work of the BCTWG and an earlier draft of this report were provided to the Task Force, the final report and recommendations were never formally presented and the finalization and publication of the report was put on hold. In 2009, due to the valuable information and the important recommendations contained in the report, the report was reviewed and updated by past member agencies of the BCTWG in preparation for its publication and distribution for use as a planning tool for future work on toxic substances in the Georgia Basin. Updated information on projects and activities has been incorporated into this revised report. Since the priority issues identified and the recommendations presented in the report were developed by consensus based on information available to the BCTWG in 2005, there was some concern that the identified priorities and the recommendations would be outdated. However, the reviewing agencies noted that the priorities and recommendations identified by the BCTWG in 2005 are still current in 2009 and, for this reason, few changes were made to the original priorities and recommendations identified in the 2005 draft report. It is hoped that this document will provide guidance on future actions needed to address toxic substance-related issues within the Georgia Basin.

[1] For a summary of priority toxics-related issues in Puget Sound and recommendations to address these issues, refer to reports by EVS Environmental Consultants (EVS 2003a,b).

Recommendations of the BCTWG

The recommendations in this report focus on the highest priority substances or substance groups as identified by BCTWG member agencies. Although the BCTWG recognized that there are a very large number of potentially toxic substances which may be of concern in the aquatic environment of the Georgia Basin (see Appendix 4), the Terms of Reference of the Work Group (Appendix 3) specified the development of recommendations to address only the highest priority substances. In order to identify the highest priority substances or substance groups, member agencies of the BCTWG consulted extensively within their organizations. Initially, a very wide range of substances were considered (Appendix 4); however, this list was refined by eliminating substances which met the following criteria:

1.) they are being adequately addressed under other initiatives (e.g., lead);
2.) they are not within the Terms of Reference of the BCTWG (e.g., those chemicals which are considered to be of much greater concern to human health than to the environment and their release to the environment is being addressed due to human health concerns (e.g., biological contaminants[2] and radiologic constituents); and/or
3.) they are exclusively air issues (e.g., ozone, respirable particulate matter, NOx, etc.).

Final consultations and consensus within the BCTWG identified the following substances to be of the highest priority within the Georgia Basin:

- the legacy or conventional persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT), hexachlorobenzene (HCB), toxaphene, hexachlorocyclohexane (HCH), polycyclic aromatic hydrocarbons (PAHs), and dioxins/furans (PCDDs/PCDFs);
- new or emerging POPs such as alkylphenol (AP) and alkylphenol ethoxylates (APnEOs), halogenated diphenyl ethers (especially polybrominated diphenyl ethers (PBDEs)), phthalate esters, chlorinated paraffins, polychlorinated naphthalenes (PCNs), and fluorinated organic compounds (FOCs);
- current-use toxic pesticides including:
  - agricultural pesticides, such as atrazine and endosulfan;
  - antisapstain chemicals, didecyldimethylammonium chloride (DDAC) and 3-iodo-2-propynyl butyl carbamate (IPBC); and
  - antifouling chemicals based on organotin and copper compounds;
- metals including cadmium, chromium, copper, manganese, mercury, nickel, silver and zinc;
- nitrogen-containing nutrients; and
- wood extractives.

The BCTWG also opted to exclude those substances for which insufficient information was available to determine whether or not they are of concern in the Georgia Basin. However, substances such as bisphenol A, ethylene glycol, pharmaceutical and personal care products and their metabolites, phenols, and phytoestrogens were identified as substances of probable concern. It was concluded that insufficient information was available, at that time, to determine whether

[2] Biological contaminants can adversely impact aquatic life and human pathogens have been detected in marine mammals. Although biological contaminants were not included in the review by the BCTWG, it is recommended that the potential for environmental impacts from pathogens in areas of untreated sewage discharges and NPS drainage from from agricultural sources be assessed.

these chemicals should be considered high priority in the Georgia Basin; however, the BCTWG recommended that these substances be further assessed to determine whether they should be added to the list of priority substances for the Georgia Basin.

While the recommendations presented in this report focus on the priority substances and substance groups for which profiles were developed, it is important to note that the BCTWG views the toxics action plan for the Georgia Basin as a “living product” and recognizes that priorities will change as new and emerging issues are identified.

Recommendations for future research, monitoring, and management actions to address priority substances in the Georgia Basin:

Recommendations of the BCTWG with respect to both research and monitoring and management actions have been separated into two categories:

1.) General: recommendations which are general in nature and, therefore, apply to most or all of the substances of highest concern in the Georgia Basin, and
2.) Substance-specific: recommendations which are specific to an individual substance or substance group.

Since the initiation of actions on the general recommendations would help to address concerns relating to a wide range of substances, the BCTWG considers these recommendations to be of the highest priority. While actions on the substance-specific recommendations would result in a better understanding of select toxic substances and could significantly reduce their release to the Georgia Basin, it was considered unlikely that the positive impacts of these actions would be as far-reaching as those for the general recommendations. Therefore, while actions on substance-specific recommendations are strongly encouraged, they are considered to be of somewhat lower priority.

The following is a summary of the high priority general recommendations. A more detailed discussion of these recommendations is provided in Section 3.2 and in Table 1a (research and monitoring) and in Section 3.3 and in Table 2a (management actions). Substance-specific recommendations for research and monitoring and management actions are presented in Tables 1b and 2b, respectively.

Priority Recommendations for Research and Monitoring[3]:

Develop a system for the better sharing, management, and communication of information and data on toxic substances. Much of the available information on toxic substances in the Georgia Basin is contained in paper files and reports that are not readily accessible to most stakeholders. A web-based centralized repository of information and contacts or linked databases would assist in the better dissemination and sharing of available information**.**

- ***Obtain current information on environmental levels of priority toxic substances and substances of probable concern in the Georgia Basin.*** Very limited routine environmental monitoring of toxic substances in the Georgia Basin is in place for most

[3] These recommendations also apply to substances identified to be of probable concern, but for which more information is needed to determine if they should be considered priority substances in the Georgia Basin. The BCTWG identified several substances to be of probable concern including pharmaceutical and personal care products and their metabolites, bisphenol A, ethylene glycol, phenols, and phytoestrogens. However, over time new substances of probable concern will be identified for the Georgia Basin and should be considered within the scope of these recommendations.

areas, particularly in the marine environment. Existing information is insufficient to identify temporal trends, emerging issues, or to measure environmental improvements which may occur as a result of the implementation of management actions. Long-term coordinated monitoring programs are required in order to fill these information gaps in priority areas of the Georgia Basin.

- ***Develop a better understanding of the potential biological impacts on local species and the factors which affect the toxicity of priority toxic substances and substances of probable concern in the Georgia Basin.*** Elevated concentrations of several priority substances (sometimes in excess of Canadian environmental quality guidelines) have been identified in some areas of the Georgia Basin. However, the potential biological impacts of current concentrations on local species, the ecological consequences of these impacts, and the factors which influence the potential of these substances to accumulate in biota and to cause adverse effects in the Georgia Basin are not well understood. This is particularly true for aquatic environments with multiple stressors (including stresses related to degraded habitats, climate change, land use, invasive species, and exposure to traditional pollutants).
- ***Develop a better understanding of the environmental fate and distribution of priority substances and substances of probable concern in the Georgia Basin.*** It is important to better understand the behaviour and environmental fate of priority substances once they enter the Georgia Basin environment. The tendency of these substances to remain in the water column, be deposited in the bottom sediments, volatilize to the atmosphere, accumulate and persist in environmental media, and degrade and/or transform to metabolites and breakdown products of greater or lesser toxicity, are important factors in predicting their environmental risks. These factors can be greatly influenced by the variations in environmental conditions found throughout the Georgia Basin.
- ***Better define sources (especially non-point sources) of priority substances and substances of probable concern which are released to the Georgia Basin in both urban and agricultural areas.*** Although concerns remain with respect to point sources of contaminants to the Georgia Basin, past initiatives have been successful in reducing the environmental loadings of contaminants from major point source discharges. Information is available on the loadings to the environment of many of the substances identified as priority substances for the Georgia Basin; however, additional information is required for several other priority substances and for substances identified to be of probable concern in the Georgia Basin. In addition, rapidly developing technologies will undoubtedly result in the future increased development and growth of new industries in BC. The potential for the release of substances of concern from these facilities will need to be assessed. For example, while discharges of toxic substances from the relatively new, but growing, nanotechnology industry in BC are likely minor, they need to be evaluated. Non-point sources (NPS), such as runoff from urban and agricultural areas and atmospheric deposition, rather than point sources, are now considered to be the major contributors of many priority toxic substances to the environment. Some watersheds within the Georgia Basin show signs of contaminant stress from NPS and more information is needed on the contribution of NPS to the overall loadings of toxic substances to the Georgia Basin. Another unassessed possible source of toxic substances to the Georgia Basin is spillage during the shipping and transport of oil and bulk industrial chemicals. While these events are very rare, they have the potential to cause catastrophic effects on the environment. Despite this potential threat, comprehensive information on the types and volumes of toxic substances being shipped which could

impact the Georgia Basin environment, in the event of a spill, is not currently available. Such information is required in order to assess potential hazards from the transport of these materials. In additional to obtaining information on specific point and non-point sources of toxic substances to the Georgia Basin, it is also important to better understand the chemical loading contributions of all local sources (both point and non-point sources) in relation to global sources such as long-range atmospheric transport.

Priority Recommendations for Future Management Actions:

The BCTWG recognized that the implementation of a successful management action plan is dependent on the mutual identification and understanding of the high priority issues by stakeholders. Addressing the knowledge gaps and research and monitoring needs identified in this report will help to identify, focus, and direct management actions in the future.

Many successful initiatives have already been implemented to reduce the release of toxic substances to the Georgia Basin and some of the concepts proposed within the following recommendations have already been implemented to some extent. A summary of the actions already implemented or currently underway is presented in Appendix 1.

The recommendations of the BCTWG concerning management actions focus on source- and sector-based pollution prevention and also on watershed-based approaches. Priority sources or sectors identified for management actions include small and medium-sized industries and activities which may discharge to sanitary sewers (including automotive repair[4], electroplating, printing, photographic imaging, paint and varnish industries, hospitals, medical laboratories and dental offices), urban stormwater (including discharges from parking lots and some street waste operations), and agricultural runoff. Several priority watersheds within the Georgia Basin have already been identified; however, it will be necessary for regulatory agencies and other stakeholders to collaborate on the development of mutually agreeable criteria for selecting additional priority watersheds for action. Many factors will have to be considered in developing these criteria including the overall watershed health, the risks associated with toxics versus other site-specific conditions and water quality issues, the criteria used for defining water quality, and the likelihood that management actions will be effective.

The BCTWG proposes a management action plan which addresses the reduction of pollution by toxic substances in the Georgia Basin in a series of sequential steps as outlined following.

- ***Review past and existing initiatives and support and further promote those which have been shown to be successful:*** It is important to build upon past and existing initiatives in the Georgia Basin and to learn from both past successes and failures. For issues identified to be of high priority, the existing or past initiatives to address specific issues should be reviewed and the promotion of successful initiatives should be continued and expanded as necessary.
- ***Implement measures to address identified hotspots and priority watersheds:*** Watersheds with elevated concentrations of toxic substances and/or observed biological impacts should be considered high priority for management action, where there is a likelihood of rehabilitation success. In addition, it is imperative to protect clean watersheds (those not currently impacted). Watersheds in areas which are potentially at risk due to impending development, or other activity, should also be considered high priority for protection via the development of proactive management actions.

[4] Automotive repair facilities typically discharge to storm sewers.

- ***Utilize voluntary pollution prevention and pollution control initiatives, where possible:*** Where past and current initiatives are shown to be inadequate and the need for additional management action is confirmed, future efforts would focus first on the development and implementation of voluntary pollution prevention and pollution control initiatives such as Best Management Practices (BMPs) and education. The implementation of voluntary initiatives should include stakeholder groups such as citizen's groups, industry associations, etc.; site audits; incentive programs; product stewardship programs; public outreach and education. Many programs initiated by community groups have been effective in reducing pollution to watersheds in the Georgia Basin. Public involvement in addressing NPS pollution is essential and and it is important to encourage increased involvement of community groups by improving communication on priority issues and by working with these groups to find ways to most effectively implement voluntary instruments such as BMPs and codes of practice to reduce contaminant releases.
- ***Review existing controls and, where required, develop mandatory regulatory activities:*** In cases where voluntary pollution prevention measures are not effective, the implementation of regulatory measures may be required along with compliance promotion activities. The BCTWG views strong enforcement of existing regulations and codes as an important component of management actions to reduce releases of toxic substances to the environment. Fraser River Action Plan (FRAP) surveys indicated that a strong presence of government officials in the field in the early implementation of regulations or codes is an effective way to encourage their implementation.
- ***Assess and ensure the efficacy of implemented management actions:*** The recommendations of the BCTWG stress that monitoring the results of the implemented management actions (whether voluntary or regulatory) is critical in order to assess their effectiveness in reducing releases of toxic substances to the Georgia Basin. The measurement of end outcomes must be included as an integral part of implementation plans for all future management actions. Ultimately, future monitoring programs should evaluate changes in appropriate indicators of environmental health and, thereby, link management actions to environmental health.

It should be noted that there is no legal requirement on the part of the member agencies of the BCTWG to implement the recommendations contained in this report. However, it is anticipated that, since these recommendations were developed through consensus by the BCTWG member agencies, activities to address these recommendations will be considered in the future work plans of these agencies. The BCTWG has now been disbanded; however, a coordinated approach to future initiatives to reduce releases of toxic substances to the Georgia Basin is still needed. It is strongly recommended that a similar multi-agency working group be formed to assume responsibility for encouraging and fostering partnerships and coordinated approaches to implementing future action plans for toxic substances. The mandates of such a working group should be to provide advice and recommendations to the senior management of the member agencies on current and emerging issues relating to toxic substances in BC and also to coordinate plans of action for addressing these issues. This will help to ensure that the recommendations of the BCTWG are utilized for the early identification and coordination of actions to address emerging issues relating to toxic substances. In addition, it is recommended that a review and evaluation of the progress on the implementation of these recommendations be conducted in 2012 and in 2015.

1. Introduction

1.1 Puget Sound/Georgia Basin International Task Force – British Columbia Toxics Work Group

1.1.1 Background

In 1992, an agreement to jointly address concerns in the shared environment of Puget Sound and Strait of Georgia was signed by the Governor of Washington State and the Premier of British Columbia (the British Columbia/Washington Environmental Cooperation Agreement). A British Columbia/Washington Environmental Cooperation Council (ECC) was created as a result of this agreement. The ECC then formed the Puget Sound/Georgia Basin International Task Force (PS/GB ITF), which included representatives from various state, provincial, and federal agencies; regional organizations; and First Nations from the United States and Canada. At the request of this Task Force, a Marine Science Panel of environmental experts from the United States and Canada was formed to develop recommendations on priority issues for the shared waters of Puget Sound/Georgia Basin. A map of this region is depicted in Figure 1. The top four priorities identified by the Marine Science Panel were habitat loss, marine plants and animals, exotic species, and marine protected areas. Issues of somewhat lower priority were also identified by the Marine Science Panel, one of which was toxic wastes in shared waters. Work groups, reporting to the PS/GB ITF, were formed in Washington State and in British Columbia to make recommendations for action plans to address these issues[5].

The British Columbia Toxics Work Group (BCTWG) (formerly the Canadian Toxics Work Group) was a multi-agency group (refer to Appendix 2 for a list of members) which was charged with identifying and setting priorities for future work to address toxics issues and making recommendations for an action plan for the Georgia Basin. This report summarizes the findings and recommendations of the BCTWG as was prepared for presentation to the PS/GB ITF under the Terms of the Reference (Appendix 3) of the Work Group. However, the PS/GB ITF was disbanded prior to the finalization of this report. Although progress reports on the work of the BCTWG and an earlier draft of this report were provided to the Task Force, the final report and recommendations were never formally presented and the finalization and publication of the report was put on hold. In 2009, due to the valuable information and the important recommendations contained in the report, the report was updated by the past member agencies of the BCTWG to allow for its publication and distribution for use as a planning tool for future work on toxic substances in the Georgia Basin. Updated information on projects and activities has been incorporated into this revised report. Since the priority issues identified and the recommendations presented in the report were developed by consensus based on information available to the BCTWG in 2005, there was some concern that these would be outdated. However, the reviewing agencies noted that the priorities and recommendations identified by the BCTWG in 2005 are still current in 2009. For this reason, very few changes have been made to the priorities identified and the recommendations made by the BCTWG in the original report. It is hoped that this document will provide guidance on future actions needed to address toxic substance-related issues within the Georgia Basin. It is important to note, however, that the BCTWG viewed the toxics action plan for the Georgia Basin as a living product and recognized that the priorities will change over time as new and emerging issues are identified.

[5] For a summary of priority toxics-related issues in Puget sound and recommendations of the Washington State Toxics Work Group to address these issues, refer to reports prepared by EVS Environmental Consultants (EVS 2003a,b).

Figure 1: **Map depicting the Georgia Basin and Puget Sound (also referred to as the Salish Sea) (from the Environment Canada Georgia Basin/Puget Sound International Airshed Strategy website: http://www.pyr.ec.gc.ca/airshed/index_e.htm)**

1.1.2 Membership

The BCTWG was co-chaired by British Columbia Ministry of Environment and Environment Canada and included representatives from federal, provincial, and municipal government agencies including:

- Environment Canada
- Fisheries and Oceans Canada
- Health Canada*
- BC Ministry of Environment (was Ministry of Water, Land and Air Protection)
- BC Ministry of Health
- BC Ministry of Agriculture and Lands (was Ministry of Agriculture, Food and Fisheries) *
- Metro Vancouver (was Greater Vancouver Regional District (GVRD))
- Capital Regional District

* These agencies participate as observers.

Refer to Appendix 2 for a list of representatives from all member agencies.

1.1.3 Scope and Objectives of the British Columbia Toxics Work Group

The main objectives of the Work Group were to:

- identify priority current and emerging issues relating to toxic substances in the Georgia Basin and potential associated risks to environmental and human health[6];
- identify gaps in existing knowledge (including research and monitoring) necessary to understand the scope and significance of toxics issues in the Georgia Basin and develop priorities and recommendations for filling these gaps;
- if necessary, immediately identify to the Puget Sound/Georgia Basin International Task Force any urgent toxic substance-related environmental or health issue and to make recommendations for action; and
- identify options and develop recommendations for management actions and mitigative measures to address priority toxic substance-related issues in the Georgia Basin.

The focus of the Work Group was on environmentally persistent substances and/or those substances known or suspected to have deleterious effects. Naturally occurring substances were included in instances where their concentrations in the environment were high enough to potentially cause harmful effects. Substances and issues being addressed by other groups or under other initiatives were not included in the focus of this study.

The development of recommendations and an action plan to address high priority toxic substance-related concerns in the Georgia Basin was to be undertaken in coordination with the Washington State Toxics Work Group and appropriate Canadian groups and/or initiatives.

Under the Terms of Reference for the BCTWG (Appendix 3), the findings and recommendations of the Work Group were to be included in a report to the PS/GB ITF and this report was prepared to fulfil this requirement. However, the PS/GB ITF was disbanded prior to the completion of the final report and, while progress reports of the BCTWG and a draft copy of this report were provided to the PS/GB ITF prior to its dissolution, a final report was never presented to the PS/GB ITF. In 2009, the value of the information contained in this report and the recommendations of the BCTWG was recognized and the report was reviewed and updated based on information provided by the past member agencies of the BCTWG. While information on projects and activities has been updated, the reviewing agencies determined that the priorities identified and the recommendations made by the BCTWG in 2005 were still current in 2009. For this reason, few changes have been made to the priorities and recommendations presented in the original report.

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[6] Human health issues are to be included only where a potentially significant threat was already recognized and being addressed by health agencies.

2. Approach of the British Columbia Toxics Work Group

The preparation of the action plan was undertaken in two phases. Phase 1 involved the identification of substances and issues of interest within the Georgia Basin, while Phase 2 built upon the information obtained in Phase 1 for the purposes of developing recommendations on research, monitoring, and management actions needed to address these issues within the Georgia Basin.

2.1 Phase 1 - Issue Identification

Several initiatives were undertaken by the BCTWG for the purpose of issue identification. The most important of these were the identification, prioritization, and profiling of toxic substances of potential concern in the Georgia Basin and the subsequent inventory of sources and loadings of the substances.

2.1.1 Identification of Substances of Interest in the Georgia Basin

Under Phase 1, a list of substances of interest in the Georgia Basin was compiled through a nomination process by member agencies. The resulting "Substances of Interest" list was extensive (refer to Appendix 4), and included information on sources, toxicity, environmental impact, regulatory status, existence of ecosystem guidelines or criteria, and status in terms of environmental studies and inventory. Members of the BCTWG consulted extensively within their organizations during this process. The list received wide distribution within agencies for input and information on toxics substances that should be considered for further work in the Georgia Basin.

The BCTWG then discussed how the Substances of Interest list could be reduced to a manageable size in terms of developing recommendations on research and monitoring and a management/action plan. The BCTWG considered, and rejected, the use of criteria based on empirical factors such as toxicity or bioaccumulation. It was thought that developing and agreeing upon criteria would be a time consuming and potentially controversial process, which could delay the development and implementation of the action plan. Instead, both expert opinion and the consensus of committee members were employed in identifying the highest priority chemicals and issues within the Georgia Basin.

The BCTWG divided the Substances of Interest list into four categories:

- List A – substances considered to be priorities because they are known to be impacting environmental quality in the Georgia Basin;
- List B – substances of concern in the Georgia Basin, but for which insufficient information is available to determine whether or not they were currently affecting environmental quality;
- List C – substances for which insufficient information was available to determine whether or not they are of concern in the Georgia Basin; and
- List D – substances which are already being adequately addressed under national or provincial initiatives or which do not fall under the Terms of Reference of the BCTWG.

While the importance of all of the substances on the original list was recognized, the BCTWG chose to exclude substances which met the following criteria (List D):

1.) they are being adequately addressed under other initiatives (e.g., lead);

2.) they are not within the Terms of Reference of the BCTWG (e.g., those chemicals which are considered to be of much greater concern to human health than to the environment and their release to the environment is being addressed due to human health concerns (e.g., biological contaminants[7] and radiologic constituents)); and/or
3.) they are exclusively air issues (e.g., ozone, respirable particulate matter, NOx, etc.).

The BCTWG also opted to exclude those substances for which insufficient information was available to determine whether or not they are of concern in the Georgia Basin (List C). Final consultations and consensus within the BCTWG identified the substances from List A and B to be of the highest priority within the Georgia Basin. These included:

- the legacy or conventional persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT), hexachlorobenzene (HCB), toxaphene, hexachlorocyclohexane (HCH), polycyclic aromatic hydrocarbons (PAHs), and dioxins/furans (PCDDs/PCDFs);
- new or emerging POPs such as alkylphenol (AP) and alkylphenol ethoxylates (APnEOs), halogenated diphenyl ethers (especially polybrominated diphenyl ethers (PBDEs)), phthalate esters, chlorinated paraffins, polychlorinated naphthalenes (PCNs), and fluorinated organic compounds (FOCs);
- current-use toxic pesticides including:
    - agricultural pesticides, such as atrazine and endosulfan;
    - antisapstain chemicals, didecyldimethylammonium chloride (DDAC) and 3-iodo-2-propynyl butyl carbamate (IPBC); and
    - antifouling chemicals based on organotin and copper compounds;
- metals including cadmium, chromium, copper, manganese, mercury, nickel, silver and zinc;
- nitrogen-containing nutrients; and
- wood extractives.

Substances such as bisphenol A, ethylene glycol, pharmaceutical and personal care products and their metabolites, phenols, and phytoestrogens were identified as substances of probable concern. It was concluded that, while insufficient information was available at that time to determine whether these chemicals should be considered high priority in the Georgia Basin, additional information on these substances should be obtained and assessed to determine whether they should be added to the priority list of substances for the Georgia Basin.

It is important to note that the BCTWG recognized that priorities in the Georgia Basin will change as new and emerging issues are identified. For this reason, the action plan prepared by the BCTWG should be viewed as a living product which is subject to change and modification with the identification of new priorities.

2.1.2 Profile Development for Priority Substances

In order to ensure that the most current information on the status and concerns associated with these priority substances was considered in the development of the action plan, the BCTWG requested that detailed life cycle information, pertinent to the Georgia Basin, be compiled for these substances. Substance profile reports were prepared for each of the priority substances and substance groups and included information on uses and sources (and loadings information where available), environmental

[7] Biological contaminants can adversely impact aquatic life and human pathogens have been detected in marine mammals. Although biological contaminants were not included in the review by the BCTWG, it is recommended that the potential for environmental impacts from pathogens in areas of untreated sewage discharges and NPS drainage from from agricultural sources be assessed.

fate, toxicity, environmental levels and hotspots, existing regulations/codes/guidelines, data gaps and research needs, management actions initiated to date, and management actions needed to address present concerns. These substance profiles, along with other tools, were used by the BCTWG in the development of recommendations for research and monitoring and management actions. Summaries of the substance profiles are provided in Appendix 8 of this report. Complete substance profiles are available in a separate supporting technical report (Garrett 2004) which is available on CD from Environment Canada..

2.1.3 Inventory of Toxic Substances Releases to the Georgia Basin

The identification and inventory of sources of toxic substances into the Georgia Basin was also identified by the BCTWG as an important step in the issue identification phase. Environment Canada contracted ENKON Environmental Ltd. to compile information on sources, concentrations, and loadings of toxic substances in wastewater discharges to the Georgia Basin. For the purposes of the inventory, substances were selected in terms of the availability of data for loading calculations, rather than their toxicity and/or environmental impact. The source inventory, therefore, provides information to aid decision making for certain substances, but does not include all substances for which management actions or research and monitoring would be required. The results of these studies have been compiled in two reports (ENKON 1999; ENKON 2002). More information on the findings of these reports is provided in Appendix 6A and B.

2.1.4 Other Activities

Other initiatives to improve the understanding of concerns relating to toxic substances in the Georgia Basin were completed under Phase 1. These included an inventory of contaminated sites situated along the BC coast; the compilation of a compendium of environmental quality benchmarks from around the world to assist in the evaluation of chemical contamination in aquatic ecosystems within the Georgia Basin; and a review of existing information on transboundary transport of contaminants from the Strait of Georgia to Puget Sound. Reports on these issues were prepared under contract to member agencies of the BCTWG. Summaries of these reports are included in Appendix 6C, D, and E.

2.2 Phase 2 – Development of the Recommendations of the British Columbia Toxics Work Group

Two major activities were completed in Phase 2 and the outcomes and findings of these were utilized by the BCTWG in the development of recommendations for future research, monitoring, and management actions to address toxic substances in the Georgia Basin. These activities included:

1.) hosting a Research and Monitoring Workshop, which focused on the Georgia Basin and helped to identify priority research and monitoring needs in the Georgia Basin through formal presentations on past and present research programs and discussions involving researchers from government and academia (Gray and Garrett 2004) and
2.) the preparation of a report, under contract, which identified cost-effective management options and mitigative measures for addressing toxic chemicals issues within the Georgia Basin.(ENKON 2003)

2.2.1 Research and Monitoring Workshop

The Research and Monitoring Workshop (Gray and Garrett 2004) provided a forum for the discussion of recent research and monitoring for toxic substances in the Georgia Basin. The workshop provided an opportunity for managers and scientists from federal, provincial, and regional governments and researchers from various universities to review and discuss the results of five years of Georgia Basin Ecosystem Initiative (GBEI)-funded research, as well as science knowledge generated by other related programs.

The overall goals of the workshop were to:

- discuss and communicate the results of research on toxic substances funded by GBEI, and other research, relevant to the assessment of toxic substances and their effects in the Georgia Basin aquatic (freshwater and marine) and terrestrial ecosystems;
- discuss and answer questions about research findings, to date, and identify links with other studies; and
- generate a prioritized list of research needs and monitoring requirements for consideration by the management of Environment Canada and partners in the development of the five-year Georgia Basin Action Plan (GBAP) which began in April 2003 and ended in March 2009.

The workshop attendees discussed the extent and possible impacts of contamination in the Georgia Basin as well as future research and monitoring priorities. Priorities identified for future research included:

- conducting research on the ecological consequences of toxic effects on performance and reproduction in selected sentinel species;
- measuring the contribution of contaminants to the cumulative stress experienced by animals coping with fragmented and degraded habitats and competitive non-native species;
- estimating loadings of "legacy" and "new" POPs and other priority contaminants from representative urban and agricultural areas to allow extrapolation of land use/export relationships to the entire water basin;
- determining the ratio of regional to global source contributions of persistent pollutants to the Georgia Basin; and
- conducting long-term research in selected ecosystems to capture temporal trends in contamination and effects due to land use changes.

The primary monitoring need identified was a long-term monitoring program to track contaminant concentrations over time. This information is essential for the identification of emerging issues (e.g., effects of land use changes, discharges of new chemicals, and impacts of climate change on contaminant transport and fate). In addition, the ability to monitor changes in environmental quality, following the introduction of initiatives aimed at reducing the release of contaminants to the environment, is an important tool for measuring the efficacy of management actions.

Recent information on environmental levels of both metals and organic contaminants in the Georgia Basin is lacking and few routine monitoring programs are in place. This is especially true of the marine environment, where ambient environment monitoring has decreased significantly since the 1980s. Most of the environmental monitoring currently underway is being conducted in support of research programs and is localized and of short-duration. As these studies tend to reflect the varied priorities among agencies and programs, they often lack consistency in both collection and analytical methods and in the parameters measured. Many of the environmental studies now underway were initiated under the Fraser River Action Plan (FRAP) and, therefore, focus on the freshwater systems within the Fraser Basin. In most areas of the Basin, existing information is insufficient to identify temporal trends in environmental concentrations of priority contaminants or to determine the efficacy of control measures.

Other monitoring needs identified by the workshop participants included the development of a list of priority emerging chemicals relevant to the Georgia Basin; increasing the capability and capacity for the analysis of new and/or emerging chemicals; and increasing the monitoring of baseline (i.e., reference) aquatic and terrestrial ecosystems.

In addition, it was noted that better communication on toxics-related issues with environmental and community groups would foster the more effective implementation of voluntary instruments such as best management practices (BMPs) and codes of practice to reduce or eliminate contaminant releases.

The findings of the research and monitoring workshop are summarized in more detail in Appendix 7A of this report.

2.2.2 Identification of Management Options for the Control of Toxics Substance Releases to the Georgia Basin

ENKON Environmental Ltd., under contract to Environment Canada, prepared a report which identified cost effective management options for select toxic substances (ENKON 2003). The terms of the contract specified that management options should focus on reducing the total loading of these substances to receiving waters in the Georgia Basin, rather than addressing site-specific toxicity issues, and that the review should emphasize controls for sources rather than management measures for specific substances.

Based on available information on sources and loadings of substances identified to be of high priority in the Georgia Basin, it was determined that the evaluation of management options should focus on specific substances, including:

- metals (specifically cadmium, chromium, copper, manganese, nickel, mercury, silver and zinc);
- PAHs; and
- nitrogen-based nutrients,

and on specific sources including:

- small and medium-sized industries that discharge to sanitary sewers (i.e., source controls for wastewater treatment plants);
- urban stormwater; and
- agricultural runoff.

The review of management options stressed a preventive approach to reducing or eliminating toxic substances at the source. An analysis of successful programs employed in other jurisdictions was conducted and the suitability of initiating similar programs within the Georgia Basin was evaluated. The costs of the various options were considered with the objective of identifying the most cost-effective solutions. Regulations applicable to, or necessary for, the various options were also considered.

The study concluded that measures to reduce loadings of toxic substances in the Georgia Basin could include a combination of two major approaches:

1.) pollution prevention (P2) planning and implementation targeted toward;
    a. discharges of metals and PAHs to sanitary sewers,
    b. discharges/spills of metals and PAHs to stormwater systems, and
    c. discharges of nitrogen-based nutrients in agricultural runoff, and
2.) watershed management/integrated stormwater management with a strong focus on identifying and addressing areas where stormwater quality is compromised by the presence of elevated levels of metals and PAHs.

3. Recommendations of the British Columbia Toxics Work Group

3.1 Background Information

This section summarizes the recommendations of the BCTWG with respect to future research and monitoring and management actions which are needed to address priority issues associated with toxic substances in the Georgia Basin. Although the BCTWG recognized that there are a very large number of toxic substances which are potentially of concern in the Georgia Basin, the Terms of Reference for the BCTWG specified the development of recommendations and an action plan to address the "highest priority" substances and issues. While the BCTWG relied on the expertise and consensus of the members in identifying substances that should be included in the development of a research and monitoring plan and a management action plan, the members of the BCTWG consulted extensively within their organizations during this process. The recommendations prepared by the BCTWG focus on the substances or substance groups considered to be of the highest priority in the Georgia Basin. These include:

- the legacy or conventional persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane (DDT), hexachlorobenzene (HCB), toxaphene, hexachlorocyclohexane (HCH), polycyclic aromatic hydrocarbons (PAHs), and dioxins/furans (PCDDs/PCDFs);
- new or emerging POPs such as alkylphenol (AP) and alkylphenol ethoxylates (APnEOs), halogenated diphenyl ethers, phthalate esters, polychlorinated naphthalenes (PCNs), chlorinated paraffins, and fluorinated organic compounds (FOCs);
- current-use toxic agricultural pesticides, such as atrazine and endosulfan;
- antisapstain chemicals, didecyldimethylammonium chloride (DDAC) and 3-iodo-2-propynyl butyl carbamate (IPBC);
- antifouling chemicals based on organotin and copper compounds;
- metals including cadmium, chromium, copper, manganese, mercury, nickel, silver and zinc;
- nitrogen-containing nutrients; and
- wood extractives.

However, it is important to note that the BCTWG views the toxics action plan for the Georgia Basin as a "living product" and recognizes that priorities will change as new and emerging issues are identified. For example, the BCTWG identified bisphenol A, ethylene glycol, pharmaceutical and personal care products and their metabolites, phenols, and phytoestrogens as substances of probable concern in the Georgia Basin. It was concluded that insufficient information was available, at that time, to determine whether these chemicals should be considered high priority in the Georgia Basin. The BCTWG recommends that these substances are assessed to determine whether they should be added to the list of priority toxic substances in the Georgia Basin and recommendations concerning the collection of information to assist in the assessment of these substances are presented in Table 1b.

Although the recommendations of the BCTWG are presented on a substance-specific rather than a source-specific basis, most point and non-point sources of toxic substances to the Georgia Basin (including municipal wastewater treatment plant effluents, industrial discharges, urban and agricultural runoff) contain complex mixtures of chemicals, including many whose potential environmental concerns have not yet been determined. For this reason, a sector or source-based approach to the implementation of management actions to reduce releases of toxic substances to the environment is often the best option. In addition, the Capital Regional District (CRD) expressed the need for an integrated approach to address pollutants, through which specific substances can be addressed following proper risk assessment (as opposed to dealing with pollutants on an individual basis).

Recommendations pertaining to both research and monitoring and management actions have been separated into two categories:

3.) General: which include those recommendations which are general in nature and, therefore, apply to most or all of the substances of highest concern in the Georgia Basin, and
4.) Substance-specific: which include those recommendations which are specific to an individual substance or substance group.

Since the initiation of actions on the general recommendations would help to address concerns relating to a wide range of substances, the BCTWG considers these recommendations to be of the highest priority. While actions on substance-specific recommendations would result in a better understanding of select toxic substances and could significantly reduce their release to the Georgia Basin, it was considered unlikely that the positive impacts of these actions would be as far-reaching as those for the general recommendations. Therefore, while actions on substance-specific recommendations are strongly encouraged, they are considered to be of somewhat lower priority.

The following two sections summarize the needs relating to toxic substances in the Georgia Basin and the highest priority (general) recommendations of the BCTWG to address these needs. A more detailed discussion of these recommendations is provided in Section 3.2 and in Table 1a (research and monitoring) and in Section 3.3 and in Table 2a (management actions). Substance-specific recommendations for research and monitoring and management actions are presented in Tables 1b and 2b, respectively.

3.2 Priority Needs and Recommendations for Future Research and Monitoring to Address Toxics-Related Issues in the Georgia Basin

The highest priority needs identified for research and monitoring in the Georgia Basin include:

- develop a system for the better sharing, management and communication of information and data on toxic substances to stakeholders;
- develop a long-term monitoring program and obtain current information on environmental levels of priority toxic substances and substances of probable concern in the Georgia Basin ;
- develop a better understanding of potential biological impacts on local species and the factors that affect toxicity of priority toxic substances and substances of probable concern in the Georgia Basin;
- develop a better understanding of the environmental fate and distribution of priority toxic substances and substances of probable concern in the Georgia Basin ; and
- better define sources (especially non-point sources) and loadings of priority toxic substances and substances of probably concern to the Georgia Basin.

The following is a summary of the recommendations of the BCTWG to address these needs.

Need I: Develop a System for the Better Sharing, Management, and Communication of Information/Data on Toxic Substances

The need to improve the reporting and dissemination of information on contaminants between stakeholders has long been acknowledged. Very little of the available data and information is available on shared or linked databases and much of it remains in paper files, which are difficult to access. This limits the ability to effectively analyze existing information, both geographically and temporally, and is a major impediment to the better understanding and tracking of concerns associated with toxic substances in the Georgia Basin and also in the evaluation of the efficacy of existing and future controls on releases. The inventory and mapping of information on both sources and environmental levels of toxic substances in the Georgia Basin in a centralized database and GIS system, or through linkages of databases on the web, has been identified as a high priority in addressing this long-standing problem.

Recommendation 1:
Establish a central link to data sources and contacts for issues relating to toxic substances in the Georgia Basin in order to improve the reporting and dissemination of information to stakeholders. This could be accomplished by the development of a publicly accessible, GIS-linked repository of current and published information on environmental levels and sources of environmental contaminants to the Georgia Basin.

Recommendation 2:
Communicate research and monitoring issues to environmental and community groups and work with these groups to effectively implement voluntary instruments such as BMPs and codes of practice and to monitor the implementation and efficacy of such instruments.

Need II: Develop a Long-term Monitoring Program and Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin

Recent information on environmental levels of many priority chemical contaminants in the Georgia Basin, particularly in the marine environment, is limited due to the lack of routine or long-term monitoring programs. Reliable information on current levels of these substances in the environment is essential for the identification of temporal trends in environmental concentrations and for the evaluation of the efficacy of control measures. It is imperative to be able to measure improvements in the environment as a result of management actions implemented to control releases to the environment, and also to identify emerging complications such as the effect of land use changes, the discharges of new chemicals, and the impacts of climate change on contaminant transport and fate. For example, there are areas within the Georgia Basin which have been identified for urbanization within the next several years and these areas provide an opportunity for the study of the effects of urbanization on the levels, transport, fate and impacts of chemical contaminants on certain biological communities and/or populations. In addition, as inputs and run-off from most human activities in the Lower Fraser Valley/Metro Vancouver area pass through the Lower Fraser, the water quality and ecosystem condition of this ecologically important reach should be routinely assessed. Future work within the Georgia Basin should include more extensive sediment core studies, in order to put current contaminant concentrations and fluxes into a historical context. In addition, existing tissue archives (e.g., bird eggs) should be maintained and new ones created (aquatic biota and sediments), to allow future studies of trends in contaminant concentrations. More emphasis should also be placed on baseline aquatic (including groundwater) and terrestrial ecosystem monitoring at an increased number of reference sites for improved assessment of environmental conditions in hotspots (e.g., harbours, contaminated sites, and aquaculture areas).

While more extensive long-term monitoring programs in the Georgia Basin are required, some monitoring programs have already been implemented and should be acknowledged. These include a joint ambient monitoring program in the Georgia Basin being conducted jointly by DFO and Metro Vancouver; an ambient monitoring program in the Fraser River being implemented by Metro Vancouver; routine water quality monitoring at several river sites in the Georgia Basin under the Canada-BC Water Quality Monitoring Agreement; and CRD's marine environmental research and monitoring program in the vicinity of three sanitary wastewater outfalls. Future studies should be coordinated with programs already underway in order to build on this work and to avoid duplication.

Recommendation 3:

Establish long-term coordinated monitoring programs to allow the identification of emerging issues and temporal trends; the evaluation of the efficacy of implemented control measures; and the assessment of the effects of stressors such as urbanization and climate change on the levels, transport, fate, and impacts of toxic substances. Monitoring programs should include the collection of sediment cores, samples from baseline and reference sites, and the archiving of representative samples of sediment and biota.

Need III: Develop a Better Understanding of Potential Biological Impacts on Local Species and the Factors that Affect the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin

Elevated concentrations of some priority substances, sometimes in excess of the Canadian environmental quality guidelines, have been identified in some areas of the Georgia Basin. The potential biological impacts of current chemical concentrations on local species are not known, particularly in aquatic environments with multiple stressors. In addition, for many of these substances, their fate and distribution and the factors influencing their potential to cause adverse effects in Georgia Basin biota are not well understood. PPCPs, pathogens and several commercially used chemicals, including some estrogenic compounds, have been detected in WWTP discharges. However, the potential for adverse environmental impacts in the BC aquatic environment as a result of this release has not been evaluated. In addition, more information is needed on the specific forms of metals and other substances present under local environmental conditions; the bioavailability of metal species and other substances present in local hotspots and contaminated sites; and the local environmental factors which could affect their potential to cause biological impacts on local species.

Long-term monitoring of biological communities is required in order to assess contaminant stress within a context of high natural variability in health status caused by climatic, habitat-related, and competitive (e.g., invasive species) stresses. Cumulative contaminant stress must be evaluated in aquatic environments with multiple stressors such as exposure to "traditional" pollutants (e.g., ammonia, nitrate, and nitrite), stressful physical-chemical conditions (e.g., low/high pH, low dissolved oxygen, and high turbidity), and toxicants (e.g., pesticides, combustion products, surfactants, and "legacy" POPs) episodically, simultaneously, and/or in sequence.

***Recommendation 4*:**

Obtain additional information on the potential biological impacts of toxic substances in the Georgia Basin on local species and the factors which affect toxicity by identifying:

a.) the specific forms of metals and other environmental contaminants present in the Georgia Basin environment, their bioavailability and potential to cause adverse biological effects in local organisms, and the local factors and environmental conditions which may affect their potential to adversely affect local species;

b.) individual watersheds and communities which are exposed to cumulative stress and/or multiple stressors;

c.) the presence of long-term stress in communities with impaired performance due to chronic/episodic exposure to contaminant mixtures at low levels;

d.) non-persistent and non-bioaccumulative toxicants causing additional stress; and

e.) watersheds and ecosystems within the Georgia Basin where there is a potential for endocrine-disrupting effects to occur.

Need IV: Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin

The environmental fate and distribution of contaminants is strongly influenced by local environmental conditions. It is difficult to accurately assess the potential long-term impacts of toxic substances in the Georgia Basin without adequate information on the potential persistence, mobility, and routes of transport of these substances in the watersheds and regions where elevated environmental concentrations and/or significant loadings to receiving waters have been identified.

Recommendation 5:

Assess the potential for concerns associated with the release of metals and organic contaminants to overlying waters as a result of sediment disturbance in harbour areas.

Recommendation 6:

Further investigate the routes/mechanisms for local transport and the distribution of endocrine-disrupting substances in environmental media.

Need V: Better Define Sources (especially Non-Point Sources) and Loadings of Priority Toxic Substances to the Georgia Basin

A better understanding of sources, particularly non-point sources (NPS), of toxic substances to the Georgia Basin is a high priority. In recent years, the implementation of regulations combined with voluntary initiatives by industry has successfully reduced environmental loadings of contaminants from point source discharges. However, concerns associated with point source releases of contaminants remain. For example, the presence of PPCPs, pathogens, and several commercially used chemicals, including various estrogenic compounds, in WWTP discharges has been reported, but information is lacking on the efficacy of wastewater treatment practices in removing these substances and on their loadings to the environment.

Information on the concentrations and loadings of many contaminants from major point source discharges is available through a variety of sources including the federal National Pollutant Release Inventory (NPRI) (http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm). The NPRI is a legislated, nationwide, publicly-accessible inventory which provides information on annual releases of specific key pollutants to air, water, land and disposal or recycling from all sectors (including industrial, government, commercial, etc.) in Canada which meet the reporting requirements of this program. Available information on the concentrations and loadings of select contaminants to the Georgia Basin from waste discharges (generated between 1990 and 1998) was summarized in reports prepared for Environment Canada (ENKON 1999; ENKON 2002). Of the wastewater discharges characterized in these studies, ENKON reported that the most significant sources of toxic substances were stormwater, municipal WWTPs and the pulp and paper industry. In the future, the rapid development of new technology will result in the growth of new industries which will need to be assessed for potential discharges of substances of concern. One such example is the nanotechnology industry. Although the discharges from this rapidly growing industry in BC are likely minor; concerns may exist due to physical size of the materials released rather than to their chemical composition. Many materials take on novel chemical and environmental properties when present at the nano scale.

Loadings of contaminants to the environment from the multitude of, often diffuse, NPS are much more difficult to quantify and, for this reason, information is limited. An attempt to characterize NPS releases to the environment in the Georgia Basin was unsuccessful due to inadequate data (ENKON 1999; 2002). However, NPS, including runoff from urban and agricultural areas and atmospheric deposition, are now recognized as the major contributor of many potentially toxic substances to the environment. Pollutants in groundwater may also enter streams or other surface water bodies through natural groundwater-surface water interaction. Local watersheds within the Georgia Basin show signs of contaminant stress from these sources; however, very little is known about the contribution of NPS to the overall toxic loadings to the Georgia Basin. Urban and agricultural streams show elevated levels of substances such as metals, PAHs, and nutrients in water and sediments and several pesticides and carrier compounds have been identified as endocrine-disrupting compounds (EDCs). Many streams and ditches have been identified as critical habitat for wildlife, particularly amphibians and salmon fry. In some agricultural areas, amphibian populations have been affected and changes have been observed in the community structure of benthic invertebrates in urban and agricultural areas. In addition, non-point sources such as agricultural and urban runoff, releases from septic systems, CSO and stormwater discharges, and boating activity have resulted in fecal and chemical contamination of shellfish populations in coastal areas of BC.

Atmospheric deposition has been identified as an important NPS for both metals and many organic contaminants in the Georgia Basin; however, currently available information is limited to select contaminants and specific areas such as the Brunette River and Abbotsford. A monitoring program is required to measure the dry and wet deposition of atmospherically transported contaminants at a greater number of locations in order to determine annual loadings directly to the Strait of Georgia; to large lakes/reservoirs; to land surfaces at low, medium and high elevations; and to assess gradients along the axes of the Georgia Basin.

Another important potential NPS source of toxic substances to the Georgia Basin which needs to be further assessed is the transport of toxic substances. Spills occurring during the shipping and transport of oil and bulk chemicals are very rare; however, these events have the potential to cause catastrophic effects on the environment. Despite this potential threat, comprehensive information on the volumes of oil and the types and volumes of bulk industrial chemicals being shipped is not currently available. Such information is required in order to assess the potential hazards to the Georgia Basin from the transport of these materials.

In addition, it is important to better understand the chemical loading contributions of local sources (both point and non-point sources) in relation to global sources such as long-range atmospheric transport.

Recommendation 7:

Obtain and compile more information on the agricultural runoff, urban stormwater, freshwater input and loadings of other non-point sources (NPS) and point sources of contaminants to various watersheds within the Georgia Basin.

Recommendation 8:

Compile information on the types and quantities of oil and bulk chemicals being transported and shipped within the Georgia Basin and assess the potential for spills during the transport of these materials to impact the environment.

Recommendation 9:

Obtain more information on the atmospheric deposition of metals and organic contaminants to the Georgia Basin.

Recommendation 10:

Determine the ratios of regional (e.g., municipal WWTP effluent, agricultural runoff, freshwater input) to global (e.g., atmospheric long-range transport, bio-transport) sources of persistent pollutants in a variety of environmental media.

Recommendation 11:

Prepare a synthesis of information on loadings of contaminants, both “legacy” and “new” (especially current-use pesticides), in runoff from representative urban and agricultural areas in order to allow extrapolation of the land use/export relationship developed at these locations to the entire basin. This will allow for the identification of priority watershed areas for further study and for the implementation of management actions to reduce loadings.

Table 1a identifies activities relating to these recommendations which are already underway or are planned.

Table 1a: Priority Recommendations for Research and Monitoring and a Summary of Current and Planned Initiatives

I. Develop a System for the Better sharing, Management, and Communication of Information/Data on Toxic Substances:

Recommendation 1:
Establish a central link to data sources and contacts and also a publicly accessible repository of current and published information relating to toxics issues in the Georgia Basin in order to improve reporting and dissemination of information to stakeholders.

Current and Planned Initiatives:

i.) Under contract to EC, information on point source releases of toxic substances to the Georgia Basin was updated in a format which allows incorporation into a GIS; also under this contract existing information on non-point sources of toxic substances to the Georgia Basin was scoped and options for future geo-referencing of this information are being examined.

ii.) Under contract to EC, existing information on the presence of toxic substances in the Georgia Basin environment was scoped and the feasibility of eventual incorporation into a database and GIS is being considered.

iii.) A web-based, GIS-linked database of information on toxic substances in the Pacific Region is currently under development. This database will reside in the Community Mapping Network (CMN) on the District of Squamish server and will include information on priority toxic substance related issues in the Georgia Basin and also published information on the environmental levels and sources of toxic substances to the Georgia Basin. While this website will initially focus on the Georgia Basin,, it allows for future expansion to include other BC watersheds and coastal areas.

iv.) EC has developed a water quality website which provides data on water quality and the ability for users to draw their own graphs to examine trends (http://waterquality.ec.gc.ca/EN/home.htm). Much of this monitoring is conducted in partnership with the province.

Recommendation 2:
Communicate research and monitoring issues to environmental and community groups and work with these groups to effectively implement voluntary instruments such as BMPs and codes of practice.

Current and Planned Initiatives:

i.) EC regional water quality website (http://waterquality.ec.gc.ca/EN/home.htm) provides data and information on the region's water quality monitoring program. Much of this monitoring is conducted in partnership with the province and includes data on potentially toxic substances, such as metals and nitrogen compounds. The site may be expanded in the future to include data from other water-related studies.

ii.) Some research and monitoring issues and information were communicated to public groups through the EC GBAP project on "communicating science to the public" – a minimal program, implemented on a time availability approach.

v.) Through the Metro Vancouver LWMP, an Environmental Monitoring Committee (EMC) has been established to identify issues, transfer knowledge and review study information. Condition C7 of the LWMP commits Metro Vancouver to seek out new ways to communicate environmental information to the public.

vi.) An important component of the CRD LWMPs is the communication of information pertaining to the monitoring and research projects conducted as part of the Regional Source Control, the Stormwater, Harbours and Watersheds, or the Wastewater and Marine Environment Programs. Program results are included in annual reports that are available for review on the CRD Environmental Services Department website at http://www.crd.bc.ca/wastewater/marine/index.htm.

Table 1a: Priority Recommendations for Research and Monitoring and a Summary of Current and Planned Initiatives

II. Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin:

Recommendation 3:
Establish long-term coordinated monitoring programs which would allow the identification of emerging issues and temporal trends; an evaluation of the efficacy of implemented control measures; and the assessment of the effects of stresses such as urbanization and climate change on the levels, transport, fate, and impacts of toxic substances. Monitoring programs should include the collection of sediment cores, samples from baseline and reference sites, and the archiving of representative samples of sediment and biota.

Current and Planned Initiatives *(cont.)*:

i.) DFO (Institute of Ocean Sciences) has carried out a number of multi-year monitoring or sediment core (17-130/year) studies on toxic chemicals, including mercury, PCBs, PBDEs, heavy metals and organic carbon as a contaminant (leading to effects on oxygen near a municipal outfall). Some of these studies were published in a Special Issue of Marine Environmental Research (Volume 66 supplement) and in a data report that arose from the collaborative Ambient Monitoring Project with Metro Vancouver (see vii in this section). In addition, DFO has published a review paper about climate and other change in the Strait of Georgia that includes a section on contaminants in the context of other changes.

ii.) EC implemented a long-term water quality monitoring program in the region, in partnership with the province. Thirteen sites are located in freshwater systems in the Georgia Basin, including a site on the Main Arm of the Fraser Estuary. Potentially toxic variables, such as metals and nitrogen compounds, are monitored; however, most toxics are not sampled, due to the high cost of analysis. EC also conducts monthly sampling for nitrate at 23 sites in the Abbotsford Aquifer.

iii.) EC has conducted sampling, under the GBAP project, *Fraser Estuary – water quality monitoring*, which includes water quality sampling at two locations in the Fraser Estuary (North Arm at Oak Street Bridge; Main Arm at Tilbury Island) for at least two years (2004 and 2005). This project included some sampling for toxic substances (PAHs, nonylphenol and ethoxylates, PBDEs, and PCBs) at different flow regimes.

iv.) EC is applying the CABIN (Canadian Aquatic Biomonitoring Network) approach, which uses the benthic community for assessing disturbances to streams and rivers. The intention is to use this over the long-term in the region, as resources permit. This work was funded under GBAP and is now funded as part of a national program. The benthic community acts as an indicator of environmental problems (e.g., contamination by toxic substances); however, further investigation and sampling is required to determine the nature and source of the problem, once detected. CABIN sampling has been conducted at 19 test sites to assess impacts from a variety of potentially toxic contaminants between 2003 and 2008, to monitor changes over time.

v.) Metro Vancouver has established ambient monitoring programs in the southern portion of the Strait of Georgia, lower Fraser River, Burrard Inlet, and Boundary Bay to complement its receiving environment programs already underway in the region.

a.) Strait of Georgia Ambient Monitoring Program: This program is set up jointly with the DFO's Institute of Ocean Sciences through a five-year collaborative agreement. The objectives of the program are to characterize the surrounding environment including natural changes, provide background data for understanding impacts from wastewater treatment plant outfall discharges, develop indicators of environmental change which can be used to distinguish anthropogenic and natural effects, and study long-term predictions of sustainability for input of organic matter and contaminants into the Strait. The research findings of the first five years of the program resulted in the publication of eight papers in a special edition of the journal Marine Environmental Research (vol 66 supplement 2008). The components of work for the recently started second cycle of monitoring include examining relationships between benthos, oxygen stress, organic forcing, climatic events and pharmaceuticals.

b) Fraser River Ambient Monitoring Program: This program is carried out jointly with the BC Ministry of Environment. The monitoring components of this program include water quality (annual), sediment (once per cycle), fish tissues and health (once per cycle). Two fish surveys were done during the first cycle (2003 to 2007). Annual monitoring program reports are produced, and the second cycle of monitoring is currently underway.

c) Burrard Inlet Ambient Monitoring Program: The monitoring components are the same as those for the Fraser River Program except that fish tissues and health are surveyed once every three years. The first cycle began in 2007-2008 with all three components sampled. Annual monitoring program reports are produced, and the second cycle is currently underway.

d) Boundary Bay Assessment and Monitoring Program: A newly established and multifaceted monitoring program is undertaken through partnerships with Canadian and American government agencies, member municipalities, First Nations, and environmental community organizations. The first stage of coordinated monitoring begins in 2009 and will focus on water quality.

vi.) EC (CWS) is completing the interpretation and reporting of data on the exposure and morphological effects of various contaminants (including butyltins, heavy metals, and organic contaminants) on surf scoters from major harbours and is conducting long-term monitoring to determine the trends of a variety of persistent contaminants in wildlife indicators.

vii.) Through its LWMP, Metro Vancouver member municipalities have committed to undertake Integrated Stormwater Management Plans (ISMPs) in about 120 watersheds in Metro Vancouver. These ISMPs include monitoring to assess the effects of development within the watershed and the success of implementing the recommended BMPs.

viii.) A long-term marine environmental research and monitoring program for the Juan de Fuca Strait (near three sanitary wastewater outfalls) has been in place in the CRD for more than 15 years. The original program, that includes the long-term monitoring of chemicals in wastewaters and sediments and the assessment of biological effects of substances on local communities near the outfalls and at reference sites, was intensified in 2000. The extensive Wastewater and Marine Environment program also includes collaborative research projects on emerging issues and persistent organic pollutants. For more information refer to the CRD Environmental Services Department website at http://www.crd.bc.ca/wastewater/marine/index.htm.

ix.) The City of Vancouver, with input from EC, DFO and BC MOE, implemented the second phase of a management plan for the historically contaminated False Creek sediments. This involved sediment sampling east of the Cambie Street Bridge (East Basin) for various contaminants. An interpretive report has been prepared for the City of Vancouver by the consultant.

Table 1a: Priority Recommendations for Research and Monitoring and a Summary of Current and Planned Initiatives

III. Develop a Better Understanding of the Potential Biological Impacts on Local Species and the Factors which Affect the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin:

Recommendation 4:

Obtain additional information on the potential biological impacts of toxic substances in the Georgia Basin on local species and the factors which affect toxicity including:

a.) the specific forms of metals and other environmental contaminants present in the Georgia Basin environment, their bioavailability and potential to cause adverse biological effects in local organisms, and the local factors and environmental conditions which may affect their potential to adversely affect local species;

b.) individual watersheds and communities which are exposed to cumulative stress and/or multiple stressors;

c.) the presence of long-term stress in communities with impaired performance due to chronic/episodic exposure to contaminant mixtures at low levels;

d.) the identity of non-persistent and non-bioaccumulative toxicants causing additional stress; and

e.) the potential for endocrine-disrupting effects to occur in the Georgia Basin.

<u>Current and Planned Initiatives</u>*:*

i.) DFO (Institute of Ocean Sciences) has carried out a number of studies to evaluate the effects of toxic chemicals on organisms, including invertebrates, fish and marine mammals, in the Strait of Georgia. Some of this work has resulted in a formal advice document and a Viewpoint article on the threat posed to marine organisms by PBDEs and by deca-BDE, in particular.

ii.) EC has, in the past (1998-2002), conducted studies addressing biological effects, such as endocrine disruption. Such studies are currently not funded.

iii.) EC (CWS) has studied the impact of agricultural drainage on local amphibian populations in the Sumas-Chilliwack area. Substances of concern include pesticides, such as endosulfan, as well as nutrients, EDCs, and hormones in animal wastes.

iv.) EC (CWS) has examined a variety of wildlife species in the Georgia Basin to determine the effects of EDCs including studies focusing on EDC exposure and impacts on mink and otter, bald eagles, surf scoters and American dippers.

v.) As part of the Core Area LWMP, the CRD Wastewater and Marine Environment program (WMEP) includes a variety of components to assess the potential effects of toxic substances (originating from sanitary wastewaters) in the marine environment and public health. Regular studies of wastewater and sediment chemistry, marine surface water indicator bacteria, benthic invertebrate and mussel community health, and the overall assessment of ecosystem health are conducted as part of the Macaulay and Clover Point WMEP. The program also includes additional collaborative investigations aimed at assessing effects of emerging substances (including PBDEs), EDCs, POPs and non-persistent contaminants. Two of the studies undertaken by the CRD WMEP as part of this component of the program include: 1.) a collaborative assessment with EC of potential toxic genomic effects of wastewater (including EDCs); and 2.) a collaborative research project with the University of Victoria to study the effects of pharmaceuticals and personal care products (Larose 2005).

vi.) Metro Vancouver is committed to the principle of managing liquid waste in a manner that protects the receiving environment while using cost-effective approaches. This commitment is detailed in the District's LWMP. The LWMP is mandated by the province and designed to ensure that an integrated, local approach to making good informed liquid waste management decisions is followed. A key component of the District's Plan involves monitoring, assessing and forecasting to evaluate the effects of its liquid waste discharges, including WWTP, CSOs, and stormwater. This monitoring, such as ongoing discharge monitoring and receiving and ambient environmental monitoring, is vital in providing information to effectively manage liquid waste discharges on a regional basis, and in furnishing a scientific basis for setting priorities and designing system upgrades. Metro Vancouver receiving environment monitoring and assessment work evaluates overall ecosystem health in these environments to determine whether the health is being negatively affected and the manner in which municipal effluent is contributing to this effect. Metro Vancouver is in the process of updating the 2001 LWMP. More information on the Metro Vancouver LWMP, and a copy of the draft updated LWMP can be found on the Metro Vancouver website http://www.metrovancouver.org/services/wastewater/planning/Pages/default.aspx.

vii.) To support its member municipalities, Metro Vancouver is undertaking studies to identify the effects of global changes on benthic communities within small streams and to determine the natural range of variability of benthic communities using the B-IBI methodology in small streams in the Lower Mainland.

viii.) Metro Vancouver has, as required in the approval of the LWMP, set up a program to study the presence and effects of micro-contaminants. This includes studies of EDCs, pharmaceuticals and POPs. In addition to effluent characterization and the development of analytical procedures, Metro Vancouver studies include various projects examining the biological impacts of contaminants including:

a) a Metro Vancouver funded project with SFU examining the utility of genomic tools, specifically studying a mussel array;
b) a project, in partnership with DFO (West Vancouver Lab), examining the potential for fish feminization under actual receiving environment conditions;
c) a collaborative project with NWRI (EC) and DFO to study the use of mussels and immune system responses as indicators of specific water qualities and the effects from various sources;
d) a possible joint study with EC (PESC) to study pharmaceuticals in ambient and receiving waters in the region;
e) the 2002 Acute and Chronic Toxicity of Marine Species at the Lions Gate WWTP study which assessed various toxicity endpoints of topsmelt, giant kelp and Mediterranean blue mussel;
f) the Draft Design of Receiving Environment Monitoring Program for the Annacis, Lulu and NW Langley WWTPs which recommends semi-annual testing of Ceriodaphnia reproduction and rainbow trout embryo viability;

III. Develop a Better Understanding of the Potential Biological Impacts on Local Species and the Factors which Affect the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin *(cont.):*

Recommendation 4 *(cont.):*
Obtain additional information on the potential biological impacts of toxic substances in the Georgia Basin on local species and the factors which affect toxicity including:

a.) the specific forms of metals and other environmental contaminants present in the Georgia Basin environment, their bioavailability and potential to cause adverse biological effects in local organisms, and the local factors and environmental conditions which may affect their potential to adversely affect local species;
b.) individual watersheds and communities which are exposed to cumulative stress and/or multiple stressors;
c.) t he presence of long-term stress in communities with impaired performance due to chronic/episodic exposure to contaminant mixtures at low levels;
d.) the identity of non-persistent and non-bioaccumulative toxicants causing additional stress; and
e.) the potential for endocrine-disrupting effects to occur in the Georgia Basin.

Current and Planned Initiatives *(cont.):*

g.) the Lions Gate WWTP near-field video survey which assessed effects of discharge on near field benthic community structure in the First Narrows;
h.) Metro Vancouver studies which consider traditional as well as emerging contaminants. For example, the work done at Lion's Gate WWTP was able to quantify the additive effect of MBAS (surfactant) and ammonia effects on the toxicity to three different organisms. This work is being done as required under the LWMP; and
i.) studies on non-persistent contaminants including the fate and effects of ammonia in the Fraser River within Metro Vancouver and the fate and effects of MBAS (LAS) in the environment.

IV. Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin:

Recommendation 5:
Assess the potential for concerns associated with the release of metals and organic contaminants to overlying waters as a result of sediment disturbance in harbour areas.

Current and Planned Initiatives:
There are no current or planned initiatives at this time.

Recommendation 6:
Further investigate routes/mechanisms for local transport and distribution of endocrine-disrupting compounds in environmental media.

Current and Planned Initiatives:
i.) DFO and EC have initiated some projects relating to Recommendation 6 and additional work is planned. These include studies mentioned in Recommendation 3 (section II) on long-term monitoring and in Recommendation 4 (section III) on toxic effects. In addition, a project comparing the environmental fate of contaminants discharged into the receiving environments of Iona Island outfall (Metro Vancouver) and Macaulay Point outfall (CRD) is currently being initiated by a Masters student working under the guidance of DFO (IOS).

V. Better Define Sources (Particularly Non-point Sources) and Loadings of Toxic Substances to the Georgia Basin:

Recommendation 7:
Better define the non-point sources (NPS) and point sources of contaminants released to the Georgia Basin in both urban and agricultural areas.

Current and Planned Initiatives:

i.) EC proposed sampling started under the GBAP-funded project, *Fraser Estuary – water quality monitoring*, which includes sampling for toxic substances at various times in the year at two locations in the Fraser Estuary (North Arm at Oak Street Bridge; Main Arm at Tilbury Island) for at least two years (2004-2005) to address inputs of these substances to the Strait of Georgia from the Fraser River.
ii.) AAFC/BC MAL, with APF funding conducted a survey of farm soils for nutrient (N/P/K) A new APF, "Growing Forward" was announced in 2008. For more information on the "Growing Forward" initiative, refer to website http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1208183748364&lang=eng

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Table 1a: Priority Recommendations for Research and Monitoring and a Summary of Current and Planned Initiatives

V. Better Define Sources (Particularly Non-point Sources) and Loadings of Toxic Substances to the Georgia Basin *(cont.):*

Recommendation 7:
Better define the non-point sources (NPS) and point sources of contaminants released to the Georgia Basin in both urban and agricultural areas.

Current and Planned Initiatives *(cont.):*

iii.) EC provided limited funding to AAFC wireworm management IPM tools and strategies project.

iv.) The CRD Stormwater Harbours and Watersheds Program (SHWP) undertakes annual sampling programs throughout the region to monitor stormwater quality to identify problems and prioritize discharges based on several factors. As part of a source control program, SHWP works in partnership with municipalities to educate residents and businesses on stormwater quality issues. To further strengthen source control efforts, SHWP also develops regulatory bylaws and codes of practice as well as non-regulatory best management practices (Larose 2005).

v.) EC is currently compiling an inventory of existing published information on non-point sources to the Georgia Basin. In addition, information on wastewater discharges to the Georgia Basin has also been compiled and loadings of some priority substances from some sectors have been estimated. A report on the wastewater discharges has been published and is available on the GBAP website.

vi.) DFO (IOS) and EC are preparing a PCB/PBDE budget for the Strait of Georgia

Recommendation 8:
Obtain more information on atmospheric deposition of metals and organic contaminants.

Current and Planned Initiatives:

i.) EC conducted studies (GBEI-funded) to determine the levels of persistent organochlorines in freshwater fish and in alpine snowpack in southwest BC; a current study conducted in conjunction with DFO measured air concentrations of PCBs and PBDEs in the Strait of Georgia for inclusion in a regional mass balance model for these contaminants..

ii.) DFO (IOS) has conducted a two-year study comparing local and long-range atmospheric sources of contaminants. The report on this project has been submitted for publication

Recommendation 9:
Determine the ratios of regional (e.g., municipal WWTP effluent, agricultural runoff, freshwater input) to global (e.g., atmospheric long range transport, bio-transport) sources of persistent pollutants in various environmental media.

Current and Planned Initiatives:

i.) DFO (IOS) has conducted studies comparing local and long-range sources of contaminants in air, salmon, marmots and grizzly bears

ii.) Work was conducted under GBAP with the intent of estimating loadings and modelling the fate of PCBs and PBDEs in the Georgia Basin ecosystem. Partners include EC, DFO, BC MOE, Metro Vancouver, SFU, and CRD.

iii.) Refer to Metro Vancouver initiative (vi) under Recommendation 4.

iv.) Metro Vancouver effluent characterization and loadings studies include:
a) a 1997 WWTP characterization study (trace metals and organics from 4 of 5 Metro Vancouver WWTPs) and an enhanced characterization study for all five Metro Vancouver WWTPs
b) several individual CSO characterization studies
c) urban stormwater characterization and loadings report (2003); and
d) prepared a compilation of agricultural data sources in Metro Vancouver and Fraser Valley (undertaken in partnership with EC and the Ministry of Environment)

Recommendation 10:
Prepare a synthesis of information on loadings of contaminants, both “legacy” and “new” (especially currently used pesticides) in runoff from representative urban and agricultural areas to allow extrapolation of the land use/export relationship, developed at these locations, to the entire basin.

Current and Planned Initiatives:

i.) Several of Metro Vancouver studies currently underway would assist in this effort.

ii.) A number of the CRD studies currently underway could provide information relating to this recommendation.

The following table (Table 1b) contains recommendations specific to individual substances or substances groups. In general, these recommendations are considered to be of somewhat lower priority that those contained in Table 1a. Where activities relating to these recommendations and needs in the Georgia Basin area already underway or are planned, brief descriptions of these activities have been included.

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Conventional or Legacy Persistent Organic Pollutants (POPs)				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of Biological Impacts on Local Species and the Factors which Affect the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a))	1.) determine the extent of current POPs contamination (including congener specific analysis), where appropriate, in water and in bed and suspended sediments in tributaries of the Fraser River and its estuary, alpine lakes, snowmelt, reservoirs (also the Lower Thompson Valley), and also determine current levels of POPs in sediments and biota from marine harbours, basins, inlets and estuaries of the Georgia Basin. For example, "hot spots" of PAH sediment contamination within the Georgia Basin should be identified. **Current and Planned Initiatives** i.) EC has proposed sampling started under the GBAP- funded project, *Fraser Estuary – water quality monitoring*, which includes sampling for PCBs at varying flow conditions in the year at two locations in the Fraser Estuary (North Arm at Oak Street Bridge and Main Arm at Tilbury Island) and at one upstream location in the Fraser for at least two years (2004-5).	5.) evaluate the potential for cumulative effects from exposure to low concentrations of many POPs on locally important species, including salmon 6.) assess the effects on early life stages of aquatic species, including salmon 7.) develop a better understanding of local and global effects of individual POPs species 8.) evaluate the effects of POPs on biota in lakes and deep water environs 9.) assess the potential for current environmental levels of POPs to cause endocrine disruption and other toxic effects 10.) investigate the use of innovative bioassay methods (e.g., gene chip technologies) for long-term monitoring of dioxin-like and endocrine-disrupting compounds) 11.) identify benthic or fish communities which are exposed to high levels of PAHs in the Georgia Basin and assess the health of these ecosystems 12.) identify specific PAHs for which more toxicity information is required for local species	14.) obtain more information on individual POPs congeners (i.e., fate, persistence, trophic transfer) under various environmental conditions 15.) determine the implications of contaminant recycling from abiotic sedimentary basin storage into the biotic compartment **Current and Planned Initiatives** i.) DFO has initiated work to address Recommendation 13. ii.) A GBAP project conducted by EC and DFO resulted in a mass-balance model of PCBs in the Georgia Basin, and will provide a better understanding of the sources, fate and distribution of these substances in the Georgia Basin. iii.) DFO is characterizing POPs in marine mammal food webs (killer whales and harbour seals). 16.) evaluate the effect of bioturbation on POPs distribution and re-distribution	19.) document and track local and global point and non-point sources and inputs to Georgia Basin, where possible, including atmospheric deposition and contributions from the Fraser River and other freshwater sources to the Georgia Basin **Current and Planned Initiatives** i.) DFO has initiated work relating to Recommendation 19 and more studies are planned. ii.) EC has proposed sampling started under a GBAP-funded project. *Fraser Estuary water quality monitoring* , which includes sampling for PCBs at varying flow conditions in the year at two locations in the Fraser Estuary (North Arm at Oak Street Bridge and Main Arm at Tilbury Island) and at one upstream location in the Fraser River for at least two years (2004-5). Data from this study will provide information on inputs of PCBs to the Strait of Georgia through the Fraser River.

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Conventional or Legacy Persistent Organic Pollutants (POPs)				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of Biological Impacts on Local Species and the Factors which Affect the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
	Current and Planned Initiatives (cont.) ii.) EC work conducted under GBEI examined POPs in alpine lakes and alpine snowpack; studies underway are addressing levels of PCBs in ecosystem components in the region for mass-balance modelling work. iii.) DFO (IOS) has conducted a number of multi-year monitoring or sediment core studies on toxic chemicals including PCBs. iv.) DFO has planned studies to measure PAHs in mussels as a baseline for the Georgia Basin. v.) EC (CWS) is determining current levels of DDE and other OC pesticides in peregrine falcons and accipiter hawks breeding in the Pacific Region to determine which toxic chemicals are having an impact on local raptor populations. vi.) EC (CWS) is monitoring great blue heron eggs from UBC and Victoria colonies for POPs (OC pesticides, PCDD/Fs, PCBs) and Hg; organic contaminants in surf scoters from major harbours; and also determining exposure and effects of POPs on mink and river otters in the Georgia Basin.	13.) determine the potential for photo-induced toxicity of PAHs in shallow water and surface sediments in the Georgia Basin Current and Planned Initiatives i). DFO has initiated work relating to Recommendation 6-11 and has long-range plans for research relating to Recommendation 12. ii). DFO is developing and applying biomarkers of toxicity in marine mammals in the Georgia Basin (endocrine and immune function). iii). DFO plans to develop methods to measure effects in biota (sea otters). iv). EC (CWS) is conducting studies to determine which OC pesticides are impacting local raptor populations. v). EC (CWS) is determining levels of exposure and biological effects of POPs on mink and river otters in the Georgia Basin.	17.) characterize the transport of POPs to the Georgia Basin through watershed pathways Current and Planned Initiatives i.) DFO has plans to conduct research on Recommendation 14. ii.) EC has proposed sampling started under a GBAP-funded project. Fraser Estuary water quality monitoring includes sampling for PCBs at varying flow conditions in the year at two locations in the Fraser Estuary (North Arm at Oak Street Bridge and Main Arm at Tilbury Island) and at one upstream location in the Fraser River for at least two years (2004-5). Data from this study will provide information on inputs of PCBs to the Strait of Georgia through the Fraser River. 18.) identify sinks for PAHs discharged to the Fraser River during low and high flows Current and Planned Initiatives i.) See Activity ii under Recommendation 15.	Current and Planned Initiatives (cont.) iii.) A GBAP project conducted by EC and DFO resulted in a mass-balance model of PCBs in the Canadian portion of Georgia Basin, and allow estimation of source contributions. iv.) EC (CWS) will be examining the contribution of POPs to osprey from their summering grounds in BC compared to their wintering grounds in Mexico and Central America. 20.) update information on annual import and stockpiles of in-use and banned POPs (e.g., PCBs) in the Georgia Basin Current and Planned Initiatives i.) The National Inventory of PCBs in Use and PCB Wastes in Storage in Canada is a compilation of items containing PCBs in use or in storage in Canada. This inventory is updated annually to account for PCBs that have been taken out of storage or destroyed and new PCB-containing materials reported. Annual reports are available on the EC PCB website: http://www.ec.gc.ca/Publications/default.asp?lang=En&xsl=IDO

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Conventional or Legacy Persistent Organic Pollutants (POPs)

Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin	Develop a Better Understanding of Biological Impacts on Local Species and the Factors which Affect the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin	Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin	Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin
	Current and Planned Initiatives (cont.) vi.) EC (CWS) is collecting eggs and blood from osprey summering in alpine areas in BC for POPs analysis. In addition, fish collected from nearby foraging lakes will be analyzed for the same suite of chemicals. Efforts will be made to determine the contribution of these substances from the summering grounds in BC vs. the wintering grounds in Mexico and Central America. 2.) identify suitable indicator organisms or media for low level contaminants 3.) utilize passive methods such as SPMDs and SPMEs to integrate time varying concentrations 4.) where required, develop best analytical and laboratory procedures to ensure accurate and reliable results **Current and Planned Initiatives** i.) DFO has initiated work relating to Recommendations 1 to 4.	**Current and Planned Initiatives (cont.)** vi) EC (CWS) is completing reports on POPs effects and interactions with thyroid hormones, Vitamin A and plasma lipids in bald eagle chicks vii) EC (CWS) is studying the morphological effects of various organic contaminants on surf scoters from major harbours. viii) The CRD Wastewater and Marine Environmental Program includes investigations aimed at assessing effects of substances such as PBDEs, EDCs, POPs, and non-persistent contaminants. This includes a collaborative assessment of potential toxicogenomic effects of wastewater.		LSearchGUIRenderer,result&n=8B8C8B5B-1&searchoffset=11&xml=&searchfunction=basicsearch&searchstring=pcb%20inventaire%20national&language=en&fromdate=&todate=&fileformat=&searchdisplaycount=10&fieldfilter=any&submit=Recherche#resulttop 21.) obtain additional information on sources of individual PAH compounds to accurately assess loadings to the Georgia Basin 22.) obtain additional information on PAH releases in stormwater discharges from select industrial sites including heavy-duty wood preservation plants using creosote, asphalt manufacturing plants and some oil refineries **Current and Planned Initiatives:** i.) The CRD Integrated Stormwater, Harbours and Watersheds program has been investigating the releases of PAHs in stormwater discharges from different business sectors. 23.)Determine levels of non-traditional POPS in pulp mill effluents

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

New or Emerging Persistent Organic Pollutants (POPs)				
Alkylphenol and Ethoxylates				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of Biological Impacts on Local Species and the Factors which Affect the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of Environmental Fate and Distribution Of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	1.) measure the presence of these compounds in the environment (all media) **Current and Planned Initiatives** i.) See Recommendation 3 in Table 1a. ii.) EC proposed sampling started under the GBAP-funded project, *Fraser Estuary – water quality monitoring*. This includes sampling for nonylphenol and ethoxylates at varying flow conditions in the year at two locations in the Fraser Estuary (North Arm at Oak Street Bridge; Main Arm at Tilbury Island) and at one upstream location in the Fraser River for at least two years (2004/05). 2.) develop standardized analytical procedures for tissue	3.) determine the toxicity to aquatic organisms (especially sediment-dwelling species, and mammalian/avian consumers of aquatic life 4.) obtain additional specific toxicity studies required for the adoption of full environmental quality guidelines 5.) assess the effect of pH on toxicity to aquatic species 6.) assess the contribution of these substances to potential endocrine disrupting effects in aquatic biota in agricultural/urban areas and near WWTPs **Current and Planned Initiatives** i.) EC (PESC) has concluded a GBAP funded study to determine molecular level (genomic) toxicology of WWTP effluent at receiving water concentrations to fish. Select pharmaceuticals and fragrance compounds will be analyzed and profiled for molecular toxicity. Sterol and select pharmaceutical chemistry is to be done on effluent samples (60). This project is scheduled to extend through funding from Genomics BC.	7.) determine the fate of lipophilic compounds in water, sediment and sludges, and biosolids **Current and Planned Initiatives** i.) DFO activities relating to Recommendation 7 include a published report on nonylphenol ethoxylates in sediments (Shang *et al*. 1999). 8.) assess the effects of photolysis on NP/NPnEOs on soil surfaces and sediment 9.) evaluate uptake and elimination in biota (including uptake by aquatic plants/terrestrial mammals) 10.) assess the effect of pH on bioavailability	11.) compile an inventory of usage and suspected sources and loadings estimates from potential sources such as sanitary sewage, storm sewers, CSOs, pulp mills, various industrial plants and agricultural runoff in heavy pesticide use areas **Current and Planned Initiatives** i.) A CEPA assessment report was prepared for nonylphenol and its ethoxylates (http://www.ec.gc.ca/substances/ese/eng/psap/final/npe.cfm). 12.) ensure that actions planned regionally relate to national initiatives under CEPA

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

New or Emerging Persistent Organic Pollutants (POPs)				
Halogenated Diphenyl Ethers				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Conern in the Georgia Basin**	**Develop a Better Understanding of Biological Impacts on Local Species and the Factors Which Affect the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	1.) identify suspected environmental hotspots based on a source inventory and confirm through select sampling to determine current environmental levels in various media, including aquatic biota Current and Planned Initiatives i.) See activities under Recommendation 3 in Table 1a ii). DFO is characterizing PBDEs in killer whales, harbour seals and their prey at multiple sites in the Georgia Basin and has also conducted analysis on select samples for CDPEs. iii.) EC (CWS) is completing the interpretation and reporting of PBDE trends in heron and cormorant eggs. iv.) DFO (IOS) conducted a multi-year monitoring or sediment core studies on toxic chemicals including PBDEs. v.) EC and DFO have analyzed aquatic biota and sediments from select coastal BC sites for CDPEs.	2.) assess potential impacts of elevated concentrations on local aquatic species 3.) obtain additional toxicity information as required for the development of environmental guidelines Current and Planned Initiatives i.) See activities under Recommendation 4 in Table 1a ii.) DFO has initiated some projects relating to Recommendation 2 and more are planned. For example, DFO is characterizing PBDE accumulation in marine mammal food webs and developing biomarkers for POPs-effects, including endocrine disruption in marine mammals. iii.) DFO (IOS) has conducted a number of studies to evaluate the effects of toxics on organisms, including invertebrates, fish and marine mammals in the Strait of Georgia. Some of this work has resulted in a formal advice document and a Viewpoint article (Ross *et al.* 2008a,b) on the threat posed to marine organisms by PBDEs and by deca-BDE, in particular.	(refer to general toxics recommendations in Table 1a) Current and Planned Initiatives i.) A project under GBAP conducted by EC and DFO resulted in a mass-balance model of PBDEs in the Georgia Basin and will provide additional information on the sources, fate and distribution of these substances in the Georgia Basin. ii.) DFO (IOS lab) has developed the analytical capability to analyse for PBDE metabolites in environmental samples.	4.) compile an inventory of suspected past/present sources to identify potential environmental hotspots 5.) obtain information on loadings from current sources Current and Planned Initiatives i.) The CRD Wastewater and Marine Environment program has undertaken monitoring and characterization of wastewater discharges for PBDEs. ii.) A GBAP project conducted by EC and DFO resulted in a mass-balance model of PBDEs in the Canadian portion of Georgia Basin, and allow estimation of source contributions. iii.) EC (Ottawa) is supporting UBC in a material mass balance to predict the fate of PBDEs in waste. Efforts are being focused on Vancouver landfill and landfill leachate. 6.) identify specific CDPE isomers in wood treatment formulations once used in BC for the purpose of fingerprinting sources of these chemicals in the Georgia Basin environment

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

New or Emerging Persistent Organic Pollutants (POPs)				
Phthalate Esters				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of Biological Impacts on Local Species and Factors Affecting the Toxicity of Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probably Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	1.) develop standardized procedures for collection/analysis of samples to improve data reliability and minimize sample contamination Current and Planned Initiatives i.) DFO developed analytical techniques and is characterizing phthalate esters in Indian Arm and False Creek fish and sediments. 2.) compile a list of potential hot spots in environments which receive wastewater and confirm by selective sampling 3.) obtain additional information on concentrations in sediments and in fish and shellfish, especially those harvested for human consumption 4.) determine presence in aquatic birds, mammals, and amphibians in the Georgia Basin Current and Planned Initiatives ii.) EC and SFU researchers have analyzed aquatic biota and sediments from select sites in south coastal areas in BC (Garrett 2002; Lin *et al.;* Mackintosh *et al.* 2004).	5.) evaluate the toxicity of sediment-associated phthalate esters to regionally relevant species	6.) obtain more information on the bioaccumulative potential of phthalate ester compounds and on their food-chain biomagnification Current and Planned Initiatives i.) SFU researchers have conducted some studies on the bioaccumulation of phthalate esters in aquatic biota (Mackintosh *et al.* 2004).	7.) Identify the major controllable sources to the Georgia Basin

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

New or Emerging Persistent Organic Pollutants (POPs)				
Chlorinated Paraffins, Polychlorinated Naphthalenes, and Fluorinated Organic Compounds				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	1.) measure the presence of these compounds in the environment (all media) in select areas of the Georgia Basin 2.) identify suitable indicator organisms for low level contamination 3.) utilize passive methods such as SPMDs and SPMEs in monitoring environmental concentrations 4.) conduct congener specific environmental measurements as total measurements are not adequate for predicting fate and effects 5.) as required, develop best analytical and laboratory procedures to ensure accurate and reliable results **Current and Planned Initiatives** i.) EC is conducting sampling for Bisphenol A, perfluorocarboxylates, and perflurorosulfonates as part of the Chemical Management Plan	6.) evaluate the cumulative effects of low concentrations of these substances on locally important species including salmon 7.) assess the effects of these substances on early life stages of aquatic species including salmon 8.) develop a better understanding of local and global effects of individual compounds 9.) determine the potential for current levels of these substances to cause endocrine disruption and other toxic effects 10.) investigate the use of innovative bioassay methods (e.g., gene chip technologies, etc.) for long-term monitoring of dioxin-like and endocrine-disrupting compounds	11.) examine the fate of these substances in water, sediments, sludge and biosolids **Current and Planned Initiatives** i.) EC in conducting sampling for Bisphenol A, perfluorocarboxylates, and perflurorosulfonates as part of the Chemical Management Plan.	12.) inventory usage and suspected sources, including the continued use of PCNs in electrical equipment, and estimate loadings from potential sources such as municipal WWTPs, storm sewers, CSOs, landfills, and urban runoff

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Current-Use Pesticides				
Current-Use Toxic Agricultural Pesticides[1] (e.g., Atrazine and Endosulfan)				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(Refer to general toxics recommendations in Table 1a).	1.) determine the presence of current-use pesticides and their metabolites in the environment, particularly in ground and surface waters in agricultural and urban areas impacted by runoff Current and Planned Initiatives i.) EC conducts sampling for current-use pesticides and selected transformation products in streams, groundwater and run-off in agricultural and urban areas of the Lower Fraser Valley as part of the national project on surveillance of current-use pesticides in Canadian waters (2003-2005). Samples are collected 1 to 2 times per year or as needed in support of specific research projects. (Collaboration with DFO and in-kind support is obtained from BCMOE and PMRA.) ii.) DFO plans to characterize priority current-use pesticides in coho salmon habitat in the lower Fraser Valley (agricultural and urban streams). iii.) EC (CWS) will be monitoring raptors and trumpeter swans for concentrations of anticholinesterase insecticides, such as chlorpyrifos. iv.) EC is developing a GIS database to inventory recent EC pesticide sampling in the Lower Fraser Valley.	2.) assess the potential impacts of releases of high current-use pesticides and their transformation products on local ecosystems in high-use agricultural areas and in stormwater affected areas Current and Planned Initiatives i.) DFO has initiated projects relating to Recommendation 2 ii.) EC (CWS) is monitoring the incidence of secondary poisoning of raptors and trumpeter swans. In particular the presence of anticholinesterase insecticides, such as chlorpyrifos, will be analyzed. Chlorpyrifos is the preferred product to control wireworm pests in potatoes since the production of fonofos was discontinued in 1998. iii.) EC (CWS) continues to respond to reports of wildlife mortality suspected to be caused by pesticide exposure. iv.) EC (CWS) has been studying the impact of agricultural drainage on local amphibian populations in the Sumas-Chilliwack area. Substances of concern include pesticides, such as endosulfan, as well as nutrients, EDCs, and hormones in animal wastes.	5.) Investigate the transformation, persistence, transport, bioconcentration and biomagnification of high volume current-use pesticides (CUPs) and their metabolites or transformation products in the Georgia Basin environment Current and Planned Initiatives: i.) DFO has initiated efforts relating to Recommendation 5 ii.) See activity i under Recommendation 1. iii.) EC is conducting surveillance of CUPs in select aquatic environments as part of the National Pesticide Science Fund initiative. Sampling of water, sediment and biota in streams is conducted downstream of current agricultural activities. 6.) determine the presence, persistence and transport in groundwater Current and Planned Initiatives i.) See activity i under Recommendation 1.	7.) obtain more specific information on localized areas of use and loadings in the Georgia Basin

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Current-Use Pesticides				
Current-Use Toxic Agricultural Pesticides (e.g., Atrazine and Endosulfan)[1] (cont.)				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
	Current and Planned Initiatives: v.) EC conducted and coordinated work under GBEI and PSF to obtain information relating to the presence of pesticides in the environment and on analytical methodologies. vi.) EC in conducting surveillance of current-use pesticides (CUP) in select aquatic environments as part of the National Pesticide Science Fund initiative. Sampling of water, sediment and biota in streams is conducted downstream of current agricultural activities.	3.) evaluate potential for causing endocrine disrupting effects on biota Current and Planned Initiatives i.) DFO has initiated efforts to address Recommendation 3 in collaboration with SFU through a study on the effects of current-use pesticides on olfaction and behaviour of coho salmon and rainbow trout. 4.) assess potential impacts of various carrier compounds (e.g. endocrine disruption)		
[1] *Note*: In the initial stage of the selection of substances for review in the Georgia Basin, endosulfan and atrazine were identified. However, more recent information has indicated that the list should be inclusive of all high-use toxic pesticides.	[1] *Note*: In the initial stage of the selection of substances for review in the Georgia Basin, endosulfan and atrazine were identified. However, more recent information has indicated that the list should be inclusive of all high-use toxic pesticides.	[1] *Note*: In the initial stage of the selection of substances for review in the Georgia Basin, endosulfan and atrazine were identified. However, more recent information has indicated that the list should be inclusive of all high-use toxic pesticides.	[1] *Note*: In the initial stage of the selection of substances for review in the Georgia Basin, endosulfan and atrazine were identified. However, more recent information has indicated that the list should be inclusive of all high-use toxic pesticides.	*Note*: In the initial stage of the selection of substances for review in the Georgia Basin, endosulfan and atrazine were identified. However, more recent information has indicated that the list should be inclusive of all high-use toxic pesticides.

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Current-Use Pesticides				
Antisapstain Chemicals – DDAC and IPBC				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	1.) measure the presence of DDAC and IPBC in deposition zones in the Fraser River/Georgia Basin 2.) determine the concentrations of DDAC and IPBC in the receiving environment downstream of mills during winter rainstorm events 3.) improve analytical methods in the presence of suspended solids re: variability, recovery, interferences and develop a protocol for the analysis of dissolved and particulate bound DDAC **Current and Planned Initiatives** i.) EC conducted and coordinated work during FRAP (1994-1996) and GBEI to obtain information relating to presence in the environment and analytical methodologies.	4.) investigate the mode of toxicity of these substances 5.) obtain additional information on acute and chronic toxicity to regionally relevant aquatic species (marine and freshwater) to determine whether the current interim water quality guideline is appropriate and also to remove the interim status of the guidelines. 6.) evaluate the toxicity of DDAC/IPBC associated with sediments/suspended particulates near mills, especially with respect to benthic invertebrates and fish 7.) assess the effects of simultaneous exposure to DDAC/IPBC and metals under varying pH and water hardness 8.) obtain additional toxicity testing on sediment dwelling invertebrates to satisfy the requirement for full freshwater and marine sediment quality guidelines	9.) study the fate, persistence, transport and bioavailability of DDAC and IPBC discharged to receiving waters in dissolved and particulate-adsorbed forms 10.) determine persistence and bioavailability of IPBC/DDAC associated with sediments and suspended particulates in deposition zones of the Georgia Basin, especially in marine and estuarine areas 11.) measure the rate of uptake and elimination in aquatic invertebrates 12.) evaluate the effect of pH and water hardness on bioavailability	13.) obtain annual and seasonal estimates of loading to Georgia Basin from antisapstain facilities in the Fraser Basin and on Vancouver Island 14.) develop protocols for use of automatic samplers with flow proportional interval sampling 15.) determine the significance of input of DDAC from other molluscicide and industrial disinfectant use by measuring loadings from stormwater and WWTP discharges

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Current-Use Pesticides

Antifouling Chemicals – Organotin- and Copper-based Compounds

Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin	Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin	Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin	Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin
Organotin compounds				
(refer to general toxics recommendations in Table 1a)	1.) implement a monitoring program including water, sediment and biota at select sites to determine the effectiveness of existing regulations. Sampling locations should include sites where previous sampling indicated concentrations in excess of environmental guidelines, recreational boating areas, and areas with sensitive shellfish populations. 2.) determine the presence of these chemicals in marine mammals	3.) conduct regular monitoring for imposex in gastropods at select sites as a means of identifying changes in environmental concentrations of TBT over the long-term and evaluating the efficacy of existing controls 4.) assess the significance of elevated organotin concentrations in grebes and seaducks from coastal BC and determine the incidence of imposex in aquatic birds *Current and Planned Initiatives* i.) EC ((CWS) conducted a study of exposure and morphological effects of butyltins and other contaminants on surf scoters from major harbours.	5.) assess the transport of antifoulant chemicals beyond harbours via currents and biotic transport mechanisms	6.) on a regular basis, determine adherence of marinas and the shipbuilding/repair industry with BMPs for these facilities; assess the adequacy of the existing BMPs in reducing releases of antifouling compounds; and estimate the loadings of organotin compounds to the Georgia Basin from these facilities *Current and Planned Initiatives* i.) In 1998, EC conducted a review of the BMP implementation within this sector and found that the average score for compliance was 42%. 7.) obtain information on other sources (WWTPs, landfills, wood preservatives, incinerators, stormwater, industrial slimicides)
Copper compounds				
(refer to general toxics recommendations in Table 1a))	1.) assess the levels of copper in harbour s, marinas and in recreational boating areas to determine whether the replacement of tributyltin-based antifouling paints with copper-based products has resulted in unacceptable environmental concentrations of copper	(refer to general toxics recommendations in Table 1a)	(refer to general toxics recommendations in Table 1a)	2.) regularly assess the adherence of marinas and the shipbuilding/repair industry with BMPs; assess the adequacy of the existing BMPs in reducing releases of these compounds; and estimate the loadings from these facilities *Current and Planned Initiatives* i.) See activity I under Organotin Compounds Recommendations

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Metals				
Cadmium				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	(refer to general toxics recommendations in Table 1a)	1.) determine the significance of the apparent trend toward increased cadmium concentrations in seabird colonies in a northerly direction along the BC coast	2.) conduct further studies on trophic transfer processes for biologically available cadmium as part of study of enriched concentrations of cadmium in BC oysters (recommendations from DFO workshop) **Current and Planned Initiatives** i.) DFO has initiated a project in collaboration with McGill Centre for Indigenous Peoples' Nutrition and Environment (CINE) to characterize cadmium and other metals in traditionally harvested shellfish species (tentatively oysters, butter clams, mussels, manila clams and geoducks), in partnership with Cowichan Tribes and Penalakat First Nations (Risk assessment of shellfish consumption to coastal communities in BC).	(refer to general toxics recommendations in Table 1a)
Chromium and Copper				
(refer to general toxics recommendations in Table 1a and to recommendations for copper-based antifoulants in this table)	(refer to general toxics recommendations in Table 1a and to recommendations for copper-based antifoulants in this table)	(refer to general toxics recommendations in Table 1a and to recommendations for copper-based antifoulants in this table)	(refer to general toxics recommendations in Table 1a and to recommendations for copper-based antifoulants in this table)	(refer to general toxics recommendations in Table 1a and to recommendations for copper-based antifoulants in this table)

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Metals				
Manganese				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	(refer to general toxics recommendations in Table 1a)	(refer to general toxics recommendations in Table 1a)	1.) assess the role of manganese in sequestering other metals in the aquatic systems 2.) determine reasons for the lack of correlation between elevated manganese levels and traffic density	3.) develop the ability to distinguish manganese in the environment originating from (methylcyclopentadienyl manganese tricarbonyl (MMT) releases from other sources
Mercury				
(refer to general toxics recommendations in Table 1a)	1.) investigate the presence of elevated concentrations of mercury in rockfish collected in the vicinity of BC salmon farms 2.) obtain additional information on mercury concentrations in various species of fish in BC in light of the fact that mercury concentrations exceeding the recommended health guidelines have recently been detected in freshwater bass from Vancouver Island and in rockfish from the west coast of Vancouver Island	(refer to general toxics recommendations in Table 1a) **Current and Planned Initiatives** i.) EC (CWS) is monitoring great blue heron eggs collected from colonies at Victoria and UBC for concentrations of select POPs and Hg.	(refer to general toxics recommendations in Table 1a) **Current and Planned Initiatives** i.) DFO has conducted research on the fate of Hg in the Georgia Basin environment (Johannessen *et al.* 2005).	(refer to general toxics recommendations in Table 1a)
Nickel				
(refer to general toxics recommendations in Table 1a)	(refer to general toxics recommendations in Table 1a)	1.) assess the bioavailability of the high levels of nickel in Sumas River sediments and suspended solids	(refer to general toxics recommendations in Table 1a)	(refer to general toxics recommendations in Table 1a)

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Metals				
Silver				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	1.) develop a means of measuring the biologically-available forms of silver as most existing criteria/guidelines are based on total silver, which includes the less toxic forms (compared to free monovalent ion) and thus may be overprotective	2.) determine if existing criteria/guidelines are protective of both hatchery fry and wild fry by assessing the toxicity of silver to anadromous salmonids, particularly to fry in soft freshwater habitats 3.) evaluate the biocidal properties of Ag2+ and Ag3+ (active ingredients in disinfectants and water purification) 4.) investigate chemical speciation effect on toxicity (silver chloride complexes in seawater)	5.) develop a better understanding of silver geochemistry and the chemical speciation of silver in the Georgia Basin	6.) identify and characterize industries discharging silver to municipal sewers in order to better determine loadings and control sources of silver to the Georgia Basin.
Zinc				
(refer to general toxics recommendations in Table 1a)	(refer to general toxics recommendations in Table 1a)	1.) assess the relative contribution of zinc to the toxicity of stormwater runoff from wood treatment facilities	(refer to general toxics recommendations in Table 1a)	(refer to general toxics recommendations in Table 1a)

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Nitrogen-based Nutrients				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	*Identified for the Georgia Basin:* 1.) compile information on areas where surface or groundwater concentrations of nitrate, nitrite and ammonia reach toxic levels for either human consumption or for aquatic-based species in the Georgia Basin 2.) identify aquifers of concern in Georgia Basin and implement monitoring to identify trends in nitrogen-based nutrients in ground and surface waters in affected aquifers	*Identified for the Georgia Basin:* 3.) employ consistency in documenting and reporting information on fish kills from accidental spills/discharges of nutrient-related compounds, as current information is not always reliable and reporting is done on a voluntary basis *Identified in national study:* 4.) assess the role of nitrogen-based nutrients in inducing algal blooms and toxin production **Current and Planned Initiatives:** i.) DFO publication on this issue (Mackas and Harrison 1997) 5.) determine the effect of long-term (decades) nitrogen (along with phosphorus) loading on aquatic ecosystems and of atmospheric nitrogen deposition in terrestrial ecosystems	refer to general toxics recommendations in Table 1a	*Identified in national study:* 6.) estimate nitrogen (and phosphorous) loadings from industries not connected to municipal WWTPs 7.) evaluate the potential impacts of climate change on nutrient loading 8.) examine effects of forest management practices on nutrient loss from forests to aquatic ecosystems *Identified for Georgia Basin:* 9.) develop nutrient budgets in agricultural areas of the Georgia Basin and estimate nutrient loadings to surface/groundwater from agricultural sources, including greenhouses **Current and Planned Initiatives:** i.) EC is interested in further development of NLOS model by AAFC. ii.) Programs under the National Agricultural Policy Framework (National Stewardship Program and the Environmental Farm Planning (EFP) Program) include a nutrient budget management planning component which is in the early stages. These programs

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Nitrogen-based Nutrients				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	Current and Planned Initiatives i.) Metro Vancouver (P2/GBAP/NPS) has prepared a report compiling data sources in Fraser Valley. EC has compiled the data in a national database format. APF/AAFC would be interested from risk scan perspective. ii.) EC has been conducting monthly sampling for nitrate at 23 sites in the Abbotsford Aquifer for over 15 years. The number of groundwater monitoring sites has increased slightly in recent years to 30 monthly sites. An annual snapshot of about 60 sites is also conducted. Many of the monitoring sites in the aquifer continue to show elevated nitrate concentrations. The average concentration of nitrate in groundwater from EC's monitoring wells is 1.5 times the drinking water guideline, with maximum concentrations being 3 to 6 times higher in some areas.	Current and Planned Initiatives i.) EC is considering a MOU to provide limited funding to UBC's IRES to pull together their Sumas monitoring (water and sediment) (nutrients and trace metals) over 25 years as well as land use information on one database on CD-ROM. ii.) EC is coordinating studies related to estimating critical loads for nitrogen deposition in the Georgia Basin. Terrestrial and aquatic critical load estimates have been made for the Georgia Basin; mathematical modelling to estimate regional N and S deposition is complete and there have been efforts at empirical estimation of N and S deposition using passive samples. iii.) EC is planning a pilot study to look at the effect of N in high-elevation lakes in SW BC in 2009.	refer to general toxics recommendations in Table 1a	Current and Planned Initiatives ii .) provide partial funding for farmers to develop and implement nutrient management plans. In addition, EFP advisors and commodity EFP delivery groups provide input. iii.) EC and UBC have been working together to refine and update nutrient balances for the Fraser Valley. . 10.) determine the relationship between agricultural application of nutrients and levels of nitrate in groundwater 11.) identify differences in regional atmospheric deposition within Georgia Basin, including deposition to coastal mountains

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Nitrogen-based Nutrients				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)			refer to general toxics recommendations in Table 1a	Current and Planned Initiatives i.) EC, in partnership with SFU and BC MOE, is developing a model on groundwater flow and contaminant transport for the Abbotsford Aquifer. There are plans to develop collaborations with agricultural agencies to link the flow and transport model to a model(s) on nitrate input to the aquifer's groundwaters. ii.) Some aspects of this recommendation will be addressed through the critical load estimation; past work of EC has examined spatial pattern in nitrogen deposition through biomonitoring using lichen tissue.

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Wood Extractives				
Facilitate the Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Biological Impacts and Factors Affecting the Toxicity of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Develop a Better Understanding of the Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
(refer to general toxics recommendations in Table 1a)	1.) evaluating existing information on environmental levels of wood extractives in the Georgia Basin and obtaining current information on the presence of these compounds in both fresh and marine environs (all media) 2.) consider developing techniques to monitor plant sterols which can also be considered wood extractives (such as the endocrine disrupter β-sitosterol) **Current and Planned Initiatives** i.) DFO (IOS lab) has developed the capability to analyze for plant sterols in fish.	3.) assess potential sublethal effects in freshwater and marine nearshore and harbour areas where chronic exposure from wood handling and milling occurs 4.) determine the contribution of plant sterols to the sublethal effects of pulp and paper effluents	5.) examine the release of wood extractives as a result of sediment disturbance in log pockets 6.) obtain information on accumulation rates and degradation rates in marine sediments	7.) compile existing information on sources of wood extractives (annual runoff volume from suspected sources, volume/type of wood handled, handling/processing, waste wood thickness on sea bed, site dredging) 8.) measure concentrations and loadings of resin acids, etc. in runoff from lumber mills, heavy duty wood preservation plants, wood chip storage areas, wood waste landfills, equestrian rings and cranberry field berms 9.) obtain information on pulp mills as a source of plant sterols

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Substances of Probable Concern (a number of substances, including pharmaceuticals and personal care products and their metabolites, bisphenol A, ethylene glycol, phenols, and phytoestrogens, were identified by the BCTWG as probable substances of concern in the Georgia Basin. They were not included in the list of priority substances due to insufficient information about their sources, presence and potential biological impacts in the Georgia Basin. The following recommendations identify additional information which is needed to determine whether these substances should be considered priority substances for action in the Georgia Basin. These recommendations will also apply to other substances of probable concern identified in the future.)

Develop a Better Sharing, Management and Communication of Information/Data on Toxic Substances	Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern	Develop a Better Understanding of Potential Biological Effects of Priority Toxic Substances and Substances of Probable Concern on Local Species and the Factors Which Affect Toxicity	Develop a Better Understanding of Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin	Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin
(refer to general toxics recommendations in Table 1a)	1.) compile a prioritized list of pharmaceuticals and personal care products (PPCPs) and other substances of probable concern in the Georgia Basin for future monitoring **Current and Planned Initiatives** i.) CRD has undertaken a collaborative program with the University of Victoria to study the effects of pharmaceuticals and personal care products. As part of this project, a list of PPCPs relevant to the CRD will be compiled. ii.) Metro Vancouver has identified a prioritized list for its WWTP effluent characterization study (current) and its PPCPs monitoring and assessment program under its LWMP; and Metro Vancouver is pursuing a joint study with EC (PESC lab) to study pharmaceuticals in ambient and receiving waters in the region.	(refer to general toxics recommendations in Table 1a) **Current and Planned Initiatives** i.) EC (CWS) has been studying the impact of agricultural drainage on local amphibian populations in the Sumas-Chilliwack area. Substances of concern include pesticides, such as endosulfan, as well as nutrients, EDCs, and hormones in animal wastes. ii.) EC and DFO co-operated on research (method development, literature review, and toxicity studies) relating to emamectin benzoate (the active ingredient in SLICE) and its metabolites.	4.) develop knowledge of transformation, persistence, availability, transport and bioconcentration of substances of probable concern in the Georgia Basin **Current and Planned Initiatives** i.) At the national level, EC is involved with risk assessment and risk management regulatory activities associated with categorization and screening of the Domestic Substances List and the Chemicals Management Plan Ministerial Challenge Program. Under these programs, screening assessments are conducted in order to identify those substances which meet or may meet "toxic" criteria under section 64 of CEPA 1999. If found to be "toxic', actions to reduce the risk presented by these substances are undertaken by EC and/or HC. Refer to website: http://www.chemicalsubstancesc himiques.gc.ca/en/index.html.	5.) obtain additional information on the sources of pharmaceuticals, personal care products, veterinary drugs, and other substances of probably concern in the Georgia Basin **Current and Planned Initiatives** i.) EC (PESC) has been working on the identification of veterinary drugs used in the poultry and dairy industry in the Fraser Valley area of BC and the development of methods for measuring their presence and stability in the environment. The next step is to look at runoff water from the areas where poultry litter and dairy manure were applied. ii.) DFO has initiated projects to characterize a "top 30" EDC list in environmental samples and also Annacis Island WWTP effluent.

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Substances of Probable Concern (a number of substances, including pharmaceuticals and personal care products and their metabolites, bisphenol A, ethylene glycol, phenols, and phytoestrogens, were identified by the BCTWG as probable substances of concern in the Georgia Basin. They were not included in the list of priority substances due to insufficient information about their sources, presence and potential biological impacts in the Georgia Basin. The following recommendations identify additional information which is needed to determine whether these substances should be considered priority substances for action in the Georgia Basin. These recommendations will also apply to other substances of probable concern identified in the future.)				
Develop a Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern**	**Develop a Better Understanding of Potential Biological Effects of Priority Toxic Substances and Substances of Probable Concern on Local Species and the Factors Which Affect Toxicity**	**Develop a Better Understanding of Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
	2.) obtain information on the presence of PPCPs and other substances of probable concern in the Georgia Basin environment **Current and Planned Initiatives** i.) Under the Strait of Georgia Ambient Monitoring Program, DFO (IOS) and Metro Vancouver are jointly working under a five-year collaborative agreement. The objectives are to characterize the surrounding environment to better understand impacts from WWTP outfall discharges, develop indicators of environmental change which can be used to distinguish anthropogenic and natural effects, and study long-term predictions of sustainability for input of organic matter and contaminants including PPCPs. ii.) EC in conducting sampling for Bisphenol A as part of the Chemical Management Plan 3.) develop methodology for analysis of emerging chemicals for which there is currently no recognized methodology, and increase the capability and capacity for analysis	**Current and Planned Initiatives** iii.) EC (PESC) conducted a GBAP funded study to determine molecular level (genomic) toxicology of WWTP effluent at receiving water concentrations to fish. Select pharmaceuticals and fragrance compounds will be analyzed and profiled for molecular toxicity. Sterol and select pharmaceutical chemistry is to be done on effluent samples (60). This project is scheduled to extend through 2006/0 .		**Current and Planned Initiatives** iii.) Ambient monitoring programs being conducted in the Georgia Bsin by Metro Vancouver in the include work on pharmaceuticals.

Table 1b: Substance-Specific Recommendations for Research and Monitoring to Address Issues Relating to Toxic Substances in the Georgia Basin and a Summary of Current and Planned Initiatives

Substances of Probable Concern (a number of substances, including pharmaceuticals and personal care products and their metabolites, bisphenol A, ethylene glycol, phenols, and phytoestrogens, were identified by the BCTWG as probable substances of concern in the Georgia Basin. They were not included in the list of priority substances due to insufficient information about their sources, presence and potential biological impacts in the Georgia Basin. The following recommendations identify additional information which is needed to determine whether these substances should be considered priority substances for action in the Georgia Basin. These recommendations will also apply to other substances of probable concern identified in the future.)				
Develop a Better Sharing, Management and Communication of Information/Data on Toxic Substances	**Obtain Current Information on Environmental Levels of Priority Toxic Substances and Substances of Probable Concern**	**Develop a Better Understanding of Potential Biological Effects of Priority Toxic Substances and Substances of Probable Concern on Local Species and the Factors Which Affect Toxicity**	**Develop a Better Understanding of Environmental Fate and Distribution of Priority Toxic Substances and Substances of Probable Concern in the Georgia Basin**	**Obtain More Information on Non-Point (and other) Sources and Loadings of Toxic Substances to the Georgia Basin**
	of those chemicals with existing recognized protocols (e.g.,pharmaceuticals, hormones, personal care products, new "POPs", and high volume chemicals such as LAS and other surfactants). **Current and Planned Initiatives** i.) DFO has initiated projects to characterize a "top 30" EDC list in environmental samples and also in Annacis Island WWTP effluent. ii.) DFO (IOS) lab has developed the capability to analyze for pharmaceuticals. iii.) Metro Vancouver is funding a project with SFU examining analytical procedures to test for pharmaceuticals and EDCs in effluent (liquid and solid fractions). iv.) EC (PESC) has been working on the identification of veterinary drugs used in the poultry and dairy industries in the Fraser Valley area of BC. For the identified compounds, methods are being developed for determining their presence and stability in the environment.			

3.3 Priority Needs and Recommendations for Future Management Actions to Address Toxics-Related Issues in the Georgia Basin[8]

Priority needs identified by the BCTWG for future management actions to address toxic substances issues in the Georgia Basin include:

- review past and existing initiatives and support and further promote those which have been shown to be successful;
- implement measures to address identified hotspots and priority watersheds;
- utilize voluntary pollution prevention and pollution control initiatives where possible;
- review existing controls and, where required, develop mandatory regulatory activities; and
- assess and ensure the efficacy of management actions.

The BCTWG recommends that management actions implemented to address issues related to toxic substances in the Georgia Basin focus on both source- or sector-based and watershed-based approaches. The targeting of specific industries or business sectors is often the most effective route to the reduction of specific contaminants over a wide geographical region. However, in some cases, particularly with respect to sensitive watersheds and watersheds at risk, it is important to focus on reducing the release of a number of toxics to the watershed from multiple sources simultaneously. Since it would be impossible to address all business sectors and/or watersheds within the Georgia Basin, regulatory agencies and other stakeholders will need to identify priority sectors and watersheds for action.

It is important to note that many successful initiatives to reduce the release of toxic substances to the Georgia Basin have already been implemented by various sectors and within various watersheds, municipalities, and regional districts. For example, some of the concepts described within the recommendations of the management plan described following are already incorporated as an integral part of the Liquid Waste Management Plans (LWMPs) of both the CRD and Metro Vancouver. In addition, there have been some successful initiatives to clean-up contaminated areas within specific priority watersheds. It is important to highlight these successes and to encourage the implementation of similar measures more widely throughout the Georgia Basin area. A summary of many of the actions and initiatives which have already been implemented to reduce contaminants releases from major identified sources to the Georgia Basin is presented in Appendix 1.

Sources of contaminants to the Georgia Basin which have been identified as priorities for management actions include small to medium sized enterprises which release toxic substances to sanitary sewers (including automotive repair, parking lots, street sweeping, electroplating, printing, photographic imaging, paint and varnish industries, hospitals, medical laboratories and dental offices), urban stormwater, and agricultural runoff. Several high priority watersheds for action have been identified in both urban and agricultural areas; however, the identification of additional priority watersheds will require regulatory agencies and other stakeholders to agree on criteria for identifying the highest priority watersheds for management actions. Factors which will need to be considered in developing these criteria include overall watershed health, the risks associated with toxics versus other site-specific conditions and water quality issues, the criteria used for defining water quality, and the likelihood that management actions will be effective.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

The priority needs for future management actions and the recommendations for addressing these needs are discussed following. As discussed in Section 3.2, some of the recommendations of the BCTWG are general in nature and pertain to most, if not all, of the substances of concern in the Georgia Basin, while other recommendations pertain to specific substances. Since actions on the more general recommendations would help address concerns relating to a wide range of substances, the BCTWG considers these recommendations to be of the highest priority. The management plan proposed by the BCTWG, and discussed following, addresses the reduction of pollution from toxic substances in the Georgia Basin through a series of sequential steps based on the identified priority needs and recommendations.

While the views and recommendations of the BCTWG presented in this report were developed by consensus, the Terms of Reference of the BCTWG provide for the views of dissenting members to be reflected. It should be noted that while all member agencies provided input to the development of the recommendations for future research and monitoring, Metro Vancouver (was Greater Vancouver Regional District (GVRD)) did not provide input to the development of recommendations relating to future management actions. This agency felt that it was not appropriate for them "to comment on programs that the federal government may consider as many of these matters are also dealt with under provincial jurisdiction, and since Metro Vancouver operates under this jurisdiction." A letter from Metro Vancouver to Environment Canada containing a more complete explanation of the Metro Vancouver decision to abstain from commenting on recommendations pertaining to management actions is presented in Appendix 5 of this report.

Need I: Review past and existing initiatives and support and further promote those which have been shown to be successful

It is important to build upon past and existing initiatives in the Georgia Basin (federal, provincial, regional, and municipal). In order to benefit from past successes and failures, existing and past initiatives to address high priority issues should be reviewed and assessed. Initiatives which have proved successful should be promoted and expanded, as necessary, while less successful initiatives should be re-evaluated.

Recommendation 1:
Review/follow-up of FRAP, BIEAP, and GBEI outcomes and recommendations to identify outstanding issues and to evaluate the effectiveness of initiatives under these programs.

It is important to note that many successful initiatives to reduce the release of toxic substances to the Georgia Basin have already been implemented by various sectors and within various watersheds, municipalities, and regional districts. For example, concepts of the recommendations of the management plan described following are already incorporated as an integral part of the Liquid Waste Management Plans (LWMPs) of both the CRD and Metro Vancouver. In addition, there have been some successful initiatives to clean-up contaminated areas within specific priority watersheds. It is important to highlight these successes and to encourage the implementation of similar measures more widely throughout the Georgia Basin area.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Need II: Implement measures to address identified hotspots and priority watersheds

While several high priority and “at-risk” watersheds within the Georgia Basin have been identified and some “hotspots” within watersheds have been documented, it will be necessary for regulatory agencies and other stakeholders to collaborate on the development of mutually agreeable criteria for selecting priority watersheds or priority areas within watersheds. The development of these criteria may be difficult as various factors must be considered in developing such criteria. These include the current state of watershed health, risks from toxics in comparison with other water quality issues, and the criteria which are being used for defining water quality (e.g., biological models vs. chemical loading). Watersheds with elevated concentrations and loadings of toxic substances (particularly metals, PAHs, current-use pesticides, and nutrients) and/or observed biological impacts should be considered high priority for management action where there is a likelihood of rehabilitation success. The percent total impervious area (TIA) within a watershed has been linked to the loadings of a variety of contaminants, including metals and PAHs, to the watershed and TIAs of more than 15% have been linked to adverse effects on fish populations. However, the TIAs for most watersheds within the Georgia Basin have not yet been determined. There is a need for information on existing TIAs in watersheds within the Georgia Basin as well as for mechanisms by which to track actual and/or projected changes over time. In order to protect clean watersheds (not currently impacted), those that are potentially at risk due to impending development or other activity should also be considered high priority.

Recommendation 2:

Incorporate water quality protection and improvements into existing planning processes which include stakeholder involvement. This would include the integration of actions to minimize runoff contaminated with nitrogen-based nutrients or other priority substances into agricultural and urban planning processes (e.g., OCP, LWMP, and ISMP); the investigation and encouragement of innovative approaches to improving water quality through low impact development techniques; and methods to minimize or, where needed, reduce total impervious surface areas.

(Note: *This recommendation acknowledges that water quality is intrinsically tied to other activities and cannot be managed as a separate issue. OCPs currently do not explicitly address water quality, but opportunities exist to achieve water quality objectives by managing the location and type of development in a particular watershed.)*

Need III: Utilize voluntary pollution prevention and pollution control initiatives, where possible

Where past and current initiatives are shown to be inadequate and the need for additional management action is confirmed, future efforts would focus first on the development and implementation of voluntary pollution prevention and pollution control initiatives such as Best Management Practices and education. The implementation of voluntary initiatives should include stakeholder groups such as citizen’s groups, industry associations, etc.; site audits; incentive programs; product stewardship programs; public outreach and education. Many programs initiated by community groups have been effective in reducing pollution to watersheds in the Georgia Basin. It is important to encourage increased involvement of community groups

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

by improving communication on priority issues and by working with these groups to find ways to most effectively implement voluntary instruments such as BMPs and codes of practice to reduce contaminant releases.

Recommendation 3:
Implement non-CEPA pollution prevention/control initiatives to address discharges of toxic substances (focusing on PAHs/metals) to sanitary sewers. Sewer use bylaws exist in some areas and could be expanded to others.

Recommendation 4:
Continue to implement and expand pollution prevention and control initiatives to address discharges and spills of toxic substances (focusing on metals, PAHs, high-use toxic pesticides, and nitrogen-based nutrients) to urban stormwater and agricultural runoff (e.g., Cecelia Creek in Victoria).

Recommendation 5:
Implement, more widely, pollution prevention/control initiatives (e.g., BMPs) to address automotive related industries, electroplating, printing, photographic imaging, paint and varnish industries, hospitals, medical laboratories, dental offices, parking lots, ship repair, street sweeping, aquaculture, landscaping and other small and medium-sized enterprises.

Recommendation 6:
Use economic measures and fiscal instruments such as cost-sharing pollution prevention/control initiatives with facilities; innovative funding schemes (e.g., money for mercury coupons for car washes/car repair to eliminate release to the environment through leaks) and business recognition; involvement of an independent third party/peer group for assistance and mentoring; and tax incentives for pollution reduction.

Need IV: Review existing controls and, where required, develop mandatory regulatory activities

In cases where voluntary measures are not effective, the implementation of regulatory measures may be required. The strong enforcement of existing regulations and codes, where necessary, is an important component of management actions to reduce toxics releases to the environment.

Recommendation 7:
Develop regulatory requirements for pollution prevention (e.g., source control) such as regulatory Codes of Practice for high priority industry and business sectors, where voluntary pollution prevention/control initiatives have not been effective.

Recommendation 8:
Encourage local regulations such as stormwater bylaws and changes to Official Community Plans to promote low impact development and re-development (such as minimizing TIAs) in order to reduce the release of toxic substances.

Recommendation 9:
Ensure regulations and requirements on Crown lands are, at a minimum, equivalent to those on non-Crown lands (e.g., contaminated sites).

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Need V: Assess and ensure the efficacy of management actions

An emphasis on monitoring the results of management actions is critical to assessing their effectiveness in reducing releases of toxic substances to the Georgia Basin. The measurement of end outcomes must be included as part of implementation plans for all future management actions and, ultimately, future monitoring programs should evaluate changes in appropriate indicators of environmental health and, thereby, link management actions to environmental health. Goals of management actions should include improvements in water quality and the overall health of aquatic ecosystems.

Recommendation 10:

Improve the reporting, management and sharing of information/data on priority issues to both encourage partnerships between stakeholders and to promote the monitoring of the efficacy of pollution reduction initiatives.

Recommendation 11:

Conduct follow-up inspections and monitoring to ensure that initiatives meet their intended goals (e.g., routinely monitor the effectiveness of management options including the efficacy of existing BMPs).

Recommendation 12:

Ensure the remediation of contaminated sites to prevent the release of toxics to the environment by employing scientifically-based guidelines and standards which are regularly reviewed for efficacy.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Table 2a summarizes the highest priority recommendations for management actions in the Georgia Basin and also identifies activities relating to these recommendations which are planned or already underway.

Table 2a: Priority Recommendations for Management Actions and a Summary of Current and Planned Initiatives[1]

I. Review past and existing initiatives and support and further promote those which have been shown to be successful:

Recommendation 1:
Review/follow-up of FRAP, BIEAP and GBEI outcomes and recommendations to identify outstanding issues and to evaluate effectiveness of initiatives under these programs.

Current and Planned Initiatives:

i.) AAFC/BC MAL, with APF funding are currently planning a survey (stratified random) of farm soils for nutrient (N/P/K) status mid-Sept to mid-Oct 2004. EC is preparing a MOU to provide some additional funding support.

ii.) EC/DFO/BC MOE members of APF Environment Working Group responsible for delivering EFP program (also encompasses National Stewardship (BMP) and Greencover incentive funding programs).

iii.) Environmental scan for APF needs to be updated to help focus program spending priorities.

iv.) Under contract to Environment Canada, Sheltair reviewed the status of outcomes and recommendations under the FRAP, FREMP, BIEAP, GBEI.

II. Implement measures to address identified hotspots and priority watersheds:

Recommendation 2:
Incorporate water quality protection and improvements into existing planning processes which include stakeholder involvement. This would include the integration of actions to minimize runoff contaminated with nitrogen-based nutrients or other priority substances into agricultural and urban planning processes (e.g., OCPs, LWMPs, ISMPs), and the investigation and encouragement of innovative approaches to improving water quality through low impact development techniques and methods to minimize and, where needed, reduce total impervious surface areas (TIAs)

(***Note:*** ***This recommendation acknowledges that water quality is intrinsically tied to other activities and cannot be managed as a separate issue. OCPs currently do not explicitly address water quality, but opportunities exist to achieve water quality objectives by managing the location and type of development in a particular watershed.)***

Current and Planned Initiatives:

i.) Metro Vancouver has been progressive in examining watershed-based approaches to land use planning. LWMPs provide more tangible mechanisms to address water quality, especially now that the Province asks for stormwater and decentralized wastewater components to these plans (for more background, see Chapter 4 of the Provincial Stormwater Planning Guidebook which is available on website http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html. Metro Vancouver has recently redrafted the LWMP (refer to website http://www.metrovancouver.org/about/publications/Publications/DraftLiquidWasteManagementPlan2008.pdf). Within the LWMP, municipalities will be committed to stormwater management for watersheds within their jurisdictions. For information on policies and commitments under the LWMP refer to website http://www.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-Stormwater.pdf.

ii.) BC Institute of Technology (BCIT), with support from EC, has studied the stormwater quantity and quality benefits of various "green roof" designs. BCIT-led green roof assessments are also being done in conjunction with the CRD. For more information on BCIT research on green roofs refer to http://commons.bcit.ca/greenroof/research.html.

iii.) The District of Maple Ridge, with support from EC, has studied the stormwater benefits of rain gardens and bioswales in a new suburban residential development. For more information refer to http://www.kwl.bc.ca/docs/CWRA2006-Silver_Ridge_Paper.pdf.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Table 2a: Priority Recommendations for Management Actions and a Summary of Current and Planned

II. Implement measures to address identified hotspots and priority watersheds *(cont.):*

Recommendation 2 ***(cont.):***
Incorporate water quality protection and improvements into existing planning processes which include stakeholder involvement. This would include the integration of actions to minimize runoff contaminated with nitrogen-based nutrients or other priority substances into agricultural and urban planning processes (e.g., OCPs, LWMPs, ISMPs), and the investigation and encouragement of innovative approaches to improving water quality through low impact development techniques and methods to minimize and, where needed, reduce total impervious surface areas (TIAs)

(***Note:*** ***This recommendation acknowledges that water quality is intrinsically tied to other activities and cannot be managed as a separate issue. OCPs currently do not explicitly address water quality, but opportunities exist to achieve water quality objectives by managing the location and type of development in a particular watershed.***

Current and Planned Initiatives (cont.):

iv.) The CRD Stormwater, Harbours and Watersheds Program (SHWP) works to protect municipal infrastructure, watercourses and the nearshore marine environment from stormwater-carried contaminants. The SHWP has developed regulatory bylaws and codes of practice as well as non-regulatory best management practices to protect stormwater quality. The program works in close collaboration with municipalities, encouraging the use and implementation of natural drainage techniques, the reduction of impervious surfaces and the increase of natural areas, the restoration of watercourses and shoreline habitats, and the provision of tools such as watershed-based planning. This program also includes a strong educational component and the CRD works with businesses and households through extensive public outreach (Larose 2005). Through area-based initiatives such as the Esquimalt Lagoon Stewardship Initiative, the Gorge Waterway Initiative, Rock Bay Contaminant Reduction Committee and Bowker Creek Urban Watershed Renewal Initiative, SHWP works with other community and government agencies to educate residents about the impact of contaminants to the streams and nearshore marine environments and to take action to protect habitat and reduce contaminant inputs. These goals are achieved through a variety of actions including, but not limited to, residential outreach, encouragement and implementation of natural drainage techniques, reduction of impervious surfaces and increase of natural areas, restoration of watercourses and shoreline habitats and the provision of tools to municipalities to assist them in achieving the above goals (www.crd.bc.ca/watersheds/index.htm).

v.) An intergovernmental partnership comprised of members from all levels of government funded the development of modelling tool for evaluating the benefits of installing various types of stormwater source controls including green roofs, infiltration facilities, etc. In addition, stormwater management workshops have been organized and a brochure on stormwater and impervious surfaces has ongoing distribution. For more information refer to http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/urban_rural_land/pdf/61.pdf.

III. Utilize voluntary pollution prevention (P2) and pollution control initiatives, where possible:

Recommendation 3:
Implement non-CEPA pollution prevention/control initiatives to address discharges of toxic substances (focusing on PAHs/metals) to sanitary sewers. Sewer use bylaws exist in some areas and could be expanded to others.

Current and Planned Initiatives:

i.) The CRD is committed to an integrated coastal zone management approach to manage liquid waste in its region. This approach prioritizes actions following risk-based and cost benefit principles to protect public health and the receiving environment in a cost-effective manner. This approach is detailed in the CRD Core Area and Saanich Peninsula Liquid Waste Management Plans. A key component to reduce toxic releases to the environment is the development of a Regional Source Control Program (RSCP). The RSCP is a pollution prevention program aimed at eliminating or reducing the amount of contaminants being discharged to the sanitary sewer by local businesses, institutions, and households. Businesses and institutions are regulated with specific requirements using permits, codes of practice, and authorizations. The programs also include a strong educational component and the CRD works with businesses and households through extensive public outreach (Larose 2005).The CRD Sewer Use Bylaw is the main regulatory instrument. Under the Bylaw, individual facilities and business sectors are regulated with specific requirements using permits, authorizations and codes of practice. There are 11 codes of practice, each applying to a specific type of operation: food services; photographic imaging; dental; dry cleaning; automotive repair; vehicle washing; carpet cleaning; fermentation; printing; laboratory; and recreation facilities. Various educational tools such as guidebooks, brochures, posters, and videos have been developed to support each code of practice. In addition, a residential outreach component has recently been developed to encourage households to adopt simple contaminant reduction practices. Enforcement is an important component of RSCP, with primary inspection of a percentage of each sector per year in addition to follow-up inspections by source control officers. Refer to. www.crd.bc.ca/wastewater/sourcecontrol/index.htm.Metro Vancouver's revised Sewer Use Bylaw came into effect May 2007. Refer to http://www.metrovancouver.org/boards/bylaws/Bylaws/GVSDD_Bylaw_244.pdf.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Table 2a: Priority Recommendations for Management Actions and a Summary of Current and Planned Initiatives[1]

III. Utilize voluntary pollution prevention (P2) and pollution control initiatives, where possible *(cont.)*:

Recommendation 4:
Continue to implement/expand pollution prevention and control initiatives to address discharges/spills of toxic substances (focusing on metals, PAHs, high-use toxic pesticides, and nitrogen-based nutrients) to urban stormwater and agricultural runoff (e.g., Cecelia Creek and Rock Bay in Victoria).

Current and Planned Initiatives:

i.) APF-EFP includes nutrient management component to address contamination of agricultural runoff.

ii.) EC and the City of Victoria monitored the performance of a municipally-owned commercial stormwater treatment unit. The City of Victoria purchased and installed a $500K "Vortechnics" unit in 2003 using Canada-BC Infrastructure Program funding. This project will establish the effectiveness of that unit at removing some of the priority toxics (metals, PAHs) from stormwater entering the Gorge Waterway in Victoria's Inner Harbour.

iii.) EC and the City of Burnaby collaborated on an education and inspection program in Byrne Creek to address ongoing stormwater quality concerns. There are several other initiatives which are driven by local watershed stewardship groups and local governments.

iv.) The CRD Stormwater Harbours and Watersheds Program (SHWP) works to protect municipal infrastructure, watercourses and the nearshore marine environment from stormwater-carried contaminants. SHWP undertakes annual sampling programs throughout the region to monitor stormwater quality identify problems and prioritize discharges based on several factors. As part of a source control program, SHWP works in partnership with municipalities, encouraging the use and implementation of natural drainage techniques, the reduction of impervious surfaces and increase of natural areas, the restoration of watercourses and shoreline habitats, and the provision of tools such as watershed-based planning. CRD also works to educate residents and businesses on stormwater quality issues through extensive public outreach. To further strengthen source control efforts, SHWP also develops regulatory bylaws and codes of practice as well as non-regulatory best management practices.

Recommendation 5:
Implement pollution prevention/control initiatives (e.g., BMPs) to address automotive related industries, electroplating, printing, photographic imaging, paint and varnish industries, hospitals, medical laboratories, dental offices, parking lots, ship repair, street sweeping, aquaculture, landscaping and other small to medium enterprises (SMEs).

Current and Planned Initiatives:

i.) BMPs, a P2 Guide, and a Code of Practice guide for the automotive sector which aim to reduce the amount of pollution entering storm sewers have been developed and promoted by (among others) the Burnside Gorge Community Association in collaboration with CRD (Cecelia Creek and Rock Bay in Victoria) and the City of Burnaby (Byrne Creek watershed). Each of these initiatives received some funding from GBAP. These tools could be adapted and applied more widely in the auto recycling industry.

ii.) CleanPrint BC is a program which addresses environmental concerns relating to the BC printing sector. It is delivered through a partnership between EC, Industry Canada, Metro Vancouver, City of Vancouver, and the BC Printing and Imaging Association. The objective of the program is to encourage BC printing facilities to adopt Environmental Management Plans (EMPs) and to reduce volumes of toxic waste. Facilities completing the EMP process receive the CleanPrint BC accreditation. Implementation of the EMPs can result in significant decreases in the amount of isopropyl alcohol, solvents and inks used, and the amount of solid wastes generated. CRD has prepared a Code of Practice for printing facilities (http://www.crd.bc.ca/wastewater/sourcecontrol/documents/bestpractices_printing.pdf).

iii.) The following websites are clearinghouses of P2 information, some of which may apply to the designated sectors:
- Canadian Pollution Prevention Information Clearinghouse (http://www.ec.gc.ca/cppic/en/index.cfm\
- Canadian Centre for Pollution Prevention (http://c2p2online.com)
- P2 Resource Exchange – USA (http://www.p2rx.org
- Pacific Northwest P2 Resource Centre – USA (http://www.pprc.org)

iv.) Metro Vancouver's Sewer Use Bylaw was amended and approved in 2007. The Bylaw includes the addition of a code of practice for dental operations to reduce mercury and other metal discharges to sewer. In 2008, the Bylaw enacted two new codes of practice: Dry Cleaning operations Code of Practice, for the discharge of tetrachloroethylene, and Photographic Imaging Operations Code of Practice, for the discharge of silver.

v.) The CRD Regional Source Control Program has developed codes of practice for different business sectors with the aim of reducing or eliminating contaminants from entering the sanitary wastewater system. The efficacy of these control measures are evaluated on a regular basis. For information on the CRD Regional Source Control Program codes of practice (to reduce or eliminate contaminants from entering the sanitary system) see Recommendation 2 or visit http://www.crd.bc.ca/wastewater/sourcecontrol/index.htm.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Table 2a: Priority Recommendations for Management Actions and a Summary of Current and Planned Initiatives[1]

III. Utilize voluntary pollution prevention and pollution control initiatives, where possible *(cont.)*:

Recommendation 5 *(cont.)*:

Implement pollution prevention/control initiatives (e.g., BMPs) to address automotive related industries, electroplating, printing, photographic imaging, paint and varnish industries, hospitals, medical laboratories, dental offices, parking lots, ship repair, street sweeping, aquaculture, landscaping and other small to medium enterprises (SMEs).

Current and Planned Initiatives:

vi.) The CRD, with assistance from EC, has developed stormwater quality BMPs for painting operations and power washing

vii.) The CRD is addressing other sectors/issues including parking lots and street sweeping under Codes of Practice contained within a regional stormwater quality bylaw (see comments under Recommendation 7).

viii.) Other BMP guides have also been developed including one for golf courses (http://research.rem.sfu.ca/frap/9626.pdf).

ix.) BC MOE, EC and ENGOs are promoting pollution control measures for the automotive industry in Rock Bay, Victoria

x.) EC has updated and actively promoted BMPs for ship repair facilities

xi.) The province requires BMPs for aquaculture under the *Finfish Aquaculture Waste Control Regulation* (refer to website http://www.env.gov.bc.ca/epd/industrial/regs/finfish/index.htm

IV. Utilize voluntary pollution prevention and pollution control initiatives, where possible *(cont.)*:

Recommendation 6:

Use economic measures/fiscal instruments such as cost-sharing pollution prevention/control initiatives with facilities; innovative funding schemes (e.g., money for mercury coupons for car washes/car repair to eliminate leaks, business recognition); involvement (assistance/mentoring) of an independent third party/peer group; and tax incentives for pollution reduction.

Current and Planned Initiatives:

i.) A number of successful economic-based initiatives have been implemented within the Georgia Basin region. Efforts have been undertaken by the Township of Langley, City of Surrey, and the City of Coquitlam (and possibly others) to establish stormwater utilities to fund drainage planning. These utilities, theoretically, provide for the ability to establish a taxation system that reflects the real use of the drainage infrastructure, but in practice have been very costly to administer to create real incentives. However, outside of the Georgia Basin, the City of Kelowna has had a successful development cost charge reduction program in place for several years where developers who opt to manage their stormwater onsite, thus alleviating the need for the municipality to build stormwater infrastructure, can obtain DCC rebates of up to 80%.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Table 2a: Priority Recommendations for Management Actions and a Summary of Current and Planned Initiatives[1]

IV. Review existing controls and, where required, develop mandatory regulatory activities:

Recommendation 7:
Develop regulatory requirements for pollution prevention (e.g., source control) such as regulatory Codes of Practice (COPs) for high priority sectors where voluntary pollution prevention/control initiatives have not been effective.

Current and Planned Initiatives:

i.) APF-EFP includes a nutrient management component.

ii.) The CRD has developed Codes of Practice (COPs) for 11 business sectors. Regular inspections by Source Control officers ensure the compliance with the COPs (http://www.crd.bc.ca/wastewater/sourcecontrol/business/index.htm). A 2005 summary of the CRD Source Control Program can be viewed at http://www.crd.bc.ca/wastewater/sourcecontrol/goals.htm.

iii.) The CRD, with support from EC, has developed a Model Bylaw to Regulate the Discharge of Waste into Storm Sewers and Watercourses. The Model Bylaw includes the following regulatory Codes of Practice which, once enacted, will be enforced by municipal bylaw officers: Automotive and Parking Lot Operations; Construction and Development Activities; Recreation Centres; and Streets and Roads. In addition, COPs for another five sectors are in planning. These stormwater COPs are under review for potential adoption by member municipalities and could also be used in other areas of the Georgia Basin.

iv.) Metro Vancouver has revised its Sewer Use Bylaw and included the addition of new codes of practice for photofinishing, dental operations, and dry cleaners. The next series of Bylaw amendments will consider the following:
- a) additional requirements for the discharge to sewer of priority contaminants to sewer, in particular, priority substances listed under CEPA;
- b) revising fees to better reflect user-pay and polluter-pay principles and to improve sustainability, fairness, and effectiveness of the source control program;
- c) codes of practice with requirements for various industrial, commercial, and institutional sectors to allow an effective and efficient means of protecting Metro Vancouver's interests and the environment;
- d) increasing maximum fines and allowing a broader array of regulatory tools, economic instruments, and administrative penalties; and
- e) Pollution Prevention Plans for the control of medical and laboratory discharges.

v.) Other local governments (outside of the CRD and Metro Vancouver) already have, or are developing, stormwater quality bylaws.

vi.) Under its new *Environmental Management Act* (EMA), BC MOE has targeted a number of sectors for regulatory Code of Practice (COP) development. For information on the current status of COP development under the EMA, refer to website: http://www.env.gov.bc.ca/epd/codes/.

vii.) CCME is developing a Canada-wide Strategy for the management of municipal WWTP effluents (http://www.ccme.ca/ourwork/water.html?category_id=81).

viii.) Environment Canada is developing a comprehensive federal strategy for municipal wastewater effluents, including addressing a number of substances found in municipal wastewater effluent that have been assessed as toxic under CEPA 1999. As part of the federal strategy, Environment Canada plans to develop a regulation under the *Fisheries Act* (refer to website http://www.ec.gc.ca/eu-ww/default.asp?lang=En&n=BC799641-1 .

Recommendation 8:
Encourage local regulations such as stormwater bylaws and changes to Official Community Plans to promote low impact development and re-development to reduce releases of toxic substances.

Current and Planned Initiatives:
There are no current or planned activities at this time.

Recommendation 9:
Ensure regulations and requirements on Crown lands are equivalent to those on non-Crown lands (e.g., contaminated sites).

Current and Planned Initiatives:
There are no current or planned activities at this time.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

V. Assess and ensure the efficacy of management actions:

Recommendation 10:
Improve the reporting, management, and sharing of information/data on priority issues to both encourage partnerships between stakeholders and to monitor the efficacy of initiatives.

Current and Planned Initiatives:

i.) These activities have been included under the role of the British Columbia Toxics Work Group (TWG). In addition, the sharing of information on priority toxics issues and the identification of partnership opportunities relating to toxics work in BC and Yukon are also included in the roles of the Federal/Provincial Toxic Chemicals Committee (FPTCC).

ii.) Under contract to EC, information on point source releases of toxic substances to the Georgia Basin has being updated in a format which will allow future incorporation into a GIS; also, under this contract, existing information on non-point sources of toxic substances to the Georgia Basin were scoped and options for future geo-referencing of this information were examined (Partners: EC, DFO).

iii.) Under contract to EC, existing information on the presence of toxic substances in the Georgia Basin environment is being scoped and the feasibility of eventual incorporation into a database and GIS is being considered. Published information on sources and levels of environmental contaminants in the Georgia Basin is being compiled for incorporation on a web-based, GIS-linked database which is currently under development (Partners: EC, DFO, and other BCTWG member agencies).

Recommendation 11:
Conduct follow-up and monitoring to ensure initiatives meet their intended goals (e.g., routinely monitor the effectiveness of management options including the efficacy of existing BMPs).

Current and Planned Initiatives:

i.) In some instances, monitoring activities can potentially be related to tracking the effectiveness of management actions, if there is a good understanding of the implementation of such actions. However, a clear link has not been established between monitoring and regulatory actions.

ii.) The CRD conducts regular follow-up and monitoring of stormwater discharges, dischargers to the sanitary sewers under permit or codes of practice, and CRD wastewater discharges to ensure that programs meet their intended goals. Results are presented in annual reports that are included on the CRD website at www.crd.bc.ca/wastewater/marine/index.htm.

Recommendation 12:
Ensure the remediation of contaminated sites to prevent the release of toxics to the environment by employing scientifically-based guidelines and standards which are regularly reviewed for efficacy.

Current and Planned Initiatives:

i.) Recent amendments to the BC *Environmental Management Act* (EMA) and to the *Contaminated Sites Regulation* have improved the ability of the province to deal with contaminated sites.

ii.) SITE, a provincial database designed to assist, monitor, and manage contaminated sites data, and also to prioritize remedial actions for contaminated sites in the Fraser Basin, was developed under FRAP. Better industrial practices employed in recent years have reduced the number of abandoned sites requiring cleanup; however, old sites are still being found along the Lower Fraser River.

iii.) The Land Remediation Section of the BC Ministry of Environment (BC MOE) directs and manages the remediation of contaminated sites to facilitate redevelopment opportunities for local communities. According to the BC MOE website on contaminated sites, there are nearly 8000 sites in the BC MOE records. For more information on the BC MOE contaminated sites program refer to the website http://www.env.gov.bc.ca/epd/remediation/cs101.htm .

iv.) There is an ongoing partnership with Comox First Nation to remediate shellfish closure site in Comox Harbour. The area classification has been upgraded.

Table 2b contains recommendations specific to individual substances or substance groups. These recommendations are considered to be of somewhat lower priority than are those contained in Table 2a, which pertain to a wide range of priority toxic substances in the Georgia Basin. Where activities relating to these recommendations and needs in the Georgia Basin are already underway or are planned, brief descriptions of these activities have also been included.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Table 2b: Substance-Specific Recommendations for Management Actions to Address Issues Relating to Toxic Substances in the Georgia Basin and Summary of Current and Planned Initiatives[1]

Conventional or Legacy Persistent Organic Pollutants (POPs)

Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities	Assess and Ensure the Efficacy of Management Actions
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)

New or Emerging Persistent Organic Pollutants (POPs)

Alkylphenol and Ethoxylates

Review Past and Existing Initiatives and Support Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities	Assess and Ensure the Efficacy of Management Actions
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	1.) develop site-specific objectives from the national guidelines to reflect the fate and behaviour of APs and the sensitivity of ecologically significant species in the Georgia Basin. These site-specific objectives could then be used to make informed management decisions and to prioritize actions on these CEPA-toxic substances	(Refer to general toxics recommendations in Table 2a.)

Halogenated Diphenyl Ethers

Review Past and Existing Initiatives and Support Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities	Assess and Ensure the Efficacy of Management Actions
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	1.) Develop/modify regulations and/or guidelines based on the results of future work on toxicity to local species, source inventories, and current environmental levels Current and Planned Initiatives i.) An environmental screening assessment on seven polybrominated diphenyl ethers (PBDEs), brominated flame retardants with widespread application in commercial, industrial and residential products. The assessment recommended that the seven PBDEs be considered "toxic" as defined in *CEPA* 1999 and, as a result, these substances were added to CEPA 1999, Schedule 1 List of Toxic Substances. In addition, three of the PBDEs (tetra, penta- and hexaBDEs) were added to the *CEPA* Virtual Elimination List.	(Refer to general toxics recommendations in Table 2a.)

8 These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

New or Emerging Persistent Organic Pollutants (POPs) cont.				
Halogenated Diphenyl Ethers *cont.*				
Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	**Implement Measures to Address Identified Hotspots and Priority Watersheds**	**Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible**	**Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities**	**Assess and Ensure the Efficacy of Management Actions**
			Current and Planned Initiatives *(cont.)* i *(cont..):* A Risk Management Strategy for these substances was developed and the *Polychlorinated Diphenyl Ether Regulations,* which prevent the manufacture and restrict the use of these substances in Canada, came into force on June 19th , 2008 under CEPA 1999). As a result of an updated review of decachlorodiphenyl ether, a State of Science report was published in the Canada Gazette, Part I on March 28, 2009. Additional concerns with deca-BDE identified in this report warranted a revision to the original Risk Management Strategy to include additional controls. A proposed revision has been posted on the EC website. For more information, refer to the following websites: http://www.ec.gc.ca/CEPARegistry/regulations/DetailReg.cfm?intReg=108; http://www.ec.gc.ca/epe-epa/default.asp?lang=En&n=0B904C67-1; and , http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=AC48ECED-6EBE-4D1F-B0BF-EC869610CBEE ii.) Screening assessments on two other brominated flame retardants, tetrabromobisphenol A (and two derivative compounds) and hexabromocyclododecane, are currently underway.	
Phthalate Esters				
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	1.) following the development of reliable standardized analytical methods: a) develop marine and freshwater sediment quality guidelines; and a) develop Canadian ocean disposal criteria	(Refer to general toxics recommendations in Table 2a.)

8 These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

New or Emerging Persistent Organic Pollutants (POPs) cont.				
Chlorinated Paraffins, Polychlorinated naphthalenes, and Fluorinated Organic Compounds				
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.) **Current and Planned Initiatives** i.). In 2005, following assessments by EC and HC, the Ministers of Environment and Health announced in the Canada Gazette, their intention to recommend that short-, medium-, and long-chain chlorinated paraffins be added to the CEPA 1999 Schedule 1 List of Toxic Substances and to propose these substances for virtual elimination (Environment Canada 2006d). For additional information refer to http://www.ec.gc.ca/substances/ese/eng/psap/PSL1_chlorinated_paraffins.cfm. ii.) Screening Level Risk Assessments (SLRA) on PFOS, its salts, and precursors conducted by EC and HC in 2006 resulted in the addition of PFOS, its salts and precursors to CEPA 1999, Schedule 1 List of Toxic Substances. *Perfluorooctane Sulfonate and Its Salts and Certain Other Compounds Regulations* were published in the Canada Gazette, Part II on June 11, 2008. For additional information, refer to website http://www.ec.gc.ca/CEPARegistry/documents/regs/PFOS/PFOS_let.cfm. ii.) assessments of four fluorotelomer-based substances conducted by EC and HC found that these substances were also likely to meet the criteria for toxicity as defined by CEPA-1999. As a precautionary measure, a two-year prohibition on these substances was implemented by EC to allow new information to be generated and reviewed. These substances have been proposed for addition to the Schedule 1 List of Toxic Substances. For more information, refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=6B9B6B28-1&xml=F68CBFF1-B480-4348-903D-24DFF9D623DC. iii.) EC and HC developed an Action Plan to address PFCAs and their precursors. For additional information refer to http://www.environmentaldefence.ca/toxicnation/whatGovDo/PFCA%20Action%20Plan%20for%20Consultations%20v6.pdf; and	(Refer to general toxics recommendations in Table 2a.)

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Table 2b: Substance-Specific Recommendations for Management Actions to Address Issues Relating to Toxic Substances in the Georgia Basin and Summary of Current and Planned Initiatives[1]

Current-Use Pesticides

Current-Use Toxic Agricultural Pesticides (e.g., Atrazine, Endosulfan)[1]

Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities	Assess and Ensure the Efficacy of Management Actions
1.) quantify sales of current-use pesticides and review and improve, if necessary, existing mechanisms for tracking regional pesticide usage and application **Current and Planned Initiatives** i.) Inventories of pesticide sales in BC were conducted in 1991, 1995, 1999 and 2003. ii.) The PMRA new *Pest Control Products Act* (PCPA) requires sales/use information from pesticide manufacturers. 2.) consistently document/verify incidents of fish and/or bird kills associated with the use of pesticides **Current and Planned Initiatives** i.) Bird kill documentation is currently being done by CWS; however, more consistency in the documentation is required. 3.) evaluate measures implemented under the Agricultural Policy Framework.(APF), which is in effect between 2003 and 2008 to address priority agricultural environmental issues throughout BC **Current and Planned Initiatives** i.) EC/DFO/BC MOE members on the APF Environment Working Group are responsible for delivering Environmental Farm Program (EFP also encompasses the agricultural use of pesticides).	4.) as necessary, implement measures to reduce pesticide losses to the environment as a result of agricultural practices including pesticide application and uncontrolled surface runoff, aquaculture practices, urban activities, and stormwater runoff	(Refer to general toxics recommendations in Table 2a.)[1]	5.) review existing mechanisms for tracking regional pesticide usage and application and make improvements where necessary **Current and Planned Initiatives** i.) *Integrated Pest Management Act* (IPMA) has a requirement for pesticide dispensers to have provincial certification, including integrated pest management ii.) IPMA regulations on the use of pesticides to protect human health and the environment were enacted on December 31, 2004. The regulations are subject to review and revision as necessary.	6.) continue to strongly encourage and monitor the use of an integrated pest management approach within the Georgia Basin 7.) track and evaluate measures implemented under the Agricultural Policy Framework (APF), which was in effect between 2003 and 2008 to address priority agricultural environmental issues throughout BC **Current and Planned Initiatives** i.) Measures for assessing the efficacy of the IPMA and regulations are under development. ii.) EC (CWS) will be determining the incidence of secondary poisoning of raptors and trumpeter swans with anticholinesterase insecticides, such as chlorpyrifos, which is used for the control of wireworm in potatoes. The results will be used to determine the effectiveness of current wireworm control technologies in reducing the incidence of poisoning in wildlife.

[1] ***Note***: In the initial stage of the selection of substances for review in the Georgia Basin, endosulfan and atrazine were identified. However, more recent information has indicated that the list should be inclusive of all high-use toxic pesticides.

[8] These recommendations do not represent the views of Metro Vancouver as this agency chose not to input to the development of recommendations on management actions.

Table 2b: Substance-Specific Recommendations for Management Actions to Address Issues Relating to Toxic Substances in the Georgia Basin and Summary of Current and Planned Initiatives[1]

Current-Use Pesticides cont.

Antisapstain Chemicals - DDAC and IPBC

Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities	Assess and Ensure the Efficacy of Management Actions
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	1.) develop sediment quality guidelines 2.) reconvene the FPTCC Antisapstain Subcommittee to evaluate the implications of the most recent aquatic toxicity information 3.) review the existing provincial stormwater discharge regulated level in light of new toxicity information	(Refer to general toxics recommendations in Table 2a.)

Antifouling Chemicals – Organotin- and Copper-Based Compounds

Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities, Where Possible	Assess and Ensure the Efficacy of Management Actions
1.) actively promote the implementation of BMPs for marinas, boatbuilding and repair facilities and conduct follow-up to encourage compliance and determine effectiveness **Current and Planned Initiatives** i.) EC conducted a significant compliance promotion effort to encourage the implementation of BMPs.	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	2.) develop sediment quality guidelines for organotins for the protection of aquatic life	3.) determine the adherence of marinas and the shipbuilding/repair industry to BMPs for these facilities and assess the adequacy of the existing BMPs in reducing releases of antifouling compounds **Current and Planned Initiatives** i.) EC conducted a compliance promotion effort to raise the awareness of antifouling paint BMPs and to prevent the release of contaminated waste material from hull maintenance involving the removal of anti-fouling paints.

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Table 2b: Substance-Specific Recommendations for Management Actions to Address Issues Relating to Toxic Substances in the Georgia Basin and Summary of Current and Planned Initiatives[1]

Metals				
Cadmium (Cd), Chromium (Cr), Copper (Cu), Manganese (Mn), Mercury (Hg), Nickel (Ni), and Silver (Ag)				
Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	**Implement Measures to Address Identified Hotspots and Priority Watersheds**	**Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible**	**Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities**	**Assess and Ensure the Efficacy of Management Actions**
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)
Zinc				
(Refer to general toxics recommendations in Table 2a.)	1.) develop options to reduce zinc in stormwater from galvanized roofs at wood treatment or other facilities where zinc levels in stormwater are of concern	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)

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Table 2b: Substance-Specific Recommendations for Management Actions to Address Issues Relating to Toxic Substances in the Georgia Basin and Summary of Current and Planned Initiatives[1]

Nitrogen-based Nutrients

Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities	Assess and Ensure the Efficacy of Management Actions
1.) participate, track, and evaluate measures implemented under the recently introduced Agricultural Policy Framework (APF), which will be in effect between 2003 and 2008 and will address priority agricultural environmental issues throughout BC **Current and Planned Initiatives** i.) AAFC/BC MAL, with APF funding, are currently planning a survey (stratified random) of farm soils for nutrient (N/P/K) status mid-Sept to mid-Oct 2004. EC (P2//NPS) is preparing a MOU to provide some additional funding support. ii.) EC/DFO/BC MOE members on APF Environment Working Group are responsible for delivering EFP program (also encompasses National Stewardship (BMP) and Greencover incentive funding programs) and includes nutrient management. iii.) The Program Coordinator for the National Agri-Environmental Standards Initiative also represents EC on the APF Environment Working Group which manages the APF environmental programs. 2.) support, by all agencies, of the initiatives and implementation strategy contained in the BC MOE Action Plan for NPS in BC. **Current and Planned Initiatives** i.) Action Plan is considered within (P2/NPS) overall strategy (e.g., funding support for Township of Langley Waterwise Initiative and Industry development and publication of Advanced Forage Management Guide)	7.) examine the feasibility of treating nitrogen-containing wastes 8.) make mandatory the regular servicing of septic systems **Current and Planned Initiatives** i.) The BC Ministry of Health introduced the *Sewerage System Regulation* in May of 2005, which requires regular sewage system servicing and maintenance. ii.) The CRD has implemented a new bylaw requiring the regular servicing of septic systems in some CRD municipalities. See http://www.crd.bc.ca/wastewater/septic/onsite.htm	9.) consider the use of limits on animal stocking densities **Current and Planned Initiatives** i.) Partnership Committee on Agriculture and the Environment has formed BC Nutrient Management Working Group to develop options for long-term management. ii.) Studies by UBC and the province indicate that nutrient balances have increased and while various multi-stakeholder groups, including Agriculture and Environment Partnership Committee and the BC Nutrient Management Work Group continue to address nutrient issues, actions to decrease stocking densities have not been implemented. 10.) encourage the implementation of BMPs for agriculture (and aquaculture) facilities **Current and Planned Initiatives** i.) Membership on the APF Environment Working Group includes EC, DFO, and BC MOE. This working group is responsible for delivering EFP program (also encompasses National Stewardship (BMP) and Greencover incentive funding programs) ii.) EC has provided funding to the BC Sustainable Poultry Farming Group and also the Raspberry Industry Development Council to support efforts to improve nutrient management by these groups. In addition, these groups receive funds from the Agriculture Environment Initiative	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)

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Table 2b: Substance-Specific Recommendations for Management Actions to Address Issues Relating to Toxic Substances in the Georgia Basin and Summary of Current and Planned Initiatives[1]

Nitrogen-based Nutrients (cont.)				
Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	**Implement Measures to Address Identified Hotspots and Priority Watersheds**	**Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible**	**Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities**	**Assess and Ensure the Efficacy of Management Actions**
Current and Planned Initiatives (cont.) ii.) With respect to agricultural sources, the BC Agriculture Council includes participation from provincial and federal governments in managing the Environmental Farm Planning (EFP) Program. In addition, BC MAL, BC MOE, and BC Agriculture Council initiated the Partnership Committee on Agriculture and the Environment, which includes various provincial and federal government agencies, private industry and regional and municipal levels of government. 3.) continue encouragement and support of interagency cooperative measurement programs **Current and Planned Initiatives** i.) Limited funding for audits of sensitive aquifers was provided through P2/GBAP/NPS.. 4.) continue existing initiatives to decrease agricultural and urban runoff of nutrients (BAWMPs) **Current and Planned Initiatives** i.) The APF Environment Working Group includes members from EC, DFO and BC MOE. This working group is responsible for delivering EFP program (also encompasses National Stewardship (BMP) and Greencover incentive funding programs) 5.) continue efforts to remove manure from areas with nutrient surpluses to areas with nutrient deficiencies **Current and Planned Initiatives** i.) Partnership Committee on Agriculture and the Environment has formed BC Nutrient Management Working Group to develop options for long-term management.		**Current and Planned Initiatives** iii.) Environmental Farm Plans are expected to be implemented by these commodity producers under the APF. iv.) EC has approximately $25 million under the APF to develop voluntary standards for agriculture. v.) BC MOE audits and enforces the *Agricultural Waste Control Regulation*. 11.) implement pollution prevention and pollution control initiatives for other demonstrated sources of nitrogen. For, WWTPs, nitrogen-based nutrients (and other toxics) are being managed through all levels of government under different regulations and initiatives such as the BC LWMPs, the CCME wastewater strategy, and CEPA. **Current and Planned Initiatives** i.) This issue could fall within the terms of APF Environmental Technology Assessment Program.	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)

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Table 2b: Substance-Specific Recommendations for Management Actions to Address Issues Relating to Toxic Substances in the Georgia Basin and Summary of Current and Planned Initiatives[1]

Nitrogen-based Nutrients (cont.)

Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities	Assess and Ensure the Efficacy of Management Actions
6.) implement additional educational programs, promotion of pollution control measures, and regulatory enforcement where required Current and Planned Initiatives i.) Llimited funding for audit over sensitive aquifers through P2/GBAP/NPS..				

Wood Extractives

Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	Implement Measures to Address Identified Hotspots and Priority Watersheds	Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible	Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities	Assess and Ensure the Efficacy of Management Actions
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	1.) review current forest industry water quality monitoring and consider wood extractives for inclusion in permit monitoring lists 2.) review and, if necessary, revise/develop regulations and guidelines for wood extractives 3.) develop guidelines/criteria for resin and fatty acids prevalent in the Georgia Basin environment	(Refer to general toxics recommendations in Table 2a.)

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Table 2b: Substance-Specific Recommendations for Management Actions to Address Issues Relating to Toxic Substances in the Georgia Basin and Summary of Current and Planned Initiatives[1]

Priority substances not listed above (e.g., emerging issues or recently identified substances of concern such as pharmaceuticals and personal care products)				
Review Past and Existing Initiatives and Support and Further Promote Those Which Have Been Successful	**Implement Measures to Address Identified Hotspots and Priority Watersheds**	**Utilize Voluntary Pollution Prevention and Pollution Control Initiatives, Where Possible**	**Review Existing Controls and, Where Required, Develop Mandatory Regulatory Activities**	**Assess and Ensure the Efficacy of Management Actions**
(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.)	(Refer to general toxics recommendations in Table 2a.) Current and Planned Initiatives i.) At the national level, EC is involved with risk assessment and risk management regulatory activities associated with categorization and screening of the Domestic Substances List and the Chemicals Management Plan Ministerial Challenge Program. Under these programs, screening assessments are conducted in order to identify those substances which meet or may meet "toxic" criteria under section 64 of CEPA 1999. If found to be "toxic', actions to reduce the risk presented by these substances are undertaken by EC and/or HC. Refer to website: http://www.chemicalsubstanceschimiques.gc.ca/en/index.html	(Refer to general toxics recommendations in Table 2a.)

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Appendix 1. Actions and Initiatives Previously Implemented to Reduce Contaminants Releases to the Georgia Basin

There is a wide range of sources of contaminants to the south coastal environment of BC including municipal WWTPs, the forest products industry, mines, CSOs, stormwater and urban runoff, agricultural runoff, contaminated sites, and atmospheric deposition. However, the quantification of contaminant loadings to the environment from some of these sources is lacking. In recent decades, concerns from the public, the fishing industry, First Nations, and ENGOs with respect to declining fish stocks, poor water quality, and compromised recreational opportunities have led to increasing pressure on regulatory agencies to address point sources of pollution. Increased regulatory actions, combined with an increased awareness and implementation of voluntary controls by industry, have significantly decreased the release of contaminants to south coastal BC from major point sources over the last two decades. Despite this considerable improvement, concerns associated with point source releases of contaminants remain. For example, the presence of PPCPs, pathogens, and several commercially used chemicals, including various estrogenic compounds, in WWTP discharges has been reported, but information is lacking on the efficacy of wastewater treatment practices in removing these substances and on their loadings to the environment. The magnitude of release and the potential for adverse environmental impacts in the BC aquatic environment as a result of the release of these contaminants have not been evaluated.

With the overall success of efforts in recent decades to reduce environmental loadings of contaminants from point source discharges, non-point sources, such as runoff from urban and agricultural areas and atmospheric deposition, are now recognized as the major contributors of many potentially harmful contaminants to the environment. Non-point sources often contribute a variety of contaminants to ambient surface waters and groundwater. Signs of contaminant stress in several watersheds in the south coastal area of BC have been attributed to non-point sources. Pesticides and nutrients enter streams through agricultural runoff and have also been detected at elevated concentrations in runoff and streams located in urban areas. Pollutants in groundwater may also enter streams or other surface water bodies through natural groundwater-surface water interaction. In addition, urban runoff contributes high loadings of PAHs, and some metals, to urban waterways. Many streams and ditches have been identified as critical habitat for wildlife, particularly amphibians and salmon fry. Adverse effects on amphibian populations and the community structure of benthic invertebrates have been observed in some urban and agricultural areas. In addition, non-point sources such as agricultural and urban runoff, releases from septic systems, CSO and stormwater discharges, and boating activity have resulted in fecal and chemical contamination of shellfish populations in coastal areas of BC. Atmospheric deposition has also been identified as an important source of both metals and organic contaminants to the south coast; however, more information is required on contributions from both local sources and long-range atmospheric transport. Developing a better understanding of non-point sources of contaminants to the Georgia Basin is a high priority.

Reductions in the release of metals and other toxic substances from a broad range of point and non-point sources have been achieved through both regulatory and non-regulatory initiatives implemented by federal, provincial and municipal government agencies, industry, industry associations, and community groups. A number of successful non-regulatory initiatives were undertaken as a result of the Fraser River Estuary Management Program (FREMP), the Fraser River Action Plan (FRAP), the Burrard Inlet Environmental Assessment Plan (BIEAP), and the Victoria and Esquimalt Harbours Environmental Action Program (VEHEAP). These initiatives provided funding and support for studies to better identify and understand toxics issues in the south coastal region of BC and helped to increase the awareness of both industry and the public. The pollution abatement component of these initiatives developed a number of Best Management Practice documents (BMPs) aimed at reducing releases of toxics from industrial and commercial sources and emphasized the implementation of voluntary actions to prevent and reduce pollution through innovative technologies and techniques. The FRAP program was succeeded by the Georgia Basin Ecosystem Initiative (GBEI), whose objective was to address industries and activities impacting both the air and water of the Georgia Basin region. The GBEI was a partnership of federal, provincial and municipal levels of government. Management actions to reduce the release of metals and organic contaminants into the Georgia Basin addressed industrial discharges, municipal WWTPs, and non-point sources such as agricultural and urban stormwater runoff, CSOs, contaminated sites, and atmospheric deposition. The GBEI was renewed as the Georgia Basin Action Plan (GBAP), from 2003 to March 2009, in order to build upon the work and accomplishments of GBEI.

Reductions in toxic releases were achieved through programs initiated under BIEAP, FRAP, and GBEI/GBAP, in conjunction with other initiatives; however, for many sources the available information is insufficient to determine the magnitude of reductions in loadings. A report prepared for Environment Canada identified wastewater sources of contaminants to the Georgia Basin environment and, where sufficient information was available, also estimated loadings of specific substances to the environment. Available information on releases from pulp mills, municipal wastewater treatment facilities, stormsewers, and CSOs in the Georgia Basin was included (ENKON 2002). However, information on NPS sources such as agricultural runoff and atmospheric deposition was lacking. For more information on these initiatives refer to the following websites:

- FRAP: http://www.ec.gc.ca/nature/default.asp?lang=En&n=0C91CAE6-1 and http://www.fraserbasin.bc.ca/about_us/history.html
- FREMP, and BIEAP: http://www.bieapfremp.org/
- GBEI/GBAP: http://www.ec.gc.ca/nature/default.asp?lang=En&n=B5519CB7-1
- VEHEAP: http://www.crd.bc.ca/partnerships/veheap/index.htm

There have been many successful initiatives to reduce the release of environmental contaminants to the south coastal environment. However, it is important to recognize that the increased generation of wastewater, other wastes, and urban runoff associated with the rapidly growing population of the south coastal area will create an even greater future need to minimize the release of contaminants to the environment. In addition, while the potential combined effects of low concentrations of the multitude of chemicals still entering the environment from these sources has been recognized, they have not been evaluated nor are they well understood. Many of the actions which have already been implemented to reduce the release of contaminants to the south coastal environment from major identified potential sources have been summarized following. However, this list is by no means complete and relevant websites which provide additional information have been included.

Appendix 1. Actions and Initiatives Previously Implemented to Reduce Contaminants Releases to the Georgia Basin

1. Municipal Wastewater Treatment Plants (WWTPs)

Federal Government Programs:

- Environment Canada has been working with provincial and territorial governments to develop a Canada-wide Strategy for the management of municipal wastewater effluents under the auspices of the Canadian Council of Ministers of the Environment (CCME). Environment Canada intends to develop a regulation under the *Fisheries Act* to achieve effluent standards for wastewater treatment systems equivalent in performance to conventional secondary treatment, with additional treatment where required. The federal regulations that will be proposed by Environment Canada will apply to all wastewater systems across Canada and will be the federal government's principal tool to implement the CCME Canada-wide Strategy for the management of municipal wastewater effluents. The comprehensive long-term federal approach for the management of municipal wastewater effluent will also address a number of substances found in municipal wastewater effluent that have been assessed as toxic under CEPA 1999 (Brydon 2009, personal communication).
- Under GBAP, Environment Canada, in cooperation with other partners, undertook projects to:
    - conduct chemical characterization of solid and liquid wastes from municipal wastewater treatment plants (Metro Vancouver and CRD);
    - determine molecular level (genomic) toxicology of municipal wastewater effluents at receiving water concentrations to fish;
    - utilize in-house developed gene micro-arrays for salmonids to evaluate gene expression to either freshwater rainbow trout or Pacific salmon which have been acclimated to seawater. Effluents will be collected from Metro Vancouver and CRD and adjusted to relevant receiving water concentrations in concert with District staff;
    - develop capabilities to analyze for selected pharmaceuticals, personal care products and antibiotics suspected of causing endocrine disruption;
    - analyze select pharmaceuticals and fragrance compounds in-house and profile for molecular toxicity;
    - conduct sterol and select pharmaceutical chemistry on effluent sample (~60); and
    - support technical and scientific conferences such as the Annual BC Waste & Water Association Conference and Tradeshow.

  For more information on federal government initiatives on municipal WWTP plant effluents, refer to the following websites:
    - Environment Canada programs to address municipal WWTP effluents: http://www.ec.gc.ca/eu-ww/default.asp?lang=En&n=BC799641-1
    - CCME Canada-wide Strategy for the management of municipal wastewater effluents: http://www.ccme.ca/ourwork/water.html?category_id=81.
- Under the Federal Government's Chemicals Management Plan, which was introduced in December 2006, the Government of Canada will work with stakeholders on the health and environmental assessment of over 9000 substances which are used in products regulated by the *Food and Drugs Act*. The government will also work with stakeholders to reduce the release of these pharmaceuticals and personal care products to the environment by promoting best practices for proper disposal. For more information, refer to http://www.chemicalsubstanceschimiques.gc.ca/plan/index_e.html#7http://www.chemicalsubstanceschimiques.gc.ca/plan/index_e.html#7.

Appendix 1. Actions and Initiatives Previously Implemented to Reduce Contaminants Releases to the Georgia Basin

Intergovernmental Partnership Programs:

- CCME developed a Canada-wide strategy for the management of municipal wastewater effluents. The strategy includes: 1.) a harmonized regulatory framework, 2.) coordinated science and research, and 3.) an environmental risk management model.
- CCME Canada-wide Standards (CWSs) on mercury for dental amalgam wastes was endorsed in 2001. Through the collection and recycling of amalgam wastes and the use of advanced amalgam separator units at dental clinics, the amount of mercury discharged to sewer systems will be reduced. The intent of the CWSs was to reduce environmental releases of dental amalgam in Canada by 95% by 2005, compared to releases in 2000.
  For more information, refer to the following websites:
  - CCME Strategy and initiatives to reduce the release of contaminants in WWTP effluent: (http://www.ccme.ca/ourwork/water.html?category_id=81
  - CCME MOU with the Canadian Dental Association: http://www.ccme.ca/ourwork/water.html?category_id=118

Metro Vancouver Programs:

- Past modifications at Metro Vancouver WWTPs in the Georgia Basin include the extension of the discharge outfall from Metro Vancouver's Iona Island WWTP beyond the intertidal area in 1988. Subsequent environmental surveys have reported a decline in metal concentrations in sediments and Macoma clams at Sturgeon Bank. In addition, in 1992, the discharge of sludge to the Burrard Inlet from the Lion's Gate WWTP was terminated and, as a result, the loadings of metals from this facility decreased by an estimated 40%. It is likely that the releases of other substances which bind to particulate matter have also been significantly decreased. For recent information on individual Metro Vancouver WWTPs, or to view the Annual Quality Control Report, refer to the Metro Vancouver website (http://www.metrovancouver.org/services/wastewater/treatment/Pages/treatmentplants.aspx).
- Secondary treatment is employed by Metro Vancouver to treat wastewater from all three municipal WWTPs (Lulu Island, Annacis Island and Northwest Langley WWTPs) which discharge to the Fraser River. Metro Vancouver plans to upgrade the remaining two primary treatment plants (Iona Island and Lions Gate), which discharge to marine waters, to secondary treatment by 2020 and 2030, respectively. This will further reduce the concentrations of metals and other contaminants in municipal wastewater discharges to the Georgia Basin. For more information refer to the Liquid Waste Management Plan (LWMP) Biennial Reports (http://www.metrovancouver.org/services/wastewater/planning/Pages/default.aspx).
- Metro Vancouver and member municipalities have adopted a liquid waste management plan (LWMP) in accordance with the British Columbia *Environmental Management Act* (formerly the *Waste Management Act*). Member municipalities and electoral areas within Metro Vancouver include: the Cities of Burnaby, Coquitlam, Langley, New Westminster, North Vancouver, Port Coquitlam, Port Moody, Richmond, Surrey, Vancouver, and White Rock; the Corporation of Delta; the Districts of Langley, Maple Ridge, North Vancouver, Pitt Meadows and West Vancouver. In addition, although the Villages of Anmore, Belcarra, and Lions Bay; Bowen Island Municipality; and a portion of Electoral Area A are not members of the Metro Vancouver Sewerage and Drainage District, Metro Vancouver policies associated with non-point source pollution issues apply in these areas. For more information, refer to http://www.metrovancouver.org/services/wastewater/planning/Pages/default.aspx.
- Under the LWMP, Metro Vancouver committed to the development of an Environmental Monitoring Committee comprising representatives from federal, provincial and municipal

governments, research institutions and the public. This committee is responsible for reviewing monitoring proposals, results, and risk assessments of waste discharges and providing recommendations for consideration by Metro Vancouver and member municipalities.

- Metro Vancouver has implemented source control programs to reduce the discharges of toxic substances to sewers as part of its LWMP. Sewer use Bylaw 299 was adopted on May 25, 2007 to supercede Bylaw No. 164. Bylaw 299 is now the primary bylaw regulating liquid waste discharges from non-residential facilities in Metro Vancouver. This bylaw includes a Code of Practice for Dental Operations which specifies that, by July 1, 2008, all dental operations using or removing dental amalgam must utilize a certified amalgam separator. In addition, the revised Metro Vancouver Sewer Use Bylaw includes other new Codes of Practice for photofinishing (for the discharge of silver) and dry cleaning (for the discharge of tetrachloroethylene. The new series of Bylaw amendments will consider the following (Bertold 2009):
    - additional requirements for the discharge to sewer of priority contaminants to sewer, in particular priority substances listed under CEPA 1999,
    - revising fees to better reflect user-pay and polluter-pay principles and to improve sustainability, fairness and effectiveness of the source control program,
    - codes of practice with requirements for various industrial, commercial and institutional sectors to allow an effective and efficient means of protecting Metro Vancouver's interests and the environment,
    - increasing maximum fines and allowing a broader array of regulatory tools, economic instruments and administrative penalties, and
    - Pollution Prevention Plans for the control of medical and laboratory discharges.

  For more information, refer to website http://www.metrovancouver.org/services/wastewater/sources/Pages/commercial.aspx**.**
- Metro Vancouver has also developed resources to address residential sewer use as well as guidance documents for homeowners to reduce contaminants releases to sewer systems. For more information, refer to website http://www.metrovancouver.org/services/wastewater/sources/Pages/resident.aspx**.**

Capital Regional District (CRD) Programs:

- A LWMP, which provides a strategy for managing liquid wastes over the next 25 years, was developed by the CRD and its municipal partners including Colwood, Esquimalt, Langford, Oak Bay, Saanich, Victoria and View Royal in 2000 (http://www.crd.bc.ca/wastewater/lwmp/documents/CALWMP.pdf). A separate LWMP was completed for the Saanich Peninsula communities of Central Saanich, North Saanich and Sidney (http://www.crd.bc.ca/wastewater/lwmp/saanich_lwmp.htm). Recently, the CRD engaged the Society of Environmental Toxicology and Chemistry (SETAC), a non-profit professional society, to do an independent review and performance audit of the CRD's LWMP. As per the terms of reference, SETAC selected an independent scientific and technical review panel to conduct a broad review of the components of the LWMP, the future risks (e.g., population growth and emerging concerns regarding specific chemicals), and alternative and new liquid waste management systems (Ferry 2006, personal communication). This review was completed and provided to the CRD in July 2006 and can be viewed at http://crd.bc.ca/wastewater/documents/SETACCRDFinalReportv2_000.pdf.
- Of the eight WWTPs operated by the CRD, the Saanich Peninsula, Port Renfrew, Canon Crescent (on North Pender Island), and Maliview (on Saltspring Island) WWTPs employ

secondary treatment; the Ganges Harbour WWTP on Saltspring Island employs tertiary treatment; and the two major facilities (Macaulay Point and Clover Point WWTPs) provide only preliminary treatment (fine screening prior to discharge). The CRD is currently in the process of planning upgrades to the Macaulay Point and Clover Point facilities. For more information, refer to http://www.crd.bc.ca/wastewater/marine/macaulay/index.htm . To view annual reports and compliance reports for each of the CRD WWTPs, refer to website http://www.crd.bc.ca/wastewater/marine/reports.htm.

- The CRD has implemented a source control programs to reduce the discharges of a range of contaminants to sewers. The CRD Regional Source Control Program (RSCP) is a pollution prevention program aimed at eliminating or reducing the amount of contaminants being discharged to sanitary sewers by businesses, institutions, and households. A combination of regulatory tools and education are used to achieve program goals. The main components of the RSCP include inspections, monitoring, enforcement, outreach, contaminants management, and planning and development. The CRD Sewer Use Bylaw is the main regulatory instrument for the RSCP. This bylaw limits the concentrations of specified contaminant levels in wastewaters entering the sewage system at the source. Under the bylaw, individual facilities and business sectors are regulated under permits, authorizations, or codes of practice. There are currently 11 codes of practice in place under this bylaw containing sector-specific pre-treatment requirements. These regulatory codes pertain to dental, food service, automotive repair, dry cleaning, photographic imaging, vehicle wash, carpet cleaning, fermentation, printing, laboratory and recreation facility operations. Facility inspections, including sector-specific outreach, are carried out on a regular basis. Enforcement is also an important component of the RSCP. The Regional Source Control Program Enforcement Policy can be viewed at http://www.crd.bc.ca/wastewater/sourcecontrol/monitor-enforce.htm. Permit compliance at each permitted facility is confirmed through regular self-monitoring and reporting. RSCP staff carry out audit monitoring two times per year at each permitted facility to check the self-monitoring data. Monitoring is also conducted annually by RSCP staff at a selected number of facilities in each sector operating under codes of practice. The RSCP launched a new residential outreach campaign in February of 2007 to encourage householders to adopt simple contaminant reduction practices. For more information on the RSCP, refer to website http://www.crd.bc.ca/wastewater/sourcecontrol/index.htm.

2. Forest Products Industry

2.1 Pulp and Paper Mills

Federal and Provincial Government Programs:

- *Fisheries Act* 1992 *Pulp and Paper Effluent Regulations* (PPER) prescribed stricter discharge limits for certain deleterious substances in the final effluents of pulp and paper mills based on what secondary treatment could achieve. Restricted substances included total suspended solids (TSS), biochemical oxygen demand (BOD) and acutely lethal effluent (rainbow trout 96 hr LC_{50} <100%). Significant improvements resulted from imposed limits including a 94% reduction in BOD materials and a 70% reduction in TSS (kg/tonne). Acutely lethal effluents changed from 75% of the mills to generally 100% compliance (LC_{50} >100%) (Boyd 2009, personal communication).
- PPER also required pulp and paper mills discharging to aquatic environments to conduct an environmental effects monitoring (EEM) program to assess if the stricter limits were adequate to protect fish, fish habitat, and the use of fisheries resources in all receiving environments. Mills conduct EEM in 3 year cycles to determine if the present mill effluent causes effects. EEM basic requirements include effluent sublethal toxicity testing, a fish survey, and a benthic invertebrate survey. Evaluation of fish tissue for dioxins and furans is required under certain conditions for mills with chlorinated bleach plants. Reporting of fish tainting complaints is also required. Environment Canada, BC MOE and other relevant parties (e.g., environmental groups or First Nations) review the EEM study designs and interpretive reports. The results of EEM monitoring conducted by BC mills are submitted to Environment Canada at the end of each cycle (Boyd 2009, personal communication). For more information on EEM, refer to http://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=4B14FBC1-1 .
- Two *Canadian Environmental Protection Act, 1999* (CEPA 1999) regulations were part of the 1992 federal regulatory package and reduced the release of dioxins and furans by 99%. These regulations include the *Pulp and Paper Mill Defoamer and Wood Chip Regulations*, which control the formation of dioxins/furans, and the *Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations*, which control the release of dioxins/furans. These regulations were put in place because of elevated concentrations of dioxins and furans detected in the environment near BC pulp mills using the chlorine bleaching process in the late 1980s. The Department of Fisheries and Oceans (DFO) imposed fishery restrictions around several coastal mills using the chlorine bleaching process. The mills were required to monitor aquatic organisms for dioxins and furans based on sampling programs coordinated by Environment Canada, with input from DFO. Based on the results, DFO re-opened or maintained fishery restrictions with advice from Health Canada. Most mills achieved compliance with the regulation by substituting chlorine dioxide for chlorine bleaching. TEQ levels (measure of the toxic potential of the dioxins/furans) in crabs have declined by 95% since 1990. While some restrictions remain, pulp mills effluents are no longer major sources of dioxins and furans to the environment (Boyd 2009, personal communication). For more information on reductions in dioxin and furan loadings to the BC environment from pulp and paper facilities, refer to the Environment Canada website on Environmental Indicators (http://www.ecoinfo.ec.gc.ca/env_ind/region/dioxinfuran/dioxin_e.cfm).
- A report prepared for BC MOE in 2008 summarized emission data for facilities using wood as fuel for heat and/or electrical power generation (including pulp mills) (http://www.env.gov.bc.ca/epd/industrial/pulp_paper_lumber/pdf/emissions_report_08.pdf).

- In the late 1980s, analysis of adsorbable organic halides (AOX) was introduced as a surrogate measure for chlorinated phenolics and other undefined chlorinated compounds in pulp and paper effluents. BC provincial permits for pulp and paper mills that use chlorine bleaching require AOX levels to be measured three times per week to estimate total loads of chlorinated organic compounds in pulp and paper effluents. AOX data has been used to demonstrate the decrease in chlorinated organics as pulp and paper mills reduced their use of chlorine. From 1991 to 2000, AOX releases from BC pulp mills were reduced by 83%.

Intergovernmental Partnership Programs:

- The major current source of dioxins and furans from pulp and paper mills is their release to the atmosphere from the combustion of salt laden wood. Hogged fuel, which includes bark and similar wood wastes, is a by-product of sawmills and is burned by pulp and paper plants to produce steam. At coastal mills, the wood absorbs salt, and consequently chlorine, from marine water during transport in log booms. Under certain conditions the burning of wood containing chlorine can result in the production of dioxins and furans. The majority of coastal mills burning salt-laden wood are located in BC and it has been estimated that this source releases 8.6 g TEQ/year to the atmosphere. Mill closures and voluntary industry initiatives have reduced releases by approximately 25% compared to 1990 releases. To address this issue, CCME developed Canada-wide Standards (CWS) for pulp and paper boilers burning salt-laden wood. These CWSs specified numeric targets and timeframes for reducing dioxin and furan emissions from boilers burning more than 10,000 oven-dried metric tonnes per year (t/yr) of salt-laden wood. The standard for existing pulp mill boiler emissions will be less than 500 pg/m^3 (based on TEQs) by 2006. The standard for new boilers constructed after May 1, 2001 is less than 100 pg/m^3 (based on TEQs). The CWSs are implemented by the province of BC, which has been working with stakeholder groups to address this issue since 2001.
  For more information refer to the following websites:
  - CCME CWSs: http://www.ccme.ca/ourwork/air.html?category_id=97
  - Pulp mill boiler emissions: http://www.env.gov.bc.ca/epd/industrial/pulp_paper_lumber/pulp_paper_boilers.htm

Industry and Industry Association Programs:

- The Canadian pulp and paper industry made extensive process changes in the late 1980s and early 1990s to meet the stricter load limits imposed by the 1992 *Fisheries Act* and CEPA 1999 regulations. Most mills installed major pollution prevention technology, including secondary biological treatment. Chlorine bleaching plants substituted chlorine for elemental chlorine, among other changes. These measures significantly improved the quality of mill effluent releases (Boyd 2009, personal communication).
- The Pulp and Paper Research Institute of Canada (Paprican) (now part of FP Innovations http://www.fpinnovations.ca/) assisted with research and testing of stack emissions for the implementation of the CCME developed CWSs for pulp and paper boilers burning salt-laden wood. For more information, refer to http://wcm.paprican.ca/wcmpaprican/publishing.nsf/AttachmentsByTitle/BO_Control_Emission_PDF_Eng/$FILE/0701-E-ControllingEmissionsCombustion.pdf.
- The Forest Products Association of Canada (FPAC), previously known as Canadian Pulp and Paper Association (CPPA), has been encouraging their members to consider possible alternatives to NP- and NPnEO-containing products since 1997. FPAC and Environment Canada conducted a national survey of pulp and paper mills to determine the use of

nonylphenol (NP) and its ethoxylates (NPnEOs) in 2001. There was a 91% response rate to the survey and, of the 136 mills that responded, only 40 reported using these compounds in 2001. In addition, 32 of these 40 mills planned to replace the NP- and NPnEO-containing products with substitutes by 2003 (Environment Canada 2003). This report can be viewed at http://www.ec.gc.ca/planp2-p2plan/default.asp?lang=En&n=64521013-1&offset=1&toc=show.

2.2 Wood Treatment Facilities

2.2.1 Antisapstain Facilities

Note: antisapstain chemicals are used by lumber mills for the short-term protection of recently produced lumber from fungus and mold during shipment to overseas markets.

Federal and Provincial Government Programs:

- Chlorophenate-based formulations for antisapstain control were de-registered in Canada under the federal *Pest Control Products Act* (PCPA) on December 31, 1990. These chemicals are no longer used for antisapstain purposes at BC mills.
- The PMRA conducted a re-evaluation under the PCPA of TCMTB, CU- 8 and Borax. An interim re-evaluation report was published in 2004 and determined that the registration of these antisapstain products should continue to be acceptable, with provisions. The PMRA report can be viewed at http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rrd2004-08/index-eng.php.For more information on PMRA re-evaluations refer to the PMRA website http://www.hc-sc.gc.ca/cps-spc/pest/protect-proteger/regist-homolog/_re-eval/index-eng.php.
  In 1983, the BC MOE published Chlorophenate Wood Protection: Recommendations for Design and Operation. In 1994, this "Code of Practice" for wood protection was updated by Environment Canada and BC MOE. This document provides guidance on the design and operation of chemical application facilities and on the prevention and control of chemical releases. In addition, the *Antisapstain Chemical Waste Control Regulation* under the BC *Environmental Management Act* was brought into force on September 1, 1990 and was revised in 2004. This regulation specifies effluent quality criteria as well as requirements for the design and operation of facilities utilizing antisapstain chemicals for the treatment of lumber in BC. Emissions of antisapstain chemical spray booth vents are also controlled under this regulation. The implementation of pollution control measures by wood protection facilities resulted in improvements to chemical handling and covered lumber storage. These measures, in combination with the compliance monitoring of the antisapstain industry by Environment Canada, have substantially reduced the release of antisapstain chemicals into the aquatic environment in BC (an estimated 99% reduction in the volume of toxic surface runoff to the environment in BC). According to the Environment Canada Pacific and Yukon Region compliance report (99-14) on the Antisapstain Wood Preservation Industry in British Columbia, the compliance rate of antisapstain facilities with the recommendations increased from 33% in 1987 to 84% in 1998. For more information on the *Antisapstain Chemical Waste Control Regulation* refer to http://www.env.gov.bc.ca/epd/industrial/regs/antisapstain/index.htm

2.2.2 Heavy Duty Wood Preservation Facilities

Note: wood preservation chemicals are used for the long-term protection of wood from insects, fungus and marine borers

Federal Government Programs:

- Environmental codes of practice for the wood preservation industry were introduced in the 1980s. The implementation of these codes, in combination with an aggressive inspections and enforcement program under the federal FRAP initiative in the 1990s, resulted in significant decreases in the release of wood preservation chemicals (including creosote (PAHs), PCP (and associated contaminants such as dioxins/furans, HCB and CDPEs), copper, chromium and arsenic). According to the Pacific and Yukon Region compliance report (99-18) on the Heavy Duty Wood Preservation Industry in British Columbia, it was estimated that contaminated effluent discharge from these facilities was reduced by more than 90% due to the enforcement initiative targeted at this industry sector as a result of FRAP.
- A risk management strategy was developed for the wood preservation sector under the Strategic Options Process (SOP) of the earlier 1988 version of CEPA. The SOP involved the development of a risk management strategy in cooperation with various stakeholders from industry, government, and non-government organizations. The SOP report for the wood preservation sector was completed in 1999. Steering committees and working groups were formed to oversee the implementation of the report's recommendations concerning the release of CEPA-toxic substances from chemical manufacturing, treatment of wood, use of treated wood, and waste management of post-use treated wood. More information on the SOP initiatives for the wood preservation industry and for managing PAHs, hexavalent chromium compounds, and creosote-contaminated wastes can be found on Environment Canada websites http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=C5039DE5-1&xml=C6502274-1535-467A-923D-34C2FE9102E8 and http://www.ec.gc.ca/planp2-p2plan/695CA3F2-6A81-4336-A234-716745C8E9B4/sor_e.pdf.
- In March 1999, Environment Canada published updated "Recommendations for the Design and Operation of Wood Preservation Facilities". Implementation of the codes is voluntary; however, as of March 31, 2000, all of the 68 wood preservation treating facilities operating in Canada signed onto the "voluntary program". Fifteen of these facilities were operating in BC. Each wood treatment facility signed a contract that commits them to meeting the objectives of the Technical Recommendations Document (TRD) over a five-year period. Audits are conducted to confirm the implementation of the recommended requirements at each facility. A CEPA 1999 Pollution Prevention Notice will be issued for those facilities that have not implemented the recommended practices. On October 22, 2005 a CEPA 1999 notice was published which requires five wood preservation facilities, including one in BC, to develop and implement a pollution prevention plan. The TRD document was updated on April 2004 to include inorganic boron and new organometallic preservatives, namely ACQ and copper azole (CA-B), which were introduced following the voluntary withdrawal of CCA use for consumer products in 2003 (Liu 2006, personal communication). For more information on wood preservatives, refer to the Environment Canada websites http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=29B3E589-1&offset=11&toc=show and

http://www.ec.gc.ca/planp2-p2plan/default.asp?lang=En&n=31F54A0D-1.

- The PMRA has conducted a re-evaluation under the federal PCPA of heavy duty wood preservatives including creosote, PCP, and CCA. For more information refer to the following websites:
    - PMRA re-evaluation process: http://www.hc-sc.gc.ca/cps-spc/pest/protect-proteger/regist-homolog/_re-eval/index-eng.php
    - .PMRA re-evaluation of the heavy duty wood preservatives: http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rev2008-08/index-eng.php

3. Metal Mines (the following summary was taken from McCandless 2006, personal communication; More 2009, personal communication; Hagen 2009, personal communication)

Federal Government Programs:

Canada has approximately 100 metal mines, most of which are in Ontario and Quebec. Environment Canada has no specific program focused on metal mines, but it has responsibility for Section 36(3) of the *Fisheries Act* and its related *Metal Mining Effluent Regulations.* Departmental inspectors visit the metal mines and ensure their compliance. Environment Canada maintains the web-based Regulatory Information Submission System (https://www.riss-sitdr.ec.gc.ca/riss/Global/Index.aspx) under which mines post their effluent flows and concentrations in accordance with those regulations. This information, which is compiled and published annually for all Canada's metal mines, is available to authorized persons only. Environment Canada does not taken an active regulatory role regarding coal, diamond, placer, industrial mineral and aggregate mines, but it does advise on potential environmental effects of new mines throughout Canada.

In BC, until 2005, Environment Canada played an active research and enforcement role in preventing pollution from abandoned mines. Some mines in the province's mountainous terrain have continuous drainage of acidic mine water, often contaminated with copper, zinc, aluminum and iron. Worst of these was the famous Britannia Mine, situated on Howe Sound, which released up to 1000 kilograms per day (kg/day) of dissolved copper and zinc into Howe Sound. In 2005, the province completed construction of a treatment plant for this drainage. More information can be obtained at http://www.agf.gov.bc.ca/clad/britannia/index.html.

Similar problems occurred at the long-closed Mt Washington copper mine on Vancouver Island, near Courtenay. In late 2003, construction of a passive treatment system lowered copper concentrations in site runoff to safe levels. This protected very important salmon habitat in the Tsolum River. More information can be found on the website http://www.tsolumriver.org/. Environment Canada Enforcement Branch actions continue at other abandoned mines in BC which have polluting drainage, including Anyox and Tulsequah Chief (which are both located outside of the Georgia Basin).

Provincial Government Programs:

High prices in 2004 and 2005 for mineral commodities like coal, copper and zinc greatly increased investment in this sector. As of January 2006, fourteen new mines were in the BC environmental assessment process and, at least, that many mine sites were undergoing advanced exploration and development. Despite the recent economic downturn, there are still numerous projects in the Environmental Assessment (EA) process. The province has no specific programs focused on the mining industry and environmental protection. Media releases from the Ministry of Energy and Mines state its intention to enhance the mine and mineral exploration approval processes, develop "user friendly" mining environmental and reclamation guidelines, and develop an integrated land use system for exploration and mining. The BC MOE has taken steps to reduce issuance of site-specific effluent and emission permits through applying codes of practice and regulations for specific sectors under the *Environmental Management Act*. While there are regulatory overlaps in regard to metal mines, the standards prescribed in provincial permits and regulations, approvals, and codes of practice usually meet or exceed requirements of the federal *Fisheries Act* and the *Canadian Environmental Assessment Act*.

The biggest concern relating to environmental contaminants associated with metal mining in BC has been the metal-contaminated acid rock drainage issues. However, requirements under the

Mines Act will prevent and/or ensure polluter funding to remediate acid rock drainage pollution at BC mines in the future. For more information refer to the BC MOE website (http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/00_96293_01).

As previously discussed, the most recognized site of ARD is the Britannia Mine on Howe Sound (as described above). The authority for the regulation of these discharges lies with BC MOE under the authority of the EMA. The Crown Contaminated Sites Branch of BC MAL is now overseeing the remediation of the site. For more information refer to website http://www.agf.gov.bc.ca/clad/britannia/index.html

4. Non-Point Sources

Non-point sources (NPS) are major contributors of environmental contaminants to the south coastal BC environment. Despite the fact that these releases can be small when considered on an individual basis, the cumulative impact of the very large number of small sources within a watershed can result in the deterioration of groundwater, surface waters, drinking water as well as freshwater, estuarine and marine habitats. Non-point sources demonstrated to be significant sources of contaminants to the aquatic environment of the southern BC coast include CSOs, urban runoff and stormwater, agricultural runoff, boating activity, septic systems, spills, atmospheric deposition, and contaminated sites. These sources can contribute contaminants such as pesticides, fertilizers, metals, oils, pharmaceuticals, hormones, surfactants, nutrients and a wide range of other chemicals including plasticizers and fire-retardants, as well as biological contaminants. The relative contributions of the various non-point sources, and the array of contaminants released to the environment from these sources, vary within the various watersheds and are highly influenced by land use. For example, in the highly urbanized Lower Mainland region, CSOs, stormwater and runoff associated with urban development are primary sources of oils, pharmaceuticals, surfactants and chemical contaminants such as PAHs and metals. However, the intensive agricultural activity in the Fraser Valley contributes pesticides, nutrients and veterinary drugs such as hormones and antibiotics to local streams and ditches.

4.1 General Non-Point Sources

Federal Government Programs:

- Environment Canada, in cooperation with interested partners, undertook GBAP-funded projects to address the following objectives:
  - assess, report, and track water quality status and trends of streams and rivers in the Georgia Basin. Seven new water quality sites were initiated under GBAP, in partnership with BCMOE, to look at impacts from a variety of anthropogenic activities (e.g., forestry, urbanization, 2010 Olympics). These are being reported on in the 2000 national CESI (Canadian Environmental Sustainability Indicators) report, and in two other regional (2009) reports. The data are also being reported on the Water Quality website at www.waterquality.ec.gc.ca.
  - assess and report on the status of streams and rivers in the Georgia Basin using benthic invertebrate community structure as an indicator and produce on-line biological assessment tools/indicator and training for the province, municipalities, environmental agencies, and stewardship groups that will be applied in identifying impaired waterways, and the associated human activities that are likely causing impairment to stream communities. This online training tool has been developed and training information is available on the CABIN website at http://cabin.cciw.ca.
  - promote environmental stewardship amongst the public, particularly in the Georgia Basin area, by informing them of environmental issues and human impacts through innovative and award winning tools like the "Interactive Non-Point Source Pollution Model" (which was developed under GBEI, by event and school appearances, and via the internet; and
  - evaluate trends in water and sediment quality in the Sumas watershed in order to identify links between land use and aquatic habitat condition..
- Environment Canada completed a GBAP-funded study of the effects of non-point source pollution on small urban and agricultural streams in the Lower Fraser Valley (Fluegel *et al.* 2004).

- EC has prepared terrestrial and aquatic critical load estimates for the Georgia Basin. Mathematical modelling to estimate regional N and S deposition is complete and there have been efforts at empirical estimation of N and S deposition using passive samplers.

Provincial Government Programs:

- In 1999, BC MOE prepared an Action Plan for tackling non-point source water pollution in BC. This Action Plan identified needs related to education and training; pollution prevention at the site; land-use planning, coordination and local action; assessment and reporting; economic incentives; and legislation and regulation. The Action Plan did not include funding options or an implementation schedule. For more information refer to http://www.env.gov.bc.ca/wat/wq/bmps/npsaction_key.html.
- BC MOE has developed a website containing a compendium of best management practices (BMPs) from around the world aimed at reducing non-point source pollution. This compendium is useful to determine what BMPs are currently being used, their efficacy, and the need for the development of new BMPs to address non-point sources in BC. For more information, refer to the BC MOE website http://www.env.gov.bc.ca/wat/wq/nps/BMP_Compendium/nps_bmp.htm.

Other Programs:

- UBC Institute for Resources and Environment is developing an overview of nutrient loading and metal contamination in sediments of major tributaries to the Fraser River in the Lower Fraser Valley. In addition, a detailed assessment of NPS pollution impact by land use in the Salmon River Watershed in the Township of Langley will be conducted. This compliments other work being done through the Canadian Water Network.

4.2 Combined Sewer Overflows (CSOs)

Combined sewers were designed and installed many decades ago to carry both sanitary wastewater and stormwater in a single pipe. For this reason, they are considered to be sources of both point (sanitary sewers) and non-point (stormwater) pollution. Although the majority of the waste collected in combined sewers is transported to municipal wastewater treatment facilities, during heavy rainfall conditions the volume of wastewater can become too great for the system to handle. In these events, the mixture of sanitary and stormwater in these systems overflows to nearby waterways. These are referred to as combined sewer overflows. While this is acknowledged as an outdated and undesirable way of dealing with wastewater, they are extremely expensive to replace. It is estimated that combined sewers make up approximately 60% of the Vancouver sewer system, most of the New Westminster sewer system, and a much smaller part of the northwest Burnaby sewer system. Since CSO discharges to the environment are untreated, they are significant sources of a variety of chemical contaminants such as metals, nutrients, PAHs, personal care products and pharmacological agents, and a variety of other organic contaminants, as well as bacteria and other pathogens. While the magnitude of CSO contributions to the overall loadings of chemical contaminants to the south coastal BC environment, Metro Vancouver calculated loadings for some chemical contaminants from CSOs in different land use areas (residential, light industrial, and heavy industrial) (Lee 1998), and a recent report prepared for Environment Canada also estimated the loadings of select contaminants to the Georgia Basin (ENKON 2002). The report provided loadings estimates for several metals, ammonia, naphthalene, benzo(a)pyrene, chrysene, chloroform, toluene and dioxins/furans. A 1993 FRAP study reported that 53 CSOs located in Burnaby, New Westminster, and Vancouver discharged to English Bay, Vancouver Harbour, False Creek, the

Brunette River and the North Arm of the Fraser River (UMA Engineering Ltd 1993). Projects are currently underway to reduce the discharge of untreated combined sewer overflow from Metro Vancouver and City of Vancouver CSOs.

Metro Vancouver (was GVRD) Programs:

- Metro Vancouver and member municipalities have developed a LWMP in accordance with the B.C *Environmental Management Act* (EMA). Member municipalities and electoral areas within Metro Vancouver include: the Cities of Burnaby, Coquitlam, Langley, New Westminster, North Vancouver, Port Coquitlam, Port Moody, Richmond, Surrey, Vancouver, and White Rock; the Corporation of Delta; the Districts of Langley, Maple Ridge, North Vancouver, Pitt Meadows and West Vancouver; the Villages of Anmore, Belcarra, and Lions Bay; Bowen Island Municipality; and a portion of Electoral Area A. However, since the three villages, Bowen Island Municipality, and Electoral Area A are not members of the Metro Vancouver Sewerage and Drainage District, only the policies associated with non-point source pollution issues apply in these areas. Provisions relating to CSOs under the LWMP include:
    - the formation of an Environmental Monitoring Committee comprising representatives from federal, provincial and municipal governments, research institutions and the public. The role of the committee is to review monitoring proposals, results, and risk assessments of waste discharges and to provide recommendations for consideration by Metro Vancouver and member municipalities; and
    - a commitment by Metro Vancouver to eliminate CSOs in the Vancouver Sewerage Area by the year 2052 and the Fraser Sewerage Area by 2077. According to the Metro Vancouver LWMP, priority will be given to reducing or eliminating CSOs which have been identified by the Environmental Monitoring Committee as having significant environmental impact. For example, Metro Vancouver and the municipalities of Vancouver and Burnaby will review the schedules for sewer separation and system upgrades necessary to fast-track the elimination of the Clark Drive CSO in Burrard Inlet.
- CSOs are located in the City of Vancouver, City of Burnaby, and City of New Westminster. In accordance with the LWMP, Metro Vancouver, BC MOE, City of Vancouver, City of Burnaby, and City of New Westminster are working on programs to eliminate CSOs by 2050. This is being accomplished by the separation of stormwater and sanitary sewers or by temporarily storing the overflow and redirecting the discharge to a WWTP once the capacity within the sewer system becomes available. The separation of sewers in the downtown Vancouver Granville and Yaletown areas are complete and work will continue in the False Creek area, the West side of the City, Downtown Eastside/Strathcona, Still Creek, and the Fraser River. The separation of the Clark Drive CSO, in particular, will result in a significant decrease in the volume of discharge. Metro Vancouver monitors the quality of effluent at all Metro Vancouver-owned outfalls and also conducts environmental studies (Brekke 2006; City of Vancouver 2008; Metro Vancouver 2008).
- Since 1994, Metro Vancouver has reduced CSOs discharges to Burrard Inlet by 35% and it is expected that initiatives currently underway will result in a further 10% decrease over the next decade. Operational improvements to the New Westminster waterfront CSOs together with a CSO storage project are underway and are expected to be completed by 2007. It has been predicted that these changes will result in a 30% decrease in annual CSO volume discharged to the Fraser River (Lewis 2002, personal communication).
- According to a recent report prepared for BIEAP (Brekke 2006), the 25 overflow outfalls which discharge into Burrard Inlet release approximately 36 billion litres of mixed wastewater and

stormwater annually (based on Metro Vancouver data from 2000), with the Clark Drive CSO contributing over 40% of the total annual discharge (Hall *et al.* 1998). Metro Vancouver has reduced the volume of discharge to Burrard Inlet from CSOs, including discharges from the Clark Drive CSO, in which high levels of several metals and PAHs have been detected, by increasing storage capacity in the sewer systems and by directing more of the combined sewage flow to the Iona Island WWTP.

For more information on CSO reduction plans within Metro Vancouver refer to websites http://public.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-CombinedSewers.pdf and http://vancouver.ca/engsvcs/watersewers/sewers/enviro/separation.htm.

Capital Regional District (CRD) Programs:

- A summary prepared by CRD in 2004 indicated that there were 21 CSOs within the CRD. The CRD LWMP identifies the location and discharge of each of these 21 CSOs and also gives a sensitivity rating for each of the receiving areas and presents an Action Plan for each CSO. The CRD and its municipal partners identified a goal of eliminating CSO discharges to areas of environmental or public health sensitivity and reducing or eliminating overflows at areas of lower sensitivity (CRD 2000). However, according to a recent Scientific and Technical Review of the CRD LWMP (Stubblefield *et al.* 2006), sampling of these sources has been very limited and no treatment has been implemented. The review committee recommended that the CRD and member municipalities proceed with plans to replace trunk sewers and reduce CSOs on a prioritized basis.

4.3 Urban Runoff and Stormwater

Urban runoff originates from rainfall and snowmelt which runs off streets, parking lots, driveways, and roof tops. This runoff is collected in storm drains and enters storm sewers where it is transported and released to nearby streams, rivers, lakes, or the ocean. Stormwater management and the operation and maintenance of storm sewer systems to collect and transport stormwater are typically the responsibilities of municipal governments. A wide variety of contaminants enter runoff and stormwater in urban areas. These include wood treatment chemicals; copper from water pipes and brake linings; hydrocarbons, gasoline, oil, and PAHs from tire wear, vehicle exhaust and parking lot and driveway sealants; antifreeze; detergents and other cleaners from vehicle washing; and suspended solids. As well, a variety of unknown contaminants enter storm drains as a result of intentional releases to storm drains and inadvertent spills. Stormwater in urban areas also contributes significant amounts of pesticides to the aquatic environment. For many current-use pesticides, the largest usage is in urban areas and some studies have shown that pesticide concentrations can be higher in urban streams than in agricultural streams.

The concentrations of contaminants in stormwater discharges and their loading to the environment increase with both the vehicular traffic and the proportion of impervious surface areas (such as roadways, rooftops, driveways, and parking lots) in the municipality. Impervious areas prevent the natural penetration of rainwater into soil and result in the channelling of large volumes of surface runoff to storm sewers. For this reason, the increase in impervious areas that will accompany the predicted population growth for the south coastal area of BC will likely result in higher loadings of contaminants, particularly metals and PAHs, to the south coastal aquatic environment from stormwater discharges. These could result in increased areas of environmental and water quality degradation. The large development projects, which continue to be built as a result of the growing population within the Georgia Basin region, heighten the need for land use plans developed by municipalities to give careful consideration to the potential environmental impacts of contaminated stormwater and increases the importance of implementing innovative measures to minimize impervious surface area and manage stormwater in both new and existing areas of development.

A report prepared for Environment Canada concluded that stormwater is currently one of the most significant sources of contaminants to the Georgia Basin. This report concluded that, while adequate information was available to estimate loadings of several chemicals of interest, particularly metals, information on individual PAHs, pesticides, and dioxin/furans was too limited for loadings to be estimated (ENKON 2002).

Federal Government, Provincial Government, and Intergovernmental Programs:

FRAP programs put a strong emphasis on public education initiatives to encourage public awareness and involvement on urban runoff issues and included the preparation of publications, brochures, workshops promoting specific guidelines. The Non-Point Source Pollution Awareness Campaign was a joint project of Environment Canada, Fisheries and Oceans Canada, the Fraser Basin Management Program, and Metro Vancouver. This project focused on three primarily residential sources of non-point pollution including landscaping and lawn care, automobile washing and maintenance, and household maintenance and cleaning products. The NPS Pollution Awareness Campaign was undertaken by public education program (posters, fact sheets, stickers, newspaper, and TV ads). The Fraser River Interactive Pollution Urban Runoff model (3-D table top model) was designed for public and educational events. This hands-on model demonstrates what NPS is, where it comes from, and what actions people can take to reduce this pollution. FRAP publications addressing stormwater and urban runoff issues can be viewed at http://www.rem.sfu.ca/research/publications/frap_pdf_list/. For more information on the Fraser River Interactive Pollution Urban Runoff model refer to website http://www.pyr.ec.gc.ca/EN/_pdf/NPSP_English.pdf. Guidelines for the monitoring and protection of stormwater quality were also developed under FRAP. For more information on FRAP initiatives refer to http://www.rem.sfu.ca/research/publications/frap_pdf_list/.

- An important objective identified in BIEAP programs was the reduction of contaminant loading to the Burrard Inlet from urban runoff. Reductions have been achieved through public education and awareness programs implemented by the federal, provincial, and municipal government agencies; BMP development; and Metro Vancouver and City of Vancouver programs to encourage the use of energy-efficient options for transportation. However, the total loading reductions achieved as a result of these initiatives have not been determined.
- The Victoria and Esquimalt Harbours Environmental Action Program (VEHEAP) is an intergovernmental initiative which was established through a Memorandum of Understanding between various federal government agencies, the BC Ministry of Environment, and the Capital Regional District. This MOU establishes a management framework to coordinate activities to protect and improve the environmental health of Victoria and Esquimalt harbours. The Harbours Ecological Inventory and Rating (HEIR) project was initiated by VEHEAP to assist in the environmental management of harbours and adjacent lands. For more information on VEHEAP and the HEIR project, refer to http://www.crd.bc.ca/partnerships/veheap/index.htm.
- The Water Balance Model for BC is a web-based modelling tool which allows users to compare various scenarios for stormwater management. It was developed by a BC-based intergovernmental partnership including various local, regional, provincial, and federal agencies and is now being expanded to allow it to be used nationally (http://www.waterbucket.ca).
- Environment Canada, in cooperation with other partners, undertook the following GBAP-funded projects to address stormwater issues:

  - support the development and implementation of watershed-based Integrated Stormwater Management Plans (ISMPs). (These plans enable municipalities to set targets for maintaining or improving aquatic habitat values in specific priority watersheds. They identify engineering, planning, and environmental considerations required to meet these targets over time.);
  - assess the effectiveness of stormwater source controls, such as green roofs and rain gardens in the Silver Ridge Subdivision, to better understand how they can be used to prevent urban non-point source pollution;
  - promote understanding of urban non-point source pollution through an interactive web-based watershed outreach tool, "Interactive Non-Point Source Pollution Model", which outlines potential sources and actions that can be taken to prevent non-point source pollution;
  - demonstrate how stormwater management and aquatic habitat protection targets can be met by planning, building, monitoring, and evaluating low impact development projects. (This will build confidence in low impact development strategies and to reduce risk over time.);
  - develop and promote the Water Balance Model, a web-based scenario modelling tool for stormwater management based on the water balance modelling approach;
  - monitor the effectiveness of a municipally-owned stormwater treatment system at removing total suspended solids and other contaminants;
  - develop Codes of Practice for Stormwater Quality in the Capital Regional District; and
  - encourage and, as possible, implement watershed-based approaches to reduce loadings of toxic substances to the Georgia Basin aquatic environment.
- A used oil recovery program was introduced by the province in an effort to reduce the release of used oils into storm sewers. In 1998 it was estimated that 56% of the approximately 50 million litres of waste lubricating oil from domestic and industrial users in BC was recycled. For information on this and other provincial government recycling programs refer the BC MOE website http://www.env.gov.bc.ca/epd/recycling/.
- BC MOE led the development of a stormwater planning guidebook as a tool for local governments to use in planning early actions to prevent adverse effects resulting from the release of stormwater. For more information refer to the BC MOE website http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html.

Metro Vancouver Programs:

- The LWMP developed by Metro Vancouver and member municipalities in accordance with the British Columbia *Environmental Management Act* (EMA) (refer to Metro Vancouver activities under Section 5.4.1 Combined Sewer Overflows) contains the following provisions under the LWMP relate to urban runoff and stormwater:
  - the Metro Vancouver LWMP states that the District will not authorize any new stormwater connections to the sanitary sewer system and will continue their policy of eliminating stormwater contributions authorized under existing industrial permits. Industrial facilities will be required to develop and implement plans for eliminating stormwater contributions from their sanitary sewer discharge.
  - through the LWMP, member municipalities of Metro Vancouver have committed to completing ISMPs on 123 watersheds within Metro Vancouver over a twelve year period. These ISMPs will identify stormwater runoff BMPs that are appropriate for each watershed. Metro Vancouver is also developing a long-term stormwater monitoring program to assess the effects of stormwater runoff on small streams. This program includes the development of a Benthic Index of Biotic Integrity (B-IBI) monitoring, analysis, and assessment protocol. As part of the LWMP, watershed-based planning studies have been implemented. In one such

program, the Brunette Basin Watershed Management Plan, the municipalities within the Brunette River Basin implemented a pilot watershed planning program. Stormwater BMPs are used to reduce runoff resulting from development. Stormwater management involves coordination and partnerships between all levels of government, businesses and communities.

For more information on policies relating to stormwater in the LWMP refer to website http://www.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-Stormwater.pdf.

- Metro Vancouver has prepared a number of technical reports on stormwater and drainage management for use by member municipalities.
- Although stormwater management is typically the responsibility of the member municipalities, Metro Vancouver provides stormwater management planning and operations services for two key watershed drainage areas including the Still Creek/Brunette River Drainage Areas (the Brunette Basin) and the Port Moody/Coquitlam Drainage Area.
- Efforts by municipalities to improve stormwater management and to protect the environment include street sweeping to remove debris and contaminants, storm drain cleaning, maintenance of creeks and watercourses and the enhancement of streams and habitat for aquatic life, monitoring stormwater quantity and quality, and the implementation of public education programs. For example, the yellow fish painted on storm drains serve to remind the public that dumping materials into storm drains can be harmful to the environment.

For more information on Metro Vancouver initiatives to address stormwater discharges and to view available reports, refer to the Metro Vancouver website http://www.metrovancouver.org/services/wastewater/sources/Pages/StormwaterManagement.aspx.

Capital Regional District (CRD) Programs:

- The CRD and its municipal partners have developed a LWMP which includes stormwater management as an integral part. The member municipalities of the CRD include Colwood, Esquimalt, Langford, Oak Bay, Saanich, Victoria and View Royal. A separate LWMP was completed for the Saanich Peninsula communities of Central Saanich, North Saanich and Sidney.
- Since the management and regulation of stormwater discharges is a municipal government responsibility, the CRD Stormwater, Harbours and Watersheds program (SHWP) works with the municipalities to protect watercourses, and nearshore marine environments from stormwater contamination. The CRD forms partnerships with municipalities to manage stormwater quality. This includes the development of regulatory compliance tools such as bylaws, codes of practice, and best management practices. The SHWP and the member municipalities work together to develop these tools and models which are then provided to all member municipalities for adoption. The Model Storm Sewer and Watercourse Protection Bylaw provides member municipalities with the regulatory power to prohibit the release of specific wastes to stormsewers and watercourses. In addition, the model bylaw has provision for the development of Codes of Practice for business sectors. Municipalities within the CRD were invited by the CRD Board to adopt this bylaw. The enhanced bylaw is designed to allow the incorporation of regulatory stormwater codes of practice to prevent the pollution of stormwater. A number of codes of practice have been developed including Automotive and Parking Lot Operations, Streets and Roads, Construction and Development Activities, Recreation Facilities, Outdoor Storage Yard Operations, and Recycling Operations. In addition, Best Management Practices (BMPs) have been developed for both painting and powerwashing operations.
- CRD conducts annual stormwater quality monitoring and the results are published in annual reports (http://www.crd.bc.ca/watersheds/monitoring.htm). In addition, CRD measures chemical

contaminants in sediments at select stormwater discharges under their Stormwater Quality Survey. When the concentrations of contaminants are too high, the CRD works with municipalities to identify and address the source of the contamination. A comparison of concentrations at these locations over a long period of time will permit the identification of trends in stormwater discharges. For more information on CRD stormwater programs refer to website http://www.crd.bc.ca/watersheds/index.htm. To view Annual Stormwater Reports, existing Codes of Practice and BMPs, Stormwater, Harbours and Watershed news, Watershed Plans and Assessments, and Liquid Waste Management Plans refer to website http://www.crd.bc.ca/watersheds/publications/listing.htm#plans.

Partnerships with Community Groups:

- Public involvement in addressing NPS pollution is essential and some community groups have initiated projects to reduce NPS pollution in affected watersheds. One such project was initiated at Cecelia Creek, which was considered to be one of the most contaminated creeks in Greater Victoria due to urban runoff. Unacceptably high concentrations of a variety of metals (and PAHs) were detected in the sediments. A partnership approach between the CRD, federal, provincial, and municipal agencies, and community groups focused on education and awareness. BMPs were compiled and local businesses were approached regarding their compliance with the BMPs. Of particular focus was the automotive industry which represents 58% of the business sector located within this catchment and contributed a large portion of the heavy metal contamination to the watershed. For more information refer to the CRD website http://www.crd.bc.ca/cecelia/
- The Byrne Creek Watershed Business Inspection and Education Program is another watershed-based program addressing stormwater quality. Environment Canada and the City of Burnaby jointly launched this program to address the improper discharge of chemicals into storm sewers leading to Byrne Creek. The purpose of this program is to conduct inspections of commercial and industrial businesses within the Byrne Creek Watershed, develop business-specific BMP guides, conduct limited water quality sampling, and increase community awareness of potential impacts to the watershed. For more information on the Byrne Creek Watershed refer to http://www.byrnecreek.org/.
- As an extension of a Georgia Basin Ecosystem initiative (the Shared Waters Roundtable), between 2004 and 2008, Environment Canada participated with the Shared Waters Alliance in efforts to reduce the contamination of Boundary Bay and key tributaries, such as the Little Campbell River. Shellfish harvesting in Boundary Bay shellfish harvest was once very important to First Nations and to the local economy. The Shared Waters Alliance is a Canada-US working group focused on improving water quality for Canadian-American shared waters. The group is focussed on non-point source pollution issues in the watershed, including urban and agricultural runoff and pollution source control initiatives. Members of the Shared Waters Alliance included representatives from federal (United States and Canada), provincial, state, and municipal agencies, First Nations, academia, and local community groups. In 2009, the Shared Waters Alliance began to focus on ambient water quality monitoring in Boundary Bay, in a coordinated effort led by Metro Vancouver. For more information, refer to the Shared Waters Alliance website http://www.sharedwaters.net/.
- Other partnerships between regional districts, government agencies, and community groups formed for the purpose of addressing NPS concerns. These included:
    - Esquimalt Lagoon Stewardship Initiative (http://www.crd.bc.ca/watersheds/protection/esquimaltlagoon/)

- Bowker Creek Urban Watershed Renewal Initiative (http://www.crd.bc.ca/watersheds/protection/bowker/)
- Gorge Waterway Initiative (http://crd.bc.ca/watersheds/protection/gorgewaterway/)

4.4 Agricultural runoff

Agricultural runoff has been identified as a leading source of water quality impact in rivers, lakes, estuaries, wetlands, and groundwater. The contamination of runoff in agricultural areas occurs as a result of the application of pesticides and fertilizers (natural and chemical), the production of excess amounts of manure in areas of high livestock density, and the administration of medications and growth-enhancing chemicals to livestock.

Inorganic fertilizers and manure, which are applied to agricultural lands to enhance crop production, are sometimes applied in amounts greater than those which can be taken up by the crops. This results in the release of excess concentrations of nutrients, such as nitrogen-based nutrients and phosphorus, to aquatic ecosystems and can result in the degradation of environmental quality. Similarly, in feed lots, and other areas where livestock are held in confined areas, the large amount of animal waste produced can result in the degradation of water quality as a result of the release of nutrients, oxygen-demanding substances and pathogens, and veterinary drugs. Impacts on water quality as a result of agricultural runoff have been documented in the Georgia Basin and in other areas of BC. Several studies in the Lower Fraser Valley, particularly in the Abbotsford-Sumas, Hopington and Brookswood areas, have identified aquifer contamination as a result of nutrient releases from manure and other fertilizers. In addition, fecal contamination from agricultural runoff has resulted in shellfish harvesting closures in Saanich Inlet and other enclosed or poorly flushed coastal areas.

A wide variety of pesticides are used by the agriculture sector for the control of pests and weeds. The improper application, spillage and improper storage, leaching from soils and runoff, and atmospheric transport and deposition of pesticides results in their entry to the aquatic environment and can adversely impact aquatic species. Surveys of pesticide use in BC in 1991, 1995 and 1999, and 2003 have provided valuable information on the amounts and types of pesticides used in BC and the trends in this usage but, in general, little information is available on the specific types and volumes of chemicals applied in various areas of the province. Several current-use and historical-use pesticides have been detected in ground, surface, and runoff waters in agricultural areas of BC. Information on the loadings of pesticides and veterinary drugs to the Georgia Basin as a result of agricultural runoff is lacking.

Federal Government, Provincial Government, and Intergovernmental Programs:

- The education of farmers and the public was recognized as an important component in efforts to reduce agricultural pollution under FRAP. A number of FRAP-supported studies addressed the management of agricultural waste and environmental issues associated with agricultural runoff. Environmental commodity guidelines were produced for some sectors to better communicate information on addressing environmental concerns to producers. The BC Horticultural Coalition used these guidelines for developing self-auditing protocols. In addition, a Watershed Stewardship Guide for Agriculture was developed by various FRAP partners as an educational product for farmers and agricultural organizations. In addition, FRAP supported the Sustainable Poultry Farming Group's Groundwater Protection Program (GPP). The GPP is a producer driven initiative that allows for excess manure to be transported away from the Abbotsford Aquifer so as to reduce the risk of manure over-application to the land. FRAP reports can be viewed at http://www.rem.sfu.ca/research/publications/frap_pdf_list/.

- The development and subsequent implementation of agricultural BMPs or guidelines for procedures such as manure application/handling and agricultural runoff control strategies have been developed in this region and can be effective in reducing nutrient and pesticide releases to surface waters. The GBEI and GBAP partially funded some aspects of the work by the raspberry producers to minimize soil and water pollution with manure and by the Pacific Field Corn Association to develop Advanced Guides for Forage and for Silage Corn production. For more information on environmental initiatives and guidelines for agricultural producers refer to website http://www.farmwest.com/.
- FRAP and GBEI have contributed funds to help model and evaluate Agricultural Census results to better understand manure and nutrient loadings to land in the Lower Fraser Valley (Derksen 2006, personal communication).
- Environment Canada, in cooperation with interested partners, undertook GBEI and GBAP-funded projects addressing the release of pesticides and/or nutrients to the Georgia Basin environment as a result of agricultural practices.
- The Agricultural Policy Framework is a five-year federal-provincial-territorial agreement on agriculture which was established in 2003 and is based on a 2001 agreement between the federal, provincial, and territorial Ministers of Agriculture. The Environment Chapter of the Agricultural Policy Framework (APF) identified soil, water, air, and biodiversity as the major areas of focus for producers. Agri-environmental programming encourages producers to voluntarily assess their current production activities and to utilize management practices that enhance their environmental stewardship. In BC, the program has been administered by the BC Agricultural Council (Derksen 2006, personal communication). The three levels of government are now working toward delivering new programs for Canadian farmers through the Growing Forward Initiative. However, during the transition period to the new Growing Forward Initiative, existing APF programs will continue for a period of up to one year (ending April 2009). For more information on the transition of the APF to the Growing Forward programs refer to websites http://www.agr.gc.ca/cb/apf/index_e.php and http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1200339470715&lang=e.
- The Canada–British Columbia Environmental Farm Plan Program was launched in 2003 and is a partnership between Agriculture and Agri-Food Canada, the BC Ministry of Agriculture and Lands and the BC Agriculture Council. This program is being delivered by the BC Agriculture Council. For more information refer to http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/368659/efp_brochure.pdf ; http://www.fraserbasin.bc.ca/programs/documents/BCCleanAir2008/Magnusson.pdf ; and http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/index.htm.
- In 2003, the BC Ministry of Agriculture and Lands developed, as part of their contribution to the APF, the Canada-British Columbia Environmental Farm Plan Program Reference Guide. The Reference Guide and its companion Planning Workbook were intended to assist agricultural planners and producers in the development of environmental action plans for their farms. Funding for identified risks is provided through the National Farm Stewardship and Greencover Programs. These reports are part of a series of publications prepared to support the implementation of the Canada-BC Environmental Farm Plan Program (Derksen 2006, personal communication).
- The Farm Practices in BC Reference Guide developed by the BC Ministry of Agriculture and Lands contains a variety of fact sheets containing environmental guidelines for various

agricultural producer groups including: beef producers, berry producers, dairy producers, field vegetable producers, tree fruit and grape producers, greenhouse growers, horse owners, mushroom producers, and the nursery and turf industry. For more information refer to the BC Ministry of Agriculture and Lands website http://www.agf.gov.bc.ca/resmgmt/fppa/refguide/intro.htm.

- In 1992, BC MOE introduced the *Agricultural Waste Control Regulation* and the Code of Agricultural Practice for Waste Management under the *Environmental Management Act* (EMA). These address activities associated with the use and storage of manure and other agricultural wastes. This was an important step forward in addressing agricultural pollution in BC; however, the success of these initiatives in reducing nutrient releases to the south coastal BC environment has not been assessed. For more information on the *Agricultural Waste Control Regulation* and the Code of Agricultural Practice for Waste Management refer to http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/10_131_92 and http://www.env.gov.bc.ca/epd/industrial/regs/ag_waste_control/index.htm.
http://www.env.gov.bc.ca/epd/industrial/regs/ag_waste_control/index.htm
- The BC provincial LWMP states that municipalities must take agricultural runoff into consideration during integrated stormwater management planning. For more information refer to http://www.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-NonPointSource.pdf.

Regional Government Programs:

- Metro Vancouver's LWMP states that "municipalities will consider stormwater runoff from agricultural lands when undertaking integrated stormwater management planning for their municipality". In addition, the District will compile past findings of scientific studies to determine base-line data for water quality in agricultural watersheds, and will include waterways in agricultural areas in its water quality monitoring and environmental assessment program. For information on the LWMP refer to the Metro Vancouver website http://www.metrovancouver.org/about/publications/Publications/LiquidWasteManagementPlan2001.pdf.

4.5 Atmospheric deposition

Atmospheric deposition has been identified as an important NPS for both metals and many organic contaminants in the Georgia Basin; however, currently available information is limited to deposition estimates for select contaminants and specific areas such as the Brunette River and Abbotsford. Atmospheric releases from various local industrial activities, waste incinerators, fossil fuel combustion, domestic burning, slash burning, motor vehicles, railways, marine vessels, the application of pesticides and fertilizers in agricultural areas, and forest fires release contaminants including nitrogen and sulphur compounds, metals, PAHs, dioxins and furans and a variety of other organic chemicals.

Atmospheric deposition is thought to be the major source of PAHs to the Georgia Basin. Sources include residential heating (especially the use of wood for fuel); transportation; municipal incinerators; agricultural, forest slash, and other open air-burning; beehive burners at sawmills; and forest fires. In addition, numerous current-use pesticides and nutrients have been detected in air and precipitation samples and deposition measurements have been reported for some agricultural areas of BC. Similarly, deposition measurements for various metals have been estimated for some areas within the Georgia Basin, particularly for the Brunette watershed. Although atmospheric releases of dioxins and furans from pulp mills in BC have been significantly reduced in recent years, the burning of salt-laden hogged fuel and wood waste to produce steam for energy is the major source of pulp mill-related releases of dioxin and furan release to the BC environment.

Long-range atmospheric transport and deposition is likely a significant source of both conventional and new POPs to the Georgia Basin environment; however, information on loadings from this source is limited. Several studies have attributed the presence of conventional and emerging POPs in high-altitude regions, in the Chilliwack River watershed, and in certain other regions of the Georgia Basin, at least in part, to long-range atmospheric transport and deposition. The sources and fate of POPs in the Georgia Basin are now being studied through the use of modelling and mass balance calculations based on PCBs and PBDEs (Shaw 2009, personal communication). However, deposition measurements for atmospherically transported contaminants at several locations is required to determine loadings directly to the Georgia Basin, to large lakes and reservoirs, to land surfaces at various elevations.

Environmental management decisions to control local sources depend on knowledge of the relative importance of local versus global sources. The better understanding of local versus global inputs of contaminants to the Georgia Basin has been identified as a priority research need.

Federal Government, Provincial Government, and Intergovernmental Programs:

- The Inventory of Sources and Emissions of Toxic Air Contaminants in BC (1995), prepared under FRAP, catalogued emissions for 1990 in all of BC and included emissions from point, area, and mobile sources. Prior to FRAP, only common air pollutants were inventoried, while toxic air pollutants were not. The results of an updated inventory for 2000 are available at ftp://ftp.env.gov.bc.ca/pub/outgoing/Air_Resources_Branch/Emission%20Inventory/2000_Inventory_Report.pdf. Other emission inventories can be viewed at http://datafind.gov.bc.ca/query.html?qp=url%3Awww.env.gov.bc.ca&mi=&qt=emission+inventory.
- Information on provincial programs, regulations, guidelines, codes of practice, and monitoring relating to industrial emissions in BC can be viewed at http://www.env.gov.bc.ca/air/industrial/index.html
- The federal National Pollutant Release Inventory (NPRI) is a legislated, nationwide, publicly-accessible inventory which provides information on annual releases of specific key pollutants to air, water, land and disposal or recycling from all sectors (including industrial, government, commercial, etc.) in Canada. However, only facilities which meet the reporting requirements of this program are required to report releases. Mobile sources of pollutants (such as vehicles), facilities which release pollutants on a smaller scale, and some sector activities (including agriculture) are not included in the NPRI. This program collects information on releases of dioxins/furans, PCBs, metals, PAHs, nonylphenol and its ethoxylates, and many other substances. For more information about the NPRI program refer to the Environment Canada website http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm/.
- Environment Canada, in cooperation with interested partners, undertook a GBAP-funded project to assess sources and fate of PCBs and PBDEs in the aquatic, marine, and terrestrial ecosystems of the Georgia Basin through a combination of mass balance and exchange process modelling as well as focused sampling to address critical data gaps identified in the modelling (Noel *et al.* 2009). Also refer to http://www.waterquality.ec.gc.ca/web/Environment~Canada/Water~Quality~Web/assets/PDFs/Acrobat%20Document.pdf .

Regional Government Programs:

- Metro Vancouver led a collaborative project with other levels of government, including Environment Canada, to assess the toxicity of existing atmospheric pollutants in the Lower Fraser Valley ("Air Toxics Emission Inventory and Health Risk Assessment – Summary Report", 2007), which is available at http://www.metrovancouver.org/about/publications/Publications/Air_Toxics_Emission.pdf. The report found that diesel particulate matter (diesel PM) is a key driver of human health risk. Sources of diesel PM include on-road diesel vehicles, marine vessels, and non-road engines. Of the significant risk drivers, three substances (benzene, formaldehyde, and 1,3-butadiene) are predominantly from "mobile" sources, with lesser contributions from "point" and "area" sources. Hexavalent chromium and carbon tetrachloride are more heavily influenced by point and area sources.
- Metro Vancouver conducts regular air quality monitoring at specific locations in the Lower Fraser Valley to compare concentrations of key air contaminants to air quality objectives. Information on Metro Vancouver air quality monitoring programs and air quality reports are available at http://www.metrovancouver.org/services/air/monitoring/Pages/default.aspx.
- Metro Vancouver works with the Fraser Valley Regional District to conduct emission inventories for the Lower Fraser Valley. Detailed inventories are conducted every five years and identify and track common air contaminants and their sources and greenhouse gas releases. For more information refer to http://www.metrovancouver.org/services/air/emissions/Pages/default.aspx.
- A 2004 report commissioned by the Fraser Valley Regional District (FVRD), in cooperation with Environment Canada, inventories agricultural emissions in the Lower Fraser Valley and summarizes best management practices (BMPs) to reduce these emissions. The report can be viewed at http://www.pyr.ec.gc.ca/airshed/Agr_BMP_EI_exec_summary_en.pdf .

4.6 Contaminated Sites

Contaminated sites are areas of land where soils, groundwater, and/or adjacent sediments contain hazardous wastes or toxic substances at concentrations exceeding provincial or federal environmental quality standards or at concentrations which are above background and are likely to pose a hazard to human or environmental health. These concentrations render the site unsuitable for specific uses. At certain sites, the concentrations of some substances are high enough to be of concern to human and/or environmental health. The most commonly detected substances at contaminated sites in BC are petroleum hydrocarbons and heavy metals, such as lead, arsenic, cadmium, and mercury. However, chlorophenols and PAHs are commonly detected at old wood treatment facilities and PCBs are commonly detected at sites where electrical equipment, such as transformers and capacitors, were used.

Federal Government Programs:

- The federal government is responsible for the management of contaminated sites on federal lands. In 1995, the Contaminated Sites Management Working Group (CSMWG) was established to ensure an efficient and consistent approach to the management of federal contaminated sites. The CSMWG comprises representatives from 15 federal departments and is co-chaired by Environment Canada and the Department of National Defence. In 2003, the Government of Canada announced its two-year Federal Contaminated Sites Accelerated Action Plan (FCSAAP). In 2003, $175 million were committed for FCSAAP. In 2004, the government announced an additional contribution of $3.5 billion for this program. In 2005, the additional funding was committed and the initial Plan was extended to a 15 year program and was renamed the Federal Contaminated Sites Action Plan (FCSAP). FCSAP provides funding, on a cost-sharing basis, to federal custodial departments for reducing human and environmental health risks associated with federal contaminated sites (FCSAP Guidance Manual 2008). Federal legislation pertinent to the management of contaminated sites includes CEPA 1999, the *Fisheries Act*, and the *Canadian Environmental Assessment Act* (CEAA). For more information on the federal contaminated sites program refer to the Environment Canada website http://www.federalcontaminatedsites.gc.ca/index-eng.aspx.

- Federal departments and agencies are required to maintain a database of contaminated sites for which they are responsible. This information is used to annually update the Federal Contaminated Sites Inventory (FCSI). The FCSI can be viewed at the Treasury Board of Canada website http://www.tbs-sct.gc.ca/fcsi-rscf/home-accueil.aspx?Language=EN&sid=wu69121627377.
- DFO (IOS) has begun working on ocean dumping of contaminated sediments in killer whale critical habitat, concentrations of PCBs and PBDEs in sediments and mussels of contaminated harbours (Vancouver and Victoria), and PAHs in sediments, under the auspices of the Federal Contaminated Sites Program (Johannessen 2009, personal communication; Ross 2009, personal communication).

Provincial Government Programs:

- Amendments to the British Columbia *Environmental Management Act* (EMA) and to the *Contaminated Sites Regulation* have improved the ability of the province to deal with contaminated sites. Annual amendments to the regulations will be conducted by the province to ensure that the environmental quality standards continue to reflect the most recent scientific knowledge. For more information on the provincial contaminated sites program, refer to the BC MOE website http://www.env.gov.bc.ca/epd/remediation/index.htm. For more information on the management of contaminated sites on provincial Crown lands refer to the BC Ministry of Agriculture and Lands website http://www.agf.gov.bc.ca/clad/ccs/. The BC MOE 2006-2007 Annual Report of the Land Remediation Section can be viewed online at http://www.env.gov.bc.ca/epd/remediation/annual_reports/pdf/annual_report_2007.pdf.
- The BC provincial Site Registry is a publicly accessible on-line provincial database which contains information on sites that have been investigated and cleaned up since 1988 and also information on sites that are currently being investigated to determine whether they should be considered contaminated. Since the Site Registry was initiated, more than 8500 sites have been registered; however, this number includes both confirmed contaminated sites and sites that are being screened to determine whether, in fact, they should be classified as contaminated sites. For more information on the Site Registry refer to the BC MOE website https://www.bconline.gov.bc.ca/pdf/site_reg.pdf.

4.7 Pleasure Boating

The operation and maintenance of boats can result in the release of environmental contaminants to both fresh and marine waters and can ultimately contribute to the impairment of water quality making it unsuitable for drinking, recreational activities, fish habitat, and shellfish harvesting. Sources of contaminants and/or pathogen release to the environment from recreational boating include discharges of sewage, garbage, food and grey water, bilge and ballast water; the release of oil and grease, fuel, and cleaning agents; and the leaching of chemicals from new paint during application and operation and from paint scrapings removed during maintenance. In addition, the presence of creosoted pilings in marinas and other areas of boat operation can be a source of PAHs to the environment. Environmental concerns are highest in marinas, small harbours, and heavy-use boating areas located in shallow, low flush regions.

Federal Government, Provincial Government, and Intergovernmental Programs:

- Laws and policies, Best Management Practices (BMPs), and various fact sheets and other BMPs relating to recreational boating in BC have been developed and can be viewed at the Environment Canada website http://www.pyr.ec.gc.ca/boatyards/index_e.htm.
- The BC MOE brochure entitled "Clean Water …It Starts with You – Pleasure Boating" can be viewed on the BC MOE website http://www.env.gov.bc.ca/wat/wq/brochures/boating.html.
- The provincial LWMP contains a policy on the release of pleasure craft sewage (http://www.metrovancouver.org/about/publications/Publications/LWMP-PoliciesCommitmentsSchedule-NonPointSource.pdf.

Non-Government Agency Programs:

- In 2007, Georgia Strait Alliance produced the comprehensive Guide to Green Boating. This document and additional information on green boating can be viewed on the Georgia Strait Alliance website http://www.georgiastrait.org/?q=node/51.
- Georgia Strait Alliance (GSA) has established a new project: to develop a voluntary environmental recognition program for marinas, harbour authorities, yacht clubs and boatyards in BC. GSA conducted a pilot program with one initial marina in Sidney, BC during 2007 and 2008, and has since added several additional marinas. "Clean Marine BC" is modelled on the highly successful "Clean Marine" program run by the Ontario Marine Operators Association (OMOA). The program includes a reference handbook that will enable marina and boatyard operators to identify where improvements are needed and what standards they must meet, such as BMPs for stormwater or waste management, vessel repair procedures, emission controls, hazardous materials handling or control of hydrocarbons. Each facility in the program will commit to the Clean Marine BC Policy. Once ready for inspection, the marina will undergo an independent audit to determine its level of environmental responsibility. The independent auditor will determine an eco-rating for the facility of between 1 and 5 anchors, with 5 being the highest level of Environmental Best Practices. GSA has awarded marinas that have passed the audits with a certificate of recognition and the right to fly the Clean Marine BC flag. Facilities that join the program and those that become eco-rated will be eligible for a range of benefits including insurance discounts.
- Based on the Guide to Green Boating produced by the Georgia Strait Alliance, a Green Boating Guide for commercial boat operators has been prepared by the T Buck Suzuki Environmental Foundation and can be viewed at http://bucksuzuki.org/publications/booklets/CGBG20Feb2007.pdf.

4.8 Aquaculture

As of 2006, a total of 741 aquaculture facilities in BC produced cultured finfish, shellfish, and marine plants (13 finfish species, 15 shellfish species, and four marine plant species). The majority of these operations were farming salt-water species on Crown land tenures; however, over 100 freshwater facilities were operating on private land. BC is the fourth largest producer of Atlantic salmon in the world.

Environmental concerns associated with aquaculture include the high concentrations of nutrients which enter the environment as a result of the discharge of organic waste such as fish feces and unconsumed fish food at fish farms. It has been estimated that aquaculture releases an estimated 2,276 t/yr of nitrogen to inland and coastal waters in Canada (Chambers *et al.* 2001;Environment Canada 2001).

Other possible sources of contaminants to the environment include the intermittent use of therapeutants to treat farmed fish, fish food with nutritional additives, disinfectants, and chemicals to prevent fouling of net pens. Chemical therapeutants, such as antibiotics, are sometimes used to treat fish for bacterial infections and the administration of antibiotics to BC farmed fish is veterinarian prescribed. All therapeutants used by the aquaculture industry must be registered with and approved by Health Canada (Pest Management Regulatory Agency or Veterinary Drugs Directorate).The drug emamectin benzoate (SLICE®) is administered to farmed fish when a sea lice outbreak is confirmed. This product is also used only under veterinary prescription. Ivermectin is another product which is available for the treatment of sea lice but, as SLICE® is considered safer for the environment, the use of ivermectin has decreased.. A variety of antibiotics are used to treat salmon. Oxytetracycline, sulfadiazine 20% and trimethoprim 80%, and florfenicol are registered for use in aquaculture in Canada (Haya *et al.* 2002). These products are added to the feed or directly into the water.

Tributyltin (TBT), an organotin compound, was once widely used in BC as an antifoulant and was the active ingredient in marine paints applied to net pens to prevent net fouling at aquaculture facilities. Organotin compounds were de-registered for use as antifoulants under the *Pesticide Control Products Act* in 2002. Sampling conducted while these products were still in use in BC detected elevated concentrations of butyltins at some BC salmon farms (Garrett and Shrimpton 1997). Copper-based antifoulants are now widely-used as replacements for organotin-based products. Several studies have found that concentrations of copper in sediments are elevated in comparison with reference areas. In addition, zinc, which is added to fish food at salmon farms for nutritional purposes, has also been detected at elevated concentrations in the sediments in some BC salmon farms. However, it was reported that, because of the presence of high sulphide levels, the zinc was not bioavailable (Brooks 2001;Brooks 2000;Brooks *et al.* 2003;Brooks and Mahnken 2003;Obee 2009;Sutherland *et al.* 2007).

A number of persistent organic pollutants (POPs) have also been in commercially farmed salmon in BC, likely due to the presence of these contaminants in commercial fish food (Easton *et al.* 2002;Hites *et al.* 2004a;Kelly *et al.* 2008a). While some studies indicate that the concentrations of POPs are higher in farmed salmon that in wild Pacific salmon (Hites *et al.* 2004a), the concentrations of POPs and metals in farmed salmon are very low (Foran *et al.* 2004;Kelly *et al.* 2008b).

While some information is available on the types of chemicals in use at BC facilities, more specific information on types and volume of chemicals used is needed.

Federal Government Programs:

- Responsibility for aquaculture management and development is shared between the Federal, Provincial, and Territorial governments. Fisheries and Oceans Canada (DFO), the lead federal department responsible for aquaculture management, works with other levels of government to develop policy and regulations to address both public and industry needs.

- DFO has the primary responsibility to ensure the preservation and conservation of wild fish stocks and reviews aquaculture applications to ensure the protection of wild fisheries and the marine environment and to ensure that safe navigation is maintained. DFO administers, monitors, and enforces compliance with regulations relating to the environment (under the *Fisheries Act* Section 35(1) and (2) and aquatic animal health (*Fish Health Protection Regulations*). At the same time, DFO is responsible for helping to improve the business climate for aquaculture.
- Environment Canada administers the pollution prevention provisions of the *Fisheries Act* (section 36(3)).For additional information on the roles and responsibilities of DFO and other government agencies, general information on aquaculture in Canada, and the results of scientific research pertaining to aquaculture refer to the DFO website http://www.dfo-mpo.gc.ca/aquaculture/aquaculture-eng.htm.
- The Canadian Food Inspection Agency (CFIA) conducts spot audits to check for the presence of drug residues in farmed fish; however, the use of these products results in their release to the environment.
- A report on the use and potential environmental effects of emamectin benzoate in the Canadian aquaculture industry was prepared for Environment Canada in 2005 and can be viewed at http://dsp-psd.pwgsc.gc.ca/Collection/En4-51-2005E.pdf.
- A report on organic waste and feed deposits on bottom sediments from aquaculture operations was published by Environment Canada in 2009 as part of the federal government's Science-Based Solutions series and can be viewed at http://dsp-psd.pwgsc.gc.ca/collection_2009/ec/En13-1-14-2009E.pdf.
- Elevated concentrations of butyltin compounds were detected in water, sediments, and biota in the vicinity of BC aquaculture facilities in the late 1980s and early 1990s (prior to the de-registration of organotin antifoulants) (Garrett and Shrimpton 1997).

Provincial Government Programs:

- In BC, there are two main provincial agencies which share the responsibility with DFO for the regulation and management of aquaculture. These include the Ministry of Agriculture and Lands (BC MAL) and the Ministry of Environment (BC MOE). BC MAL has the lead provincial role in aquaculture development and administers the *Aquaculture Regulation* under the *British Columbia Fisheries Act*. BC MOE is responsible for the development and enforcement of waste standards for the aquaculture industry under the *Finfish Aquaculture Waste Control Regulation* and the *Land-based Finfish Waste Control Regulation*. The *Finfish Aquaculture Waste Control Regulation* is currently under review. To view these regulations, and proposed revisions, refer to the BC MOE website http://www.env.gov.bc.ca/epd/industrial/aquaculture/index.htm. For more information on the aquaculture industry in BC, refer to the BC MAL website at http://www.al.gov.bc.ca/fisheries/index.htm.
- Annual environment monitoring at fish farms is conducted by the BC MOE to ensure compliance with the regulation and to assess effects on the environment. Reports on sampling programs can be viewed at http://www.env.gov.bc.ca/epd/industrial/aquaculture/salmon_farming.htm.
- The sale of medicated feeds is monitored by BC MAL and recorded in a database (to view antibiotic use in BC aquaculture from 1995 to 2006 refer to http://www.al.gov.bc.ca/ahc/fish_health/Antib%20Use%2095-2006%20graphs%20only.pdf). In addition, the salmon farmers must document and track the administration of all therapeutants.

The drug emamectin benzoate (SLICE®) is administered to farmed fish when a sea lice outbreak is confirmed. This product is also used only under veterinary prescription. Ivermectin is another product which is available for the treatment of sea lice; but as SLICE® is considered safer for the environment, the use of ivermectin has decreased.

Non-Government Agency Programs:

- A document titled "Sustainable Shellfish: Recommendations for Responsible Aquaculture" was prepared by the David Suzuki Foundation and is available online at http://www.davidsuzuki.org/Oceans/Aquaculture/Shellfish/.

4.9 Septic Systems (Sewerage Systems)

Numerous homes and cottages located in rural areas on freshwater lakes, rivers, and streams and in coastal areas of BC utilize septic systems (also called sewerage systems) for on-site sewage treatment. However, the improper installation and/or maintenance of septic systems can result in the release of nutrients, contaminants, and pathogens to the environment. While releases of nutrients and pathogens are the primary concerns, septic systems are also a potential source of various other contaminants including cleaning compounds, pharmaceuticals, and personal care products.

Federal Government, Provincial Government, and Intergovernmental Programs:

- As of May 31st, 2005 a new provincial regulation under the *Health Act* puts the onus on the homeowner to ensure that systems are designed, installed, and maintained properly. Under the new regulation, the *Sewerage System Regulation*, a septic or sewage system must be installed by a Registered Onsite Wastewater Practitioner. However, it has been quite widely suggested that these provisions are not adequate and should be revised. For more information on the *Sewerage System Regulation* refer to website http://www.hls.gov.bc.ca/protect/lup_regulation.html.
- Environment Canada, in cooperation with other partners, undertook a GBAP-funded project to educate homeowners on the correct ways to care for their septic systems through the development and distribution of a video.
- For information on septic systems and their proper maintenance and operation of septic systems refer to the following websites:
    - the BC Ministry of Health website http://www.bchealthguide.org/healthfiles/hfile21.stm;
    - the BC MOE website http://www.env.gov.bc.ca/wat/wq/nps/NPS_Pollution/Onsite_Sewage_Systems2/Onsite_Main.htm;
    - information on the BC *Sewerage System Regulation* http://www.hls.gov.bc.ca/protect/lup_regulation.html; and
    - the Can*ada Mortgage and Housing* Corporation website http://www.cmhc-schl.gc.ca/en/co/maho/gemare/gemare_009.cfm.

Regional Government Programs:

- Information on septic systems and their proper maintenance and operation is provided on the following regional government websites:
    - the Interior Health website http://www.interiorhealth.ca/health-and-safety.aspx?id=496, and.
    - Capital Regional District (CRD) website http://www.crd.bc.ca/wastewater/septic/savvy.htm.

Appendix 2. Puget Sound/Georgia Basin International Task Force – British Columbia Toxics Work Group Members

CO-CHAIRS:			
Leslie Churchland **(until January 2005)**	**Environment Canada** **Environmental Protection** 201 - 401 Burrard Street Vancouver, BC. V6C 3S5	Phone: Fax: E-mail:	Retired
Bruce Kay **(May 2007 to March 2008)**	**Environment Canada** **Environmental Protection** 201 - 401 Burrard Street Vancouver, BC. V6C 3S5	Phone: Fax: E-mail:	Retired
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Madeline Waring **(observer)**	**BC Ministry of Agriculture and Lands** **Abbotsford Agriculture Centre** 1767 Angus Campbell Road Abbotsford, BC. V3G 2M3	Phone: Fax: E-mail:	(604)556-3027 (604)556-3030 madeline.waring@.gov.bc.ca

Appendix 2. Puget Sound/Georgia Basin International Task Force – British Columbia Toxics Work Group Members

FEDERAL GOVERNMENT MEMBERS			
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Appendix 2. Puget Sound/Georgia Basin International Task Force – British Columbia Toxics Work Group Members

FEDERAL GOVERNMENT MEMBERS			
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Appendix 2. Puget Sound/Georgia Basin International Task Force – British Columbia Toxics Work Group Members

REGIONAL DISTRICTS MEMBERS			
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Celine Larose	**Capital Regional District** **Environmental Programs** P.O. Box 1000, 524 Yates Street Victoria, BC. V8W 2S6	Phone: Fax: E-mail:	C. Larose is no longer at CRD. New contact at CRD: Chris Lowe Capital Regional District Environmental Services P.O. Box 1000, 625 Fisgard Street Victoria BC V8W 2S6 Phone: (250) 360-3296 Fax: (250) 360-3254 E-mail: clowe@crd.bc.ca
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Appendix 3. Terms of Reference for the Canadian Toxics Work Group

1. Identify potential risks to the environment and human health[8] from anthropogenic toxic chemicals. Identify and assign priorities to current and emerging issues, including: quantitative estimates of toxic chemical inputs, pathways, sinks and environmental effects and areas of significant contamination (hot spots). Identify environmental information which could be used for assessments of human health and determine projections for population growth. Summarize the current state of knowledge on the transport of toxic chemicals across the border.

2. Identify gaps (not addressed by current programs) in existing knowledge, including research and monitoring, and priorities for filling the gaps. The priorities should address the key information needed to understand the scope and significance of toxics issues, and the need for an implementation plan.

3. Identify immediately to the Puget Sound/Georgia Basin International Task Force, if necessary, any urgent environmental or health issue (pertaining to toxic chemicals) requiring immediate action, and actions required.

4. Prepare a report identifying those items in #1 - #3 by March 31, 2001.

5. Co-ordinate the development of the British Columbia Toxics Work Group report (#4) with counterparts from the United States and appropriate Canadian groups, as needed.

6. Provide advice on public consultation for the work of the Toxics Work Group, including timing and form of proposed consultation. Public consultation for the Toxics Work Group will be handled through the Puget Sound/Georgia Basin International Task Force.

7. For the priority issues identified in Phase I, develop options (including recommended options) for mitigative measures, including strategies for implementation. These should be developed both for toxic chemicals originating in Canada affecting only Canadian waters and, in co-operation with the United States work group, for toxic chemicals affecting the shared waters. These should include recommendations for policy, legislative, or regulatory changes which need to be made. Major barriers to implementation should be identified, and recommendations on resolution provided. The implementation plan will also include recommended monitoring programs to fill in data gaps, and ongoing monitoring to ensure the health of the shared waters. The implementation plan, containing these recommendations, should also identify lead agencies and their potential roles. The implementation plan will not deal with toxics issues that are already being covered by other groups, although recommendations may be made to these groups.

[8] Human health issues are to be included only where a potentially significant threat was already recognized and being addressed by health agencies.

Appendix 3. Terms of Reference for the Canadian Toxics Work Group

Scope:

It is expected that the primary focus for the work of this group will be on persistent chemicals or those known or suspected to have deleterious effects, including naturally occurring chemicals where they occur in sufficient concentrations to be of concern to aquatic ecosystems or human health.

Monitoring will be considered to include all data collection activities pertaining to toxic chemicals in the study area.

The geographical area to be considered includes the common boundaries of both the Puget Sound Georgia Basin Initiative and the Georgia Basin Ecosystem Initiative.

Membership: BC Ministry of Environment (BC MOE), BC Ministry of Health (BC MOH), Environment Canada (EC), Fisheries and Oceans Canada (DFO), Metro Vancouver (was Greater Vancouver Regional District or GVRD), Capital Regional District (CRD), with Health Canada (HC), Pest Management Regulatory Agency (PMRA), and BC Ministry of Agriculture and Lands (BC MAL) as observers.

Reporting relationship: The Toxics Work Group will report to the Puget Sound/Georgia Basin International Task Force.

Operational Guidelines for Toxics Work Group:

Members will serve as single windows to their agencies for the purposes of the work of the committee.

Linkages will be made to the various groups who are addressing related issues in the study area, i.e.: Federal/Provincial Toxic Chemical Committee, Georgia Basin NPS Working Group (includes Shellfish), Clean Water Action Plan Planning and Implementation Team, Metro Vancouver Air Quality Committee, and others. The members will contribute to the development of the annual plan for the toxics component of the Clean Water Action Plan of GBEI.

The committee will operate by consensus and, where this is not achieved, the views of dissenting members will be reflected.

Industrial chemicals; chemical by-products, etc. (cont.)

Substance	Source Profile	Toxicity Profile	Environmental Profile	Acts, Regulations, Controls	Ecosystem Guidelines/Criteria	Status
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	*Canadian Environmental Protection Act* (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Antimony (US EPA priority for Puget Sound)	natural sources; runoff and effluents from manufacturing and in municipal discharges	toxic to mammals				
Arsenic (see chromium, copper, arsenic)	naturally occurring arsenic in groundwater		naturally occurring arsenic detected at concentrations above drinking water guidelines in groundwater (including water supply wells) in the Lower Fraser Valley	BC *Drinking Water Protection Act*	Canadian Drinking Water Quality Guidelines	groundwater quality studies for specific aquifers or multi-aquifer areas
Benzene (VOC)	combustion of gasoline, refinery operations, and production of chemicals using benzene as a feedstock	defined as toxic under PSL 1	human carcinogen; has been detected in the Metro Vancouver airshed (4.62 µg/m³) with emissions estimated at 1943 tonnes in 1989-93	SOR emission reduction agreement for natural gas dehydrators; CEPA *Gasoline Regulations*: reduction in benzene content; steel manufacturing sources under review; BC *Environmental Management Act* (was *Waste Management Act)* cleaner gasoline and other regulations result in direct or collateral education in benzene emissions; BC *Special Waste Regulation;* BC *Waste Management Permit Fees Regulation*.	CWQG- 0.005 mg/L (drinking water); 0.3 mg/L (freshwater aquatic life), 0.005 mg/L (drinking water); BCWQC- 0.4 mg/L (freshwater), 0.1 mg/L (marine), 0.005 mg/L (drinking water)	environmental studies/research; national source inventory available; NPRI data available
Bisphenol A	wastewater treatment effluents (WWTP); canned foods; an ingredient of lacquers used to coat metal containers such as food cans; leaches into canned foods	probable endocrine disrupter	estrogenic to human breast cancer cell culture; detected in WWTP effluent and sediments from the Lower Fraser estuary			

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Cadmium (see lead, cadmium, mercury)						
Chloramines	secondary disinfection of drinking water; sewage treatment and industrial waste discharges; potential sources include water main breaks and domestic and fire fighting runoff	being assessed for toxicity under CEPA PSL 2	highly toxic to fish and aquatic organisms; can persist in water from hours to days; documented fish kills in the lower Fraser Valley (e.g., Fergus Creek)	FA Section 36(3) is applicable to toxic substances discharged into waters frequented by fish	CWQG- 3.0 mg/L (drinking water); BCWQC- same	source inventory available; environmental studies
Chlorophenols (tetra and penta)	wood preservative in heavy duty pressure/ thermal industry; antisapstain use (historical); stormwater discharges and contaminated sites at wood treatment facilities and wood storage yards are the major inputs to the basin; ambient air sources: combustion products from incinerators and long range transport	suspected endocrine disrupter	have been detected in soil, sediments, and biota in Lower Fraser/Georgia Basin (LF/GB); ambient air measurements in LF/GB:	registered as heavy duty wood preservatives under PCPA; de-registered for use as antisapstain chemicals in 1990; BC *Environmental Management Act (was Waste Management Act)*: *Antisapstain Chemical Waste Control Regulation*; *Fisheries Act* Section 36(3) is applicable to toxic substances discharged into waters frequented by fish	CWQG- 1 µg/L (tetra); 0.5 µg/L (penta) for freshwater life; 100 µg/L (Tetra) and 60 µg/L Penta for drinking water; BCWQC- aquatic life criteria range from 0.02 µg/L to 0.30 µg/L depending on pH values	source inventory available; environmental studies

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Chlorine and Chlorine Dioxide	pulp and paper bleaching processes, chemical plants, disinfection of drinking water, WWTPs		acutely toxic to aquatic organisms; historical problem of chlorine in Lower Fraser River/Georgia Basin from spills into the aquatic environment	FA Section 36(3) is applicable to toxic substances discharged into waters frequented by fish; BC *Environmental Management Act* (was *Waste Management Act*) BC *Special Waste Regulation*/BC *Waste Management Permit Fees Regulation.*	CWQG- 0.002 mg/L (total residual chlorine)- freshwater aquatic life; BCWQC- 2 µg/L TRC- fresh water, 3 µg/L- TRC - marine and estuarine	source inventory available; NPRI data available
Chlorinated Diphenyl Ethers	use in heat transfer fluids, high temperature lubricants, herbicides, and the bacteriostat Triclosan; perchlorination of industrial or sewage effluent containing parent diphenyl ether	toxicity and pharmokinetics are similar to PCBs.; detected in sediments and biota in selected BC harbours	acutely toxic to fish and are taken up rapidly and excreted slowly; induces mixed function oxidase (MFO) activity in organs of mammals and fish; of concern due to environmental persistence, bioaccumulation potential, and potential to be converted to toxic PCDDs and PCDFs through photo-chemical or thermal conversion	FA Section 36(3) is applicable to deleterious substances discharged into waters frequented by fish. Potential PSL candidate under CEPA.		environmental studies/ research in Vancouver, Esquimalt, and Victoria harbours
Chlorinated Organics- Pulp and Paper (see dioxins/furans)						

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Chromium, Copper, Arsenic	stormwater discharges from wood preservation facilities; treated wood structures; abandoned mines i.e., Mt. Washington; chromium (Cr), copper (Cu), arsenic (As) in emissions from plating, refining, smelting operations; long range atmospheric transport	inorganic arsenic compounds and hexavalent chromium compounds defined as toxic under PSL 1 and added to CEPA Schedule 1 list of toxic substances	chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA) are highly toxic to fish and aquatic organisms and have been detected in stormwater discharges from wood preservation facilities in the LF/GB; significant heavy metals (copper) released from mine site and have severely impacted the Tsolum River and its fisheries resources; ambient air measurements in LF/GB:	CCA, ACA registered under PCPA; Best Management Practices for use of treated wood in aquatic environments (CITW); Guidelines for use of preserved wood in and near fish habitat (DFO) ; FA Section 36(3) is applicable to toxic discharges from mine sites; BC *Environmental Management Act* (EMA) (was *Waste Management Act* : BC *Special Waste Regulation;* BC *Waste Management Permit Fees Regulation*; BC *Integrated Pest Management Act* (was the *Integrated Pest Management Act* (was *Pesticide Control Act*)) (arsenic)	CWQG- chromium (total) 0.002-0.02 mg/L; copper (total) 0.002-0.004 mg/L; arsenic (total) (fresh water aquatic life); BCWQC- chromium (total) 0.001-0.009 mg/L, copper (total) <0.002 mg/L depending on water hardness, 0.005 mg/L arsenic (total) for freshwater aquatic life	environmental studies/research; wood preservation source inventory available; NPRI data available
Cyanide (US EPA priority for Puget Sound)	effluents of copper smelters and metal manufacturing facilities; poisons, fumigants, photographic solutions	toxic to mammals				
Dichloromethane	use in commercial and consumer paint strippers; flexible foam blowing; cleaning solvent	defined as toxic under PSL 1	has been detected in the Metro Vancouver airshed (1.86 μg/m^3) with emissions estimated at 94 tonnes in 1989-93; 1993 Environment Canada study concluded that approximately180 t was released to air and 1.5 t to land in the BC lower mainland	final SOR completed; BC *Environmental Management Act* (EMA) (was *Waste Management Act*): BC *Waste Management Permit Fees Regulation*	CWQG- 98 μg/L (freshwater aquatic life), 50 μg/L (drinking water); BCWQC- same	national source inventory available; environmental studies; NPRI data

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Dioxins and Furans (other chlorinated organics in pulp and paper, e.g., chlorinated guaiacols; mono-and di-chlorodehydro-abietic acids)	combustion by-product from various industries, transport vehicles, hazardous waste incinerators, pulp and paper effluents, industries burning salty hog fuel, leachate from wood treated with chlorophenols, contaminant in commercial chemicals, and natural combustion sources (forest fires)	endocrine disrupters: defined as toxic under PSL 1	have been detected in air, soil, sediments and biota in LF/GB, particularly in harbours and adjacent to pulp mills; abnormal thyroid function reported in salmon; ubiquitous in the environment; toxic equivalents(TEQs) in sediments from the Fraser estuary exceeded interim federal guidelines; ambient air measurements in LF/GB:	UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3] CEPA, FA regulations for pulp mill effluents, PCPA registration standards for dioxin/furan content in pesticides (e.g.,chlorophenols and 2,4-D); national inventory underway; BC *Environmental Management Act* (EMA) (was *Waste Management Act*): regulations for pulp and paper mills; BC *Special Waste Regulation*/BC emission criteria for biomedical and municipal solid waste	IJC- 10 parts-per-quadrillion (ppq) TCDD (water quality objective); 15 ppq TCDD toxic equivalents (drinking water objective)	source inventory available; environmental studies/research
Didecyl Dimethyl Ammonium Chloride **(DDAC); 3-iodo-2-propynyl-butyl carbamate (IPBC)**	stormwater discharges from antisapstain wood treatment facilities		have been found to be highly toxic to aquatic organisms (e.g., white sturgeon); high concentrations have been detected in stormwater discharges in LF/GB.	registered under the PCPA; FA Section 36(3) is applicable to toxic substances discharged into waters frequented by fish; BC *Environmental Management Act* (was *Waste Management Act*): *Antisapstain Chemical Waste Control Regulation*	interim water quality guidelines developed by Environment Canada for fresh water aquatic life (0.0074 µg/L for DDAC; 1.9 µg/L for IPBC)	source inventory available; environmental studies
Ethylene Glycol	automotive antifreeze, aircraft de-icers; large volumes are potentially released into the LF/GB via stormwater runoff	possible endocrine disrupter; being assessed for toxicity under CEPA PSL 2	acutely toxic to fish	FA Section 36(3) is applicable to toxic substances discharged into waters frequented by fish; BC *Environmental Management Act (was Waste Management Act)* BC *Waste Management Permit Fees Regulation.*	CWQG- 3.0 mg/L (under review)- freshwater aquatic life; BCWQC- 192 mg/L for freshwater aquatic life	source inventory available; NPRI data available

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Hexachlorobenzene	contaminant by-product in manufacture of chlorinated solvents and chlorine/caustic soda; was used as seed grain fungicide. Chlor-alkali industry, landfills, municipal wastewater effluents sources of contamination in LF/GB. Carried into LF/GB via long range transport.	defined as toxic under PSL 1; probable endocrine disrupter	has been detected in air, groundwater, soil, resident fish, and sediments in lower Fraser Basin; ambient air measurements in LF/GB:	CEPA and PCPA (no longer registered for use as a fungicide); UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3]; BC *Environmental Management Act* (was *Waste Management Act)*: BC *Special Waste Regulation*	CWQG- 0.0065 µg/L (drinking water); BCWQC- 0.5 µg/L (livestock)	national source inventory available; environmental studies
Lead, Cadmium, Mercury	industrial effluents and emissions; Britannia mine releases up to 5 kg/day of dissolved cadmium into the waters of Howe Sound; atmospheric sources: lead (Pb) from gasoline, cadmium (Cd) from vehicle catalytic converters, smelting, battery mfg; mercury (Hg) from biogenic sources, chlorine dioxide (ClO2) production, pulp and paper mills	possible endocrine disrupters; inorganic cadmium compounds defined as toxic under PSL 1, lead and mercury on CEPA Schedule 1 list of toxic substances	lead and cadmium linked to defeminization in croaker fish; mercury linked to demasculinization in panthers; lead elevated in sediments in the Fraser estuary relative to upstream; lead and cadmium detected in air, lead and mercury detected in sediments in lower Fraser; ambient air measurements in LF/GB:	CEPA-controls on leaded gasoline; FA- *Chlor-Alkali Mercury Liquid Effluent Regulations*; reduction measures recommended for inorganic cadmium compounds in CEPA SORs for steel manufacturing, base metals smelting, and metal finishing industries; BC *Environmental Management Act* (EMA) (was *Waste Management Act*): BC *Special Waste Regulation*; BC *Waste Management Permit Fees Regulation*; BC *Integrated Pest Management Act* (was *Pesticide Control Act*) (Hg); BC emission criteria for biomedical and municipal solid wastes	CWQG- lead (Total) 1-7 µg/L: cadmium (Total) 0.2-1.8 µg/L; mercury (Total) 0.1 µg/L in freshwater aquatic life; BCWQC- lead (Total): 4-16 µg/L depending on water hardness, cadmium (Total): 0.01-0.05 µg/L depending on water hardness, mercury (Total): 0.02 µg/L for freshwater aquatic life	environmental studies; source inventory information available; NPRI data available

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Methyl tertiary-butyl ether (MTBE)	octane enhancer additive in some gasoline; combustion of petroleum products and leakage of underground storage tanks. Other sources include pipelines, stormwater runoff, precipitation, recreational watercraft	defined as non-toxic under PSL 1 (based on mathematical modelling only); US EPA classification: "possible to probable carcinogen"	detected in a pilot sampling by Environment Canada and US Geological Survey in ground waters from the Abbotsford-Sumas aquifer; highest levels detected in air samples in Vancouver; concern about occurrence of MTBE in drinking water supplies from leaking storage tanks, atmospheric exposure at gas stations, near highways, and transporting MTBE	non-toxic, according to CEPA assessment (assessment was not based on environmental concentrations, which did not exist at the time of the assessment)		NPRI data available; environmental studies
Nickel (US EPA priority for Puget Sound)	released in effluents and emissions from its use in electroplating, metallic alloys, in batteries, enamels, ceramics, and glass	some evidence for carcinogenicity of nickel and certain nickel compounds in humans				
Non-ionic Surfactants (alkylphenols and alkylphenol ethoxylates; alcohol ethoxylates)	WWTP effluents, pulp mill effluents, textile mills, reported to leach from plastics used in food packaging	estrogenic properties, nonylphenol and its ethoxylates being assessed for toxicity under CEPA PSL 2	Bioaccumulative and estrogenic; 4-NP detected up to a maximum of 64 ng/g in bed sediments from the Fraser basin; WWTP effluents in Fraser estuary a source of 4-NP to the Fraser River; detected in resident fish tissue from the Fraser River.	FA Section 36(3) is applicable to deleterious substances discharged into waters frequented by fish		environmental studies/research

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Nitrogen (ammonia, nitrate, nitrite)	sewage treatment plants, wood products industries, petroleum and chemical industries, runoff from intensive agriculture; evaporation from biogenic sources; vehicle emissions	being assessed for toxicity under CEPA PSL 2 (ammonia in the aquatic environment)	acutely toxic to aquatic organisms; detected in lower Fraser River; nitrates are major pollutants in the Abbotsford aquifer; ambient air measurements in LF/GB:	FA Section 36(3) is applicable to deleterious substances discharged into waters frequented by fish; BC *Environmental Management Act (was Waste Management Act): BC Waste Management Permit Fees Regulation*/ BC *Special Waste Regulation*	CWQG- total ammonia- 0.08-2.5 mg/L (depending on temp and pH); nitrite- 0.06 mg/L max. for freshwater aquatic life; 45.0 mg/L- drinking water (equivalent to 10.0 mg/L nitrate as nitrogen). BCWQC-total ammonia- 0.75-27.7 mg/L (depending on temp and pH); nitrate- 200 mg/L N (max); 40 mg/L (average); nitrite- same	environmental studies; source inventory available; NPRI data available
Organotin Compounds	TBT marine antifouling paints resulted in contamination of harbours by international shipping, contamination of recreational and commercial marinas, ship building and repair facilities; phenyltin and cyclohexyltin used as an insecticide in agriculture	endocrine disrupter	water from harbours and marinas show levels >100ng/L and >1000 ng/L detected (<10 ng/L in reference areas); causes imposex in six species marine gastropods; ducks in Burrard Inlet had highest levels measured in Canada.	Regulations have been introduced in Canada and many other countries to restrict the use of TBT-based antifoulants; currently under review by IMO (ban proposed on TBT paints by 2006)	CWQG- 0.008 µg/L (TBT- freshwater aquatic life); 0.001 µg/L (TBT- marine water aquatic life) BCWQC- same	source inventory available; environmental studies

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Polycyclic Aromatic Hydrocarbons (PAHs)	by-product of fossil fuel combustion; creosote wood preservatives on marine pilings; wood preservation discharges; urban runoff; combustion sources: incinerators, pulp and lumber mills, open burning, forest fires	defined as toxic under PSL 1; probable endocrine disrupters	detected in air, sediments, and biota in the LF/GB.; benzo(a)pyrene concentrations exceed federal and provincial guidelines and criteria for the protection of aquatic life in sediments from the Fraser estuary; ambient air measurements in LF/GB:	CEPA SOR (steel)- reduction measure recommended; CEPA SOR (creosote contaminated sites)- recommendations under development; creosote wood preservatives registered under the PCPA have undergone regulatory re-evaluation; BC *Environmental Management Act* (was *Waste Management Act)*: B.C *Special Waste Regulation*; BC emission criteria for biomedical and municipal solid waste	CWQG- 0.01 µg/L (drinking water) for benzo(a)pyrene BCWQC- 0.01 µg/L (drinking water) for benzo(a)pyrene; chronic water quality criteria developed for twelve PAHs ranging from 0.01 to 12.0 µg/L for freshwater and marine aquatic life	environmental studies/research; source inventories available
Polychlorinated Biphenyls (PCBs)	dielectric fluid in electrical equipment; historically used in many products such as paints, heat exchange fluids; urban runoff, WWTP effluents, long range transport atmospheric deposition.	endocrine disrupter, CEPA toxic	have been detected in air, soil, sediments, and biota in LF/GB, particularly fish and other aquatic biota; disrupt hormone pathways; involved in male fertility; abnormal thyroid function in salmon; defeminizing effects in croakers; PCBs in sediments exceeded the regional sediment quality objectives for the Fraser North Arm; elevated PCB levels in sediments, birds and resident fish from Fraser estuary; ambient air measurements in LF/GB:	UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3] CEPA regulations covering use, sale, storage, and disposal; BC *Environmental Management Act* (was *Waste Management Act) BC Special Waste Regulation*; BC *Waste Management Permit Fees Regulation*; BC emission criteria for biomedical and municipal solid waste	CWQG- 0.01 µg/L (aquatic life); BCWQC- total PCBs is 0.1 ng/L for freshwater and marine aquatic life (criteria set for specific congeners range from 0.00025 ng/L to 0.09 ng/L)	source inventory available; environmental studies

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Phthalate esters (e.g., dibutylphthalate (DBP), Di-(2-ethylhexyl) phthalate (DEHP), butyl-benzyl-phthalate, other phthalates)	WWTP effluents; vehicle emissions; incinerators	probable endocrine disrupter; being assessed for toxicity under CEPA PSL 2	present in WWTP effluent and air samples from the lower Fraser; used widely as plasticizers. Ambient air measurements in LF/GB:		CWQG- 19 µg/L - fresh water aquatic life; BCWQC- 19 µg/L for DBP, 16 µg/L for DEHP, 0.2 µg/L for all other phthalate esters for freshwater aquatic life; BCWQC- 19 µg/L DBP, 16 µg/L DEHP for fresh water aquatic life	environmental studies; national source inventories are available
Phenol and Substituted Phenols	phenolic resins; petroleum refineries, sewage treatment plants, plastics industries	being assessed for toxicity under CEPA PSL 2	acutely toxic to fish, amphibians, and reptiles; acute effects occur in respiratory and nervous systems, liver, and kidneys of mammals; detected in lower Fraser River.	BC *Environmental Management Act (was Waste Management Act)*: BC *Special Waste Regulation*; BC *Waste Management Permit Fees Regulation*	CWQG- 1 µg/L (total phenols)- freshwater aquatic life; BCWQC- same	NPRI data available
Silver (US EPA priority for Puget Sound)	discharges of photographic wastes in effluents; mining of copper, lead, zinc ores	toxic to aquatic organisms				
Tetrachloroethylene (VOC)	use in dry cleaning of clothing and metal degreasing	defined as toxic under PSL 1	detected in the Metro Vancouver airshed (0.58 µg/m^3) with emissions estimated at 370 tonnes in 1989-93; 1993 Environment Canada study concluded that approximately 408 t was released to air and 395 t to land in the BC lower mainland	SOR completed; CEPA regulations under development for the dry cleaning sector; BC *Environmental Management Act (was Waste Management Act)*: B.C *Special Waste Regulation*	CWQG- 110 µg/L (freshwater aquatic life), 30 µg/L (drinking water- under review); BCQWC- same	environmental studies; regulation implementation at drycleaners; national source inventory available

Industrial chemicals; chemical by-products, etc. (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Industrial releases, commercial products, and waste releases	Priority Substance List (PSL) 1 & 2 substance assessments, possible endocrine-disrupting compound (EDC) effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	Canadian Environmental Protection Act (CEPA); *Pest Control Products Act* (PCPA); *Fisheries Act* (FA);BC *Environmental Management Act* (BC EMA) (was *Waste Management Act)*; CCME Policy for the Management of Toxic Substances (PMTS); CEPA Strategic Options Reports (SORs); Metro Vancouver Bylaws	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	Source inventory, National Pollutant Release Inventory (NPRI); environmental studies, research, etc
Trichloroethylene (VOC)	use in vapour degreasing and cold cleaning of metals	defined as toxic under PSL 1	detected in the Metro Vancouver airshed (0.22 µg/m³) with emissions estimated at 57 tonnes in 1989-93; 1993 Environment Canada study concluded that approximately 98 tonnes were released to air and 0.5 tonnes to land in the BC lower mainland.	SOR completed; CEPA regulations under development for solvent degreasing; BC *Environmental Management Act (was Waste Management Act)*: BC *Waste Management Permit Fees Regulation*	CWQG- 20 µg/L (freshwater aquatic life), 50 µg/L (drinking water); BCWQC- same	environmental studies/research; national source inventory available
Wood Extractives tannins/lignins, and resin acids	stormwater runoff from lumber storage yards, bulk log handling areas		acutely toxic to aquatic organisms; detected in lower Fraser River; toxicity associated with antisapstain chemicals and other lumber yard runoff contaminants	FA Section 36(3) is applicable to toxic substances in stormwater and other sources of aquatic toxicity discharged or released into waters frequented by fish	BCWQC- total tannin & lignin- 400 µg/L for drinking water, 1- 62 µg/L total resin acids depending on pH for fresh water aquatic life	source inventory available; environmental studies
Zinc	stormwater runoff from antisapstain treatment facilities and other industries- galvanized roofing and other sources were the main source of zinc contamination; atmospheric sources: vehicle catalytic converters, tires, incinerators, industrial air emissions, open burning		research from MacMillan Bloedel has shown zinc combined with water softness were the major sources of aquatic toxicity in stormwater effluents from sawmills in LF/GB; aquatic toxicity measured in receiving environments adjacent to sawmills and export terminals; ambient air measurements in LF/GB:	FA Section 36(3) is applicable to toxic substances discharged from sawmills and lumber export terminals into waters frequented by fish; BC *Environmental Management Act (was Waste Management Act)*: BC *Special Waste Regulation*; BC *Waste Management Permit Fees Regulation*	CWQG- 0.03 mg/L (total)- freshwater aquatic life; BCWQC- same	environmental studies/research; some source inventory information available from M&B Research; NPRI data available

Pharmaceutical products and metabolites						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/ Criteria**	**Status**
	human contraceptives, hormone replacement steroids, endogenous sex hormones, veterinary hormonal drugs					
17β-estradiol, 17α-ethinyl estradiol, mestranol, levonorgestrel, norethindrone, desogestrel, norgestimate, estrone, equilin, 17α-dihydro-equilin, testosterone	sewage treatment plant effluents	natural/synthetic estrogens, androgens, progestogens, and metabolites, potential environmental EDCs, bacterial resistance	suspected of causing hermaphroditic syndrome in fish in Britain; not yet measured in lower Fraser; threshold for most prominent estrogenic effect associated with ethynyl estradiol is low (0.3 ng/L).	FA Section 36(3) is applicable to deleterious substances discharged into waters frequented by fish		some environmental studies/research
17β-estradiol, estradiol benzoate, melengestrol acetate, trenbolone acetate, progesterone , zeranol (non-steroidal), testosterone propionate, estrone, trenbolone	veterinary hormonal drugs used in disease treatment/prevention and growth enhancement in poultry and swine. Possibly present in dairy, poultry, and swine manures.	as above		*Food and Drug Act* and *Regulations*; *Feeds Act and Feed Regulations*		
2-(4)-chloro-phenoxy-2-methyl propionic acid (clofibric acid); phenobarbitol, meprobamate, phensuximide	clofibric acid is used to reduce blood cholesterol levels, others are barbiturates, tranquilizers, and anti-convulsants	as above	clofibric acid has been detected in sewage treatment plant effluents, tap water, and aquatic receiving environments in Europe; other drugs have been detected in landfill leachate and groundwater in the United States			

Appendix 4. Substances of Interest in the Lower Fraser River and Georgia Basin

Pesticides (still registered for use in Canada)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/ Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Atrazine	agricultural herbicide and soil sterilant	possible endocrine disrupter	detected in stormwater runoff, soil, sediment from agricultural and industrial sites in the LF/GB; ambient air measurements in LF/GB:	FA Section 36(3) is applicable to toxic substances discharged into waters frequented by fish; BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act*)	CWQG- 2 µg/L (freshwater aquatic life), 5 µg/L (drinking water); BCWQC- same, 10 µg/L for marine aquatic life	environmental studies/research; source inventory available
Dicofol	insecticide	possible endocrine disrupter	avian reproduction impaired; detected in air from lower Fraser; not used LF/GB; long range transport from Asia-Pacific.	organochlorine pesticide still registered for use in Canada; BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act*)		environmental studies/research
Dinoseb	dinitrophenol herbicide for control of grassy and broadleaf weeds; potato top-killer	very toxic to aquatic organisms: 96hr LC50 to cutthroat trout and Daphnia is respectively 67 and 680 µg/L	detected in air in the Abbotsford area and in lower Fraser ditch water (0.3 to 18.6 µg/L)	used in Fraser Valley for weed control (uses are slowly being removed as alternatives are found); FA Section 36(3) is applicable to toxic substances discharged into waters frequented by fish; BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act*)	CWQG- 1.75 µg/L (freshwater aquatic life), 10 µg/l (drinking water); BCWQC- same except for freshwater aquatic life- 0.05 µg/l	environmental studies/research; source inventory available
Endosulfan I,II,sulphate	organochlorine pesticide used to control insect pests on vegetables in lower Fraser Valley	probable endocrine disrupter	very toxic to fish and aquatic invertebrates (e.g., 96 hr LC50= 1.7 µg/L for rainbow trout); avian reproduction impaired; reduced egg production; detected in ditch water, groundwater, sediments, air and resident fish from the lower Fraser; ambient air measurements in LF/GB:	FA Section 36(3) is applicable to toxic substances discharged into waters frequented by fish; BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act*)	CWQG- 0.02 µg/L (freshwater life); BCWQC- same	environmental studies/research; source inventory available

Pesticides (still registered for use in Canada) (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/ Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Gamma-hexachlorocyclohexane (Lindane) Also other isomers (alpha, beta & delta)	chlorinated pesticide used to control insects on cereal crops and for veterinary pest control; historical use in control of ambrosia beetle in stored logs	probable endocrine disrupter	detected in air, resident fish, and groundwater in the lower Fraser Basin; possibly carried to LF/GB via long range transport from Asia-Pacific; ambient air measurements in LF/GB: Note: Monitoring programs for lindane (gamma-HCH) should also include detection of alpha-beta-delta isomers of HCH which are components of benzene hexachloride	FA Section 36(3) is applicable to toxic substances discharged into waters frequented by fish; BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act*); BC *Environmental Management Act* (was *Waste Management Act*): BC *Special Waste Regulation*	CWQG- 4 µg/L (drinking water); 0.01 µg/L (freshwater life); BCWQC- same	environmental studies/research; source inventory available
Malathion	insecticide - domestic and commercial pest control; mosquito control	possible endocrine disrupter	fish growth reduced; present in air samples from lower Fraser Basin; measured in agricultural soils, runoff, and in birds in the lower Fraser Valley.	BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act*)	CWQG- 190 µg/L (drinking water); BCQWC- drinking water is the same, 0.1 µg/L for freshwater and marine aquatic life	environmental studies/research; source inventory available
Methoxychlor	organochlorine insecticide used against a large number of insects	possible endocrine disrupter	related to DDT but not stored in biota or human tissues; fish growth reduced; avian reproduction impaired; impaired hatching success; detected in resident LF fish; ambient air measurements in LF/GB:	Organochlorine pesticide still registered for use in Canada; BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act*); BC *Environmental Management Act* (was *Waste Management Act*) BC *Special Waste Regulation*	CWQG- 0.04 µg/L (freshwater life) 900 µg/L (drinking water); BCWQC- same	environmental studies/research; source inventory available

Pesticides (still registered for use in Canada) (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/ Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Metolachlor	acetanilide compound used as a selective, pre-plant or pre-emergence herbicide for control of grasses in corn			BC *Integrated Pest Management Act* (was *Pesticide Control Act*) *Regulation*	CWQG- 8 µg/L (freshwater life); 50 µg/L (drinking water), 28 µg/L (irrigation water); BCWQC- same	source inventory available
Parathion	insecticide used to control insects in vegetable crops and fruit trees.	probable endocrine disrupter	avian reproduction impaired; reduced egg production; reduced adult body weight, fish reproduction impaired; vertebral anomalies; mysid growth reduced; present in atmosphere, surface and groundwater from the Lower Fraser River basin.	BC *Integrated Pest Management Act* (was *Pesticide Control Act*) *Regulation* BC *Environmental Management Act* (was *Waste Management Act*): BC *Special Waste Regulation*	CWQG- 50 µg/L (drinking water); BCWQC- same	environmental studies/research; source inventory available
Simazine	pre-emergence herbicide used in field and fruit and vegetable crops		similar properties to atrazine; measured in shallow groundwater in the Lower Fraser Valley	BC *Integrated Pest Management Act* (was *Pesticide Control Act*) *Regulation*	CWQG- 10 µg/L (maximum)- freshwater aquatic life; 10 µg/L- drinking water; BCWQC- same	environmental studies/research; source inventory available
Trifluralin	herbicide - dinitro-analine used to control weeds in vegetable crops and ornamentals	probable endocrine disrupter	fish vertebral abnormalities; measured in air and groundwater from Lower Fraser River.	BC *Integrated Pest Management Act* (was *Pesticide Control Act*) *Regulation*	CWQG - 0.1 µg/L (fresh water aquatic life), 45 µg/L (drinking water); BCWQC- same	source inventory available; environmental monitoring

Pesticides (no longer registered) (cont.)						
Organochlorine (OC) Pesticides						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Aldrin/dieldrin	aldrin is a persistent chlorinated agricultural pesticide formerly used to control insect pests; dieldrin is the persistent metabolite of aldrin	probable endocrine disrupter	Aldrin -released from contaminated soil and sediments; carried into the LF/GB via long range atmospheric transport from North America and Asia-Pacific sources. Dieldrin - avian reproduction impaired; banned from use; detected in air, sediments and resident fish from the lower Fraser; ambient air measurements in LF/GB:	no longer registered for use in Canada; UNECE[1] LRTAP POPS[2]; Fast Tract for Virtual Elimination (PMTS Track I)[3] BC *Environmental Management Act* (was *Waste Management Act*): BC *Special Waste Regulation;* BC *Integrated Pest Management Act* (was *Pesticide Control Act*) *Regulation*	CWQG- 0.7 µg/L (drinking water), 0.004 µg/L (freshwater life); BCWQC- same	environmental studies/research
Chlordane/ oxychlordane	chlordane is a persistent chlorinated agricultural pesticide formerly used to control insect pests in soil and on crops; also used for structural pest control in buildings; oxychlordane is the persistent metabolite of chlordane	probable endocrine disrupter	Chlordane -released from contaminated soil and sediments; carried into the LF/GB via long range atmospheric transport from North America and Asia-Pacific sources; oxychlordane -; detected in resident fish and sediment from the lower Fraser; ambient air measurements in LF/GB:	no longer registered for use in Canada; UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3] BC *Integrated Pest Management Act* (was *Pesticide Control Act*) *Regulation*	CWQG- 7 µg/L (drinking water), 0.006 µg/L (freshwater life); BCWQC- same	environmental studies/research
Chlordecone	chlordecone is a persistent chlorinated agricultural pesticide used to control insect pests	probable endocrine disrupter	unlikely that chlordecone is a potential problem substance in the Lower Fraser River or the Georgia Basin	not registered for use in Canada; UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3]		

Pesticides (no longer registered) (cont.)						
Organochlorine (OC) Pesticides (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
DDT **(DDD + DDE)**	DDT is a persistent chlorinated pesticide formerly used in agriculture and vector-transmitted disease control; DDE and DDD are toxic metabolites of DDT	endocrine disrupter	DDT - released from contaminated soil and sediments; carried into LF/GB via long range atmospheric transport from North America and Asia-Pacific sources. DDE is associated with reproductive failures in raptors; avian reproduction impaired; reduced egg production; feminizing in gulls; DDT levels high in urban runoff in Brunette watershed exceeding federal water quality guideline of 1 ng/L; detected in air sediments, groundwater, resident fish, and birds from Lower Fraser River.	no longer registered for use in Canada; UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3] BC *Integrated Pest Management Act* (was *Pesticide Control Act*) *Regulation*	CWQG- 0.001 µg/L (freshwater life), 30 µg/L (total) (drinking water); BCWQC- same	environmental studies/research
1,4-dichlorobenzene	use in insecticides, germicides, and space deodorants	CEPA PSL 1 (insufficient data to conclude toxicity)	possible sources in the BC lower mainland; was detected in the Metro Vancouver airshed (0.38 µg/m^3).		CWQG- 4.0 µg/L (freshwater aquatic life-under review); 5 µg/L (drinking water); BCWQC- 26 µg/L (freshwater aquatic life), 5 µg/L (drinking water)	
Endrin	persistent chlorinated pesticide formerly used in agriculture to control insect pests	probable endocrine disrupter; most toxic chlorinated organic pesticide	releases from contaminated soil and sediments; carried into LF/GB via long range atmospheric transport from North America and Asia-Pacific sources; detected in resident fish at Mission	no longer registered for use in Canada; UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3] BC *Integrated Pest Management Act (was Pesticide Control Act)) Regulation*	CWQG- 0.2 µg/L (drinking water; 0.002 µg/L (freshwater life); BCWQC- same	environmental studies

Pesticides (no longer registered) (cont.)						
Organochlorine (OC) Pesticides (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Heptachlor/ heptachlor epoxide	heptachlor is a persistent chlorinated agricultural pesticide formerly used to control insect pests in soil and on crops; heptachlor epoxide is the persistent metabolite of heptachlor	probable endocrine disrupter	heptachlor -released from contaminated soil and sediments; carried into LF/GB via long range atmospheric transport from North America and Asia-Pacific sources; heptachlor epoxide - detected in resident fish from the lower Fraser; ambient air measurements in LF/GB:	no longer registered for use in Canada; UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3]BC *Integrated Pest Management Act* (was *Pesticide Control Act) Regulation*; BC *Environmental Management Act* (was *Waste Management Act*): *BC Special Waste Regulation*	CWQG- 3 µg/L (drinking water); 0.01 µg/L (freshwater life); BCWQC- same	environmental studies/research
Mirex	mirex is a very persistent chlorinated pesticide an industrial chemical; serious contamination in Lake Ontario	probable endocrine disrupter	Major sources to Lake Ontario have been eliminated and chemical was banned in Canada; detected in resident fish from the lower Fraser; unlikely potential problem substance in the lower Fraser or Georgia Basin;	industrial uses banned under CEPA; not registered for use as a pesticide; UNECE[1] LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3]	US EPA tolerance for mirex in fin fish is 0.1 mg/kg.	
Toxaphene	toxaphene is a persistent chlorinated insecticide formerly used in agriculture and for veterinary pest control and as a piscicide	probable endocrine disrupter	releases from contaminated soils, sediments, hazardous waste landfills; carried to the LF/GB via long range atmospheric transport primarily from sources in the Asia-Pacific region and in the southern United States; fish growth reduced; vertebral anomalies; shortened egg-laying period; reduced hatchability; detected in resident fish from lower Fraser; ambient air measurements in LF/GB.	no longer registered for use in Canada; UNECE[1]; LRTAP POPS[2]; Fast Track for Virtual Elimination (PMTS Track I)[3]	CWQG- 8.8 µg/L (drinking water); 0.008 µg/L (freshwater life); BCWQC-same	environmental studies/research

Pesticides (no longer registered) (cont.)						
Organochlorine (OC) Pesticides (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Diazinon	agricultural and domestic insecticide		detected in air in the Agassiz and Abbotsford areas of LFV	BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act)*; BC *Environmental Management Act* (was *Waste Management Act)*: *BC Special Waste Regulation*	CWQG- 0.1 µg/L (max.), 0.003 µg/L (average)- freshwater aquatic life, 14 µg/L drinking water; BCWQC- same for aquatic life, 20 µg/L for drinking water	environmental studies/research; source inventory available
Dichlorvos	greenhouse and stored products insecticide; mosquito and fly control		detected in air and rainfall in the Agassiz and Abbotsford areas	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*		environmental studies/research
Dimethoate	systemic organophosphate insecticide used in agriculture and as a residual spray on farm buildings		detected in air in the Agassiz area	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*	CWQG- 6.2 µg/L (freshwater aquatic life), 20 µg/L (drinking water); BCWQC- same	environmental studies/research; source inventory available
Fonofos	granular organophosphate insecticide used as a soil treatment for wireworm control		detected in raptors in the LFV and is associated with bird poisonings; detected in air in the Abbotsford and Agassiz areas	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*		environmental studies/research; source inventory available
Mevinphos	extremely toxic organophosphate insecticide used on vegetable crops		detected in air in the Abbotsford area	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*		environmental studies/research; source inventory available

Pesticides (no longer registered) (cont.)						
Organochlorine (OC) Pesticides (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Phorate	granular organophosphate insecticide and miticide used to control sap-sucking and soil insects		detected in raptors in the Lower Fraser Valley (LFV) and has been associated with bird poisonings	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*	CWQG- 2 µg/L (drinking water); BCWQC- same	environmental studies/research
Terbufos	granular organophosphate insecticide used to control soil insects		detected in raptors in the LFV and has been associated with bird poisonings	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*	CWQG- 1 µg/L (drinking water); BCWQC- same	environmental studies/research

Other Pesticides of Potential Interest						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Azamethiphos	insecticide used in aquaculture for sea lice control; not used in British Columbia			PCPA- registered for use in Atlantic Canada only; FA Section 36(3) is applicable to toxic substances released into waters frequented by fish		environmental studies/research planned
Carbaryl	insecticide – domestic and commercial pest control; used for the control of ants and agricultural pests.	possible endocrine disrupter	avian reproduction impaired; fish reproduction impaired; not yet measured in lower Fraser River sediments and biota	BC *Integrated Pest Management Act Regulation* (was *Pesticide Control Act)*; BC *Environmental Management Act (was Waste Management Act)* BC *Special Waste Regulation*	CWQG- 90 µg/L (drinking water), 0.2 µg/L (freshwater aquatic life), 0.3 µg/L (marine aquatic life); BCWQC- same	environmental studies/research; source inventory available
Captan	agriculture and domestic fungicide	possible mutagen	detected in air and rainfall in the Abbotsford area	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*	CWQG- 2.8 µg/L (freshwater aquatic life), 17.5 µg/L (drinking water); BCWQC- same except for drinking water- 15 µg/L	environmental studies/research; source inventory available
Carbofuran	granular and liquid agricultural insecticide		historically associated with extensive waterfowl acute poisonings in the LFV	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*	CWQG- 1.75 µg/L (freshwater life), 90 µg/L (drinking water); BCWQC- same	environmental studies/research; source inventory available
2,4-D	agricultural and domestic herbicide	probable endocrine disrupter	detected in air and rainfall in the Agassiz and Abbotsford areas.	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*; BC *Environmental Management Act (was Waste Management Act)*: BC *Special Waste Regulation*	CWQG- 4 µg/L (freshwater aquatic life), 100 µg/L (drinking water); BCWQC- same	environmental studies/research; source inventory available
1,2-dichloro-propane; **1,3 dichloropropene**	nematicides historically used in LFV.	probable endocrine disrupter	contamination detected in groundwater in Abbotsford aquifer	no longer used in Fraser Valley		environmental studies/research

Other Pesticides of Potential Interest (cont.)						
Substance	**Source Profile**	**Toxicity Profile**	**Environmental Profile**	**Acts, Regulations, Controls**	**Ecosystem Guidelines/Criteria**	**Status**
	Agriculture, veterinary, domestic, commercial, mosquito, aquaculture pest control	Toxicity to non-target organisms; EDC effects	Transport and detection in air, water, soils, sediments, and biota; documented biological effects	All pesticides are registered under the *Pest Control Products Act* and regulated under the BC *Integrated Pest Management Act* (EMA) (was *Pesticide Control Act*) except as indicated below	Canadian Water Quality Guidelines (CWQG) and BC Water Quality Criteria (BCWQC)	
Mancozeb	fungicide – controlling fungus diseases in vegetable crops, ornamentals, and tree fruits.	probable endocrine disrupter	avian reproduction impaired; delay in egg laying; not yet measured in Lower Fraser River.	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*		source inventory available
Metiram	fungicide – controlling fungus diseases in vegetable crops, cereals, grapes and turf.	probable endocrine disrupter	avian and mysid reproduction impaired; reduced egg production; reduced fertility; embryonic deaths; not yet measured in Lower Fraser River.	BC *Integrated Pest Management Act Regulation(was Pesticide Control Act)*		source inventory available
Synthetic pyrethroids – cypermethrin	insecticides – potential for use in aquaculture for sea lice control; used experimentally on east coast, not in British Columbia; cypermethrin registered for use in agriculture and in structural pest control	possible endocrine disrupters	avian reproduction impaired; egg shell thinning; fish reproduction impaired; not measured in Lower Fraser River; highly toxic to fish and aquatic invertebrates.	PCPA – used under special use permit from Agriculture Canada in Atlantic Canada; not registered for use in Canada; FA Section 36(3) is applicable to toxic substances released into waters frequented by fish; BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*		
Vinclozolin	fungicide – controlling diseases in vegetable crops	probable endocrine disrupter	anti-androgen; impairment of avian reproduction; reduced egg production; reduced fertility; impaired testicular development; not yet measured in lower Fraser; used in LF/GB	BC *Integrated Pest Management Act Regulation (was Pesticide Control Act)*		

Substance	Source Profile	Toxicity Profile	Environmental Profile	Acts, Regulations, Controls	Ecosystem Guidelines/Criteria	Status
Drinking Water Disinfection By-products						
	trihalomethanes (THMs) from chlorine disinfection; haloacetic acids, halo acetonitriles, haloketones, choropicrin, cyanogen chloride, aldehydes, chlorophenols from chloramine disinfection	chloroform is a probable carcinogen in humans	commonly present in drinking water as a result of chlorination and/or bromination of organic matter present in raw water supplies; THMs include chloroform, bromodichloromethane, chlorodibromomethane and bromoform; chloroform is present in greatest concentrations in drinking water		CWQG- total THMs: 0.1 mg/L (drinking water)	
Radiologic constituents						
	natural and artificial radionuclides	low level radiation exposure induction of cancer following a variable latent period of up to several decades	radiologic constituents of drinking water (e.g., cesium-137, iodine-131, radium-226, strontium-90, tritium)			
Biological contaminants						
	E. Coli as an indicator or pollution cryptosporidium/giardia (emerging issues)		fecal coliform bacteria are occasionally detected in groundwater wells in the Lower Fraser Valley (Hii *et al.* 2006)			refer to http://www.waterquality.ec.gc.ca/EN/navigation/publications/Publications/2004Nitrate/toc.html

1 - (UNECE) United Nations Economic Commission for Europe
2 - (POPs) Persistent Organic Pollutants
3 - (Track 1) Persistent Bioaccumulative toxic substances destined for virtual elimination

Appendix 5 Metro Vancouver Comments on Input to the BCTWG Recommendations for Management Actions

While views and recommendations of the BCTWG presented in this report were developed by consensus, the Terms of Reference of the BCTWG provide for the views of dissenting members to be reflected. The BCTWG relied on the expertise and consensus of the members in the development of the following recommendations on both future research and monitoring and management actions. However, concerns over some aspects of the recommendations were expressed by members from both Metro Vancouver (was the Greater Vancouver Regional District) and Capital Regional District (CRD). These concerns are presented in the following comments received by Environment Canada.

Metro Vancouver Comments:

The following letter was sent from Albert van Roodselaar of Metro Vancouver to Gevan Mattu of Environment Canada on September 8th, 2004.

Gevan,

"With respect to the PS/GB Recommendations for Management Actions, the GVRD has reviewed the updated document summary sent out on September 7th and we find that we cannot respond specifically to many of the listed items since they deal with potential Federal initiatives which may parallel other processes already established at the GVRD through its provincially mandated Liquid Waste Management Plan. We feel that it is not appropriate for us to comment on programs that the federal government may consider as many of these matters are also dealt with under provincial jurisdiction, and since the GVRD operates under this jurisdiction. The GVRD has consistently articulated that federal and provincial authorities should operate through a single regulatory window. It is not clear from the PS/GB document as to the process under which this might occur.

Having said this, the GVRD supports concepts such as scientific risk assessment and the development of standards based on sound science. We also utilize the concept of Best Management Practices in many of our activities. Protection of the environment is articulated in our LWMP. We do not question that certain specific chemicals need to be addressed through proper risk assessment.

We have submitted specific responses to the Recommendations for Research and Monitoring document. We appreciate being part of the PS/GB process and look forward to continuing to address all relevant issues."

Thanks.

*Albert van Roodselaa*r

Appendix 6 Summary of Phase 1 Accomplishments

The first initiatives undertaken by the BCTWG in the identification of priority toxic substance-related issues in the Georgia Basin (Phase 1) included the identification, prioritization and profiling of toxic substances of potential concern in the Georgia Basin as described in Sections 2.1.1 and 2.1.2 of this report. These activities were followed by an inventory of sources and loadings of the substances into the Georgia Basin (Section 2.1.3). The results of the inventory information were compiled in two reports, which are available on the GBAP website (ENKON 1999; ENKON 2002). Other reports prepared under Phase 1 included a BC MOE inventory of contaminated sites along the BC coast, a compendium of worldwide environmental quality benchmarks which could be used in assessing pollution in freshwater and marine ecosystems in the Georgia Basin, and a summary of information on the transboundary transport of contaminants from the Strait of Georgia to the Puget Sound. The scope and major findings of these reports are summarized following.

A. Sources and Releases of Toxic Substances in Wastewaters within the Georgia Basin (GBEI Report EC/GB-99-003) (ENKON 1999)

ENKON Environmental Ltd has compiled information on the sources, concentrations, and loadings of 44 substances in point and non-point source effluents discharged to the Georgia Basin. The substances inventoried are those included in Environment Canada's "Substances of Interest in the Lower Fraser and Georgia Basin" (Appendix 4). The inventory involved gathering and compiling monitoring data on toxic substances, evaluating data quality (quality assurance and quality control), and determining the usefulness of the data. The data compilation was limited to sampling and studies undertaken between 1990 and 1998.

Most of the information contained in the report pertains to industrial and municipal effluent point sources, industrial stormwater discharges, urban area surface runoff, and discharges from combined sewer overflows. Very little information on agricultural surface runoff was found. The data was presented on spreadsheets showing source name, industry type, waste type, chemicals, number of samples, concentration ranges in the data, evaluation of the validity of the chemistry, and the availability of flow data. The report identified 18 substances for which sufficient data was available to quantify loadings.

Over 200 sites representing 39 different industry or waste types have been monitored for toxic substances discharging to the Georgia Basin. The numbers of samples collected at a particular industry or in a particular study range from one (for some source inventory and effluent characterization studies) to an estimated 3285 (parameters for which Waste Management Permits require daily monitoring).

In studies for which quality assurance/quality control (QA/QC) information was available, data quality generally was high. Data quality problems identified in several studies included the detection of phthalate esters, dichloromethane, zinc and/or naphthalene in laboratory and/or field blanks. Analytical detection limits for most parameters were adequate to measure concentrations in effluents or to demonstrate that undetectable levels could be no more than ten times the levels recommended to protect aquatic life. Exceptions included PCBs, DDAC, endosulfan, and hexachlorobenzene and, possibly, antimony.

Source characterization for arsenic, chromium, copper, lead, nickel, zinc, cyanide, total residual chlorine, and chlorophenols was found to be adequate for the next phase of the inventory. Characterization may also be adequate for the following substances released from specific sources: nitrogen (except discharges from agriculture), mercury and cadmium (except discharges from small industries to sewer), phenol (with the possible exception of one chemical plant effluent), PAHs (except stormwater from selected industries), PCBs in wastewater treatment plant effluents, and AOX, dioxins/furans, and resin acids in pulp mill effluents. The report recommended that data identified for these chemicals (including provincial permit monitoring data) be assembled and reviewed and the loadings calculated to identify major sources for which controls are required.

Concentrations of certain toxic substances have been poorly characterized. These substances include household or pharmaceutical products that are potential endocrine disrupters, pesticides and organotin compounds. There has been only limited monitoring for the antisapstain chemicals DDAC and IPBC at lumber mills. The characterizations for a number of other substances are incomplete.

The report concluded that, to fill these data gaps, additional source characterization is necessary. It was recommended that the most toxic of chemicals (generally those having water quality guidelines or effects levels of less than 1 mg/L) should be the highest priorities for source identification and (ultimately) for control. Thus the following parameters and sources were recommended for high priority monitoring:

- pharmaceuticals (estradiol and sterols) in WWTP effluent and agricultural runoff;
- DDAC and IPBC in stormwater from lumber mills;
- pesticides and wetting agents (nonyl and octylphenol ethoxylates) in agricultural runoff; and
- TBT in runoff from ship repair facilities.

Monitoring the following chemicals and sources was also recommended, but as a lower priority:

- nitrogen compounds in agricultural runoff;
- bisphenol A in WWTP effluent and landfill leachate;
- chloramines in WWTP effluent and chlorinated cooling waters;
- resin acids in runoff from lumber mills, heavy duty wood preservation plants, and other places where wood chips are stored or used (e.g. landfills, equestrian rings, berms around cranberry fields);
- PAHs in stormwater from heavy duty wood preservation plants, asphalt manufacturing plants and oil refineries;
- ethylene glycol in urban runoff and stormwater from airports other than Vancouver International;
- MTBE in urban runoff; and
- hexachlorobenzene in effluents from chlor-alkali plants.

In addition, the report noted that it will be necessary to develop or improve the analytical methods to allow for some priority substances to be monitored. For example, low detection limit methods for analyzing estradiols and sterols in WWTP effluent are required and a lower detection limit for measuring DDAC appears warranted. Developmental work on the analytical methods for these chemicals should be a priority.

B. Loadings Estimates of Selected Toxic Substances in Wastewaters Discharged to the Georgia Basin (GBEI Report EC-GC-02-039) (ENKON 2002)

This study involved acquiring data from 1990 to 1998 and calculating estimated annual loadings for 18 identified substances. At the same time, information on 20 additional substances was reviewed and compiled for loading calculations, where appropriate.

The primary data source was the BC Ministry of Environment (Lower Mainland and Vancouver Island Regions) files containing effluent monitoring reports submitted by industries in compliance with Waste Management Permits. Other significant data sources included reports prepared by Metro Vancouver (was GVRD) and Capital Regional District (CRD) characterizing loadings of toxic substances in wastewater treatment plant (WWTP) effluents and combined sewer overflows (CSO). Modelled loadings of toxic substances in stormwater from Metro Vancouver and Fraser Valley were taken from a report by Stanley Associates (1992). Stormwater loadings for Vancouver Island municipalities were estimated using Stanley Associates' (1992) method.

Due to lack of data, loadings from two potentially significant sources were not characterized. These sources are agricultural runoff and direct deposition of air pollutants. However, a portion of the loadings of substances deposited from air is captured in the stormwater loadings and certain wastewater treatment plant loadings for plants associated with combined sewer systems.

Loadings were summarized to provide total loadings per year by source category. Data availability and trends were evaluated to identify "typical" estimated annual loadings from major sources. This analysis demonstrated the following:

- of the sources characterized, the most significant wastewater sources of toxic substances are stormwater, municipal WWTPs and the pulp and paper industry;
- stormwater potentially supplies most of the cadmium, lead, zinc and PAHs discharged annually to the Georgia Basin;
- municipal WWTPs apparently discharge most of the ammonia, copper and phenols of the sources examined. (However, the loading of ammonia from stormwater may have been underestimated.);
- the pulp and paper industry discharges almost 1000 t/yr of chlorinated compounds as measured by AOX, but these loadings are substantially lower than they were in the early 1990s;
- total loadings of chlorinated organic compounds, lead and residual chlorine have decreased significantly over the period 1990-1998; and
- there is limited local information on the concentrations of individual PAHs (such as naphthalene), pesticides, and dioxins/furans in stormwater and, therefore, stormwater loadings have not been calculated for these substances.

The loadings alone do not reflect the significance of toxic substances discharged to the Georgia Basin. Persistence in the environment, the potential to bioaccumulate, and toxicity are important factors to be considered when selecting the toxic substances for which to develop management strategies. However, from a basin-wide management perspective, the relatively low total loadings of more persistent toxic substances like PAHs, other organic compounds and some metals are of greater concern than the higher loadings of non-persistent, less toxic substances such as ammonia.

Based on the data compilation and loading calculations, ENKON made the following recommendations:

- when identifying substances for which to develop basin-wide management strategies, the BCTWG should consider their toxicities, potential to bioaccumulate, and environmental persistence of the substances, in addition to the relative magnitudes of their loadings;
- management strategies should focus on the major sources of toxic substances, taking into account management programs that are planned or already in place;
- the focus on sources should not ignore site-specific factors as some smaller sources (in terms of total loadings) could have significant environmental effects due to the local receiving water quality, available dilution, and/or conditions that affect deposition of particle-bound toxic substances;
- before management strategies are finalized, some additional loading characterization is necessary and should include loadings from agricultural runoff and air, and also stormwater loading estimates for PAHs, pesticides, and dioxins/furans;
- any management strategies developed for stormwater should not be limited to the end-of-pipe but should consider the potential for "source control", including control of substances discharged to air; and
- Environment Canada should conduct source characterization studies as a first step in developing management strategies for the other toxic substances identified during the inventory phase of this study (GBEI Report EC/GB-99-003) (ENKON 1999). These substances include pharmaceuticals (estradiols and sterols), the antisapstain chemicals DDAC and IPBC, other pesticides and wetting agents (nonyl and octylphenol ethoxylates), and tributyltin (TBT).

C. Contaminated Sites Inventory

Under contract to BC MOE an inventory of contaminated sites along the BC coastline was developed and known environmental remediation sites were mapped. The terms of the contract were as follows:

- Using the provincial and federal Contaminated Sites Registry, identify all contaminated sites (on land and in water) along the Canadian coast line which may impact the marine environments of the Georgia Basin and the Strait of Juan de Fuca. (Note: while the intent was to capture all contaminated sites, initial efforts were focussed on the geographical area extending from Victoria to Campbell River on the east coast of Vancouver Island, Victoria to Port Renfrew on the south and the south-west coasts of Vancouver Island, from the Canada-United States border to Powell River on the west coast of the Mainland, and on Fraser River from the mouth to Hope.)
- List priority toxic contaminants, their possible sources (municipal, industrial, urban, agricultural), and concentrations found at the contaminated sites. (Note: the initial focus was on sites listed on the provincial and federal Contaminated Sites Registry)
- Estimate potential loading of toxic contaminants/compounds, if possible, from the contaminated sites to the marine environments of Georgia Basin and the Strait of Juan de Fuca.
- Prepare an inventory of sites that were: a.) nominated to be contaminated; b.) actually contaminated; and c.) contaminated but now are clean as a result of remedial efforts.

- Prepare an inventory of remediation techniques used to clean up the contaminated sites. It is intended here to document successful techniques.

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D. Compendium of Environmental Quality Benchmarks (MacDonald *et al.* 1999)

Using water quality, sediment and/or tissue residue criteria, standards and guidelines (collectively termed “environmental quality benchmarks”) for evaluating chemical contamination in aquatic ecosystems is usually the first step taken to assess whether existing pollution control measures are adequate. Because a compendium of freshwater ecosystem benchmarks for the Fraser Basin had been completed in 1994, it was decided to update the compendium and to include benchmarks for marine and estuarine systems from around the world in order to increase the compendium’s usefulness for assessing pollution in both freshwater and marine ecosystems in the Georgia Basin.

While a direct comparison of American and Canadian benchmarks was tabulated by Environment Canada, it was always known that a simple comparison of the numerical values was meaningless because the Canadian and American approaches for setting and applying guidelines (in Canada) and standards (in the United States) are so different. It was recognized, however, that there is a need to determine what the consequences are to ecosystem health outcomes in the long term if the adequacy of control programs is assessed using different objectives or targets based on guidelines in Canada and standards in the United States.

The report entitled “A Compendium of Environmental Quality Benchmarks” was prepared by MacDonald Environmental Sciences Ltd under contract to Environment Canada. The report consists of four volumes based on the collection of guidelines, standards, criteria and objectives from around the world. The report (GBEI/EC-99-01) is available in Adobe Acrobat PDF format on CD from Environment Canada.

E. Transboundary Transport of Contaminants

The transport of contaminants via oceanic currents is an important route of contaminant redistribution. The potential for the transboundary transport of toxics from the Strait of Georgia to Puget Sound has long been recognized, but has not been evaluated. Information on such transport was of interest to the BCTWG. A contract was issued jointly by Environment Canada and Fisheries and Oceans Canada for the preparation of a report on transboundary transport of contaminants. The objectives of the contract were as follows:

- to present evidence for transport of material from Canadian to American waters of the Strait of Georgia/Puget Sound - Juan de Fuca inland sea system together with an expert opinion on whether it occurs and how important it might be;
- to identify present databases and models that could be applied to this problem; and
- to make recommendations on future research approaches to answer definitively whether such transport occurs and to assess it quantitatively.

The contract report concluded that there is insufficient “knowledge of contaminant processes and transport mechanisms in the Strait of Georgia and Strait of Juan de Fuca to assess the significance of transboundary transport in the vicinity of Point Roberts or the movement of contaminants into or out of the San Juan Islands or Puget Sound”. The report made recommendations regarding further actions and research tasks which were considered necessary for the better understanding of the transport of toxic substances between the shared waters. Various study approaches and suggested sampling programs were presented. One suggested method was the identification and use of a suitable tracer, either natural or anthropogenic in origin, which could be used cost-effectively to provide more information. Future collaborative work between researchers in Canada and the United States is recommended to pursue this issue. The report has not been published and is not available on the GBAP website; however, it is available on request.

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Appendix 7 Summary of Phase 2 Accomplishments

A. Georgia Basin Research and Monitoring Workshop

In November of 2002, the BCTWG organized a workshop to discuss recent research and monitoring of toxics in the Georgia Basin and to expand upon the data gaps and research/monitoring needs identified in the chemical profiles (summarized in Appendix 8). The goal of the workshop was to identify priority toxics research/monitoring needs in the Georgia Basin. Proceedings of the Georgia Basin Research and Monitoring Workshop have been finalized and have been published in a separate supporting technical report (GBEI Report EC/GB/04/80) (Gray and Garrett 2004) which is available on CD from Environment Canada.

The general conclusions from the research studies presented at the workshop were as follows:

- A wide variety of synthetic organic compounds and heavy metals can be detected in the air, water, sediment, and biota in all of the ecosystems in the Georgia Basin; from the sediments on the bottom of the Strait to the snow on the top of the mountain peaks.
- The concentrations across most of the basin are low, relative to more developed areas in North America or Europe, except in harbours receiving urban runoff and/or pollutants migrating from contaminated industrial sites.
- Over-wintering birds such as surf scoters (which eat filter feeders like mussels) and resident, non-migratory mammals such as otters can be exposed to high levels of contaminants in harbours. While the impact of this contamination on total population numbers of scoters was not determined, the over-wintering population is declining. Otter populations appear to be stable but contaminated sub-populations may be relying on in-migration from clean areas to replace themselves.
- Killer whales are especially vulnerable to POPs because of their long life and the fact that they occupy the position at the top of the food chain in the ocean, which is the final resting place for most of these contaminants. In order to determine the contribution of local basin sources to the POPs accumulating in killer whales, it is necessary to obtain more information on the deposition of POPs from the atmosphere and on the concentrations in salmon returning from the North Pacific.
- Biochemical and developmental effects were observed in invertebrates, fish and amphibians in streams receiving agricultural and, especially, urban runoff. These effects would be expected to occur in all similarly developed watersheds in the basin. While the effects on fish and amphibian populations cannot be quantitatively determined from these studies, many of the salmon stocks relying on these streams are not thriving. To what extent contaminant stress has contributed to the declines is not known, but could be significant.
- Impairment of normal development in biota by relatively non-toxic and non-persistent chemicals, like nonylphenol, may be possible if their use increases in the basin due to human population increases or new industrial developments. While developmental effects were shown to be possible in amphibians at concentrations less than an order of magnitude higher than recently observed levels, studies on the toxicity of this class of contaminant to other kinds of biota have not been extensive to date.

Based on the results of the research presented at the workshop, several priority needs relating to future research and monitoring in the Georgia Basin were identified by the workshop participants and are summarized following.

Research Questions and Needs

- What is the ratio of regional (e.g., municipal WWTP effluent, agricultural runoff) to global (e.g., atmospheric long range transport, bio-transport) sources of persistent pollutants (organics and metals) in media (i.e., air, water, sediments) and biota in the Georgia Basin?

- Which biological communities demonstrate impaired performance caused by chronic or episodic exposure to low levels of contaminant mixtures?

- What are the ecological consequences of impairment of performance, reproduction, and other physiological markers of contaminant stress observed in selected species of invertebrates, fish, birds and mammals? We need to have better links between the new endpoints being identified and ecological implications.

- Are there locations in the Georgia Basin where releases of non-persistent and non-bioaccumulative toxicants are causing additional contaminant stress over that caused by persistent and bioaccumulative contaminants? What are the chemicals responsible for this stress?

- How can the cumulative contaminant stress be evaluated in aquatic environments with multiple stressors such as exposure to "traditional" pollutants (e.g., ammonia, nitrate, and nitrite), stressful physical-chemical conditions (e.g., low/high pH, low dissolved oxygen, high turbidity), and toxicants (e.g., pesticides, combustion products, surfactants, and "legacy" POPs) episodically, simultaneously, and/or in sequence?

- What is the contribution of toxic stress to the total cumulative stress experienced by organisms living in degraded habitats and competing with invasive species?

- Are the releases of endocrine disrupting substances in the Georgia Basin sufficient to cause measurable effects on survival, performance, and reproduction of selected species in the basin? What is the importance of natural human and animal hormone exposure relative to persistent organic pollutant exposure?

- Long-term research is needed in selected ecosystems (e.g., urban/rural streams, harbours, forested areas) to capture temporal trends in contamination and its effects due to land use changes. For example, some areas within the Georgia Basin, which have been identified for urbanization within the next several years, provide an opportunity for the study of the effects of urbanization on the levels, transport, fate, and impacts of chemical contaminants on certain biological communities and/or populations.

- A synthesis of information on loading of both "legacy" and "new" contaminants (especially current use pesticides) in runoff from representative urban and agricultural areas is needed to allow extrapolation of the land use/export relationship, developed at these locations, to the entire basin.

Monitoring Needs

- An increased capability and capacity for analysis of new and/or emerging chemicals (e.g., pharmaceuticals, hormones, personal care products, new "POPs", and high volume chemicals such as LAS and other surfactants.

- A prioritized list of pharmaceuticals and other emerging chemicals, which are relevant to the Georgia Basin, for future monitoring.

- Long-term monitoring of biological communities to allow the assessment of contaminant stress within a context of high natural variability in health status caused by climatic, habitat-related, and competitive (e.g., invasive species) stresses.

- Baseline aquatic (including groundwater) and terrestrial ecosystem monitoring at an increased number of reference sites to allow improved assessment of monitoring undertaken at hotspots (e.g., harbours, contaminated sites, aquaculture areas).

- Long-term monitoring to track contaminant levels over time (we need to be able to measure improvements in the environment as a result of management actions to initiate control releases to the environment and to identify emerging complications such as the effect of land use changes, the discharges of new chemicals, and the impacts of climate change on contaminant transport and fate).

- A monitoring program measuring the dry and wet deposition of atmospherically transported contaminants at sufficient locations to determine annual loadings directly to the Strait of Georgia and to large lakes/reservoirs, to land surfaces at low, medium and high elevations, and to assess gradients along the axes of the Georgia Basin.

Management Needs to Support Research and Monitoring

- Better communication: develop better ways to communicate issues to environmental and community groups and to work with these groups to find ways to most effectively implement voluntary instruments such as BMPs and codes of practice to reduce levels and sources of contaminant releases.

- An accessible data repository for data and information on toxic substances in the Georgia Basin.

B. Identification of Management Options for the Control of Toxic Substances to the Georgia Basin

On behalf of the BCTWG, Environment Canada contracted ENKON Environmental Ltd. to identify cost effective management options for 24 toxic substances. The management options were to focus on reducing the total loadings of these substances to receiving waters in the Georgia Basin, rather than addressing site-specific toxicity issues.

After an initial review of chemical profiles completed for priority substances or groups of substances in the Georgia Basin (Garrett 2004) and consideration of the information obtained on sources and loadings of toxic substances to the Georgia Basin under Phase 1, it was determined that the evaluation of management options would focus on metals (specifically cadmium, chromium, copper, manganese, nickel, mercury, silver and zinc), PAHs, and nitrogen-based nutrients. Furthermore, it was decided that the review would emphasize controls for sources rather than management measures for specific substances. The final objectives of the study were:

- to gather information and identify non-regulatory management options, in addition to the regulatory requirements of the various agencies in the GBEI, which could reduce loadings of priority toxic substances as identified by the BCTWG; and
- to identify policy, legislative, or regulatory changes that may be required to implement the management options.

The objective of identifying regulatory changes was not intended to deny or detract from the current regulatory requirements of the various agencies involved in managing toxic substances in the Georgia Basin. Rather, the focus of the study was to identify the potential reductions in loadings of toxic substances that agencies from various levels of government could accomplish by working together. The study objective thus was to identify additional regulations, if any, which might be necessary to achieve the desired reductions.

Based on a review of the major effluent sources of priority substances and/or substance groups in the Georgia Basin and input from BCTWG members, the study focused on the following sources of toxic substances:

- small and medium-sized industries that discharge to sanitary sewers (i.e., source controls for wastewater treatment plants);
- urban stormwater; and
- agricultural runoff.

The management options reviewed followed the Canadian Council of Ministers of the Environment (CCME) Toxic Substances Management Policy, which stresses a preventive approach to reducing or virtually eliminating releases of toxic substances at the source. The costs of the options were considered with the objective of identifying the most cost-effective solutions. Regulations applicable to, or necessary for, the various options also were considered.

The identification of management options consisted of two parts:

1.) interviews with federal, provincial, and municipal government stakeholders within the Georgia Basin; and
2.) an Internet search to identify management and regulatory strategies used in other jurisdictions followed by telephone and/or e-mail contacts, where possible, to clarify the success and costs of the management options.

Based on an analysis of successful programs, the study concluded that measures to reduce loadings of toxic substances in the Georgia Basin could include a combination of two major approaches:

1.) pollution prevention (P2) planning and implementation targeted toward:
    - discharges of metals and PAHs to sanitary sewers;
    - discharges/spills of metals and PAHs to stormwater systems;
    - discharges of nitrogen-based nutrients in agricultural runoff; and
2.) watershed management/integrated stormwater management that include a strong component of identifying and addressing areas where stormwater quality contains elevated levels of metals and PAHs.

These types of initiatives already are underway throughout the Georgia Basin and future management actions should build on the strengths of current programs. Existing and future programs may be improved by adding some innovative approaches to voluntary pollution prevention programs and watershed planning, which are being applied in other areas.

The study identified industries and watersheds that should be the initial focus of new or expanded management actions. Small to medium-sized industries that are sources of metals and/or PAHs in sanitary sewers should be targeted for P2 programs. These include automotive repair, electroplating, printing, photographic imaging, paint and varnish industries, and hospitals, medical laboratories, and dental offices. Since automobile-related activities, including wear and tear, are the primary sources of metals and PAHs in stormwater, P2 programs for stormwater should target automotive-related industries and operators of parking lots (including commercial lots and large parking for customers or employees). In addition, management action should ensure that local governments responsible for street cleaning are practicing pollution prevention by following Best Management Practices.

Specific watersheds were identified as priorities for integrated stormwater management planning based primarily on recommendations from a strategic review of Fraser Valley streams conducted under the Fraser River Action Plan. Urban watersheds considered high priorities have impervious areas >20%, identified water quality problems, and no identified integrated stormwater management planning process. Some watersheds identified to be of high priority include Cougar Canyon Creek (Delta), MacKay Creek (North Vancouver), Matsqui Slough and its tributaries, and Luckakuck Creek (Chilliwack). In addition, opportunities for involvement with watershed planning initiatives were noted for Mosquito Creek (North Vancouver) and the Coquitlam River and with follow-up for the Como Creek (Coquitlam) watershed management plan.

Target watersheds for Vancouver Island were identified by a representative of the Capital Regional District's (CRD) stormwater program and include Rock Bay on the Gorge waterway and Bowker Creek. A watershed management plan has been developed for Bowker Creek, but there is potential for Environment Canada and the BCTWG to help with implementing the water quality component of the plan.

Watersheds identified as priorities for action to address agricultural issues include the Sumas River and its tributaries and Hope Slough and its tributaries. There also may be opportunities for follow-up with watershed management plans developed for the Salmon River and Serpentine River (Bear/Mahood Creek).

An initiative to address agricultural runoff is underway at this time. The federal department of Agriculture and Agri-Foods Canada and BC Ministry of Agriculture and Lands were developing a bilateral agreement for the province of British Columbia. The cornerstone of the environmental component of the program is the voluntary Environmental Farm Plan Program. The implementation of the program, which extends from 2003 to 2008, should be a major factor in addressing agricultural issues in the Basin over this period.

The review concluded that pollution prevention planning and implementation may be most successful if the program includes management and assistance/mentoring by an independent third party or peer group. Financial incentives such as cost-sharing are important to gaining industry's cooperation, but the financial benefits of pollution prevention also can be an incentive. Analysis of the attitudes or behaviours of the groups targeted for participation in pollution prevention programs can help to identify incentives that will increase buy-in to voluntary programs. Despite incentives, regulatory requirements for pollution prevention may be necessary in some cases, such as regulatory Codes of Practice for particular industrial sectors that discharge to sanitary sewers.

Watershed management/integrated stormwater management programs can be designed to address toxic loadings in stormwater or agricultural runoff by:

- including, as a goal of the overall watershed management program, improvements in water quality, sediment quality, and the related health of aquatic ecosystems, as are appropriate to the characteristics of the particular watershed;
- conducting an initial monitoring program to identify "hot spots" where stormwater/runoff quality is impacting the aquatic or marine ecosystem;
- assessing the source and severity of the problem and other relevant site-specific conditions or issues;
- proceeding with the development of site-specific corrective measures only when the analysis of monitoring results and other factors indicates that intervention is necessary and that management measures are likely to be effective;
- setting objectives for site-specific management programs that include measurable goals for appropriate environmental indicators and a timeframe for attaining them;
- identifying and assessing the attitude of target stakeholders who can affect stormwater quality through their daily actions and/or by supporting government-industry partnership programs and assessing their attitudes and behaviours;
- selecting appropriate, cost effective management measures, which could include structural source controls, pollution prevention programs or a combination of measures as well as educational programs;
- implementing the management measures; and
- monitoring the effectiveness of implemented measures.

Legislation to enable or require watershed level planning is probably unnecessary in British Columbia. Metro Vancouver has incorporated Integrated Stormwater Management Planning into its Liquid Waste Management Plan, and watershed level initiatives are being developed in the CRD. However, watershed planning should consider the need for local regulations such as:

- changes to Official Community Plans to require low impact developments in certain watersheds; or
- stormwater bylaws that prohibit the discharge or dumping of certain substances to stormwater conveyance systems.

Monitoring the results of management actions in the Georgia Basin is critical. All of the management strategies identified in the current review have been implemented in one or more areas of the Basin. Now it is necessary to determine whether the management measures are effective or whether additional measures need to be developed. The monitoring should focus on changes in loadings of toxic substances. In the early stages of implementing pollution prevention and outreach/education programs, there is value to measuring administrative and intermediate outcomes (i.e., those related to program participation). However, monitoring the success of all types of management measures must include measurement of end outcomes (changes in concentrations and loadings of toxic substances). Ultimately, monitoring programs also should link management actions to environmental benefits. That is, monitoring programs should address changes in appropriate indicators of environmental health.

Appendix 8: Summaries of the Profiles for Priority Substances (from Garrett 2004)

This Appendix contains information on the substances or groups of substances identified by the BCTWG to be of the highest priority within the Georgia Basin. The process for selecting these substances is discussed in Section 2 of this report. The following summaries contain information relevant to the presence of these substances in the Georgia Basin including information on uses and potential sources (and estimated loadings where available), potential environmental concerns, environmental levels, and existing regulations, codes and guidelines controlling the release of these substances.

Management actions which have already been implemented to address concerns associated with these substances in the Georgia Basin have also been summarized. Actions implemented to reduce releases of toxic substances to the Georgia Basin address a wide variety of sources including industrial discharges, municipal wastewater treatment plants (WWTPs), and non-point sources such as agricultural and urban stormwater runoff, combined sewer overflows (CSOs), contaminated sites, and atmospheric deposition. These actions are discussed in Appendix 1. Management actions already implemented to address issues specific to individual substances are discussed in the summaries for those substances.

In addition, needs relating to future research and monitoring and management actions are presented. Needs specific to the individual substances or substance groups are discussed in the individual summaries. However, many of the needs identified for both future research and monitoring and future management actions apply to many, if not all, of the toxic substances of concern in the Georgia Basin. It is these needs, which are general in nature and apply to a wide range of priority substances in the Georgia Basin, which the BCTWG considers to be of the highest priority for action. These high priority needs and recommendations are discussed in Section 3 of this report.

The following summaries are based on more extensive substance profiles which were prepared for each of the substances or substance groups identified as priorities by the BCTWG. For the complete profiles, refer to GBEI Report EC/GB/04/79 (Garrett 2004), which is available on CD from Environment Canada. Where updated information was available, this information and relevant references have been noted within each section.

1 Legacy or Conventional Persistent Organic Pollutants (POPs)

1.1 Background Information

Persistent organic pollutants (POPs) are anthropogenically produced substances that are widespread and persistent in the environment. They are capable of bioaccumulating and causing adverse effects in a variety of living organisms, including humans. For this reason, they are referred to as P-B-T (persistent, bioaccumulative, and toxic) substances. Many of these substances were intentionally developed for use as pesticides, piscicides, and as industrial chemicals for use in plastics, paints, paper, sealants, additives to oil, and electrical equipment coolants. However, some POPs, such as dioxins, furans and PCBs, have not been produced intentionally, but enter the environment as by-products of industrial and natural combustion and associated processes.

The term POPs has been used to encompass a large number of substances and substance groups. *Legacy or conventional* POPs refer to those substances whose environmental concerns have long been acknowledged, such as those targeted for global action by the United Nations under the Stockholm Convention and for phase-out in eastern and western Europe, Canada, and the United States by the United Nations Economic Commission for Europe. The use of many of these substances has been virtually eliminated in many areas of the world, including Canada. However, they are still detected in elevated concentrations in some areas as a result of their past widespread use, their environmental persistence, and to their long-range atmospheric transport from countries where these substances continue to be used. In addition, volatilization from past areas of heavy use can contribute to the redistribution of the chemicals in the environment.

Several other substances, whose chemical and physical properties are very similar to those of the legacy POPs, are still in widespread use throughout the world. Controls on their use and release to the environment have not yet been widely developed as the potential threats posed by many of these new or emerging POPs have only recently been recognized and, for many of these substances, are not well understood. These substances are discussed in the following section on new or emerging POPs.

Several legacy or conventional POPs have been identified to be of concern in the Georgia Basin. These include PCBs, PCDDs/PCDFs, PAHs, HCB, and the organochlorine pesticides, DDT, toxaphene, and hexachlorocyclohexane (HCH). Recent and current usage of these substances in Canada is summarized following.

- ***PCBs*** have been used as dielectric fluids in electric equipment; fluids in heat exchangers, additives in investment casting waxes, and in other products such as paints, plastics, carbonless copy paper and pesticides. PCBs were never manufactured in Canada, but were imported almost exclusively from the United States. The manufacture of PCBs in the United States was discontinued in 1977 and formally banned in 1979. Regulations under the federal *Canadian Environmental Protection Act, 1999* (CEPA 1999), prohibit the use of PCBs as a constituent of any new product, machinery, or equipment manufactured or imported into Canada. The continued use of PCBs is permitted in older closed electrical equipment, such as transformers, until the end of their service life. Environment Canada prepares annual summaries of the national inventory of PCBs in use or in storage**.** In addition, there are specific requirements under the regulations regarding the storage and destruction of PCBs. The continued use and storage of PCBs in Canada has been identified as a potentially significant source of release to the environment and Environment Canada has revised the PCB regulations to address these potential sources (http://www.ec.gc.ca/CEPARegistry/regulations/detailReg.cfm?intReg=105).
- ***Dioxins and Furans*** are not manufactured intentionally, but are formed as by-products of chemical manufacture and incomplete combustion. In the 1980s, the chlorinated bleaching process used at pulp and paper mills was identified as a major source of dioxins and furans to the environment. Changes to process technology, and the introduction of stringent federal regulations under CEPA 1999, have significantly reduced the release of these substances in pulp and paper mill effluents. In the 1980s, the estimated annual input of PCDDs to the Canadian environment was 1.5 t; however, since 1994 the annual output has been significantly reduced (90-95%) (CCME 1992). Pulp and paper mill effluents are no longer considered to be a significant source of dioxins and furans to the aquatic environment in BC. Currently, the major source of these substances from coastal pulp and paper facilities is from the combustion of salt-laden bark and wood wastes to produce steam. Dioxins and furans (mainly hexa-, hepta-, and octa- dioxins and furans) are also present as impurities in chlorophenols and chlorophenates, which were used extensively in Canada for antisapstain wood protection and heavy duty wood preservation. The use of chlorophenols for antisapstain control was banned in Canada in 1990. Pentachlorophenol is still used for heavy duty wood preservation in Canada; however, its use in BC has declined significantly in recent years. The application of specific pesticides in agricultural and urban environs, domestic and industrial wastewater and stormwater discharges, landfill leachate, diesel emissions, coal combustion, municipal solid waste and other incineration stack emissions, chimney soot from home heating, black liquor recovery furnace flue gas, and scrap and car incineration have also been identified as sources of dioxins. Dioxins and furans released to land and air reach the aquatic environment through surface runoff and groundwater contamination, atmospheric transport, and precipitation.
- ***PAHs*** are not intentionally produced, but are released to the atmosphere and aquatic environment from both natural and anthropogenic sources. Significant releases occur from the use and spillage of petroleum products, coal, and creosote, which contain high levels of PAHs. In particular, the release

of PAHs from creosote-treated wood products is thought to be significant. Municipal WWTP discharges, stormwater, urban runoff, and certain industrial discharges also release PAHs to the aquatic environment; however, atmospheric deposition is considered to be the major source of PAHs to most aquatic systems. PAHs enter the atmosphere as a result of forest and grass fires, volcanic eruptions, residential heating (especially the use of wood as fuel), transportation, aluminum smelters, steel and coking plants, municipal incinerators, agricultural and forest slash burning, wood waste combustion, and other open-air burning (NRC 1983). A 1990 Environment Canada survey identified forest fires and aluminum smelters as the major sources of PAHs to the atmosphere, accounting for 47% and 21% of the total, respectively (Environment Canada/Health Canada 1994a; LGL 1993).

- ***HCB*** is not manufactured in Canada; however, it has been imported for use in dye manufacturing, porosity control in electrode manufacture, wood preservatives, and pyrotechnic applications. Commercial formulations of HCB once contained toxic impurities, including dioxins and furans. Its use as a fungicide to control wheat bunt and smut on seed grains was terminated in Canada in the 1970s and it is no longer registered under the *Pest Control Products Act* (PCPA) for use as a pesticide. HCB is no longer used as a commercial product in Canada. Intentional production, use, import, and export of HCB are prohibited under CEPA 1999; however, HCB is sometimes inadvertently produced as a waste product. HCB has been detected as a contaminant in commercial PCP-based wood preservatives, chlorinated solvents, and ferric/ferrous chloride. In the past, HCB was formed as a process residue by the chlor-alkali industry, but process changes introduced by this industry now prevent HCB formation. Other potential sources of HCB to the environment include municipal waste and sewage sludge incineration, chemical production, cement kilns, and coal combustion. It was estimated that HCB releases to the Canadian environment were more than 1000 kg/yr in the early 1990s. Environmental HCB contamination in some areas of the world has been attributed to losses from the manufacturing and use of chlorinated solvents, the use of HCB-contaminated pesticides, the incineration of HCB-containing wastes, and long-range atmospheric transport and deposition (CCME 1992; CCME 1999; Schmitt *et al.* 1999).
- ***DDT*** was never manufactured in Canada, but was used to control insect pests on crops and also for domestic and industrial application. Most pesticidal uses were phased out in the early to mid-1970s; however, the registration of DDT was maintained in Canada for restricted purposes (mainly for killing bats and rodents) until 1985. The sale and use of existing pesticide stocks was permitted until the end of 1990. DDT is no longer registered for pesticidal use in Canada and its use and import into Canada is prohibited. While the pesticidal use of DDT is prohibited under the *PCPA*, it has been proposed that DDT be included in the CEPA *Prohibition of Certain Toxic Substances Regulations*, to ensure that the manufacture, use, sale, offer for sale, and import of DDT for any non-pesticidal purposes is also prohibited. The long-range atmospheric transport of DDT from tropical countries where DDT is still used for malaria control is a continuing source of DDT to some countries, including Canada, where the use of this substance has been banned.
- ***Toxaphene***, an organochlorine pesticide, is a mixture of polychlorinated bornanes and camphenes. It was used widely to replace DDT as an agricultural insecticide and was the most heavily used insecticide worldwide prior to its ban in several countries. Most uses of toxaphene were de-registered in Canada in 1982 and its use was banned in 1985 under the PCPA.
- ***Hexachlorocyclohexane (HCH)*** is an organochlorine pesticide made up of a mixture of five isomers. HCH has been used in Canada, since the 1950s, for insect control in domestic, agricultural and silvicultural applications. Lindane, which is the purified gamma (γ) isomer of HCH, is currently registered under the PCPA for restricted uses including moth sprays, seed treatment, and the control of domestic insects. Lindane enters the aquatic environment through surface runoff, leaching from treated lumber, wash-off from treated livestock, and long-range atmospheric transport and deposition.

POPs can be introduced into the environment directly, as in pesticide application, or indirectly through processes such as re-volatilization and re-deposition which recycle and redistribute POPs already present in the environment as a result of historical releases. Local and long-range atmospheric and oceanographic processes distribute these substances. Elevated concentrations of some POPs, such as PCBs, dioxins/furans, HCB, DDT, toxaphene and HCH, have been detected in the snow in northern and high altitude regions and in the sediments and biota of remote lakes. These substances are typically very resistant to degradation in the environment and can persist for a very long time.

Most POPs readily accumulate in aquatic organisms as they are highly soluble in lipids and can accumulate in fatty tissues. Bioaccumulation of these compounds occurs at all trophic levels and biomagnification through the food chain has been observed. Bioconcentration factors reported for aquatic organisms are up to 10^6 for PCBs and DDT, 10^2 to 10^4 for HCB and toxaphene, and up to 10^4 for dioxins and furans with a 2,3,7,8-chlorine substitution pattern on the molecule. Dioxins with a 2,3,7,8-chlorine substitution pattern tend to be more readily metabolized by fish, birds, and mammals. However, elevated concentrations of some non-2,3,7,8-chlorine substituted compounds have been detected in crustaceans (CCME 1992; Environment Canada/Health Canada 1990). In general, LMW PAHs concentrate more readily in aquatic organisms than do the less soluble HMW PAH compounds. Bioconcentration factors (BCFs) of 21,428 and 394 were observed in mussels exposed to benzo[a]pyrene and fluorene, while calculated BCFs ranging from 1,280 for phenanthrene to 10,000 for perylene were reported for clams exposed to PAHs in water. Fish can accumulate PAHs from food, water, and bottom sediments; however, since they have a greater ability to metabolize these compounds, the half-lives of PAHs in fish are relatively short compared to those in aquatic invertebrates (Lawrence and Weber 1984; Majewski and Scherer 1985; McLeese 1982; Veith *et al.* 1979).

Exposure of aquatic organisms to POPs can result in acute lethality and also a wide variety of sublethal effects. Concentrations comparable to those detected in the natural environment have been associated with effects on metabolism, neurological functioning, growth, development, and behaviour. In addition, exposure to these substances has been linked to organ damage, suppressed immune function, increased incidence of cancer, birth defects, endocrine disruption, long-term reproductive impairment, and intergenerational effects (Borrell *et al.* 1999; Goksoyer and Husoy 1998; Lorenzen *et al.* 1999; Ross *et al.* 1997; Simms *et al.* 2000; Van Loveren *et al.* 2000).

Several POPs, including PCB, DDT, and its metabolites, toxaphene and lindane, have been shown to be acutely toxic to aquatic organisms in the 1 μg/L to the low μg/L concentration range. Debruyn *et al.* (2004) reported that the TEQs (toxic equivalents) calculated from PCB, PCDD, and PCDF concentrations in roe from post-migration or pre-spawning sockeye salmon stocks migrating to spawn in Great Central Lake in BC ranged from 1.5 to 7 pg/g (lw). These concentrations indicate that certain stocks approach or exceed the concentration of 3 pg/g (lw), which has been associated with 30% egg mortality in *Oncorhynchus mykiss*.

Although the acute toxicity of DDT and its metabolites to birds and mammals is generally less than their toxicity to fish and invertebrates, a number of serious effects have been observed in both birds and mammals following long-term exposure. These include impaired growth, reproduction, and immunocompetence; mutagenicity; carcinogenicity; neurotoxicity; and estrogenicity (Anderson and Hickey 1972; CCME 1992; CCME 1999; Colburn and Smolen 1996; Henshel *et al.* 1997; Kolaja 1977; Lincer 1975; Thompson and Hamer 2000). Some studies suggest that both PCBs and DDE may contribute to impaired reproduction and premature death in sea lions (Reijnders 1986). In addition, since several POPs have been shown to cause adverse effects in salmon, it has been suggested that these substances, alone or in combination, could be adversely affecting Pacific salmon populations. Reductions in Pacific salmon populations have been documented. Since Chinook salmon are the main prey of resident killer whales, declining salmon populations would also pose a substantial threat to the south resident killer whale population, which has been identified as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

The toxicity of dioxins and furans varies substantially. The most highly toxic forms are those which are chlorinated at the 2,3,7, and 8 positions on the molecule, with TCDD, or 2,3,7,8-tetrachlorodibenzo-p-dioxin, being the most toxic compound. For this reason, the toxicity of dioxins, furans, and other dioxin-like substances is usually expressed in terms of 2,3,7,8-TCDD toxic equivalents (TEQs). The behaviour, growth, and survival of rainbow trout were impaired following exposure to 39 pg/L TEQ (CCME 1999; Environment Canada/Health Canada 1990).

Adverse effects have been observed in BC birds exposed to dioxins and furans in the environment. Eagle chicks taken from nests near BC coastal pulp mills had significantly higher liver enzyme activity than did chicks from nests at reference sites. Similarly, elevated liver enzyme activity and/or brain asymmetry was observed in cormorants from all BC colonies sampled between 1973 and 1989. Birds from some colonies sampled during the 1990s also exhibited these abnormalities (Elliott *et al.* 1996a,b; Harris *et al.* 2003b; Henshel *et al.* 1997; Sanderson *et al.* 1994). Mammals tend to be less sensitive to acute exposure to dioxin than are birds and fish; however, mortality, reduced growth, reproductive impairment, fetal abnormalities, immune system suppression, and cancer have been observed in mammals exposed to TCDD (CCME 1999; Environment Canada/Health Canada 1990).

Exposure of aquatic organisms to PAH concentrations in the microgram per litre (μg/L) range can cause adverse effects on growth, immunocompetence, reproduction, and survival. The toxicity of PAHs is determined largely by their molecular weight. While the HMW PAH compounds are more acutely toxic to aquatic organisms than are the LMW compounds, their low water solubilities make it less likely that they will reach acutely toxic levels in aquatic systems. For this reason, LMW compounds are more likely to be acutely toxic to aquatic organisms in laboratory toxicity tests. However, several of the HMW compounds have been shown to be carcinogenic and mutagenic. High concentrations of PAHs in bottom sediments can also result in adverse effects in aquatic organisms. High incidences of liver lesions have been observed in fish from several areas where bottom sediments are contaminated with high concentrations of PAHs (Hawkins *et al.* 1989; Hawkins *et al.* 1990; Krahn *et al.* 1986; Landahl *et al.* 1990; Malins *et al*. 1984; Malins *et al.* 1985; Millemann *et al.* 1984; Myers *et al.* 1991; Stehr *et al*. 2003). In addition, the toxicity of PAH compounds in the environment can be increased as a result of natural processes. For example, the degradation of HMW compounds by photooxidation is significant and can result in the formation of compounds of greater toxicity than the parent compounds. As a result, the toxicity of some PAHs to aquatic species can be increased several fold in the presence of light (phototoxicity) (Moore and Ramamoorthy 1984; Nagata and Kondo 1977; Neff 1979).

Environment Canada and Health Canada have determined that several conventional or legacy POPs are toxic as defined by the CEPA 1999. CEPA-toxic substances are those which have been determined by Environment Canada and Health Canada to present a potential risk to human and/or environmental health in Canada. Conventional POPs on CEPA Schedule 1 List of Toxic Substances include PCBs, HCB, dioxins and furans, PAHs, and DDT. The Schedule 1 List of Toxic Substances and the assessment reports on these substances can be viewed at http://www.ec.gc.ca/CEPARegistry/subs_list/Toxicupdate.cfm.

The Canadian Council of Ministers of the Environment (CCME) has developed Canadian environmental quality guidelines for some legacy POPs. Guidelines for both freshwater and marine sediments have been developed for PCBs (as total PCBs and Aroclor 1254); dioxins/furans; PAHs, DDT, DDD and DDE; HCB; lindane; and toxaphene. Surface water guidelines for the protection of freshwater aquatic life have been developed for lindane (γ-HCB) and PAHs, while guidelines for dioxins and furans in water are currently under development. Tissue residue guidelines for the protection of wildlife consumers of aquatic biota have been developed for DDT, DDD, DDE, PCBs, dioxins/furans, and toxaphene. In addition, the BC Ministry of Environment has developed provincial environmental quality guidelines and/or objectives for some legacy POPs (CCME 2006; BC MELP 2001). CCME environmental quality guidelines can be viewed online at http://www.ccme.ca/publications/ceqg_rcqe.html. BC provincial guidelines are available online at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html.

1.2 Georgia Basin

1.2.1 Sources and Loadings

Limited information is available on sources and loadings of legacy POPs to the Georgia Basin. Potential sources include municipal WWTP discharges, combined sewer overflows (CSOs), stormwater and runoff from urban and agricultural areas, landfill leachate, and occasional spills of PCB-contaminated fluids from in-use electrical equipment and leakage from electrical equipment at abandoned contaminated sites. Several conventional POPs have been detected in atmospheric deposition in the Georgia Basin. Atmospheric deposition is thought to be a significant source; however, contributions of POPs to the Georgia Basin aquatic environment from this source have not been evaluated.

Information on past and current loadings of PCBs to the Georgia Basin is very limited. Potential sources include municipal WWTP discharges, contaminated sites, landfill leachate, incineration and atmospheric deposition. A recent report prepared for Environment Canada estimated that loadings to the Georgia Basin from municipal WWTP effluents were 4.11 kilograms/year (kg/yr) total PCBs (based on available information collected between 1990 and 1998). The report concluded that insufficient information was available to estimate PCB loadings from other wastewater discharges to the Georgia Basin (ENKON 2002).

Long-range transport and atmospheric deposition likely make significant contributions of PCBs and other persistent organic contaminants to the Georgia Basin environment; however, information is limited. Harner *et al*. (2005) looked for evidence of trans-Pacific atmospheric inputs of organochlorine pesticides to the Lower Fraser Valley using high-volume air samplers. A study currently underway will assess the sources and fate of POPs in the aquatic, marine, and terrestrial ecosystems of the Georgia Basin through the use of mass balance calculations and exchange process modelling. Available information for PCBs and PBDEs is being used as an indicator. Sampling will be conducted to fill crucial data gaps identified by the modelling work (Shaw 2009, personal communication). Lichota *et al*. (2004) concluded that the presence of conventional and emerging POPs in endangered Vancouver Island marmots living at high-altitude was primarily due to atmospheric deposition from regional and distant (e.g., Asian) sources. Similarly, Morrissey *et al*. (2005) studied the Chilliwack River watershed to determine whether biota (salmon fry, invertebrates, and eggs of American dippers) in mountain streams were accumulating organic pollutants from remote sources via atmospheric inputs and/or from marine sources via migrating salmon. Several persistent chlorinated organic pollutants were detected in the watershed and the authors concluded that the primary source of these contaminants was atmospheric deposition.

In general, releases of PCBs from current sources are minor in comparison to those that occurred prior to the introduction of regulations, and significant point sources have now been virtually eliminated. Recycling within the environment via atmospheric deposition and release from historically contaminated sediments is likely the major current source to the environment. Prior to the introduction of regulations, the release of PCBs to the environment resulted in a large repository of PCBs in soils and sediments that are still available for recycling and redistribution. However, the continued use and storage of PCBs is a potentially significant source to the environment as occasional spills do occur.

Potential sources of PAHs to the Georgia Basin include pulp mills, municipal WWTPs, oil refineries, historic coal gasification plants, CSOs, stormsewers, historic coal-use, leaching from creosote-treated wood structures, boat traffic, fuel spillage, urban runoff, and atmospheric deposition (Garrett and Shrimpton 2000). The use of parking lot sealcoats, which are used to protect and to enhance the appearance of pavement on parking lots and driveways, has recently been identified in the United States as a significant source of PAHs to urban runoff. These products are typically made from a coal-tar pitch or an asphalt-based emulsion. Studies in some areas of the United States indicate that contributions of PAHs from this source to urban runoff can exceed contributions from all other sources (Mahler *et al.*

2005). The contribution of PAHs originating from sealcoats to urban runoff in the Georgia Basin has not been investigated. Average annual loadings of PAHs to the Georgia Basin between 1990 and 1998 were estimated to be 4.98 kg from refined petroleum and coal products discharges, 149 kg from municipal WWTP discharges (based on plants for which information was available), and 667 kg from stormwater discharges (ENKON 2002). Another study estimated that annual PAH loadings from urban runoff were 0.50 t in the Fraser River and 0.44 t in the Lower Fraser River (McGreer and Belzer 1998; Stanley Associates 1992).

In the past, the use of creosote for wood preservation was an important source of PAHs to the Georgia Basin environment due to the release of large quantities of creosote-contaminated stormwater. The implementation of codes of practice and inspection and enforcement programs in the 1980s resulted in the reduction of contaminated stormwater discharges from these facilities by more than 90% (Environment Canada 1998a). Creosote is currently used for wood preservation at only three heavy-duty wood preservation plants in BC. While the total usage in BC has decreased in recent years, the amounts applied are still very high. In 1999, 5,388 t (5,387,761 kg) of creosote were sold in BC with approximately 1,159 t of this being sold in the Lower Mainland area. In comparison, in 2003, a total of 2,163,142 kg (approximately 2,200 t) of creosote were sold in BC, with 1,320,313 kg (approximately 1,300 t) of this total being sold in the Lower Mainland (ENKON 2005).

Atmospheric deposition is thought to be a major source of PAHs to the Georgia Basin, but available information is limited. Studies in the Brunette River estimated that mean atmospheric deposition of PAHs to this area was 924 $ng/m^2/d$ for LMW PAHs and 204 $ng/m^2/d$ for HMW PAHs (Hall *et al.* 1999).

In the 1980s, the chlorinated bleaching process used at pulp and paper mills was identified as a major source of dioxins and furans to the environment. The introduction of stringent federal regulations has substantially reduced the release of these substances to the environment from pulp and paper mills. Loadings of 2,3,7,8-TCDD from BC pulp mill effluents have decreased 98.8% from 163 mg/day to 1.8 mg/day. Based on data available for 1998, it was estimated that the pulp and paper effluents contributed dioxin and furan loadings of 0.0010 kg/yr (ENKON 2002). Effluent from pulp and paper mills is no longer considered to be a major source of dioxins and furans to the BC environment.

Atmospheric releases from the combustion of salt-laden wood are the major current sources of dioxins/furans to the environment from pulp and paper mills. Hogged fuel, a by-product of sawmills which includes bark and similar wood wastes, is burned by pulp and paper plants to produce steam. At coastal mills, logs absorb salt (and consequently chlorine) from the water during their transport in log booms. The burning of salt laden wood can result in the production of dioxins and furans under certain conditions. The majority of these burners are located in BC. To address this issue, CCME developed Canada-Wide Standards (CWSs) for pulp and paper boilers burning salt-laden wood. For more information on the CWSs refer to http://www.env.gov.bc.ca/epd/industrial/pulp_paper_lumber/pulp_paper_boilers.htm. Dioxin emissions from coastal power burners using salt-laden hog fuel were estimated to be 10.5 grams/year (g/yr) and 7.9 g/yr (based on TEQs) in 1995 and 1997, respectively. In both 2001 and 2002, the estimated releases of dioxins from this source were 3.3 to 3.4 g/yr (Uloth *et al.* 2004).

Bright *et al*. (1999) concluded that pulp mills were not the major source of dioxins/furans to the lower Strait of Georgia prior to 1990. An examination of sediment cores collected from Howe Sound and the lower Strait of Georgia in 1990 and demonstrated that the main source or sources of these substances released predominantly OCDD and HpCDD, while pulp mill effluents released predominantly HxCDDs and 2,3,7,8-TCDF. The authors suggested that potential sources of OCDD and HpCDD included the past widespread use of pentachlorophenol-based wood treatment chemicals, diesel emissions, coal combustion, municipal solid waste incinerations and others types of incineration, stormwater runoff, and municipal WWTP discharges.

The past widespread use of chlorophenol-based chemicals for wood treatment in BC was another source of dioxins and furans to the Georgia Basin. These compounds were present as contaminants in commercial formulations of chlorophenols and chlorophenates, which were used extensively for antisapstain control in BC until this use was banned in Canada on December 31, 1990. Oil-based mixtures of chlorophenols are still registered for wood preservation in Canada, although pesticide inventories indicate that their use is declining. In 1999 and 2003, approximately 202 t and 148 t, respectively, of pentachlorophenol were sold in BC compared with 789 t in 1991. Of the total amounts being sold in 1999 and 2003, 56 t and 80 t, respectively, were sold in the Lower Mainland area (ENKON 2005). The introduction of stringent pollution control measures at wood treatment facilities in BC has significantly reduced the release of wood treatment chemicals to the environment. It is estimated that stormwater discharges from these facilities have decreased by approximately 90% as a result of the implementation of codes of practice and federal government enforcement and inspection programs (Environment Canada 1998a).

Other potential sources of dioxins and furans to the environment include municipal and industrial wastewater discharges, accidental loss of PCB fluids from older electrical equipment, stormwater, CSOs, landfill leachate, municipal and industrial incineration, diesel emissions, soot, and the use of chlorophenols and other pesticides which contain these substances as micro-contaminants. The contributions of most of these potential sources to the Georgia Basin environment have not been evaluated; however, a report prepared for Environment Canada estimated loadings of dioxins and furans to the Georgia Basin from CSOs to be 0.00014 kg/yr (based on available information for 1990 to 1998) (ENKON 2002).

Low concentrations of HCB have been detected as contaminants in commercial PCP formulations and the release of PCP wood treatment chemicals to the Georgia Basin environment was also a likely source of HCB. Also, prior to the implementation of process changes, HCB was formed as a process residue at chlor-alkali plants and elevated concentrations of HCB were detected in the process sludges of a, now closed, chlor-alkali plant located in Howe Sound (Wilson and Wan 1982). The introduction of changes to process technologies at chlor-alkali plants has eliminated this source of contamination. Information on current sources of HCB to the Georgia Basin environment is lacking; however, it has been estimated that, between 1990 and 1998, annual loadings from municipal WWTPs (based on those plants for which data was available) were 0.171 kg (ENKON 2002).

Very limited information was available on loadings of the organochlorine pesticides, DDT and its metabolites, toxaphene, and HCH to the Georgia Basin. DDT and toxaphene are no longer used in Canada; however, toxaphene was used to remove unwanted fish species from some BC lakes prior to stocking with rainbow trout (Stringer and McMynn 1960). Inventories of pesticide sales in BC indicate lindane sales have been relatively stable over the last several years; 326 kg in 1995, 272 kg in 1997, 239 kg in 1999, and 249 in 2003 (ENKON 2005). A recent report prepared for Environment Canada estimated that loadings of lindane and total HCH to the Georgia Basin from municipal WWTPs were 9.45 and 9.38 kg/yr (based on plants for which data was available) (ENKON 2002). While the long-range atmospheric transport of organochlorine pesticides from countries where these chemicals are still in use is thought to be a current source to the Georgia Basin, loadings from this source have not been estimated.

1.2.2 Environmental Concentrations

Conventional POPs have been detected in groundwater, marine and freshwater sediments, aquatic organisms, birds, wildlife and marine mammals in the Georgia Basin. Available information indicates that, in general, concentrations of PCBs and DDT in the environment increased from the 1940s until the 1970s, at which time concentrations started to decline due to the introduction of controls on the use and release of these chemicals. Recent information on the environmental levels of most POPs substances is limited and information available for the Georgia Basin and other areas of BC is insufficient to determine temporal trends (Garrett and Goyette 2001). However, declines in environmental levels have been noted for some substances. For example, PCBs have declined in bed sediments, fish, and wildlife in the Fraser

River estuary and HCB concentrations have declined in Fraser River fish (Elliott and Norstrom 1998; Elliott *et al.* 1989a,b; Elliott *et al.* 2001; Elliott *et al.* 2003; Gray and Tuominen 1998; Harris *et al.* 2003a,b; Karau and Pierce 2000; Macdonald *et al.* 1992; Macdonald *et al.* 1998; Raymond *et al.* 1998a,b). In addition, there has been a dramatic decrease in dioxin/furan concentrations in all media in the Fraser Basin since 1991 and also in the vicinity of coastal pulp mills. High concentrations of dioxins and furans were detected in shellfish, mainly in the vicinity of pulp and paper mills in the 1980s and closures on the harvesting of shellfish were implemented in many coastal BC areas. By February 1995, restrictions on shellfish harvesting had been placed on approximately 1200 km^2 of BC coastal waters due to dioxin/furan contamination. However, following the introduction of voluntary controls by the pulp and paper industry and stringent federal regulations on dioxin and furan releases, the concentrations in the environment decreased substantially. The concentrations of dioxins and furans in the hepatopancreas of crabs collected near nine coastal mills have decreased by more than 90% and shellfish harvesting restrictions have been lifted; however, consumption advisories are still in effect for crab hepatopancreas from some coastal areas (Environment Canada 2000; Hagen *et al.* 1995; Karau and Pierce 2000; Yunker and Cretney 1995). Canadian Food Inspection Agency (CFIA) and Health Canada are responsible for determining the suitability of shellfish for human consumption.

Studies on fish-eating birds indicate that the presence of elevated levels of TCDD and related chemicals in south coastal BC may have caused adverse biological effects. Eagle chicks from nests located near pulp mills in coastal BC contained significantly elevated levels of liver enzyme activity compared to chicks from reference sites. In addition, cormorants exhibited significantly elevated liver enzyme and/or brain asymmetries at all BC colonies sampled between 1973 and 1989 and from some colonies sampled during the 1990s (CCME 1999; Elliott *et al.* 1996a,b; Environment Canada/Health Canada 1990; Harris *et al*. 2003b; Henshel *et al*. 1997; Sanderson *et al.* 1994). In addition, evidence of toxicity was observed in herons in southern BC and was attributed to TCDD and related chemicals (Bellward *et al.* 1995).

Dioxin and furan levels in eggs from cormorant and heron colonies in the Strait of Georgia decreased dramatically in the early 1990s because of the reduced releases of these chemicals from BC pulp mills. Similar downward trends were observed in bald eagles in the Georgia Basin and in osprey nesting downstream of pulp mill sites on the Fraser and Columbia rivers (Elliott and Norstrom 1998; Elliott *et al.* 1996b; Elliott *et al.* 2001; Harris *et al.* 2003b; Whitehead *et al.* 1992). The results of Canadian Wildlife Service studies on POPs in osprey are presented on the Environment Canada contaminants indicator website http://www.ecoinfo.ec.gc.ca/env_ind/region/osprey/osprey_e.cfm.

Elevated PAH concentrations have been detected in the sediments at several locations in the Fraser River and the Georgia Basin. Wood preservation facilities utilizing creosote, creosote-treated wood structures, pulp mills, sewage treatment plants, boat traffic, surface runoff, and stormwater discharges are potential sources of PAHs to the Georgia Basin. According to Yunker *et al*. (1999), the Fraser River is the predominant source for both natural and anthropogenic hydrocarbons (including PAHs) to the Strait of Georgia. In the 1980s and 1990s, high PAH concentrations were detected in the sediments from False Creek and from Vancouver, Victoria, and Esquimalt harbours. At several locations, PAH concentrations exceeded sediment quality guidelines, indicating that they may have been high enough to cause adverse environmental impacts, depending on local environmental conditions. Historically, there has been extensive industrial activity in these harbours. However, much of the shoreline in these areas is being redeveloped and many of the old facilities, which were potential sources of PAHs, have now closed (Boyd and Goyette 1993; Bright *et al.* 1993; Garrett and Shrimpton 2000; Goyette and Boyd 1989; Goyette and Wagenaar 1995; Macfarlane 2001, personal communication).

Elevated PAH levels were detected in aquatic biota from harbour areas of BC. Especially high concentrations were detected in mussels and in the hepatopancreas tissue of crabs. Much lower PAH concentrations were detected in crab muscle and in fish tissue; however, concentrations were higher in fish from the Fraser River, False Creek, Vancouver, Victoria and Esquimalt harbours than in fish from reference areas. In the late 1980s, a high incidence of liver neoplasms (up to 75%) was observed in English sole (greater than 20 centimetres in length) in the vicinity of a petroleum refinery in the Port Moody area of Burrard Inlet. However, in the early 1990s, a decline in the frequency of liver lesions (to 30-45%) was observed and was attributed to the fact that the refinery process effluent was no longer discharged to the Inlet (Bright *et al*. 1993; Garrett and Shrimpton 2000; Goyette 1991; Goyette 1994; Goyette and Boyd 1989; Goyette and Wagenaar 1995; Goyette *et al*. 1988; Yunker 2000). Very little information was available on PAH concentrations in wildlife; however, PAH metabolites were detected in the bile of surf scoters in the Georgia Basin (Wilson and Elliott 2004).

The organochlorine pesticides, toxaphene and DDT and its metabolites, are also commonly detected in the Georgia Basin environment. Total DDT (sum of DDT and its breakdown products) is the most prevalent pesticide measured in biota and sediments in the Fraser Basin (Gray and Tuominen 1998).

Bans and associated federal regulatory controls for POPs, such as PCBs and dioxins/furans, have been successful in reducing environmental levels, although elevated levels persist in some areas. In some cases, environmental concentrations exceed the Canadian environmental quality guidelines for sediments. In addition, while the environmental concentrations of several POPs declined steadily following the introduction of controls, there is evidence that the rate of decrease of POPs in environmental compartments in recent years has slowed and future declines will likely be less evident.

Ambient environmental levels of POPs present a continued risk to aquatic species, especially some populations of marine mammals. Conventional and/or new POPs have been detected in harbour seals, otters, porpoises, dolphins, and whales in the Georgia Basin (Addison *et al.* 1996; Addison and Ross 2000; Cullon *et al*. 2005; Jarman *et al*. 1996; Rayne *et al*. 2004; Ross *et al*. 2000; Ross 2006). An analysis of prey items of harbour seals in the Georgia Basin found that, despite the fact that strict controls have been in effect on the use and release of these substances for many years, PCBs and DDT are still the contaminants present at the highest concentrations (Cullon *et al*. 2005). Similarly, PCB concentrations in scat from otters collected from Victoria harbour contained high concentrations of PCBs, with the geometric mean exceeding the levels found to cause adverse effects on reproduction (Elliott and Wilson 2003). A variety of POPs have been detected in gray whales found beached on the west coast. These include PCBs, DDT and metabolites, chlordane, dieldrin, and hexachlorobenzene (HCB) (Varanasi *et al*. 1994). Resident and transient killer whales, which frequent the Georgia Basin, are among the most contaminated in the world and studies to date indicate that this contamination originates from a combination of local and offshore contaminant sources (Ross *et al*. 2000; Ross 2006; Ylitalo *et al.* 2001).

1.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to legacy POPs include:

Obtain current information on environmental levels by:

- determining the extent of current POPs contamination, where appropriate, in water and bed and suspended sediments in tributaries of the Fraser River and its estuary, alpine lakes, snowmelt, and reservoirs (and also the Lower Thompson Valley), as well as current levels in sediments and biota from marine harbours, basins, inlets, and estuaries of the Georgia Basin. Hot spots of PAH sediment contamination within the Georgia Basin should be identified. Future work should include the measurement of congener specific POPs as total measurements are inadequate for predicting fate and effects;
- identifying suitable indicator organisms for low level contaminants;
- where appropriate, utilizing passive methods such as SPMDs and SPMEs in monitoring environmental concentrations; and
- where required, developing best analytical and laboratory procedures to ensure accurate and reliable results.

Develop a better understanding of biological effects by:

- evaluating the cumulative effects of low POPs concentrations on locally important species, including salmon;
- assessing the effects of POPs on early life stages of aquatic species, including salmon;
- developing a better understanding of the local and global effects of individual POPs species;
- evaluating the effects of POPs on biota in lakes and deep water environs;
- assessing the potential for current levels of POPs to cause endocrine disruption and other toxic effects;
- investigating the use of innovative bioassay methods (e.g., gene chip technologies) for long-term monitoring of dioxin-like and endocrine-disrupting compounds;
- identifying benthic or fish communities which are exposed to high levels of POPs (e.g., PAHs) in the Georgia Basin and reassessing the health of these ecosystems;
- identifying specific PAHs for which more toxicity information is required for local species; and
- determining the potential for photo-induced toxicity of POPs (e.g., PAHs) in shallow water and surface sediments in the Georgia Basin.

Develop a better understanding of environmental fate and distribution by:

- obtaining more information on individual POPs congeners with respect to persistence, fate, and trophic transfer under various environmental conditions;
- determining the implications of contaminant recycling from abiotic sedimentary basin storage into the biotic compartment;
- characterizing the transport of POPs to the Georgia Basin through watershed pathways;
- evaluating the effect of bioturbation in the sediments on POPs distribution and re-distribution; and
- identifying sinks for PAHs discharged to the Fraser River during low and high flows.

Obtain more information on non-point (and point) sources and loadings by:

- documenting and tracking local and global sources and inputs of legacy POPs to the Georgia Basin, where possible, including atmospheric deposition and contributions from the Fraser River and other freshwater sources to the Georgia Basin;
- updating information on annual imports and stockpiles of in-use and banned POPs (e.g., PCBs) in the Georgia Basin;
- determining the levels of other potential contaminants of concern in pulp mill effluents;
- obtaining additional information on sources of individual PAH compounds, in order to accurately assess loadings of PAHs to the Georgia Basin; and
- obtaining information on the current releases of PAHs in stormwater discharges from select sources including heavy duty wood preservation plants using creosote, asphalt manufacturing plants, parking lot sealants, and some oil refineries.

1.4 Management Actions and Needs

No management actions to specifically address POPs in the Georgia Basin have been implemented, nor have specific needs relating to the Georgia Basin been identified. However, a number of international and national initiatives are of importance in reducing local and global sources to the Georgia Basin.

While the use and release of most legacy POPs have been banned or severely restricted in Canada for many years, these substances still enter the Canadian environment through atmospheric transport from the several countries where they are still in use. These countries include the United States, Mexico, Central America, some eastern European countries, and some southern and southeastern Asian countries. International actions to reduce global releases of POPs are required to ensure reductions in the environmental concentrations of POPs in Canada and elsewhere, and several international initiatives are currently underway.

The Stockholm Convention, which came into effect on May 17, 2004, is an international initiative of the United Nations which originally targeted twelve priority POPs (the dirty dozen) including PCBs, PCDDs, PCDFs, HCB, DDT, aldrin, dieldrin, endrin, chlordane, heptachlor, mirex, and toxaphene for global action to eliminate or restrict their intentional production and use. However, several new chemicals have now been listed under the Convention. They include alpha- and beta- hexachlorocyclohexane; Tetra-, penta-, hexa- and hepta-dibromodiphenyl ether; chlordecone; hexabromobiphenyl; lindane; pentachlorobenzene; and perfluorooctane sulfonic acid and its salts; and perflurorooctane sulfonyl fluoride.

In May of 2001, Canada became the first country to both sign and ratify the global POPs convention. Canada has committed $20 million to fund developing countries in addressing POPs issues and in finding alternatives for the use of POPs. The unintentional production and release of specific POPs have also been targeted for reduction or elimination under the Stockholm Convention. Signatory countries were required to develop National Implementation Plans for unintentionally produced POPs before May 17, 2006. Canada published, in May of 2006, "Canada's National Implementation Plan under the Stockholm Convention on Persistent Organic Pollutants". A National Action Plan (NAP) which identifies Canada's plans for meeting obligations under the Stockholm Convention was included as Part II of this document. This document can be viewed at http://www.pops.int/documents/implementation/nips/submissions/canada/stockholm_eng_sm.pdf. For more information, refer to the Environment Canada website http://www.ec.gc.ca/cleanair-airpur/default.asp?lang=En&n=8DDE4B39-1.

The Protocol on Persistent Organic Pollutants (POPs) under the Convention on Long-Range Transboundary Air Pollution (LRTAP) was developed under the United Nations Economic Commission for Europe (UNECE) and identifies 16 POPs for phase-out by countries in the Russian Federation, the Newly Independent States, Central and Eastern Europe, Western Europe, Canada, and the United States. These POPs include the "dirty dozen" identified under the Stockholm Convention and also PAHs, chlordecone, hexachlorocyclohexane/lindane, and hexabromobiphenyl. For more information refer to http://www.unece.org/env/lrtap/.

In addition, under the North American Agreement on Environmental Cooperation (NAAEC). Canada has developed action plans with the United States and Mexico for addressing several persistent environmental contaminants including chlordane, DDT, lindane, PCBs, and mercury. For more information refer to http://www.cec.org/Page.asp?PageID=1325&SiteNodeID=312 .

In Canada, national initiatives and regulations under CEPA 1999 have been introduced to address POPs and the use of legacy POPs has been eliminated or curtailed in Canada under federal legislation. Several POPs have been determined to be toxic as defined under CEPA 1999, thus requiring the federal government to develop management strategies for these substances. Under the federal Toxic Substances Management Policy, management strategies are developed for CEPA-toxic substances within a strict timeframe. These strategies can include the preparation of regulations, pollution prevention plans, environmental emergency plans, environmental codes of practice, and environmental release guidelines. Under CEPA 1999, regulations have been developed to prohibit the import, manufacture, and use of PCBs, Mirex, and HCB, although the continued use of PCBs is allowed in specified equipment. The federal TSMP provides for the management of CEPA-toxic substances under one of two "Tracks". Under Track 1 management, substances are identified for the virtual elimination of their release to the environment. CEPA requires that CEPA-toxic substances, which are also bioaccumulative, persistent, and anthropogenic, be identified for Track 1. CEPA-toxic substances, which do not meet all of the criteria for Track 1 management are identified for Track 2 management, which requires the life-cycle management of the substance to prevent or minimize its release to the environment. CEPA 1999 does not regulate pesticides unless the active ingredient also has a non-pesticidal use. PCBs, dioxins and furans, toxaphene, aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, and mirex have been proposed for virtual elimination under CEPA. For more information on the federal TSMP refer to http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=2A55771E-1. To view an up-to-date list of

CEPA-toxic substances (Schedule 1) refer to http://www.ec.gc.ca/CEPARegistry/subs_list/Toxicupdate.cfm.

Regulations under CEPA 1999 have been developed for PCBs, dioxins and furans. PCBs are controlled under a series of CEPA regulations that prohibit and/or control the manufacture, sale, import, and use of PCBs as well as releases to the environment. The continued use of PCBs is permitted in older electrical equipment until the end of their service life. However, this continued use and the long-term storage of PCBs in Canada has been determined to be of potential concern to the environment and the existing PCB regulations under CEPA 1999 are currently under revision. For more information on PCB regulations refer to http://www.ec.gc.ca/ceparegistry/regulations/detailReg.cfm?intReg=105.

There are also two CEPA regulations relating to dioxin/furan releases from pulp mills. These include: 1.) the *Pulp and Paper Mill Defoamer and Wood Chip Regulations*, which limit the allowable concentrations of dioxins and furans in defoamers and prohibit the import, sale, and use of wood chips made from wood treated with chlorinated phenols, and 2.) the *Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations*, which limit the allowable concentrations of dioxins and furans in pulp and paper mill effluents. For more information on CEPA regulations refer to http://www.ec.gc.ca/CEPARegistry/regulations/default.cfm.

CCME, which represents all federal, provincial, and territorial governments, has developed Canada-Wide Standards (CWSs) for various sources of dioxins/furans to the atmosphere including emissions from incineration facilities, coastal pulp and paper boilers, iron sintering, steel manufacturing electric arc furnaces, and conical waste combustion of municipal waste. In BC, CWSs are implemented by the provincial government. For more information on CWSs refer to the CCME website http://www.ccme.ca/ourwork/environment.html?category_id=108 and the BC MOE website http://www.env.gov.bc.ca/epd/industrial/pulp_paper_lumber/pulp_paper_boilers.htm.

The use and release of POPs to the Canadian environment is also controlled under the federal PCPA, which is administered and enforced by the Pest Management Regulatory Agency (PMRA) for the Minister of Health. All compounds used for pesticidal purposes in Canada must be registered under the PCPA. By the late 1990s, the registration under PCPA of all twelve legacy POPs targeted by the Stockholm Convention, had been discontinued. Similarly, the use of chlorophenate-based formulations for antisapstain control was de-registered in Canada under the PCPA on December 31, 1990, and these chemicals are no longer used for antisapstain treatment in Canada. Although pentachlorophenol and creosote are still used for long-term heavy duty wood preservation in Canada, the introduction of environmental codes of practice and the initiation of an aggressive inspection and enforcement program in the 1990s resulted in significant decreases in the release of wood preservation chemicals. In BC, it was estimated that contaminated effluent discharges from these facilities were reduced by more than 90%. PMRA is currently conducting a re-evaluation of all heavy duty wood preservatives in Canada. For more information on the PCPA and regulations affecting wood treatment chemicals and other pesticides in Canada, refer to the PMRA website http://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php. For more information on the re-evaluation of heavy duty wood preservatives, refer to the PMRA website http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rev2008-08/index-eng.php.

CEPA management strategies, such as the Recommendations for the Design and Operation of Wood Preservation Facilities, reduce environmental releases of wood preservative chemicals and also chemicals such as PAHs, HCB, CDPEs, and dioxins/furans, which are present as contaminants in commercial wood preservative formulations. These recommendations were updated in 1999. While the implementation of this "code" is voluntary, as of March 31st, 2000, all of the 68 wood preservation facilities in Canada had signed onto this program. Fifteen of these facilities are located in BC.

The BC MOE regulates allowable levels of antisapstain chemicals in stormwater runoff from wood protection facilities under the *Antisapstain Chemical Waste Control Regulation* of the EMA. Emissions of antisapstain chemicals from spray booth vents are also controlled under this regulation. For more information on this regulation refer to http://www.env.gov.bc.ca/epd/industrial/regs/antisapstain/index.htm.

In addition, under the mandate of the PCPA, the PMRA conducted a special review of lindane. This review was completed in 2001 and the PMRA announced that all uses of lindane, for which alternatives were available, would be phased out by 2002 and all other uses would be phased out by the end of 2004. This decision was based on the potential health risks associated with occupational exposure. All but one of the registrants of this pesticide requested voluntary discontinuation of sales for the remaining uses of lindane. At the request of this one remaining registrant, a Board of Review was established by the Minister of Health to review the PMRA decisions. As a result, the PMRA initiated a new review and considered new information and data and risk mitigation proposals from former registrants of lindane products and other interested parties. As a result of this new review, the PMRA Re-evaluation Note REV2009-08 was prepared and posted on the Health Canada website for public comment. The public comment period is from August 27, 2009 to October 26, 2009. For more information, or to review this document, refer to http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/_rev2009-08/lindane-eng.php

2. New or Emerging Persistent Organic Pollutants (POPs)

A number of substances and substance groups with properties similar to those of the legacy or conventional POPs have recently been identified as potential threats to environmental and human health. Some of these substances have been in use for many years; however, their widespread presence and persistence in the environment have only recently been acknowledged and, in most cases, their potential environmental and health impacts are not yet well understood. In contrast to the legacy or conventional POPs, the use and release of these substances to the environment are not yet widely regulated. New and emerging POPs of concern in the Georgia Basin include alkylphenol and alkylphenol ethoxylates (APnEOs), halogenated diphenyl ethers (polybrominated diphenyl ethers (PBDEs) and chlorinated diphenyl ethers (CDPEs)), phthalate esters, chlorinated paraffins, polychlorinated naphthalenes (PCNs), and fluorinated organic compounds (FOCs).

2.1 Alkylphenol and Alkylphenol Ethoxylates

2.1.1 Background Information

Alkylphenol ethoxylates or alkylphenol polyethoxylates (APnEOs) enter the environment as a result of their use as detergents, degreasers, emulsifiers, wetting agents, and dispersing agents by the textile, pulp and paper, metal processing, petroleum refining, oil and gas recovery, power generation, food and beverage processing, plastics manufacture, building and construction, and paint and coatings industries. They have also been used in a variety of pesticide products (Bennie *et al.* 1997; Renner 1997).

In 1997, a survey conducted by Environment Canada identified 189 Canadian companies that used or handled nonylphenol (NP) or nonylphenol ethoxylates (NPnEOs) in quantities of over 1 t (1,000 kg) per year. In 1996, total releases of NP and NPnEOs from their manufacture and industrial use in Canada were estimated to be 96.5 t. Formulators and distributors of surfactants and the industrial users of cleaning products, degreasers, and detergents were identified as the major industrial sources of these substances, each releasing 25 to 60 t of NP and NPnEOs. Paint, coating, resin and adhesive manufacturers released 5 to 10 t, while formulators of cleaning products, degreasers and detergents; pulp and paper mills; formulators and distributors of products for the pulp and paper industry; oil and gas recovery; wastewater treatment product manufacturers; and miscellaneous industries accounted for the release of 0.1 to 5.0 t per industry. Releases from Canadian pulp mills have likely decreased in recent years as a result of industry initiatives to reduce the use of these substances. Due to the widespread use of commercial products containing these substances, residences and institutions are thought to be significant sources of NP and NPnEOs to municipal wastewater treatment facilities in Canada, but this source has not been evaluated. While wastewater treatment plants (WWTPs) can degrade and transform APnEOs prior to their release to the environment, some of the degradation and transformation products of these substances are more persistent, lipophilic, toxic and estrogenic than the parent compounds. This is also true for some of the degradation products formed as a result of biodegradation in the environment (Ahel *et al.* 1994; Environment Canada/Health Canada 2001; Maguire 1999; Metcalfe *et al.* 1996; Reinhard *et al.* 1982; Stephanou 1985).

Several researchers have reported rapid uptake and elimination of NP in aquatic organisms. Bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) of three to more than 3000 have been reported for various fish species, shrimp, and mussels. Concentrations in the 17 to 3000 μg/L range were acutely toxic to aquatic organisms exposed to NP. A review of the literature on the toxicity of NP and its ethoxylates indicated that the acute to chronic toxicity ratio was 4:1. Impairment of reproduction, growth, fecundity, and photosynthesis has been observed in aquatic organisms exposed to concentrations below the acutely toxic range. Alkylphenol (AP) and APnEOs bind to the estrogen receptor and cause estrogenic responses in aquatic organisms at concentrations in the range shown to cause other chronic effects (Ahel *et al.* 1993; Brooke 1993; Ekelund *et al.* 1990; Environment Canada/Health Canada 2001; Grammo *et al.* 1991; Jobling *et al.* 1996; McLeese *et al.* 1981; Nimrod and Benson 1996; Ward and Boeri

1991; Wahlberg *et al.* 1990). In 2000, NP and its ethoxylates were designated as toxic substances under Section 64 of CEPA 1999.

Canadian water quality guidelines for NP, and its ethoxylates, for the protection of freshwater and marine aquatic life, are 1.0 and 0.7 μg/L, respectively. Interim guidelines for sediments in fresh and marine systems are 1.4 and 1.0 μg/g (dw), respectively (at total organic carbon (TOC) of 1%) (CCME 2006). CCME guidelines can be viewed online at http://www.ccme.ca/publications/ceqg_rcqe.html. There are no BC provincial guidelines for NP or other alkylphenols.

2.1.2 Georgia Basin

In BC, sales of nonylphenoxypolyethoxyethanol as an active ingredient in pesticides were 5,585 kg in 1991, 8,929 kg in 1995, 9,245 kg in 1999, and 8,791 kg in 2003. This represents a 57% increase in sales of this chemical between 1991 and 2003. The majority of the sales were in the Lower Mainland region of the province (5,823 kg). Sales of octylphenoxypolyethoxyethanol as an active ingredient in pesticides were lower; 2,563 kg in 1991, 5,957 kg in 1995, 4,680 kg in 1999, and 3,133 kg in 2003 (ENKON 2005).

NP and NPnEOs have been detected in WWTP discharges, combined sewer overflows (CSOs), and urban runoff in the Georgia Basin area; however, existing information was insufficient to determine current loadings. In particular, information on APnEOs in agricultural runoff is lacking (Bertold 2000; Bertold and Stock 1999; ENKON 1999).

Information on environmental concentrations of AP compounds is limited and most of the available information pertains to NP and its ethoxylates. The results of limited sampling within the Georgia Basin suggested that concentrations of sediments are higher near urban centres, downstream of pulp mills, and near WWTP discharges (Bennie *et al.* 1997; Brewer *et al.* 1998a,b; Dods *et al*. 2005; Hodgins and Hodgins 2000; Paine and Chapman 2000; Shang *et al.* 1999; Sylvestre *et al.* 1998; Wilson 2001, personal communication). This is in agreement with the findings of environmental monitoring studies in other areas. Shang *et al.* (1999) studied sediment samples collected near the Iona Island WWTP outfall and concluded that little degradation of these compounds occurs in the sediments and estimated the half-life in sediments to be more than 60 years. The authors estimated that the entire Strait of Georgia sediments contained over 170 t of NPnEO.

2.1.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to AP and APnEOs in the Georgia Basin include:

Obtain current information on environmental levels by:

- measuring the presence of these compounds in the environment (all media); and
- developing standardized analytical procedures for tissue.

Develop a better understanding of biological effects by:

- assessing toxicity to a variety of organisms, particularly sediment-dwelling organisms and mammalian and avian consumers of aquatic life;
- assessing the effect of pH on aquatic toxicity;
- conducting the specific toxicity studies required for the adoption of full environmental quality guidelines; and
- evaluating the endocrine disrupting effects of these chemicals in aquatic biota in both agricultural and urban areas and in the vicinity of WWTPs.

Develop a better understanding of environmental fate and distribution by:

- examining the fate of these compounds in water, sediments, sludge and biosolids;
- investigating the effects of photolysis on NP/NPnEOs on soils surfaces and sediments in shallow water;

- measuring uptake and elimination rates in biota; and
- assessing the effect of pH on bioavailability.

Obtain more information on non-point (and other) sources and loadings by:

- inventorying usage and suspected sources and estimating loadings from potential sources such as sanitary sewage, storm sewers, CSOs, pulp mills, various industrial plants, and agricultural runoff in areas of heavy pesticide use; and
- ensuring that actions planned regionally relate to national initiatives under CEPA.

2.1.4 Management Actions and Needs

Nationally, CEPA 1999 requires that Environment Canada and Health Canada develop a Risk Management Strategy, which proposes tools for the management of substances determined to be toxic as defined under CEPA 1999, including NP and its ethoxylates. As part of this strategy, Environment Canada is initiating pollution prevention (P2) planning requirements for effluents from wet process-type textile mills and NP and NPnEOs used at these mills and also for NP and NPnEOs contained in products. Although municipal WWTPs were also identified as a source of these substances to the Canadian environment, Environment Canada has chosen to control the sources of these substances to the WWTPs by targeting importers and manufacturers of these products and the industrial users of these products (pulp and paper mills and textile mills). The implementation of pollution prevention plans will be required by all manufacturers and importers of products containing NP and NPnEOs and also by textile mills using wet processing. For more information on the federal Risk Management Strategy for nonylphenol and its ethoxylates refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1&xml=8DD95B0E-9364-4BBE-A5F4-D93D8AADEE3E.

The pulp and paper industry has agreed to voluntarily reduce their use of NP and NPnEOs. Since 1997, the Forest Products Association of Canada (FPAC) has been encouraging its members to consider using alternatives to products containing NP or NPnEOs. Only 40 of the 136 mills that responded to a national survey had used these compounds in 2001. The majority of these mills were in the process of implementing plans to eliminate their use by 2002/2003 (Environment Canada 2003).

Management action needs specific to APs and APnEOs in the Georgia Basin include:

Review existing controls and, where required, develop mandatory regulatory activities by:

- developing site-specific objectives from the national guidelines to reflect the fate and behaviour of APs and the sensitivity of ecologically significant species in the Georgia Basin. These site-specific objectives could then be used to make informed management decisions and to prioritize actions on these CEPA-toxic substances.

2.2 Halogenated Diphenyl Ethers (Chlorinated Diphenyl Ethers and Brominated Diphenyl Ethers)

2.2.1 Background Information

Chlorinated diphenyl ethers (CDPEs) have been released to the environment in association with wood treatment chemicals, due to their presence as impurities in commercial chlorophenol-based formulations; in flyash from incinerators; as a result of the chlorination of discharges containing diphenyl ether at municipal WWTPs and industrial facilities; in past spills of transformer fluid oils containing CDPEs as contaminants; as a result of leaks from improperly disposed of transformers; and in association with industrial bacteriostats, antimicrobials in cosmetics, sanitizing products, and fabric softeners containing CDPE derivatives and nitro-substituted CDPE-based herbicides. The widespread use of 5-chloro-2-(2,4-dichlorophenoxy)phenol (product names include Triclosan and Irgasan) as a antimicrobial agent in cosmetics, sanitizing products, fabric softeners and as an industrial bacteriostat for treating textiles, leather, plastic and rubber also contributes CDPEs to the environment (Environment Canada 1988; Willis *et al.* 1978).

Information on the toxicity of CDPEs to aquatic species found locally is very limited; however, the potential of these chemicals to produce biological effects in fish and mammals has been demonstrated in the laboratory. CDPEs are embryotoxic to fish and are acutely toxic at the μg/L concentration. They have low solubility in water and tend to accumulate in bottom sediments. Although their environmental persistence has not been well studied, they are chemically and physically similar to other highly persistent organic compounds. CDPEs are readily taken up by aquatic species, even at low environmental concentrations, and bioconcentration factors (BCFs) in the order of 1000 have been observed. CDPEs are moderately to highly persistent in fish, leading to speculation that biomagnification through the food chain may be a concern. CDPEs have been detected in fish-eating birds and marine mammals; however, information on environmental concentrations of CDPEs is limited. High concentrations have been found near chemical plants, and other industrial facilities where diphenyl ether-based heat transfer fluids have been used, and in the vicinity of past chlorophenol wood preservative spills (Choudry *et al.* 1977a,b; Choudry and Hutzinger 1982; Kanetoshi *et al.* 1988a,b; Lindahl *et al.* 1980; Nilsson *et al.* 1974; Norstrom *et al.* 1977).

Polybrominated diphenyl ethers (PBDEs) are used mainly as flame retardants in polymer resins and plastics, sealants, adhesives, and coatings. They are present in a variety of consumer products including furniture, stereos, televisions, computers, carpets, and curtains. There are three commercial mixtures including pentabromodiphenyl ether (PeBDE), octabromodiphenyl ether (OBDE), and decabromodiphenyl ether (DBDE). The PeBDE commercial product contains mainly penta-BDE, tetra-BDE, and hexa-BDE and is used mainly in polyurethane foam in furniture and in the automobile upholstery. OBDE contains mainly hepta-BDE, octa-BDE, and hexa-BDE and is used primarily in acrylonitrile-butadiene-styrene (ABS), which is used in computers and other electronic equipment. DBDE contains deca-BDE, almost exclusively, and is used largely in high-impact polystyrene and other polymers and is commonly found in computer and television cabinets, in electrical and electronic components, cables, and textile back coatings. The manufacturing of PBDEs and the use and ultimate disposal of articles containing these compounds can result in their release to the environment. In addition, PBDEs have been detected in municipal WWTP effluents. While PBDEs are not manufactured in Canada, they are imported for use in manufacturing and also in a wide range of finished products (Environment Canada 2006a).

Some countries have initiated actions to reduce the use and release of PBDEs to the environment. The only manufacturer of PeBDE and OBDE in the United States stopped the production of these products in 2004, while the European Union prohibited the marketing and use of these PBDEs in products as of August 15, 2004 (Environment Canada 2006a).

PBDEs have received attention worldwide as a result of studies showing that their presence in the environment is widespread and that their environmental concentrations have increased markedly in recent decades and are continuing to increase. They are resistant to biodegradation and there is evidence that deca-BDE can persist for up to two years in anaerobic sediments. Degradation to lower brominated compounds by UV light and sunlight has been observed in the laboratory; however, the importance of this degradation in the natural environment is not known. The fact that PBDE concentrations are increasing in the Arctic indicates that they are capable of long-range transport to remote areas of the world (Environment Canada 2006a).

Predicted and measured bioconcentration factors (BCFs) of up to several thousand have been reported for tetra- to hexa-BDEs. Due to their potential for biomagnification, these compounds pose a higher risk to marine mammals. Elevated concentrations of tetra- and penta-BDEs have been detected in marine mammals in Canada. While the bioconcentration potential of the more highly brominated compounds (hepta- to deca-BDE) is thought to be limited due to their large molecular size and their extreme hydrophobicity, these compounds have been detected in fish, mammals, and bird eggs, indicating that low level uptake is occurring (Environment Canada 2006a).

Seven PBDEs (tetra- to deca-BDEs) were recently assessed by Environment Canada and Health Canada and were determined to be toxic as defined under CEPA 1999 (Environment Canada 2006a; Health Canada 2006a), and a regulation to prevent the manufacture and limit the use of these substances in Canada has been developed under CEPA 1999.

There are currently no Canadian environmental quality guidelines for CDPEs or PBDEs (CCME 2006).

2.2.2 Georgia Basin

The major source of CDPEs and their derivatives to the Georgia Basin was likely associated with their presence as impurities in chlorophenol-based wood treatment formulations. Chlorophenol-based antisapstain chemicals were once used extensively in BC (Garrett and Shrimpton 1988); however, their use in Canada was discontinued in 1990. PCP is still permitted for use as a heavy duty wood preservative; however, the use of PCP for wood preservation in BC is declining (148 t in 2003 compared to 789 t in 1999) (ENKON 2005). In the past, large quantities of wood treatment chemicals were released to the aquatic environment in contaminated stormwater; however, industry and government initiatives introduced in the 1980s substantially decreased the release of contaminated stormwater (Environment Canada 1998a).

Sources of PBDEs to the Georgia Basin have not been studied; however, the widespread use and disposal of consumer products containing these substances can result in their release to the environment. PBDEs have been detected in municipal WWTP discharges in the Okanagan area of BC and were primarily sorbed to sludges (de Boer *et al.* 2003; Rayne and Ikonomou 2005). Rayne and Ikonomou (2005) reported that, while the wastewater treatment processes did not substantially degrade or otherwise remove PBDEs, the overall removal efficiency due to sorption onto wastewater sludges was 93%. WWTP biosolids contained approximately 2.4 mg/kg dry weight (dw). The authors also observed that the much lower concentrations present in the aqueous WWTP effluents (2.6 ng/L) could pose a threat to drinking water and to fisheries resources due to the very high volume of effluents discharged to the environment. No information was available on loadings of CDPEs or PBDEs to the Georgia Basin. Should insert update on the work that Pat et al have done with PBDEs and PCBs.

It is thought that long-range transport and atmospheric deposition make significant contributions of both conventional and new POPs to the Georgia Basin environment; however, information is limited. The sources and fate of POPs in the aquatic, marine, and terrestrial ecosystems of the Georgia Basin are now being studied through the use of mass balance calculations and exchange process modelling (using available information for PCBs and PBDEs as indicators). Sampling will be conducted to fill crucial data gaps identified by the modelling work (Shaw 2009, personal communication). Lichota *et al*. (2004) concluded that the presence of conventional and emerging POPs in endangered Vancouver Island marmots living at high-altitude was primarily due to atmospheric deposition from both regional and distant (e.g., Asian) sources.

Elevated concentrations of CDPEs have been detected in sediments, fish, and aquatic invertebrates from some areas of the Georgia Basin including Vancouver, Victoria, and Esquimalt harbours. Environmental CDPE concentrations may also be elevated in other areas of the Georgia Basin, particularly at sites of past chlorophenol usage. CDPEs were not detected in samples collected from reference sites including sediments and rock sole from Crescent Beach and sediments from the Queen Charlotte Islands (Garrett and Ikonomou 2002).

PBDEs have also been detected in sediments, fish, invertebrates, birds, and terrestrial and marine mammals in the Georgia Basin. A variety of aquatic species from coastal BC contained PBDEs including Dungeness crab, farmed and wild salmon and other species of fish, harbour porpoise, and killer whales.

A recent study found that the concentrations of PBDEs were generally higher in farmed salmon than in wild salmon, likely due to the higher concentrations of PBDEs in commercial fish food than in natural prey species (Hites *et al.* 2004). Chinook salmon contained higher concentrations of PBDEs than did the other wild salmon species. This was thought to be due to the fact that Chinook salmon feed at a higher level in the food web than do other species and grow to be a much larger size. Ikonomou *et al.* (2002) detected PBDEs in Dungeness crab, English sole, and harbour porpoise in the Georgia Basin. The concentrations of PBDEs were substantially higher (approximately 80 fold) in the hepatopancreas tissue of Dungeness crabs collected from industrialized and urban areas than in crabs collected from the reference site. PBDE concentrations in English sole liver tissue were generally lower and more consistent; however, higher concentrations were detected in sole from Vancouver Harbour. Harbour porpoises contained higher levels of PBDEs than did crab and sole; however, concentrations were not high in comparison to levels detected in porpoises and dolphins from other areas of the world (Ikonomou *et al.* 2002). Elevated concentrations of PBDEs have also been detected in the blubber of porpoises and in killer whales collected from coastal BC (Rayne *et al.* 2004; Ross 2006). An analysis of the prey items of harbour seals in the Georgia Basin found that the contaminants present at the highest concentrations were PCBs, DDT, and PBDEs (Cullon *et al*. 2005). Terrestrial species such as endangered Vancouver Island marmots and grizzly bears in BC also contain detectable concentrations of PBDEs. Atmospheric deposition was identified as the major source to the marmots, which are herbivorous and live at high altitudes (Lichota *et al*. 2004). Salmon was identified as the likely source of 85% of the lower brominated PBDEs to grizzly bears feeding on salmon (Christensen *et al.* 2005). Environment Canada (Canadian Wildlife Service) examined trends in PBDE concentrations in great blue heron eggs from the Fraser River estuary, double-crested cormorant eggs from the Strait of Georgia, osprey eggs from the lower Fraser River, and Leach's storm petrel eggs from the Queen Charlotte Islands over the last twenty to thirty years. The highest concentrations were detected in heron eggs collected in the Fraser River estuary in 2002, while concentrations in cormorant and osprey eggs were approximately half the level in heron eggs. Very low levels were detected in osprey eggs. Within the study period, the concentrations of PBDEs in both heron and cormorant eggs increased substantially, while concentrations of PCBs and DDE remained stable or decreased (Elliott *et al.* 2005). PBDEs have also been detected in eagles from south coastal BC (McKinney *et al.* 2006).

2.2.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to halogenated diphenyl ethers in the Georgia Basin include:

Obtain current information on environmental levels by:

- identifying suspected environmental hotspots based on a source inventory and confirmed through select sampling of various media, including aquatic biota.

Develop a better understanding of biological effects by:

- assessing the potential biological effects of elevated concentrations on local species of aquatic organisms; and
- obtaining additional toxicity information as required for the development of environmental guidelines.

Obtain more information on non-point (and other) sources and loadings by:

- inventorying suspected past and present sources of halogenated diphenyl ethers to the Georgia Basin in order to identify potential hotspots;
- obtaining loadings estimates, where possible, for current sources; and
- identifying specific CDPE isomers in chlorophenol-based wood treatment formulations used (past and present) in BC for the purpose of fingerprinting sources of these chemicals in the Georgia Basin environment.

2.2.4 Management Actions and Needs

While there have been no management actions to specifically address the presence of halogenated diphenyl ethers in the Georgia Basin, the termination of the use of chlorophenate-based antisapstain chemicals in 1990 eliminated a major source of CDPE. Oil-based pentachlorophenol is still used for wood preservation in BC; however, the introduction of environmental codes of practice in the 1980s and the initiation of an aggressive inspection and enforcement program in the 1990s resulted in significant decreases in the release of wood preservation chemicals to the environment. Only one facility within the Georgia Basin is still using PCP for this purpose.

Recent upgrades at municipal WWTPs, and the implementation of bylaws and source control initiatives to reduce the discharge of chemicals to storm sewers, have undoubtedly reduced the release of a variety of toxic substances. The efficiency of advanced treatment of sewage wastewaters in reducing loadings of halogenated diphenyl ethers is not known.

Nationally, Environment Canada and Health Canada conducted screening level risk assessments (SLRAs) under CEPA 1999 on seven PBDEs (including tetra-BDE, penta-BDE, hexa-BDE, hepta-BDE, octa-PBDE, nona-BDE, and deca-BDE) (Environment Canada 2006a; Health Canada 2006a). These substances were chosen for assessment due to their potential for environmental persistence, and/or bioaccumulation, and their inherent toxicity. SLRAs are conducted to determine, in an expeditious manner, whether substances present, or may present, a risk to either human or environmental health in Canada. In a SLRA, conservative assumptions are used to determine whether the substance is "toxic" or capable of becoming "toxic" as defined under CEPA 1999. The assessment does not provide an exhaustive review of all of the available information and data, but focuses on the most critical of the available studies and lines of evidence to support conclusions (Suffredine 2006, personal communication). As a result of these assessments, these substances were added to CEPA 1999, Schedule 1, List of Toxic Substances. In addition, it was determined that tetra-, penta- and hexa-BDE meet the criteria for virtual elimination under CEPA 1999 and these substances have been added to CEPA 1999 Schedule 1 List of Toxic Substances. A Risk Management Strategy for these substances was developed and the *Polychlorinated Diphenyl Ether Regulations*, which prevent the manufacture and restrict the use of these substances in Canada, came into force on June 19th, 2008 under CEPA 1999. The regulation can be viewed at http://www.ec.gc.ca/CEPARegistry/regulations/DetailReg.cfm?intReg=108. As a result of a recent updated review of decachlorodiphenyl ether, a State of Science report was published in the Canada Gazette, Part I on March 28, 2009. Additional concerns with deca-BDE identified in this report warranted a revision to the original Risk Management Strategy, which now proposes stricter controls on decaBDE and on the other PBDEs contained in the PentaBDE and OctaBDE products. It also proposes a prohibition o the import, manufacture, and use of decaBDE in electronic and electrical equipment, as well as other controls. The proposed revision has been posted on the EC website. The public comment period is from March 28th to May 27th, 2009 (Pasternak 2009, personal communication).

For more information on PBDEs and federal management strategies, refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1&xml=5046470B-2D3C-48B4-9E46-735B7820A444 .

Screening assessments on two other brominated flame retardants, tetrabromobisphenol A (and two derivative compounds) and hexabromocyclododecane, are currently underway.

Data gaps and research/monitoring needs should be addressed prior to the development of recommendations for management actions specifically to address halogenated diphenyl ethers in the Georgia Basin. However, there is a need to develop guidelines based on the results of future work on toxicity to local species, source inventories, and current environmental levels. In addition, continued efforts to reduce the release of other contaminants to the environment from wood preservation facilities, contaminated sites, wastewater discharges, and other potential sources would likely be effective in removing or reducing the release of these compounds to the Georgia Basin environment.

2.3 Phthalate Esters[1]

2.3.1 Background Information

Phthalate esters are used mainly as plasticizers in polyvinyl chloride resins, adhesives, and cellulose film coatings to impart flexibility to products such as food wraps, plastic tubing, floor tiles, plastic furniture, upholstery, toys, shower curtains, and medical equipment. Smaller amounts are used in cosmetics, insect repellents, insecticide carriers, lacquers, propellants, and defoaming agents in paper manufacturing. While approximately 20 phthalate esters are used commercially, DEHP accounts for 40 to 50% of the global use. Two facilities in eastern Canada manufacture DEHP and a variety of phthalate esters are imported into Canada as commercial chemicals and in association with manufactured products. The manufacture of phthalate esters can result in their release to the environment, as can the manufacture, use, and disposal of products containing these chemicals. Losses associated with the production of phthalate esters are primarily to the atmosphere. Other potential sources include effluents from a variety of industries, wastewater treatment plants, combined sewer overflows, urban stormwater, stack emissions from coal-fired power plants and hazardous waste combustion, and flyash from municipal incinerators (Environment Canada/Health Canada 1993a,b,c; Environment Canada/Health Canada 2000; Garrett 2004; Giam *et al.* 1984; Pierce *et al.* 1980).

Uptake of phthalate esters has been observed in a variety of aquatic species; however, there is evidence that some laboratory studies have overestimated the potential for uptake. In general, bioconcentration factors (BCFs) are highest for algae, intermediate for invertebrates, and lowest for fish, since the ability to metabolize these compounds tends to increase in the higher levels of the food chain. It has been speculated that biomagnification in the aquatic food chain is unlikely; however, studies on biomagnification are lacking (Brown and Thompson 1982; Carr *et al.* 1997; Staples *et al.* 1997a; Tarr *et al.* 1990; Wofford *et al.* 1981; Wolfe *et al.* 1980a,b; Yan *et al.* 1995).

Low molecular weight phthalate esters (alkyl chain lengths of up to 4 carbon atoms), such as DMP, DEP, DBP, and BBP, were acutely toxic to aquatic organisms in the μg/L to mg/L range. The higher molecular weight compounds (such as DEHP and DiDP) are less water soluble and did not exhibit acute toxicity at water concentrations approaching solubility. Aquatic organisms exposed to phthalate esters in laboratory experiments exhibited decreased survival of various life stages, decreased growth and development, reduced locomotor activity, impaired reproduction and fertility, and alterations in steroid metabolism. Weak estrogenic activity has also been attributed to some phthalate compounds (Adams *et al.* 1995; DeFoe *et al.* 1990; Parkerton and Konkel 2000; Rhodes *et al.* 1995; Staples *et al.* 1997a,b).

DBP, DEHP, DnOP, and BBP were assessed by Environment Canada and Health Canada to determine whether these substances were toxic as defined by CEPA 1999. Only DEHP was found to be toxic; however, it was recommended that no further risk management actions be pursued at this time since a link has not been established between the manufacture and/or use of DEHP and human exposure (Environment Canada/Health Canada 1993a,b,c; Environment Canada/Health Canada 2000).

Interim Canadian water quality guidelines for the protection of freshwater aquatic life are 16 μg/L for DEHP and 19 μg/L for DBP. Canadian guidelines have not been developed for marine waters or for sediments (CCME 1999; CCME 2006). CCME guidelines are available on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. There are no BC provincial guidelines for phthalate esters.

1 Phthalate esters are referred to by the following abbreviations:
DMP - dimethyl phthalate
DEP - diethyl phthalate
DBP - di-n-butyl phthalate
BBP - butylbenzyl phthalate
DEHP - bis(2-ethylhexyl)phthalate or di(2-ethylhexyl) phthalate
DnOP - di-n-octyl phthalate
DIDP - diisodecyl phthalate
DAP - diallyl phthalate
DIBP - diisobutyl phthalate

2.3.2 Georgia Basin

Phthalate esters are used by the paints, coatings, rubber, and resin industries in BC. The BC plastics industry did not report the use of phthalate esters as raw materials, but it is likely that this industry sector imports resin bases already containing phthalate ester plasticizers (Krahn 1985a,b; Sigma, 1985; Sigma, 1986). The phthalate esters contained in numerous products in BC can be released to the environment during product use and/or following disposal. Information on sources and loadings of phthalate esters to the Georgia Basin is limited; however, these compounds have been identified in WWTP effluents, CSOs, and urban runoff in Metro Vancouver, and in WWTP discharges in the Capital Regional District (CRD). Atmospheric deposition is thought to be an important source of phthalate esters to the aquatic environment; however, no information was available on the atmospheric deposition of these compounds in the Georgia Basin.

Due to their widespread use, phthalate esters can occur as contaminants in laboratory air and reagents as well as in analytical and sampling equipment (Ishida *et al*. 1980). This has resulted in the inadvertent contamination of environmental samples during collection and/or analysis. Although recent information on concentrations of phthalate esters in the environment is considered to be more reliable, care must be taken in the interpretation of all analytical results for phthalate esters due to the potential for sample contamination.

Environmental concentrations of phthalate esters are typically highest in industrial and urban areas, particularly near facilities manufacturing or using these compounds. Information on concentrations of phthalate esters in the aquatic environment of Georgia Basin is limited and, as in studies conducted elsewhere, problems associated with sample contamination have been documented. However, several phthalate esters compounds were present in blank-corrected data for sediments and aquatic biota from several sites in the Georgia Basin including the Fraser River, False Creek, and Vancouver, Victoria, Esquimalt and Ladysmith harbours (Garrett 2002, Garrett 2004; Lin *et al*. 2003; Mackintosh *et al*. 2004). In addition, phthalate esters have been detected in surf scoters from Burrard Inlet (Wilson and Elliott 2004).

While there are currently no Canadian sediment quality guidelines for phthalate esters, some samples contained concentrations of individual phthalate ester compounds that exceeded the non-regulatory apparent effects threshold (AET) values for Puget Sound and also the Puget Sound Dredged Disposal Analysis Sediment Quality screening levels (Garrett 2002; Mackintosh *et al.* 2004; Paine and Chapman 2000).

2.3.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to phthalate esters in the Georgia Basin include:

Obtain current information on environmental levels by:

- developing and employing standardized procedures for the collection and analysis of samples in order to minimize sample contamination and improve data reliability;
- compiling a list of possible hot spots of environmental contamination in the Georgia Basin in the vicinity of wastewater discharges and obtaining loadings estimates, where possible;
- obtaining additional information on phthalate ester concentrations in sediments and in shellfish and fish, particularly those species which are harvested commercially and/or recreationally for human consumption; and
- determining the presence of phthalate esters in amphibians, aquatic birds, and mammals in the Georgia Basin.

Develop a better understanding of biological effects by:

- evaluating the toxicity of sediment-associated phthalate esters to regionally relevant species.

Develop a better understanding of the environmental fate and distribution by:

- obtaining more information on the bioaccumulative potential of phthalate ester compounds and on their food-chain biomagnification.

Obtaining more information on non-point (and other) sources and loadings by:

- identifying current sources of phthalate esters to the Georgia Basin which have the potential to be controlled.

2.3.4 Management Actions and Needs

To date, there have been no management actions to specifically address the presence of phthalate esters in the Georgia Basin; however, various national initiatives have been implemented. Four phthalate ester compounds (DBP, DEHP, DnOP, BBP) were assessed under CEPA 1999 (and the earlier version, CEPA 1988), and DEHP was found to be toxic (as defined by CEPA) due to human health concerns. Under the requirements of CEPA a risk management strategy was developed for DEHP by Environment Canada and Health Canada; however, it was recommended that further risk management actions not be pursued at this time as an identifiable link between human exposure and the manufacture and/or use of DEHP-containing plastics has not been established. Health Canada is continuing to monitor the levels of DEHP in foods through its market basket survey program (Environment Canada/Health Canada 1993a,b,c; Environment Canada/Health Canada 2000; Government of Canada 2000).

In general, data gaps and research/monitoring needs should be addressed prior to the implementation of additional management actions to address the presence of phthalate esters in the Georgia Basin. However, Canadian marine and freshwater sediment quality guidelines for the protection of aquatic life and Canadian ocean disposal criteria for these compounds are needed. In addition, efforts to reduce the release of contaminants to the environment from contaminated sites, municipal WWTPs, storm sewers, CSOs, and agricultural runoff should continue and will help to reduce phthalate ester loadings to the environment.

2.4 Chlorinated Paraffins, Polychlorinated naphthalenes, and Fluorinated Organic Compounds

2.4.1 Background Information

Chlorinated paraffins are chlorinated derivatives of n-alkanes whose chlorine content ranges from 30 to 70% by weight. The carbon chain lengths range from 10 to 38 carbons. Short-chain chlorinated paraffins (chain lengths of 1 to 13 carbons) are imported into Canada while the medium-long (chain lengths of 14 to 17 carbons) and long-chain chlorinated paraffins (chain lengths of 18 or more carbons) are both imported and produced in Canada. One Canadian plant, located in Cornwall Ontario, produces medium- and long-chain chlorinated paraffins. These compounds are used primarily as plasticizers and flame retardants in plastics and in extreme-pressure lubricants. In 2000 and 2001, the annual use of chlorinated paraffins in Canada was approximately 3000 t. Most of this was used in plastics, lubricants, and metalworking (Environment Canada/Health Canada 1993d).

Chlorinated paraffins can potentially be lost to the environment during their manufacture, use, transport, and disposal; however, information on such losses is limited. Manufacturing and lubricant applications are thought to be among the major sources and losses can occur from the manufacture, use, and disposal of products such as polyvinyl chloride (PVC) plastics and from the use of metalworking and metal cutting fluids containing chlorinated paraffins. Losses from manufacturing facilities and from the use of metalworking fluids would likely enter sewer systems. Short-chain chlorinated paraffins have been detected in municipal WWTP effluents and medium-chain chlorinated paraffins have been detected in sewage sludge. There are no natural sources of chlorinated paraffins to the environment (Alcock *et al.* 1999; Campbell and McConnell 1980; Environment Canada 2004; Iino *et al.* 2001; Metcalfe-Smith *et al.* 1995; Muir *et al.* 1999).

Polychlorinated naphthalenes or PCNs (also called chlorinated naphthalenes or polychloronaphthalenes) consist of naphthalene rings where one to eight hydrogen atoms are replaced with chlorine atoms forming 75 possible isomers. They are structurally similar to PCBs, PCDDs, and PCDFs and trace concentrations of these substances have been detected in technical PCN formulations. Commercial products are mixtures of several congeners and are used primarily in electroplating, insulation for cables, impregnators for condensers and capacitors, refractive index testing oils, dye carriers and feedstocks for dye productions, and as additives to engine oil. In the 1940s and 1950s, these substances were also used for wood preservation. The production of these substances was discontinued in the United States and Europe in the 1980s. At the time that the production of PCNs was discontinued in the United States, they were being used primarily in refractive index testing oils and as dielectric fluids in capacitors. PCNs have been detected in the environment in the vicinity of some municipal sewage and industrial discharges (including chlor-alkali plants) and in chlorine bleach pulp mill effluents. In addition, the chlorination of drinking water supplies has been shown to cause its formation. Other sources to the environment include waste incineration and the landfill disposal of products containing PCNs. PCNs are also present as micro-contaminants in commercial PCB formulations and; therefore, PCNs likely entered the environment in association with PCBs. PCNs have been detected in the flue gas and fly ash of municipal incinerators, in emissions from the incineration of chlorinated phenols, HCB, and PCBs, and in the percolating water at a city dump in Sweden. The domestic burning of coal and wood as fuel was also identified as a minor source in the United Kingdom (Abad *et al.* 1999; Haglund *et al.* 1993; Helm and Bidleman 2003; Howe *et al.* 2001; Iino *et al.* 2001; Imagawa and Takeuchi 1995; Jarnberg *et al*. 1993; Jarnberg *et al.* 1997; Jarnberg *et al.* 1999; Kannan *et al.* 1998a; Kannan *et al.* 2000; Kim and Mulholland 2005; Kodavanti *et al.* 2001; Lee *et al.* 2005; Oehme *et al.* 1987; Oehme *et al.* 1996; Shiraishi *et al.* 1985; Yamashita *et al.* 2000). Unlike PCBs, there is currently no information on the volume of PCNs still present in electrical equipment in Canada and no inventory of potential sources or estimation of loadings to the Canadian environment have been conducted (Mendoza 2005, personal communication).

Fluorinated organic compounds (FOCs), particularly the perfluorinated acids (PFAs), have received considerable attention recently due to their widespread presence and persistence in the environment. These compounds have a wide range of uses including refrigerants, agricultural chemicals, chemical catalysts, surfactants, and fire-fighting foams. The perfluoroalkyl sulfonic acid, perfluorooctane sulfonate (PFOS), and the perfluoroalkyl carboxylate, perfluorooctanoate (PFOA), have been identified in air, water, and biota worldwide and are of global concern (Butt *et al*. 2005; Environment Canada 2006b; Houde *et al*. 2006; Tomy *et al*. 2004b; Tomy *et al*. 2005).

Environment Canada conducted a use pattern survey on PFOS, its salts, and precursors in 2000. The survey found that, while these compounds are not manufactured in Canada, they were imported as raw chemicals and in products and manufactured items. Approximately 318 tonnes of these compounds were used in Canada between 1997 and 2000. Their major uses included stain repellents for fabric, leather, packaging, rugs, and carpets; additives in fire-fighting foams; additives in paints and coatings; and in chemical formulations. The primary Canadian supplier, 3M, voluntarily phased out the production of these substances at the end of 2002. The production of these substances continues in other countries; however, and it is possible that PFOS-containing substances could be imported into Canada from sources outside of the United States (Environment Canada 2006b).

Similar use pattern information is not available for PFOA; however, Dupont and several other American companies recently announced that they will reduce PFOA emissions during manufacturing and also reduce the presence of PFOA in consumer products by 90% by 2010 and virtually eliminate them by 2015. In addition, Dupont will make changes to their manufacturing methods for Teflon® to prevent exposure to PFOA (US EPA 2008; Washington Post 2006).

Chlorinated paraffins, PCNs, and FOCs are persistent in the environment, have the potential to bioaccumulate, and are toxic to a wide variety of organisms.

It has been estimated that both the short- and medium-chain chlorinated paraffins have a half-life in lake sediment of more than one year. While the persistence of the long-chain forms has not been determined, their physical and chemical properties indicate that they would also be persistent in sediments. The BCFs for chlorinated paraffins in aquatic biota are high. BCFs of 16,440 to 25,650 for short-chain paraffins were reported for trout from Lake Ontario, and BCFs of 5785 to 138,000 were measured in mussels. Medium- and long-chain chlorinated paraffins also bioaccumulate in aquatic organisms and the potential for some chlorinated paraffins to biomagnify has been reported (Fisk *et al.* 1996; Fisk *et al.* 1998; Marvin *et al.* 2003).

Short-chain chlorinated paraffins exhibit the highest toxicity to aquatic organisms. Adverse effects have been observed in fish and aquatic invertebrates at concentrations of less than 1 µg/L. In addition, exposure to short-chain chlorinated paraffins has resulted in cancer in experimental animals (Environment Canada 2004; Environment Canada 2006d; Environment Canada/Health Canada 1993d; WHO 1996).

Chlorinated paraffins were assessed by Environment Canada and Health Canada under the provisions of CEPA 1999. On June 11, 2005 in the Canada Gazette, the Ministers of Environment and Health announced their recommendation that short, medium, and long-chain chlorinated paraffins be added to the List of Toxic Substances in Schedule 1 of CEPA 1999 and proposed these substances for virtual elimination (Environment Canada 2006d).

Chlorinated paraffins have been detected in the Canadian environment in various environmental media including surface waters, sediments, fish, invertebrates, and marine mammals. In addition, the presence of short-chain chlorinated paraffins in Arctic regions removed from known sources indicates that long-range transport of short-chain chlorinated paraffins does occur. Short-chain chlorinated paraffins have been detected in municipal WWTP effluents, while medium-chain compounds have been detected in sewage sludge. Medium-chain chlorinated paraffins have been detected in the effluents from a chlorinated paraffin manufacturing plant and also in sediments collected near this facility. Long-chain chlorinated paraffins have been detected in sediments and aquatic biota collected in the vicinity of a chlorinated paraffin manufacturing facility in Australia. The highest concentrations of chlorinated paraffins are typically detected in urban areas (Bennie *et al.* 2000; Helm *et al.* 2002; Muir *et al.* 1999; Muir *et al.* 2001; Reth *et al.* 2005; Reth *et al.* 2006; Tomy *et al.* 1997; Tomy *et al.* 1998; Tomy *et al.* 1999; Tomy *et al.* 2000).

PCNs are also widespread and persistent environmental contaminants and are expected to bind to sediments and soils, with the more highly chlorinated congeners having a stronger tendency for sorption. Little information is available on the atmospheric transport and deposition of these chemicals; however, the potential for volatilization is greater for the lower chlorinated congeners. There is some evidence that PCNs associated with particulate matter can be removed from the atmosphere by rain; however, the presence of these compounds in Arctic and Antarctic regions is indicative of long-range transport and atmospheric stability (Corsolini *et al.* 2002; Harner *et al.* 1998; Helm *et al.* 2004; Herbert *et al.* 2005).

BCFs of PCNs are moderate to high, depending on the level of chlorination of the compound. Bioaccumulation of PCN congeners, up to and including the hexachlorinated naphthalenes, has been observed. The bioaccumulation of the hepta- or octachlorinated forms is considered unlikely due to the large size of the higher chlorinated molecules which makes it difficult for them to permeate membranes. Despite this fact, hepta-isomers have been detected in some fish. PCNs have been detected in sediments, invertebrates, fish, several fish-eating birds and birds of prey, and marine mammals. In addition, PCNs have been detected in endangered Vancouver Island marmots and in three distinct killer whale communities which frequent the waters of coastal BC. Tetra- and pentachloronaphthalenes are among the dominant congeners detected in species from all trophic levels. There is evidence that some PCN congeners can be biomagnified (Falandysz *et al.* 1996; Ishaq *et al.* 2000; Lundgren *et al.* 2002; Oliver and Niimi 1984; Oliver and Niimi 1985; Opperhuizen *et al.* 1985; WHO 2001).

PCNs are acutely toxic to aquatic organisms in the µg/L to mg/L range. The tri- to hexachlorinated naphthalenes are typically the most toxic congeners, while octachlorinated naphthalene is less toxic due to the fact that it is not readily accumulated by organisms. Some PCN congeners cause toxic effects similar to those of dioxins and enzyme induction tests indicate that the relative potencies of some of the higher chlorinated PCN congeners, especially the 2,3,6,7-chlorine substituted compounds, are similar to or greater than those of many non- and mono-ortho substituted PCBs (Abernethy *et al.* 1986; Blankenship *et al.* 2000; Buccafusco *et al.* 1981; Green and Neff 1977; Heitmuller *et al.* 1981; Ward *et al.* 1981; US EPA 1980). Hepatotoxicity, induction of EROD activity, delayed development, and impaired ovaries were observed in Baltic salmon fed PCN-contaminated food (Akerblom *et al.* 2000).

Despite the widespread occurrence of FOCs in the environment, the environmental fate, distribution, and transport of these substances is not well understood. These substances have been detected in a variety of media throughout the world, including surface waters, biota, and humans. PFOS and PFOA are biologically and chemically stable due to the strength of their carbon-fluorine bonds. These compounds are extremely persistent in the environment and resist both metabolism and degradation. Their presence in Arctic regions is of interest in that their chemical and physical properties suggest that they would be less likely to be transported via long-range atmospheric transport than are most of the other POPs detected in Arctic regions. It has been speculated that the more volatile and environmentally mobile precursors of these substances are transported to Arctic regions, where they are then transformed to PFOS and PFOA. Of the perfluorinated chemicals which have been measured in the environment, PFOS is detected more commonly than other FOCs and at higher concentrations. Samples collected in the environment near coastal and urban areas typically have higher concentrations than do samples collected at sea (Bossi *et al.* 2005; Boudreau *et al.* 2003; Giesy and Kannan 2001; Hekster *et al.* 2003; Holmstrom *et al.* 2005; Houde *et al.* 2006; Hurley *et al.* 2003; Kannan *et al.* 2001a,b; Kannan *et al.* 2002a,b; Martin *et al.* 2003a,b; Smithwick *et al.* 2005; Solomon and Muir 2006; Tomy *et al.* 2004a,b; Van de Vijver *et al.* 2004; Verreault *et al.* 2005).

Several studies have confirmed that PFOS bioaccumulates in aquatic organisms. BCFs for juvenile rainbow trout (*Oncorhynchus mykiss*) were estimated to be 1100 in the carcass, 5400 in the liver, and 4300 in the blood. Another study estimated that BCFs in the liver tissue of 23 different species of fish from Japan ranged from 274 to 41,600 (with a mean of 5500). Unlike many other POPs, PFOS does not accumulate in the fat tissue, but elevated concentrations have been detected in the blood and liver of a variety of species, particularly higher trophic level species which feed on fish. Evidence of biomagnification has been observed in the Arctic food chain (Giesy and Kannan 2001; Martin *et al.* 2003a,b; Martin *et al.* 2004; Smithwick *et al.* 2005; Smithwick *et al.* 2006; Taniyasu *et al.* 2003; Tomy *et al.* 2004a; Van de Vijver *et al.* 2003a,b).

Information on the toxicity of FOCs is limited and most of the available toxicity information pertains to PFOS. Adverse effects have been observed in both aquatic and terrestrial species exposed to PFOS. These included inhibition of growth, thymus atrophy, histopathological effects, and increased mortality. No-observed-effect concentrations (NOECs) for aquatic species, based on various endpoints, were in the mg/L range. The lowest NOEC for aquatic species was 0.086 mg/L and was based on a study with bluegill (*Lepomis macrochirus*). NOECs for birds and mammals exposed to PFOS in dietary studies were in the low mg/L or mg/kg range. Exposure to PFOS precursors can cause adverse effects at similar concentrations (Health Canada 2006b). There is some information suggesting that birds and mammals have a greater ability to biotransform PFOS precursors to PFOS than do organisms at lower trophic levels. It has been suggested that both PFOS and PFOA may function as hepatocarcinogens, but the potential long-term effects of both PFOS and PFOA have not been well studied (Boudreau *et al.* 2002; Boudreau *et al.* 2003; Environment Canada 2006a; Health Canada 2006b). In addition, the US Environmental Protection Agency (EPA) has expressed concern that human fetuses may be exposed to PFOA concentrations high enough to cause adverse effects (Renner 2005).

There are currently no Canadian environmental quality guidelines for chlorinated paraffins, PCNs, or FOCs (CMME 2006).

2.4.2 Georgia Basin

Sources of chlorinated paraffins, PCNs, and FOCs to the Georgia Basin have not been determined. However, the fact that these substances have been detected in the effluents and/or sludges from municipal WWTPs in other areas suggests that these types of facilities are also likely sources of these compounds to the Georgia Basin. In addition, the ultimate use and disposal of products containing these substances results in non-point releases to the environment.

Information on the presence of chlorinated paraffins, PCNs, and FOCs in the Georgia Basin environment is lacking; however, PCNs have been detected in Vancouver Island marmots and in south resident, north resident, and transient killer whales frequenting the BC coast (Lichota *et al.* 2004; Rayne *et al.* 2004).

2.4.3 Data Gaps and Research/Monitoring Needs

Many of the data gaps and research/monitoring needs specific to chlorinated paraffins, PCNs, and FOCs in the Georgia Basin are similar to those identified for legacy POPs and include:

Obtain current information on environmental levels by:

- measuring the presence of these compounds in the environment (all media) in select areas of the Georgia Basin;
- identifying suitable indicator organisms for low level contaminants;
- utilizing passive methods such as SPMDs and SPMEs to monitor environmental concentrations;
- conducting congener-specific environmental measurements of these substances as total measurements are inadequate for predicting fate and effects; and
- as required, developing best analytical and laboratory procedures to ensure accurate and reliable results.

Develop a better understanding of biological effects by:

- evaluating the cumulative effects of low concentrations of chlorinated paraffins, PCNs, and FOCs on locally important species including salmon;
- assessing the effects of chlorinated paraffins, PCNs, and FOCs on early life stages of aquatic species including salmon;
- developing a better understanding of local and global effects of individual substances;
- determining the potential for current levels of chlorinated paraffins, PCNs, and FOCs to cause endocrine disruption and other toxic effects; and
- investigating the use of innovative bioassay methods (e.g., gene chip technologies, etc.) for long-term monitoring of dioxin-like and endocrine-disrupting compounds.

Develop a better understanding of environmental fate and distribution by:

- examining the fate of new and emerging POPs such as chlorinated paraffins, PCNs, and FOCs in water, sediments, sludge, and biosolids.

Obtain more information on non-point (and other) sources and loadings by:

- inventorying usage and suspected sources of chlorinated paraffins, PCNs, and FOCs, including the continued use of PCNs in electrical equipment, and estimating loadings from potential sources such as municipal WWTPs, storm sewers, CSOs, landfills, and urban runoff.

2.4.4 Management Actions and Needs

Chlorinated paraffins were assessed by Environment Canada and Health Canada to determine whether these substances were toxic as defined by CEPA 1988. The assessment report, which was published in 1993, concluded that short-chain chlorinated paraffins were toxic to human health. However, insufficient information was available on the medium- and long-chain chlorinated paraffins to make a conclusion regarding their toxicity to human health. In addition, information was insufficient to determine whether short-, medium-, and long-chain chlorinated paraffins were toxic to environmental health. In 2004, Environment Canada and Health Canada completed subsequent assessments of short-, medium-, and long-chain chlorinated paraffins. On June 11, 2005, the Ministers of Environment and Health announced in the Canada Gazette, their intention to recommend that short-, medium-, and long-chain chlorinated paraffins be added to the CEPA 1999 Schedule 1 List of Toxic Substances and to propose these substances for virtual elimination (Environment Canada 2006d). For additional information refer to http://www.ec.gc.ca/substances/ese/eng/psap/PSL1_chlorinated_paraffins.cfm.

Environment Canada and Health Canada recently conducted Screening Level Risk Assessments (SLRA) on PFOS, its salts, and precursors (Environment Canada 2006b; Health Canada 2006b). As a result, it was recommended that PFOS, its salts and precursors be added to CEPA 1999, Schedule 1 List of Toxic Substances. Proposed *Perfluorooctane Sulfonate and Its Salts and Certain Other Compounds Regulations* were published in the *Canada Gazette*, Part I, on December 16, 2006 and final regulations were published in the Canada Gazette, Part II on June 11, 2008. For additional information, refer to the website http://www.ec.gc.ca/TOXICS/EN/detail.cfm?par_substanceID=230&par_actn=s1.

In addition, assessments of four fluorotelomer-based substances conducted by Environment Canada and Health Canada found that these substances were also likely to meet the criteria for toxicity as defined by CEPA-1999, and are sources of long-chain perfluorinated carboxylic acids (PFCAs) to the environment. As a precautionary measure, a two-year prohibition on these substances was implemented by Environment Canada to allow new information to be generated and reviewed (Environment Canada 2006c). These substances have been proposed for addition to the Schedule 1 List of Toxic Substances. For more information, refer to http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=6B9B6B28-1&xml=F68CBFF1-B480-4348-903D-24DFF9D623DC. Environment Canada and Health Canada have also developed an Action Plan to address PFCAs and their precursors. For additional information refer to http://www.environmentaldefence.ca/toxicnation/whatGovDo/PFCA%20Action%20Plan%20for%20Consultations%20v6.pdf.

No management action needs specific to these substances have yet been identified for the Georgia Basin.

3. Current-Use Pesticides

A wide range of pesticides are used in BC for the protection of agricultural crops from diseases and pests, for the treatment of standing and cut timber by the forest products industry, for the control of unwanted vegetation in electrical and railway rights-of-way, for the prevention of fouling on boat and ship hulls, and for the treatment of insect and fungal pests and unwanted vegetation by both businesses and homeowners in urban areas.

The use of pesticides can result in their entry to aquatic systems in a variety of ways. In most cases, the release of pesticides to surface waters is unintentional. For example, inadvertent overspraying during the aerial application of pesticides to crops and forested regions can release pesticides directly to adjacent waterways. However, the indirect release of pest control products to nearby surface waters as a result of agricultural runoff or infiltration to groundwater and by atmospheric deposition are more common concerns. Similarly, urban runoff transports pest control products used by businesses and homeowners to storm sewers and, ultimately, to surface waters. In some instances, pesticides are intentionally applied directly to aquatic systems for the control of mosquito larvae or unwanted vegetation. In addition, pesticides contained in antifouling paints applied to the hulls of boats and ships to prevent the build-up of algae and barnacles, enter surface waters as a result of leaching from painted hulls and during the removal and application of paints to hulls. While the number of pesticides detected in groundwater is usually less than in surface water, the relatively slow movement of groundwater and closed geochemical conditions, compared to surface water, allow some pesticide compounds (e.g., 1,2-DCP) to persist in groundwater for decades after application of the product has been discontinued at the land surface (Graham 2009, personal communication).

In 1991, 1995, 1999 and 2003, surveys of pesticide sales in BC were conducted to help identify trends in pesticide use in BC. The top twenty pesticides sold or used in BC in 2003 are presented in Table 1. The greatest volume of pesticides sold in BC (approximately 72%) is used for wood preservation and for antisapstain treatment of cut lumber (ENKON 2001a; ENKON 2005; Norecol, Dames & Moore 1997; Norecol Environmental Consultants 1993).

Table 1 The Top Twenty Pesticides Sold or Used in BC in 2003 (from ENKON 2005)[1]

Pesticide Active Ingredient	Pesticide Type	Quantity (kg)
Creosote	Anti-microbial	2,163,142
CCA	Anti-microbial	824,100
Mineral Oil	Insecticidal or adjuvant	317,108
Didecyl dimethyl ammonium chloride	Anti-microbial	174,606
Pentachlorophenol	Anti-microbial	147,684
Glyphosate - Trimethylsulfonium salt	Herbicide	120,724 5,545
Bacillus thuringiensis Berliner ssp.*kurstaki*	Insecticide	85,765
ACQ	Anti-microbial	74,448
Sulphur	Fungicide	73,408
Bacillus thuringiensis, Serotype H-14	Insecticide	39,153
Mancozeb	Fungicide	34,888
Chlorothalonil	Fungicide	33,505
Metam	Fumigant	28,582
Diazinon	Insecticide	27,074
Captan	Fungicide	25,500
Disodium octaborate tetrahydrate	Anti-microbial	24,679
MCPA a.) amine salts; b.) esters; c.) potassium or sodium salt	Herbicide	23,598 (total) a.) 9,125; b.)12,810 c.) 1663
Mineral oil	Herbicide	23,575
Formaldehyde	Anti-microbial	21,822
Lime sulphur	Fungicide	20,524
Copper oxychloride (as Cu)	Fungicide	19,562

[1] This list does not include domestic-use pesticides

Forty of the pesticide active ingredients sold in BC appear on one or more lists of chemical contaminants of potential concern in the Georgia Basin and/or the Puget Sound. These lists include the Substances of Interest List for the Lower Fraser River and the Georgia Basin (Appendix 4), which is utilized by the BCTWG; the list of contaminants of concern in the Puget Sound which was prepared for the United States National Oceanic and Atmospheric Administration (NOAA) for consideration by the PS/GB ITF; the list of contaminants identified in report prepared for the Southern Resident Killer Whale Recovery Team, whose presence in the environment pose a health risk to southern resident killer whales; and the list of contaminants identified in a DFO report, whose presence in the environment may pose a risk to late-run sockeye salmon. Eight of these active ingredients were found on two or more of these lists. These include atrazine, simazine, chlorpyrifos, malathion, metolachlor, endosulfan, trifluralin, and lindane. Four of the active ingredients, atrazine, endosulfan, malathion, and metolachlor, were among the top 20 list of pesticides sold in the Georgia Basin (ENKON 2005; Grant and Ross 2002; Johannessen and Ross 2002; Verrin *et al.* 2004).

Pest control products identified by the BCTWG to be of the highest potential concern in the Georgia Basin include toxic high volume current use agricultural pesticides such as atrazine and endosulfan, antisapstain chemicals including IPBC and DDAC, wood preservatives including creosote and the copper-, chromium- and arsenic-based compounds, and butyltin and copper-based antifoulants.

3.1 Current-Use Agricultural Pesticides

In the initial identification of priority substances of concern in the Georgia Basin, the BCTWG selected atrazine and endosulfan as the current-use agricultural pesticides of highest priority and profiles were prepared for these substances (Garrett 2004). However, after further consideration, the BCTWG made the decision to include all current high-use toxic pesticides. The following summary focuses primarily on atrazine and endosulfan (as summarized from Garrett, 2004). However, the recommendations presented for both research/monitoring and management actions apply to all high volume toxic pesticides currently in use by the BC agricultural sector.

3.1.1 Background Information

In general, pesticides currently used in Canada are much less persistent and present fewer environmental concerns than did many of the pesticides used in the past. However, several agricultural pesticides currently used within the Georgia Basin have the potential to impact non-target species of fish, aquatic invertebrates, and vegetation if they enter aquatic systems in elevated concentrations. In addition, some pest control products, such as endosulfan, are toxic to birds and mammals. Atrazine and endosulfan are on two or more lists of chemical contaminants of concern in the Georgia Basin and/or the Puget Sound and both pesticides are also among the top 20 reportable pesticides used in BC (ENKON 2005).

Atrazine is a selective, systemic herbicide used mainly for the pre- and post-emergence control of annual broadleaf and grass weeds in corn and lowbrush blueberries. Other uses include the treatment of turf grasses and asparagus; forestry applications; domestic application for algae control in aquariums and ponds; commercial weed control; and soil sterilization on non-croplands, such as airfields, parking lots, and industrial sites (CCME 1987; CCME 1999).

Endosulfan is an organochlorine insecticide which is used for the control of a large spectrum of insect pests. It exists in two isomeric forms, alpha (α) and beta (β) (also called I- and II- isomers, respectively). In Canada, 11 products containing endosulfan are registered for domestic and commercial use for the control of insects on fruit and ornamental trees and shrubs and also for the control of insects on alfalfa, clover, corn, melons, potatoes, sunflowers, strawberries, and tobacco (CCME 1987).

Pesticides may enter the aquatic environment during production, spillage, use, and disposal. Pesticides applied to crops can enter nearby waterways in surface runoff and can contaminate groundwater, drinking water wells, and surface water bodies receiving groundwater baseflow or discharge. It is estimated that up to 3% of the atrazine applied to agricultural land may ultimately enter nearby aquatic systems via runoff, drainage, and spills. The majority of atrazine loss via surface runoff occurs immediately following application (usually at the end of June and July) and during rainstorm runoff events (CCME 1987; US EPA 2002). Endosulfan is applied either aerially or by ground spraying and enters the aquatic environment primarily as a result of pesticide drift during spray application, leaching from soils into runoff, and vapour transport. Incidents of accidental environmental contamination have also been reported (CCME 1987; Raupach *et al.* 2001). Atmospheric deposition is another important route of pesticides to the aquatic environment. Pesticides used in agricultural areas can volatilize and can then be deposited in other areas in rainfall and dry deposition.

Adverse effects observed in fish and aquatic invertebrates exposed to pesticides include developmental effects, immunosuppression, renal function alteration, olfactory effects, reduced hatching success, larval mortality, acetylcholinesterase inhibition, and endocrine disruption. The toxicity of pesticides to aquatic organisms varies significantly between species. Phytoplankton are the most sensitive aquatic organisms to atrazine followed by macrophytes, benthic invertebrates, zooplankton, and fish. Acute toxicity of atrazine ranges from a low of 4 μg/L in phytoplankton to a low of 550 μg/L in fish. Chronic and sublethal effects can occur at much lower concentrations. For instance, renal function alteration was observed in rainbow trout exposed to atrazine concentrations of 5 to 40 μg/L. Some studies reported olfactory effects in salmon following exposure to atrazine. Atrazine can also cause reductions in primary productivity and changes in the structure and function of aquatic communities as a result of the loss of sensitive species, and may be implicated in global declines in amphibian populations. Hermaphroditic and de-masculinizing effects of atrazine on the larval development of African clawed frog have been reported at concentrations of 1.0 μg/L or higher (Hayes *et al.* 2002). Metabolites of atrazine can continue to pose risks to the microbial food web after the parent material has disappeared, indicating that widespread and long lasting effects on photosynthetic inhibition can occur in areas where atrazine is commonly used. Atrazine is reported to be slightly acutely toxic and chronically toxic to birds and mammals (CCME 1999; US EPA 2002).

Endosulfan is one of the most toxic pesticides to freshwater, marine, and estuarine fish. The mean acute toxicity for the most sensitive species tested ranged from 0.1 μg/L in striped bass (marine) to 0.34 μg/L in rainbow trout (freshwater) and endosulfan is as, or slightly less, toxic to invertebrate species. In addition, studies have shown that the intermediate degradate, endosulfan diol, was highly toxic to freshwater invertebrates (Thurman *et al.* 2001). Poisoning of aquatic organisms by endosulfan is one of the most frequently reported causes of pesticide poisoning in the United States. Endosulfan has also been shown to be highly toxic to birds and mammals. Reproduction and growth were the most sensitive endpoints in chronic studies (CCME 1987; Thurman *et al.* 2001).

The potential adverse effects of substances added to pest control products as carriers to improve their performance, application, efficacy, and shelf life needs further investigation. These substances can constitute up to 90% of commercial pesticide formulations. There is a potential for large quantities of these substances to enter the environment in areas of heavy pesticide use. These substances are often referred to as adjuvants or "inert" ingredients; however, some of these ingredients are known to be toxic and some can cause endocrine disruption. Recent revisions to the PCPA require pesticide manufacturers to remove toxic additives or to list these substances on the label. PMRA developed a list of substances which were to be removed from commercial formulations by January 2005 and also a list of substances which formulators were required to identify on pesticide labels by January 2006. For more information, refer to the PMRA website (http://www.pmra-arla.gc.ca/english/appregis/memoranda-e.html).

While some current-use agricultural pesticides do not significantly bioaccumulate in aquatic biota, others are capable of significant bioaccumulation in some species. Atrazine is not expected to significantly bioconcentrate or biomagnify due to its tendency to be metabolized and eliminated in biota. Dietary exposures of molluscs, leeches, Cladocera and fish to atrazine have not resulted in its accumulation (CCME 1999). However, the bioaccumulation of endosulfan has been demonstrated in aquatic species and bioconcentration factors (BCFs) ranged from 10 to 10^2 for fish, 10^2 to 10^3 for algae, and mosquito larvae and 10^3 to 10^4 for snails. The BCF for saltwater mussels was approximately 10^2. However, endosulfan is rapidly eliminated by aquatic organisms once exposure has terminated. There is evidence to suggest that the isomers of endosulfan can persist in fish and that endosulfan is poorly metabolized and converted mainly to endosulfan sulphate (CCME 1987; Ramaneswari and Rao 2000).

Canadian environmental quality guidelines have been developed for some current-use pesticides including atrazine and endosulfan (CCME 1999; CCME 2006). Interim water quality guidelines for atrazine and endosulfan for the protection of freshwater aquatic life are 1.8 μg/L and 0.02 μg/L, respectively. There are currently no Canadian guidelines for atrazine and endosulfan in marine water or in sediments. CCME guidelines can be viewed on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. BC provincial guidelines have also been developed for some current-use pesticides and are available on-line at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html.

3.1.2 Georgia Basin

Surveys of pesticide sales in BC indicate that the sales of agricultural pesticides doubled in BC between 1991 (42,083 kg) and 1999 (86,565 kg). Information on the types and quantities of agricultural pesticides sold in BC for use on specific crops is contained in the use survey report for 2003. This report also contains some information on the adjuvants or "inert" ingredients in pest control products sold in BC; however, the information is not considered to be complete (ENKON 2005).

Atrazine is used primarily in BC as a selective herbicide on corn. In addition, some atrazine products are labelled for use on triazine tolerant canola. Based on past pesticide sales inventories, the use of atrazine in BC appeared to have decreased over the last decade with sales of this pesticide for 1991, 1995 and 1999 being 22,898, 10,928 and 9,991 kg, respectively. However, sales of atrazine were higher in 2003 (11,535 kg) than in 1995 (10,928 kg) or 1999 (9,991 kg). Of the 11,535 kg of total atrazine sold in BC in 2003, 9,696 kg were sold in the Lower Mainland region (ENKON 2005).

Inventories of pesticide sales in BC indicate that the use of endosulfan has decreased over the last decade with sales for 1991, 1995, 1999, and 2003 being 6,857, 7308, 4,712, and 4,729 kg, respectively. Of the 4,729 kg of endosulfan sold in 2003, 3,195 kg was sold in the Southern Interior region of the province and 1,504 kg was sold in the Lower Mainland. The 1991 and 1999 pesticide inventories indicated that agriculture services in the Lower Mainland used 92 and 35.8 kg of endosulfan, respectively; however, no usage was reported by agricultural services in 2003. In addition, while very minor amounts of endosulfan were used by landscape services in 1991 and 1999, no use was reported for 2003 (ENKON 2001a; ENKON 2005; Norecol, Dames & Moore 1997; Norecol Environmental Consultants 1993).

A wide range of pesticides have been detected in air samples collected in agricultural areas of BC. The most commonly detected pesticides were 2,4,-D, 2,4,5-trichlorphenoxypropionic acid (2,4,5-TP), atrazine, captan, diazinon, dicamba, dichlorvos, dieldrin, dinoseb, endosulfan, fonofos, heptachlor, malathion, mevinphos, and terbufos (Belzer *et al.* 1998a,b; McGreer and Belzer 1998). Atmospheric deposition of current-use pesticides within the Georgia Basin has been identified; however, information is limited and additional studies are currently underway.

Several current-use pesticides have been detected in agricultural areas in the lower Fraser Valley area of BC. Environment Canada sampling has detected more than 60 current-use pesticides and/or their transformation products in surface waters, sediments, field runoff, wellwater, and/or precipitation. All samples contained multiple pesticides. Pesticides detected included aminomethylphosphonic acid (AMPA), atrazine, azinphosmethyl, α-chlordane, DDT, desethylatrazine, diazinon, dieldrin, dinoseb, dimethoate, endosulfan, endosulfan sulphate, fensulfothion, glyphosate, lindane, malathion, metalochlorparathion, metalaxyl, methoxychlor, parathion, simazine, atrazine, trifluralin and soluble/extractable Cu^{++} ions (Cox and Liebscher 1999; Tuominen 2004; Tuominen *et al.* 2005; Wan

1989; Wan *et al.* 1994; Wan *et al.* 1995; Wan *et al.* 2005; Wan *et al*. 2006). Environment Canada studies conducted in 2003, 2004, and 2005 detected current-use pesticides in surface waters, groundwaters, field run-off, and rainwater in high pesticide use areas of the Lower Fraser Valley. The highest concentrations of pesticides were detected in field runoff samples. The most commonly detected pesticides were the fungicides quintozene and chlorothalonil, the insecticide endosulfan, and desethylatrazine, a breakdown product of the herbicide atrazine. Surface water, groundwater, and rainwater contained several pesticides at pg/L to ng/L concentrations, while some run-off and surface water samples contained concentrations in the µg/L range. With the exception of diazinon and chlorpyriphos, concentrations in surface water and groundwater were well below the guidelines for the protection of aquatic life (Tuominen 2004; Tuominen *et al.* 2005). Woudneh *et al.* (2007) examined five acidic herbicides in surface waters from reference, agricultural, urban and mixed agricultural/urban areas of the Lower Fraser Valley. They reported that only (4-chloro-2-methylphenoxy)acetic acid and triclopyr were detected at reference sites (up to 0.109 ng/L). In urban areas, 2-(4-chloro-2-methylphenoxy)propanoic acid was detected at the highest concentration (66 ng/L), while at agricultural and mixed agricultural/urban locations 2,4-D ((2,4-dichlorophenoxy)acetic acid) was present at the highest concentrations (345 ng/L and 1230 ng/L, respectively). Overall the herbicides were detected at the highest concentrations and with the greatest frequencies at the mixed agricultural/urban sites.

Endosulfan is persistent in the environment and can contaminate surface and groundwaters. Although information on endosulfan concentrations in the Georgia Basin environment is limited, concentrations in surface waters and sediments are typically low or non-detectable. However, detectable concentrations were present in ditch water and sediment collected in agricultural areas of the Lower Mainland. Endosulfan was one of only two organochlorine pesticides which are currently registered for application in BC that were detected in environmental samples. Endosulfan concentrations in Lower Fraser Basin fish were highest at sites where elevated concentrations of this pesticide were also detected in ditch water samples (McPhersen *et al.* 2001; Paine 1993; Raymond *et al.* 1998a,b; Sekela 2002, unpublished data; Sekela *et al.* 1995; Stewart and Bertold 1994; Swain and Walton 1990; Swain and Walton 1991; Swain and Walton 1993; Swain and Walton 1994; Wan *et al.* 1995). In addition, very low concentrations of atrazine have been detected in stormwater discharges in the agricultural Saanich Peninsula on Vancouver Island (Cameron and Miller 2001).

In the Lower Mainland area of BC, 82 carp were killed as a result of endosulfan poisoning in 2001 (Kuo 2002, personal communication). In addition, there is evidence that agricultural runoff may contribute to lower reproductive success and reduced population viability in amphibians in the Lower Fraser Valley. Additional work is needed to determine the possible effects of exposure to endosulfan, atrazine, and other current-use pesticides (Schreier *et al.* 1998; Solla *et al.* 2002; Wilson 2002, personal communication).

3.1.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to atrazine, endosulfan, and other high volume current-use toxic pesticides in the Georgia Basin include:

Obtain current information on environmental levels by:

- determining the presence of atrazine, endosulfan, and other high volume current-use toxic pesticides and their metabolites in the environment, particularly in ground and surface waters in agricultural areas impacted by runoff.

Develop a better understanding of biological effects by:

- assessing the potential impacts of releases of atrazine, endosulfan, and other current-use toxic pesticides and their transformation products on local ecosystems in agricultural areas and in high use areas and in areas affected by stormwater discharges;
- evaluating the potential endocrine-disrupting effects of these pesticides in agricultural runoff on populations of amphibians and other aquatic species in the Lower Fraser Valley; and

- assessing the potential impacts of various carrier compounds as they can constitute up to 90% of the pesticide formulation and some of these compounds have demonstrated endocrine-disrupting effects.

Develop a better understanding of environmental fate and distribution by:

- investigating the transformation, persistence, transport, and the bioconcentration and biomagnification potentials of atrazine, endosulfan, and other high volume current-use pesticides and their transformation products in the Georgia Basin environment and, in particular, determining their presence, persistence, and transport in groundwater; and
- studying the potential long-term persistence of previous common-use pesticides (e.g., 1,2-DCP) that have been discontinued.

Obtain more information on non-point (and other) sources and loadings by:

- obtaining more specific information on localized areas of pesticide use and loadings in the Georgia Basin.

3.1.4 Management Actions and Needs

Management actions taken or underway to deal with issues specific to atrazine, endosulfan, and other current-use toxic pesticides in the Georgia Basin include historic regulatory actions such as the development of a linkage between the province and the federal departments to control and monitor pesticide usage in the region including, most recently, the promotion of integrated pest management (IPM). Traditionally, the system has included point of sale vendor controls of products to farmers and to licensed pest control services; however, most pesticide applications in the province do not require licences as the application is by farmers to their own property. Inventories of pesticide sales in BC were conducted in 1991, 1995, 1999, and 2003. This has provided valuable information on the high volume pesticides currently being applied in various regions of the province and, to some extent, has also allowed the identification of use trends (ENKON 2001a; ENKON 2005; Norecol, Dames & Moore 1997; Norecol Environmental Consultants 1993).

Nationally, the Pesticide Management Regulatory Agency (PMRA) is currently conducting a re-evaluation of products containing endosulfan to determine whether the recent risk-management actions taken in the United States would provide adequate safeguards in Canada (Solomon *et al.* 1996). In 2004, the PMRA announced its proposal to implement interim mitigation measures prior to the completion of the full re-evaluation. This action was taken as a precautionary measure to mitigate potential dietary, worker-related, and environmental risks. An update to the interim measures, which were published by PMRA in 2004, was developed and was posted on the Health Canada website for public comment period. This period is now over and PMRA will consider comments received and then make a decision on interim risk mitigation measures to be adopted by registrants of pesticides containing endosulfan and propose a risk management strategy. For more information refer to the PMRA website http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/_rev2009-03/endosulfan-eng.php.

In addition, PMRA completed a re-evaluation of the human health risk assessment of atrazine in 2003 and, more recently, conducted an environmental assessment of atrazine. This assessment addressed use in Canada, with the exception of BC, as registrants of atrazine have voluntarily withdrawn this product from use, distribution, or sale in BC. For additional information refer to http://dsp-psd.pwgsc.gc.ca/collection_2008/pmra-arla/H113-28-2007-5E.pdf.

Management actions needed to address atrazine, endosulfan, and other high volume current-use toxic pesticides in the Georgia Basin include:

Review past and existing initiatives and support and further promote those which have been shown to be successful by:

- quantifying sales of current-use pesticides and reviewing and improving, as necessary, existing mechanisms for tracking regional pesticide usage and application; and

- developing a mechanism for the more consistent documentation/verification of incidents of fish and/or bird kills associated with the use of pesticides.

Implement measures to address identified hotspots and priority watersheds by:

- as necessary, implementing measures to reduce pesticide losses to the environment as a result of agricultural practices including pesticide application and uncontrolled surface runoff, aquaculture practices, urban activities, and stormwater runoff.

Review existing controls and, where required, develop mandatory regulatory activities by:

- reviewing the existing mechanisms for tracking regional pesticide usage and application and make improvements where necessary.

Assess and ensure the efficacy of management actions by:

- tracking and evaluating measures implemented under the Agricultural Policy Framework (APF), which is in effect between 2003 and 2008 to address priority agricultural environmental issues throughout BC; and
- continuing to strongly encourage and monitor the use of an integrated pest management approach within the Georgia Basin.

3.2 Antisapstain Chemicals

The lumber industry in moist coastal areas of BC uses antisapstain chemicals for the treatment of freshly cut softwood lumber to prevent staining caused by the growth of fungus and molds. Pesticide inventories have shown that the use of antisapstain chemicals in BC has declined by more than 79% between 1994 and 2003. A variety of chemicals have been used for this purpose in BC since the first inventory of pesticide use in BC was conducted in 1991. Chlorophenate-based antisapstain formulations were used extensively in BC in the 1980s; however, their use was banned as of the end of 1990. Copper 8-quinolinolate has not been used for antisapstain purposes since 1992, and the use of TCMTB (2-(thiocyanomethyhlthio)benzothiazole) was also virtually eliminated by 1992; however, small amounts were used until 1999. The one mill using TCMTB in 1999 did not report to the inventory in 2003 and it is not known if this facility is still using TCMTB. Sodium carbonate, a component of borax-based antisapstain has not been used since 1998. Information obtained from the 2003 pesticide inventory indicates that there are currently four antisapstain chemicals in use at BC facilities. These are DDAC (didecyl dimethyl ammonium chloride) and IPBC (3-iodo-2-propynyl butylcarbamate or iodocarb), disodium octaborate tetrahydrate, and propiconazole. In the Georgia Basin region (Vancouver Island and the Lower Mainland), DDAC (150,635 kg) and IPBC (13,005 kg) were used in the greatest volumes, with DDAC use accounting for the vast majority (ENKON 2005).

3.2.1 Background Information

DDAC belongs to a group of chemicals called quaternary ammonium compounds (QACs), which are frequently used for their germicidal, fungicidal, and algicidal properties. DDAC is registered for use in Canada as a molluscicide and as an industrial disinfectant. As of 1991, this chemical has also been registered for use as an antisapstain treatment to prevent the growth of fungus and molds on freshly cut softwood lumber for export. DDAC can be released to the environment in stormwater runoff from lumber mills as a result of spillage and leaching from treated lumber (CCME 1999; Henderson 1992).

IPBC is a carbamate compound, which is registered in Canada for use as a preservative in paints, adhesives, and caulking. As of 1990, it was also temporarily registered for use as an antisapstain chemical for application to freshly cut softwood lumber to prevent the growth of fungus and molds. This registration is subject to an annual review (CCME 1999; Henderson 1992; Juergensen *et al.* 2000).

DDAC is acutely toxic to freshwater fish with 96-h LC_{50} values ranging from 21 µg/L for 3-day-old sturgeon to 466 µg/L for rainbow trout. The sensitivity of fish to DDAC varies with the life stage. For instance, 3-, 11-, 42-, and 78-day old white sturgeon exposed to DDAC had LC_{50} values of 10 to 50 μg/L, 58.45 μg/L, 101.77 μg/L, and 100 to 250 μg/L, respectively. Sublethal exposure (12 and 24-h exposures to 50% and 100% of the 96-h LC_{50}) have been found to reduce the swimming performance of rainbow trout by up to 25%. Sublethal concentrations of DDAC can cause reduced growth, cellular damage to gills and the digestive tract, increased biochemical indicators of stress, and reduced swimming performance in fish. Information on the acute toxicity of DDAC to marine species was limited. Available literature indicated that the 48-hour exposure toxicity to marine invertebrates ranged between 39 μg/L for *Mysidopsis bahia* and 972 μg/L for the local estuarine species *Neomysis mercredis.* The 14-day exposure LC_{50} for *Hyalella azteca* exposed to DDAC associated with sediments was 1100 μg/g (dw) (Farrell *et al.* 1998; Farrell and Kennedy 1999; Henderson 1992; Johnston *et al.* 1998; Szenasy *et al.* 1998a,b; Teh *et al.* 2001; Wood *et al.* 1996).

IPBC at concentrations in the μg/L range are also toxic to aquatic fish and invertebrates. Toxicity studies indicated that 67 μg/L (active ingredient) was the lowest IPBC acutely lethal concentration to freshwater fish, based on a 96-h LC_{50} test with rainbow trout. The lowest observable effect concentration (LOEC) reported was 19 μg/L, based on reduced weight gain and growth in fathead minnow embryos over a 35-day exposure period (CCME 1999; Farrell and Kennedy 1998; Farrell and Kennedy 1999; Springborn Laboratories Inc. 1992).

Preliminary studies on the toxicity of IPBC associated with sediments indicated that a concentration of 1.94 μg/g (dw) would kill 50% of *Hyalella* over a 14-day exposure period. IPBC was 300 times more toxic in sediment exposures than was DDAC. Simultaneous exposure to IPBC and DDAC produced additive toxicity in fish, but variable toxicity in invertebrates (Raymond *et al.* 2000; Szenasy *et al.* 1998a,b).

The bioaccumulation of DDAC and IPBC in aquatic species is not expected to be significant. Bluegill sunfish exposed to DDAC over a 28-day period quickly reached steady state and then rapidly depurated this chemical. Bioconcentration factors in bluegill sunfish ranged from 38 to 140 depending upon the tissue (Springborn Laboratories Inc. 1990). The log K_{ow} for IPBC was estimated to be 2.81. A bioconcentration factor of <4.5 was observed in Japanese carp exposed to 0.5 to 5.0 μg/L IPBC (MRI 1990).

Canadian interim water quality guidelines for DDAC and IPBC for the protection of freshwater aquatic life are 1.5 μg/L and 1.9 μg/L, respectively. There are no guidelines for marine water and sediment due to the lack of sufficient toxicity data (CCME 2006). CCME guidelines are available on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. There are currently no BC provincial guidelines for DDAC or IPBC.

3.2.2 Georgia Basin

Available information is inadequate to estimate loadings of DDAC and IPBC to the Georgia Basin; however, the major source of these substances to the aquatic environment is associated with their use as antisapstains on cut lumber in moist coastal areas of the province. DDAC is one of the most heavily used pesticides in the province; however, the use of this product has declined substantially in recent years. Approximately 310 metric tonnes (t) of DDAC were used for antisapstain treatment at 46 BC facilities in 1999 (primarily in the Lower Mainland and on Vancouver Island), compared to approximately 175 t in 2003. In 2003, the use of DDAC accounted for 85% of the total antisapstain chemical usage in the province. The use of IPBC in antisapstain formulations at BC facilities has also declined; 42 t in 1993, 26.5 t in 1999, and 11.8 t in 2003 (ENKON 2005).

While antisapstain use is the major source of DDAC and IPBC to the Georgia Basin environment, best management practices introduced at BC mills have greatly reduced releases of antisapstain chemicals in stormwater runoff. Smaller amounts of these substances may enter the Georgia Basin from other sources such as the use of DDAC as a molluscicide and an industrial disinfectant and the use of IPBC as a preservative in paints, adhesives, and caulking.

DDAC and IPBC do not occur naturally and their presence in the aquatic environment is attributed primarily to spills and discharges from lumber facilities using these compounds. Very little information was available on levels of DDAC and IPBC in the aquatic environment of the Georgia Basin. It is expected that environmental concentrations would be most elevated in the vicinity of stormwater runoff at lumber mills using DDAC and IPBC antisapstain formulations; however, discharges from mills utilizing these substances are episodic. The fate of DDAC entering the environment adsorbed to particulate matter is not known. IPBC is not expected to be strongly adsorbed to sediments or particulate matter; however it was detected at environmentally significant concentrations in sediment samples collected from the lower Fraser River in 1998. DDAC has been detected in the sediment and surface water of the Fraser River at sites located in the vicinity of lumber mills. It has been suggested that these substances may accumulate in downstream deposition zones in sloughs or delta areas (Szenasy *et al.* 1998a,b).

3.2.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to antisapstain chemicals in the Georgia Basin include:

Obtain current information on environmental levels by:

- measuring the presence of DDAC and IPBC in deposition zones in the Fraser River and Georgia Basin;
- determining the concentration of DDAC and IPBC in the receiving environment downstream of mills during winter rainstorm events;
- improving analytical methods for DDAC and IPBC prior to the initiation of sampling programs to eliminate analytical problems associated with high detection limits, analytical variability, and interferences, as well as poor recovery rates in the presence of suspended solids; and
- developing a protocol for the analysis of dissolved and particulate bound DDAC and IPBC.

Develop a better understanding of the biological effects by:

- investigating the mode of toxicity on aquatic life;
- evaluating the toxicity of DDAC and IPBC associated with sediments and suspended particulates, particularly in the vicinity of coastal mills;
- assessing the effects of the simultaneous exposure to DDAC and/or IPBC and metals under varying conditions of water hardness and pH;
- conducting additional toxicity testing on sediment-dwelling invertebrates to satisfy the requirement for developing full freshwater and marine sediment quality guidelines; and
- obtaining additional information on chronic toxicity and, where necessary, acute toxicity to regionally relevant marine and freshwater species to determine whether the current interim water quality guideline is appropriate and to remove the interim status of the current guideline. For example, a recent study has shown that the growth and mortality of sturgeon are impacted in comparison with control fish, even after the fish were removed to clean water.

Develop a better understanding of environmental fate and distribution by:

- studying the fate, persistence, bioavailability, and transport of DDAC and IPBC discharged to receiving waters in dissolved and particulate-adsorbed forms;
- determining the persistence and bioavailability of DDAC and IPBC associated with sediments and suspended particulates in deposition zones of the Georgia Basin, particularly in marine and estuarine environs; and
- measuring the rate of uptake and elimination of DDAC and IPBC in aquatic invertebrates and evaluating the effect of pH and water hardness on the bioavailability of these substances.

Obtain more information on non-point (and other) sources and loadings by:

- developing protocols for the use of automatic samplers with flow proportional interval sampling;

- obtaining annual and seasonal estimates of DDAC and IPBC loadings to the Georgia Basin from lumber mills using antisapstain chemicals in the Fraser Basin and on Vancouver Island (additional information on the concentrations of DDAC and IPBC in stormwater runoff from these facilities is required in order to estimate loadings); and
- determining the significance of other potential sources of DDAC and IPBC to the Georgia Basin, including the use of DDAC as molluscicides and industrial disinfectants and the use of IPBC as a fungicide in paints and adhesives, by measuring loadings from stormwater and WWTP discharges in the Georgia Basin.

3.2.4 Management Actions and Needs

Management actions implemented specifically to address antisapstain chemicals in the BC environment include the development of a limit on the concentration of these substances in stormwater runoff under the British Columbia *Environmental Management Act* (was *Waste Management Act*) regulatory and the implementation of Best Management Practices (BMPs), including improvements to chemical handling at mills and covered lumber storage. These measures combined with the implementation of compliance monitoring for the antisapstain industry by Environment Canada have substantially reduced the release of antisapstain chemicals into the aquatic environment.

Additional management action needs to further address antisapstain issues in the Georgia Basin include:

Review existing controls and, where necessary, develop mandatory regulatory activities by:

- developing Canadian sediment quality guidelines for antisapstain chemicals, since the lack of such guidelines hinders the evaluation of the ecological relevance of current levels of DDAC and IPBC in the Fraser River and Georgia Basin;
- reconvening the Antisapstain Subcommittee, which reported to the Federal/Provincial Toxic Chemicals Committee (FPTCC), for the purpose of evaluating the implications of the new aquatic toxicity information and the implications of these findings on the end-of-pipe standards used for DDAC and IPBC to protect aquatic life. Specific guidance on setting site-specific effluent guidelines should be developed to account for the strong influence of suspended sediment on the biological toxicity of DDAC concentrations in the effluent and the receiving environment; and
- reviewing the existing BC provincial stormwater discharge guidelines in light of the most recent toxicity information and updating these guidelines, if deemed necessary.

  Note: The existing guideline specifies a maximum concentration of 700 μg/L DDAC in stormwater discharges from wood treatment facilities. However, aquatic toxicity information which has become available since the development of this guideline indicates a higher sensitivity of some species to DDAC than previously reported. Because of this new information, it has been suggested that the current BC effluent regulations may not be sufficiently protective of juvenile rainbow trout or white sturgeon. Similarly, some researchers have concluded that the maximum concentration of 120 μg/L specified for IPBC in the existing guideline may not adequately protect the most sensitive life stages and species including juvenile coho salmon.

3.3 Antifouling Chemicals

3.3.1 Background Information

Organotin compounds are synthetic organometallic substances whose toxic properties have contributed to their diverse and widespread use. These compounds have been used mainly as heat stabilizers in polyvinyl chloride, industrial cooling water slimicides and agricultural biocides, wood preservatives, antifouling agents, and industrial catalysts in chemical reactions. Organotin compounds are not manufactured in Canada, but are imported for use.

Tributyltin (TBT), an organotin compound, was once widely used in BC as an antifoulant and was the active ingredient in marine paints applied to boat hulls, marine structures, and net pens in aquaculture. The use of tributyltin compounds in antifouling paints has resulted in widespread environmental contamination and adverse effects in marine organisms worldwide. As a result, many countries have taken action to restrict the use and release of these substances to the environment. For example, the International Maritime Organization (IMO), a United Nations body, adopted a convention calling for a global ban on the application of organotin-based antifouling paints on ships by 2003. Due to risks to the Canadian environment, and consistent with the IMO Convention, the Canadian Pesticide Management Regulatory Agency (PMRA) terminated the registration of organotin-based antifouling paints in Canada on October 31, 2002. The sale and distribution of these products in Canada ended September 1, 2002 (Garrett 2004).

TBT is toxic to aquatic organisms at low concentrations and can affect energy production, survival, growth, metabolism, and reproduction in aquatic organisms at ng/L to μg/L concentrations. Larval and juvenile life stages are often more susceptible to the effects of organotin compounds than are adults. Molluscs are particularly sensitive to TBT and concentrations of less than 1 μg/L in both laboratory and field situations resulted in mortality in larval stages, abnormal shell and gonad development, and reduced larval settlement and growth. In some areas of the world, TBT resulted in the depletion of commercial oyster growing areas in the 1980s. Organotin compounds are endocrine disrupting chemicals and a condition known as 'imposex' (the development of male sex organs in females) has affected gastropod populations in coastal areas worldwide and has been attributed to TBT contamination (summarized from Garrett 2004).

Organotin compounds are readily accumulated by aquatic organisms and many species have bioconcentration factors of several thousand. The presence of elevated concentrations of butyltin compounds in fish-eating birds and marine mammals indicates that these species accumulate butyltin compounds more efficiently than do fish and lower trophic level organisms and that biomagnification in the food chain can occur (Blair *et al.* 1982; Iwata *et al.* 1994; Iwata *et al.* 1995; Kannan and Falandysz 1997; Laughlin *et al.* 1986).

CCME developed Canadian environmental quality guidelines for some organotin compounds. Interim guidelines for the protection of freshwater aquatic life are 8 ng/L (3 ng Sn/L) for tributyltin and 20 ng/L (7 ng Sn/L) for triphenyltin, and the interim guideline for the protection of marine and estuarine life is 1 ng/L (0.4 ng Sn/L) tributyltin. Due to the lack of adequate toxicity information, guidelines have not been developed for other organotin compounds (CCME 1999; CCME 2006). CCME guidelines are available on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. There are currently no BC provincial guidelines for organotin compounds.

Following the de-registration of TBT-based antifouling paints in 2002, the use of copper-based antifouling paints increased significantly. As with the TBT-based antifoulants, copper can be released to the environment during the application and removal of copper-containing paint from boat hulls and as a result of the copper in hull paints leaching directly into surrounding waters. Environmental concerns associated with the release of copper to the aquatic environment are discussed in Section 4.3.1.

3.3.2 Georgia Basin

TBT-based antifouling paints have been used extensively in the coastal waters of BC on boat hulls, marine structures, and on net pens at aquaculture facilities until 2002, when organotin compounds were de-registered under the PCPA for this purpose. Copper-based antifoulants are now widely-used as replacements for organotin-based products. Loadings of TBT- and copper-based antifoulants to the Georgia Basin have not been estimated.

The major source of organotin compounds to the aquatic environment of the Georgia Basin was the past use of TBT-based antifouling paints on the hulls of boats and ships (Garrett and Shrimpton

1997). The registration, sale, and distribution of organotin-based antifouling paints in Canada terminated in 2002; however, TBT continues to enter the Georgia Basin as a result of the continued use of these products on foreign vessels entering Canadian waters. Other potential sources of organotin compounds include discharges from wastewater treatment plants, landfills, municipal incinerators, and the use of industrial slimicides and wood preservatives. In addition, the organotin-based pesticide Vendex® is still registered for use in Canada. Releases of organotin compounds to the Canadian environment as a result of these uses have not been determined (Garrett and Shrimpton 1997).

In the Georgia Basin, elevated levels of butyltin compounds have been detected in surface waters, bottom sediments, fish, aquatic invertebrates, and/or fish-eating birds collected in the vicinity of some marinas, harbours, shipyards, recreational boating areas, and salmon farms in the late 1980s and early 1990s. Kannan *et al.* (1998b) detected elevated concentrations of butyltins in the liver tissue of seaducks collected from harbour and marinas areas on the BC coast between 1989 and 1992. These authors reported that seaducks feeding on molluscs accumulated greater concentrations of butyltins than did predatory birds feeding on other prey, such as fish, other birds, and small mammals. Although sampling by Environment Canada indicates that environmental levels of butyltins have decreased in BC coastal marinas (and likely salmon farms and recreational boating areas) since the introduction of controls under the PCPA in 1989, levels in harbour areas remained elevated in 1995 due to the continued release of TBT-based antifoulants from vessels over 25 metres in length and from foreign vessels. In some areas, surface water concentrations greatly exceeded the Canadian water quality guideline for the protection of marine life (Garrett and Shrimpton 1997). Sediment samples collected from Vancouver, Victoria, and Esquimalt harbours in 2003 also contained elevated concentrations of butyltins (Thompson *et al.* 2005). In the 1980s, evidence of TBT toxicity was observed in select commercial oysters stocks within the Georgia Basin and studies of neogastropod populations in south coastal BC harbours and boating areas indicated that imposex was widespread (Harding and Kay 1988; Tester *et al.* 1996). A recovery of neogastropod populations was observed in low and moderate traffic boating areas in south coastal BC following the introduction of controls on the use of butyltin-based antifoulants on boat hulls in 1989. However, recovery was not observed in neogastropod populations in large harbours, such as Vancouver Harbour, where environmental concentrations of butyltin compounds remained elevated (Horiguchi *et al*. 2003; Reitsema *et al*. 2002; Tester *et al.* 1996).

Available information on environmental levels of copper in the Georgia Basin as a result of the use of copper-based antifoulants is limited; however, elevated copper concentrations in the sediments and organisms of Vancouver, Victoria, and Esquimalt harbours have been attributed, primarily, to the leaching of copper-based antifoulants from boat hulls. Information on the presence of copper in the vicinity of aquaculture facilities in BC is very limited; however, a study at one aquaculture facility in BC found that the concentrations of copper inside and outside net pens treated with copper-based antifoulants were similar and that concentrations in an area removed from the influence of the net pens were not significantly different (Lewis and Metaxas 1991). This finding is similar to that of a Norwegian study which found that copper concentrations in fish, invertebrates, and macro-algae collected near aquaculture facilities using copper-treated nets were not significantly different from copper concentrations in organisms from areas where copper-treated nets were not used (Borufsen Solberg *et al.* 2002). Brooks (2000) tested 117 sediment samples from 14 farms using copper treated nets and determined that concentrations in some samples were elevated compared to sediments collected from 10 reference sites and also compared to sediments from farms not using copper treated nets. In two of the samples, concentrations exceeded NOAA's Effects Range Median of 270 µg/g (dw) and the Washington State sediment quality criterion of 390 µg/g (dw). A total of 13 sediment samples exceeded the mean TEL and PEL used as a screening benchmark in British Columbia. However, the elevated concentrations occurred at farms where net washing on barges was conducted. Sediment copper concentrations at most farms using copper treated nets, but not conducting net washing, were much lower. Brooks (2000) also reported that copper levels in sediments from farms not using copper treated nets were well below any recognized effects benchmarks indicating that the small amount of copper micronutrients added to fish food did not pose an environmental risk. Several other studies have reported that both zinc and copper concentrations are elevated in sediments collected within fish farms relative to sediments from remote areas (Belias *et al*. 2003; Chou *et al.* 2004; Erikson *et al*. 2001; Kempf *et al.* 2002; Mendiguchia *et al*. 2006; Schendel *et al.* 2004; Uotila 1991; Yeats *et al.* 2005), including one study in the Broughton Archipelago of BC (Sutherland *et al.* 2007).

3.3.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to organotin compounds and copper-based antifoulants in the Georgia Basin include:

Obtain current information on environmental levels by:

- monitoring organotin compounds in water, sediment, and aquatic biota at select sites to determine the efficacy of existing regulations and to provide baseline information; *Note:* This work is important in light of the proposed United Nations IMO global ban on organotin antifoulants and the termination of the registration of these products in Canada. Future surveys should include sites where previous sampling found environmental concentrations in excess of guideline values and also recreational boating areas, particularly those with sensitive shellfish populations
- measuring the presence of butyltin compounds in marine mammals from the coast of BC; and
- measuring environmental concentrations of copper in harbour areas, marinas, and in recreational boating areas to determine whether the replacement of TBT-based antifouling paints with copper-based products has resulted in unacceptable environmental concentrations of copper.

Develop a better understanding of biological effects by:

- monitoring the incidence of imposex on a regular and ongoing basis at select sites within the Georgia Basin to identify changes in environmental levels of TBT over the long term and the efficacy of control measures; and
- determining the incidence of imposex in birds and assessing the biological significance of the elevated organotin concentrations in grebes and sea ducks from coastal areas of BC.

Develop a better understanding of the environmental fate and distribution of priority substances in the Georgia Basin by:

- assessing the transport of antifoulants beyond harbours via currents and biotic transport mechanisms.

Obtain more information on non-point (and other) sources and loadings by:

- determining the level of adherence of marinas and the shipbuilding and repair industry to updated BMPs and assess the efficacy of pollution prevention measures on an ongoing basis;
- estimating the loadings of butyltins and copper to the Georgia Basin from marinas and shipbuilding and repair facilities; and
- obtaining information on organotin releases to the Georgia Basin from other potential sources such as wastewater treatment plants, landfills, municipal incinerators, stormwater, and from the use of organotin-based industrial slimicides and wood preservatives.

3.3.4 Management Actions and Needs

Regulatory actions have been taken nationally to reduce the release of organotin-based antifoulants to the aquatic environment. In 1989, the use of TBT-based antifoulants on vessels less than 25 metres in length (most recreational boats) was prohibited under the PCPA. However, since the use of these products on larger vessels and on aluminum hulls was still permitted, TBT continued to enter Canadian waters from shipbuilding and repair facilities and as a result of leaching from the hulls of domestic and foreign vessels exceeding 25 metres in length. Studies conducted in the Georgia Basin, and in other areas in Canada, indicated that environmental levels of butyltin compounds remained elevated in harbours. To further address this issue, the PMRA terminated the registration of organotin-based antifouling paints in Canada on October 31, 2002 and prohibited the sale and distribution of these products as of September 1, 2002. This action was taken in support of the IMO adoption of a convention to ban the use of these compounds in antifouling paints used on ships globally.

Management actions implemented specifically to address antifouling compounds in the Georgia Basin include the preparation and promotion of BMPs for shipbuilding/repair facilities and marinas in 1995 under the Fraser River Action Plan (FRAP), http://www.rem.sfu.ca/research/publications/frap_pdf_list/. The implementation of these guidelines decreases the release of antifouling chemicals to the environment. Inspections of ship and boatyards in 1998 by Environment Canada found that the implementation within this sector of the eight sections of the BMPs was variable and ranged from 2% for record keeping to 74% for waste fluids management. The average score was 42%. These BMPs have been updated and their implementation has been promoted widely among these facilities (refer to website http://www.pyr.ec.gc.ca/boatyards/index_e.htm).

The findings of Environment Canada audits are as follows:

- **1996 to 2000 -** the BMPs for hull maintenance (i.e., containing wash water and paint scraping for proper disposal) were not being implemented;
- **2004 to 2007 -** Compliance Promotion Program initiated including: creation of EC's Boatyards Best Management Practices web site, and associated brochures for boaters and boatyards;
- **2005 -** creation of the 'Shipyards Database' by Enforcement to track inspections and maintain records of continuing enforcement inspections; and related compliance promotion efforts (since reduced in scope). Feedback from Enforcement personnel indicated general improvements in the application of Best Management Practices as a result of the above programs;
- **2006** – Hull Maintenance Best Management Practices Workshops were held in Vancouver, Victoria and Nanaimo. These involved boatyards, marinas and wastewater treatment companies (consultants and equipment providers); and
- **2007 -** Boatyard, Boater and Tidal Grid BMPs signs were distributed

Management actions needed to further address antifouling compounds in the Georgia Basin include:

Review past and existing initiatives and support and further promote those which have been successful by:

- encouraging the widespread implementation of recently revised BMPs at BC marinas and shipbuilding and repair facilities by actively promoting the BMPs.

Review existing controls and, where necessary, develop mandatory regulatory activities by:

- developing Canadian sediment quality guidelines for organotin compounds for the protection of aquatic life.

Assess and ensure the efficacy of management actions by:

- determining the adherence of marinas and the shipbuilding and repair industry with BMPs developed for these facilities; assessing the efficacy of current management actions and controls in reducing the release of antifouling compounds to the Georgia Basin, implementing changes where necessary. For example, periodic inspections and monitoring should be conducted to evaluate both the compliance and the efficacy of the recently updated BMPs for marinas and shipbuilding and repair facilities.

4. Metals

Metals are present in the environment as a result of natural sources such as the weathering and erosion of rocks, forest fires, and emissions from volcanic eruptions. In addition, there are numerous anthropogenic sources of metals to the environment.

Although metals do not break down in the environment, they can be present in a variety of forms, depending on environmental conditions such as pH, dissolved oxygen levels, water hardness, salinity, organic carbon levels, and the presence of suspended particulates in the water column. The form of metal present in the environment determines its mobility, transport, bioavailability, and toxicity. Specific forms of metals have been found to be highly toxic to aquatic organisms. Several metals and metal compounds including lead, mercury, inorganic arsenic compounds, inorganic cadmium compounds, and hexavalent chromium compounds, have been assessed by Environment Canada and Health Canada and have been determined to be CEPA-toxic and added to the CEPA Schedule 1 List of Toxic Substances.

Recent information on the concentrations of metals in the Georgia Basin environment is lacking; however, the available information indicates that, with the exception of samples collected in the vicinity of acid rock drainage (ARD), metal concentrations in surface waters are generally low. The highest metal concentrations in sediments and aquatic biota are typically detected in industrial and urban areas. Elevated concentrations are most commonly detected in harbours and in the vicinity of shipbuilding/repair facilities, bulk loading facilities, pulp mills, wood treatment facilities, and mines with ARD. Concentrations exceeding the Canadian environmental quality guidelines have been detected in some areas within the Georgia Basin including Vancouver, Victoria, and Esquimalt harbours; the Fraser River and estuary; and near the now-closed Britannia Mine in Howe Sound. At some sites, elevated concentrations of metals have been attributed to natural enrichment rather than to anthropogenic inputs.

4.1 Cadmium

4.1.1 Background Information

Cadmium enters the environment through both natural and anthropogenic sources. The most important natural source is the weathering and erosion of cadmium-bearing rocks; however, forest fires and volcanic emissions also release cadmium. Anthropogenic sources include discharges to water and air from metal mines (zinc, lead, copper) and smelters; industries manufacturing alloys, paints, batteries and plastics; agricultural application of sludges, fertilizers and pesticides containing cadmium; urban runoff; marine disposal of sewage sludges; fossil fuel combustion; and the deterioration of galvanized materials and sacrificial anodes (CCME 1987).

Approximately 159 tonnes (t) of cadmium were released to the Canadian environment annually in association with metal production (82% from base metal smelters and refineries), stationary fuel combustion, transportation, solid waste disposal, agriculture, and select sources in Ontario for which data were available. It was estimated that 92% (147 t) of the total cadmium released to the environment entered the atmosphere, while the remaining 12 t entered the aquatic environment. The major atmospheric sources of cadmium were iron and steel industries (blast furnace), primary zinc production (especially the roasting phase), and primary copper and nickel production. Recent information indicates that the use of cadmium in electroplating (metal finishing) has decreased substantially in recent years and now accounts for only 4.3% of the total Canadian consumption of cadmium (Environment Canada 1999).

Bioaccumulation of cadmium in aquatic organisms has been reported. Bioconcentration factors (BCFs) reported for freshwater and marine biota ranged from one to several thousand, with the highest BCFs being reported for algae. Most evidence suggests that little or no biomagnification occurs in either aquatic or terrestrial ecosystems; however, the fact that some researchers have reported that higher cadmium concentrations occur in organisms from the higher trophic levels indicates a need for further studies on biomagnification (CCME 1999; Environment Canada 1993 draft; Environment Canada/Health Canada 1994b,c).

Marine and freshwater crustaceans demonstrate the greatest sensitivity to cadmium, with LOELs of 0.17 μg/L (for *Daphnia magna*) and 1.2 μg/L (for *Mysidopsis bahia*), respectively. Salmonids are the most sensitive fish species. Atlantic salmon exposed to $CdCl_2$ for 42 days exhibited a LOEL of 0.47 μg/L. Concentrations of 0.5 to 1.0 μg/L $CdCl_2$ were acutely toxic to rainbow trout over 96 hours. Sublethal effects included reproductive impairment; reduced production and survival of young; morphological changes and organ damage in the kidney, liver, intestine, testes, and gills; reduced antibody levels; decreased resistance to disease; reduced red blood cell production and hemoglobin synthesis; reduced rate of fin regeneration in fish, limb regeneration in amphibians, and shell growth in shellfish; loss of colour and markings definition; and abnormal behaviour (Dethloff and Bailey 1998; Environment Canada/Health Canada 1994b; Gerhardt 1993; Reddy *et al.* 1997; Romero *et al.* 1999; Selck *et al.* 1998).

In 1994, inorganic cadmium compounds were determined to be toxic as defined under CEPA 1988 (Environment Canada/Health Canada 1994b).

The Canadian interim guideline for cadmium in freshwater systems (developed by CCME) is 0.017 μg/L (in soft waters) and varies with water hardness. The water quality guideline for the protection of aquatic life in marine and estuarine systems is 0.12 μg/L. The interim sediment quality guidelines (ISQGs) (equivalent to a threshold effects level or TEL) for freshwater and marine/estuarine sediments are 0.6 and 0.7 mg Cd/kg (dw), respectively, while the probable effects levels (PEL) values are 35 and 42 μg/g (dw), respectively (CCME 2006). CCME guidelines are available on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. There are no BC provincial approved guidelines for cadmium; however, working water quality guidelines can be viewed on-line at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html#working.

4.1.2 Georgia Basin

Total cadmium loadings to the Georgia Basin are not known; however, loadings from select sectors have been estimated. Stanley Associates (1992) estimated that 5,000 kg (5 t) of cadmium are released to the Fraser Basin (4,400 kg (4.4 t) of this to the Lower Fraser) annually in stormwater discharges. Average annual loading to the Georgia Basin from stormwater discharges was estimated to be 5,421 kg (5.4 t) (ENKON 2002). Based on the available information for the period of 1990 to 1998, estimated cadmium contributions were 4,600 kg (4.6 t) from the Lower Mainland Fraser Valley, 618 kg from the CRD, and 203 kg from the City of Nanaimo. Municipal wastewater treatment plants (WWTPs) in the Georgia Basin (based on plants for which data was available) discharged approximately 144 to 175 kg cadmium annually, while loadings from CSOs and metal mines (Westmin Myra Creek Mines) were approximately 13.2 kg and 14.6 kg, respectively (ENKON 2002). In addition, the now closed Britannia Mines on Howe Sound has been identified as one of the largest metal pollution sources in North America. ARD was the major source of metals to the environment; however, other sources included waste rock disposal, concentrate spills, and tailings disposal. Pollution prevention measures are being implemented; however, metals-contaminated discharges will continue until the treatment facility, presently under construction, is completed (Government of BC 2006).

Atmospheric deposition is another source of cadmium to the Georgia Basin environment. A 1995 study estimated that the mean wet deposition rate was 1.39 μg/m^2/day in Burnaby Lake/Still Creek/Brunette Basin area (Belzer and Petrov 1997). In addition, it was estimated that the atmospheric deposition of particulates contributed 24 kg/yr of cadmium to the Brunette River watershed (Brewer *et al.* 1998b; Brewer *et al.* 2000). In 1996, a decreasing trend was observed in atmospheric deposition of cadmium, as reflected in the concentrations of cadmium in moss collected in the Lower Fraser Valley (Pott and Turpin 1996).

Naturally high background concentrations of cadmium occur in the Georgia Basin and likely account for the unexpectedly high concentrations found in some areas. However, elevated cadmium concentrations were detected in sediments from many coastal locations of BC near industrial plants and waste treatment facilities, most commonly in the vicinity of mines, pulp mills, and active harbours. In the late 1980s, sediments from Vancouver, Victoria, and Esquimalt harbours and several other coastal BC locations contained cadmium concentrations higher than the Canadian ISQG value of 0.7 μg/g. The PEL value of 4.2 μg/g was also exceeded at several sites. While concentrations at some locations were still elevated in the 1990s, overall, cadmium concentrations in Vancouver Harbour sediments were lower in the 1990s than in the 1980s, likely due to the extensive shoreline development in the harbour and the closure of many industrial sites (Boyd *et al.* 1997; Boyd *et al*. 1998; Bright and Reimer 1996; Bright *et al*. 1993; Colodey and Tyers 1987; ESG 1996; Garrett 1985a; Garrett 1995; Goyette and Boyd 1989).

Studies conducted in the late 1980s and 1990s detected cadmium concentrations in the low μg/g range in a wide range of aquatic organisms in south coastal areas of BC. Aquatic organisms collected from harbour, urban, and industrial areas generally contained cadmium concentrations which were elevated in comparison to reference areas (Bright and Reimer 1996; Bright *et al*. 1993; ESG 1996; Garrett 1985a; Garrett 1995; Harbo *et al.* 1983; Stewart and Bertold 1994). As there are currently no Canadian guidelines on acceptable concentrations of cadmium in aquatic species for the protection of human and wildlife consumers, it is difficult to determine the significance of the concentrations detected. However, of recent concern to the BC aquaculture industry is the fact that several shipments of cultured BC oysters were rejected for import to Hong Kong as they exceeded the Hong Kong maximum allowable limit of 2 μg/g cadmium wet weight (ww). Following a request by the Canadian Food Inspection Agency (CFIA), the Department of Fisheries and Oceans (DFO) investigated the reasons for these elevated concentrations in oysters and determined that the primary source of the cadmium in oysters is natural. However, the elevated levels are of concern to the BC aquaculture industry as they make, at least some, BC oysters unsuitable for export to Hong Kong. In addition, the European Community and various agencies throughout the world have announced that they are considering lowering the import limit to 1 μg/g (ww) (Kruzynski 2001, personal communication). The findings of the DFO investigations on cadmium concentrations in BC oysters are discussed in Kruzynski (2000) and Kruzynski (2004).

Studies by Environment Canada have shown that cadmium concentrations in seabirds from northern areas of coastal BC, such as the Queen Charlotte Islands, are significantly higher than cadmium concentrations in seabirds from the Georgia Basin. The reason for this difference has not been determined. The highest concentrations were detected in Leach's Storm Petrels (Barjaktarovic *et al.* 2002; Elliott and Scheuhammer 1997; Wilson and Elliott 2004).

Gray whales found stranded in the Strait of Georgia/Strait of Juan de Fuca contained cadmium concentrations of 0.29 to 4.4 μg/g (ww) in the liver, kidney, and stomach contents (Varanasi *et al.* 1994).

4.1.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to cadmium in the Georgia Basin include:

Develop a better understanding of biological effects by:

- determining the significance of the apparent trend toward increased cadmium concentrations in seabird colonies in a northerly direction along the BC coast.

Develop a better understanding of environmental fate and distribution by:

- conducting further studies on the trophic transfer processes for biologically available cadmium as part of a study of the "enriched" concentrations of cadmium in BC oysters.

4.1.4 Management Actions and Needs

Nationally, inorganic cadmium compounds have been determined to be CEPA-toxic and have been added to the CEPA Schedule 1 List of Toxic Substances. Under the federal Toxic Substances Management Policy, the federal government must develop a risk management strategy for managing CEPA-toxic substances. Risk management options have been developed for the base metal smelting, steel manufacturing, fossil fuel power generation, and metal finishing sectors and include recommendations for specific actions to decrease the release of cadmium and other CEPA-toxic substances to the environment. Since the metal finishing industry in Canada is no longer a major user of cadmium, and since present releases are well controlled, no additional actions to decrease cadmium releases from that industry sector were required. For additional information on risk management strategies to address cadmium releases to the Canadian environment, refer to the Environment Canada website (http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1&xml=B1F78D6F-21C9-470B-AB05-FFCB5B215D3C).

No management actions to specifically address the presence of cadmium in the Georgia Basin have been implemented and no specific needs have been identified.

4.2. Chromium

4.2.1 Background Information

Chromium is used for corrosion inhibition and decoration by the metal-plating industry, for the production of stainless steel and heat-resistant steel, for making consumer products such as cutlery and decorative trims, for electrical applications which require strength and good conductivity, and in alloys used by the automotive industry. In addition, chromium-containing chemicals such as chromium oxide, chromium chloride, and chromium sulphate are used in pigments, wood preservatives, and in leather tanning (CCME 1999; Environment Canada/Health Canada 1994d; Outridge and Scheuhammer 1993).

Chromium enters the aquatic environment via natural and anthropogenic sources. An Environment Canada assessment of chromium in 1994 estimated that total annual loadings to the atmosphere, water, and land were 84,000 kg (84 tonnes (t)), 27,000 kg (27 t) and 5,000,000 kg (5000 t), respectively. Fossil fuel combustion, various industrial processes (including iron and steel production and refractory and chemical processing), and transportation-related sources such as motor vehicles were the main sources to the atmosphere, contributing 51%, 29%, and 12%, respectively. Sources to the aquatic environment include base metal mine smelters and refineries, iron and steel plants, metal finishing plants, and petroleum refineries. Copper chromium arsenate (CCA) is registered in Canada for wood preservation and this use has been identified as a source of chromium to the environment through the improper storage and handling of preserved wood (Environment Canada/Health Canada 1994d).

Chromium is bioaccumulated by aquatic organisms and bioconcentration factors (BCFs) of <100 to 1000 have been reported; however, the presence of sediments can bind chromium and other metals, thus making them less available for bioaccumulation in aquatic organisms (Environment Canada/Health Canada 1994d).

The mean 96-h LC_{50} for Cr (III) was reported to be about 4-fold lower than that of Cr (VI) in salmonid species. Cr (III) is deposited in the fish gills and can lead to tissue damage and interfere with osmoregulation and respiration. Cr (VI) does not accumulate in the gills, but affects other organs including the liver, kidney, and spleen. Fertilization in rainbow trout was reduced by 60 to 70% when eggs and spermatozoa were exposed to 5 µg/L of Cr (III). While mammals are typically more sensitive to hexavalent chromium (Cr (VI)) than to trivalent chromium (Cr (III)), this is not always the case for aquatic biota and some studies with fish indicated that Cr (III) is more toxic than is Cr (VI) (Environment Canada/Health Canada 1994d; Gendusa and Beitinger 1992; Outridge and Scheuhammer 1993).

Hexavalent chromium was determined to be 'toxic' as defined by the federal CEPA 1988; however, there was insufficient information to determine whether trivalent chromium compounds were also "CEPA-toxic" (Environment Canada/Health Canada 1994d).

Canadian water quality guidelines (developed by CCME) for the protection of freshwater aquatic life are 1.0 μg/L for Cr (VI) and 8.9 μg/L for Cr (III) (interim guideline), while guidelines for the protection of marine life are 1.5 µg/L Cr (VI) and 56 µg/L Cr (III) (interim guideline), respectively. Interim sediment quality guidelines (ISQGs) (equivalent to a threshold effects level or TEL) and probable effects levels (PELs) for total chromium in sediments are 37.3 and 90 μg/g (dw), respectively, in freshwater systems and 52.3 and 160 μg/g (dw), respectively, in marine and estuarine systems (CCME 2006). CCME guidelines can be viewed on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. BC provincial approved guidelines have not yet been developed for chromium; however, working water quality guidelines can be viewed on-line at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html#working .

4.2.2 Georgia Basin

Information on chromium loadings to the Georgia Basin is limited; however, a recent Environment Canada study estimated loadings of chromium and other select chemical contaminants to the Georgia Basin from major wastewater discharges (based on available data from 1990 to 1998). Average annual chromium loadings from stormwater and municipal WWTP discharges were estimated to be 4.2 t (4245 kg) and 6.7 t (6723 kg), respectively (based on stormwater information for the Lower Mainland Fraser Valley, the Capital Regional District, and the City of Nanaimo and WWTPs for which information was available). Combined sewer overflows (CSOs) released 289 kg annually, while much smaller amounts were released in wastewaters from metal fabricators and metal mines (9.76 kg and 45 kg, respectively). Urban runoff has been identified as an important source of chromium to the aquatic environment in the Georgia Basin. Urban runoff contributes an estimated 5 t (5000 kg) of chromium to the Fraser Basin with the runoff to the lower Fraser River accounting for 4.4 t (4400 kg) (Stanley Associates 1992). A review of industrial sources of contaminants to the Fraser Basin, conducted under the Fraser River Action Plan (FRAP), identified pulp mills to be a source of chromium to the Fraser Basin. Chromium was detected in all but one of the samples of pulp mill effluents analyzed and loadings from the mills ranged from 0.2 to 100 kg/day (ENKON 2002; Environment Canada 1998b).

Pesticide sales inventories indicate that copper chromium arsenate (CCA) is the second most commonly used pesticide in BC and accounted for 18% of the total pesticide sales in BC in 2003. Sales of this product in BC were 923,987 kg (924 t) in 1997 and 824,100 kg (824 t) in 2003 with the majority of this product being sold in the Lower Mainland (542,438 kg or 542 t in 2003). Most wood preservation facilities in BC use only CCA; however, other chemicals are used at some facilities. The past discharge of contaminated stormwater from wood preservation facilities resulted in the release of unacceptable concentrations of wood preservative chemicals, including CCA, into the Georgia Basin environment. The implementation of environmental codes of practice at these facilities, combined with federal government inspections and enforcement programs, have resulted in a 90% reduction in contaminated stormwater discharges (ENKON 2005; Environment Canada 1998a).

Estimates of chromium loadings to the Georgia Basin from atmospheric deposition were not available. However, chromium deposition in the Brunette River watershed was estimated to be 180 kg/yr (Brewer *et al.* 2000). Wet deposition of chromium was estimated to be 8.92 $\mu g/m^2$/day in the Brunette Basin. This is similar to the chromium loading reported for wet deposition in the Sudbury Ontario region (Belzer and Petrov 1997). A significant decrease in the atmospheric deposition of chromium in the Fraser Valley between 1966 and 1993 was reported by Pott and Turpin (1996).

Although recent information is limited, in the late 1980s and early 1990s, elevated chromium concentrations were detected in sediment samples from many coastal BC areas receiving discharges from industry and/or municipal wastewater treatment plants. These areas include Burrard Inlet, False Creek, the Fraser River and estuary, Victoria Harbour, Esquimalt Harbour, Crofton, and Harmac. Chromium concentrations above the Interim Sediment Quality Guideline (ISQG) values were commonly observed; however, concentrations were well below the Probable Effects Level (PEL) in almost all samples. The highest concentrations of chromium in Burrard Inlet sediments (up to 267 μg/g (dw)) were detected near the oil refinery in Port Moody, which was reported to be the major source of chromium to the harbour. Chromium concentrations in sediments at Sturgeon Bank commonly exceeded the Canadian ISQG; however, concentrations in sediment samples from nearby reference sites were also elevated and the authors concluded that the elevated chromium concentrations in the area were natural and not due to significant contamination from the Iona Deep-Sea outfall, which discharges to Sturgeon Bank. Similarly, the widespread presence of elevated chromium throughout the Fraser Basin was attributed to natural sources. Background levels for Vancouver Harbour, Loughborough Inlet, and the Fraser River estuary were estimated to be 50, 34 to 38, and 48 μg/g (dw), respectively (Boyd *et al.* 1997; Boyd *et al.* 1998; Brewer *et al.* 1998a,b; Garrett 1995; Goyette and Boyd 1989; Johnson 1991; Pedersen and Waters 1989).

Recent information on chromium concentrations in fish and shellfish in the Georgia Basin is also limited. In the late 1980s and early 1990s, elevated chromium concentrations were detected in biota from the vicinity of some pulp mills and wood treatment facilities in south coastal BC (Garrett 1995). Information on chromium levels in wildlife is lacking. A study of mustelids collected from the lower Fraser River area between 1990 and 1994 concluded that chromium discharges did not pose a risk to mustelid populations (Harding *et al.* 1998). Stranded grey whales in the Straits of Georgia and Juan de Fuca contained chromium concentrations of 150, 540, and 8200 ng/g (ww) in the liver, kidney, and stomach contents, respectively (Varanasi *et al.* 1994).

4.2.3 Data Gaps and Research/Monitoring Needs

No data gaps or research/monitoring needs specific to chromium in the Georgia Basin have been identified.

4.2.4 Management Actions and Needs

The development of environmental codes of practice and the implementation of inspection and enforcement programs in BC have been effective in reducing contaminated stormwater discharges from wood treatment facilities by more than 90% and, as a result, the environmental releases of chromium and other chemicals used for wood treatment in BC have decreased. New recommendations for the design and operation of wood preservation facilities were developed and agreement was reached with virtually all of the wood preservation facilities in Canada to voluntarily implement these recommendations by 2005. For more information on chromium wood preservatives and initiatives to reduce the release of chromium and other wood preservation chemicals to the Canadian environment refer to the following websites http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1&xml=2F07427C-18EA-4DD4-AC30-380B332993AA, and http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=C5039DE5-1&xml=C6502274-1535-467A-923D-34C2FE9102E8.

Nationally, CEPA 1999 requires that Environment Canada and Health Canada develop risk management options for the management of hexavalent chromium and all other substances which have been designated as toxic under CEPA 1999. Risk management options which make recommendations for actions to reduce chromium releases have been developed for the base metal smelting, steel manufacturing, and metal finishing sectors and also for fossil fuel power generation. For more information refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-1&xml=2F07427C-18EA-4DD4-AC30-380B332993AA).

In addition, heavy duty wood preservatives (including CCA, creosote, and pentachlorophenol) have been jointly re-evaluated by Health Canada's PMRA and the United States Environmental Protection Agency (USEPA). For more information on this re-evaluation, refer to website http://www.hc-sc.gc.ca/cps-spc/pubs/pest/_decisions/rev2008-08/index-eng.php.

PMRA reached an agreement with the industry to move away from the use of CCA on lumber for residential use by December 31, 2003. This agreement was implemented due to concerns over the presence of arsenic in this compound and does not affect the application of CCA on wood for use on industrial sites.

No management actions to specifically address the presence of chromium in the Georgia Basin have been implemented and no specific needs have been identified.

4.3 Copper

4.3.1 Background Information

Copper is released to the environment from natural sources such as weathering, leaching, and erosion, and also through anthropogenic activities. Anthropogenic sources include corrosion of brass and copper pipes by acidic waters, municipal wastewater treatment plant (WWTP) effluents, urban stormwater runoff, copper-based aquatic algicides and antifoulant products, contaminated runoff and groundwater from the agricultural use of copper-based fungicides and pesticides and the use of copper chromium arsenate (CCA) wood preservatives, industrial effluents, and atmospheric emissions. The major industrial sources of copper include mining, smelting, and refining industries; copper wire mills; coal-burning industries; and iron and steel-producing industries (CCME 1987).

Copper is readily accumulated by both plants and animals and bioconcentration factors (BCFs) for various aquatic species range from 100 to 26,000. However, in general, whole body concentrations of copper tend to decrease with increasing trophic level and there is no evidence of significant biomagnification of copper (CCME 1987; CCME 1999).

Copper is an essential trace element; however, excess concentrations can be toxic. The toxicity of copper depends on the form in which it is present. Local environmental factors, such as water hardness in freshwater systems, can affect the toxicity of copper. At a water hardness of 50 mg/L, copper was acutely toxic to aquatic organisms at concentrations ranging from a few µg/L to more than 10,000 µg/L. Sublethal exposures can adversely affect development, growth, immune response, enzyme production, metabolic processes, and photosynthesis in aquatic species (CCME 1999; Dethloff and Bailey 1998; Dickman 1998; Konasewich *et al.* 1982; Stauber and Florence 1987; Taylor *et al.* 1998).

Canadian interim water quality guidelines for copper for the protection of freshwater aquatic life range from 2 to 5 µg/L (total copper) depending on water hardness. There are currently no Canadian water quality guidelines for copper in marine waters. BC provincial water quality criteria for copper in freshwater systems also vary with water hardness. Criteria for marine/estuarine systems are $\leq$ 2 µg/L (as a 30-day average) and 3 µg/L (as a maximum). Canadian ISQGs (equivalent to a threshold effects level or TEL) for copper are 35.7 µg/g for freshwater sediments and 18.7 µg/g for marine and estuarine sediments. Probable effects levels (PELs) are 197 µg/g for freshwater sediments and 108 µg/g for marine and estuarine sediments. CCME guidelines are available on-line at http://www.ccme.ca/publications/ceqg_rcqe.html (CCME 2006). There are currently no approved BC provincial sediment quality guidelines for copper; however, working water quality guidelines can be viewed on-line at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html#working.

4.3.2 Georgia Basin

A complete inventory of copper releases to the Georgia Basin was not available; however, a report prepared for Environment Canada identified a number of sources and estimated copper loadings from select wastewater discharges. Based on information collected between 1990 and 1998, it was estimated that 23,000 kg (23.5 tonnes (t)) of copper entered the Georgia Basin annually in stormwater discharges (based on information for the Lower Mainland, Fraser Valley, the Capital Regional District, and the City of Nanaimo), while 41,000 to 46,000 kg (41 to 46 t) were released from municipal WWTPs (based on information from plants for which data was available). Estimated loadings from other wastewater sources such as pulp and paper facilities, marine cargo handling, metal mines, CSOs, chemical products industries, and metal fabricators were 1109 kg, 383 kg, 382 kg, 1765 kg, 11.4 kg, and 3.42 kg, respectively (ENKON 2002). Stanley Associates (1992) estimated that stormwater accounts for a loading of 17,600 kg (17.6 t) of copper to the Fraser Basin annually, with 15,300 kg (15.3 t) of this entering the Lower Fraser River. A Fraser River Action Plan (FRAP) study estimated that 2400 kg (2.4 t) of copper enter the Fraser Basin (exclusive of the Lower Fraser River) from urban runoff (McGreer and Belzer 1998).

Past discharges of contaminated stormwater from wood preservation facilities have resulted in the release of unacceptable amounts of wood preservative chemicals (including CCA) into the Georgia Basin; however, the implementation of environmental codes of practice has been effective in reducing contaminated stormwater discharges by approximately 90% (Environment Canada 1998a). However, large quantities of wood preservative chemicals containing copper are still used in BC. Pesticide sales inventories indicate that CCA is the second most commonly used pesticide in BC and accounted for 18% of the total pesticide sales in BC in 2003. Sales in BC were 923,987 kg (924 t) in 1997 and 824,100 kg (824 t) in 2003, with the majority of this product being sold in the Lower Mainland (542,438 kg or 542 t in 2003). The majority of wood preservation facilities in BC use only CCA; however, alkaline copper quaternary (ACQ), which is now being used as a replacement for CCA, is being used at three plants. Small amounts of another copper-based compound, ammoniacal copper arsenate (ACA), were sold in BC in 1991 and 1995 (500 and 909 kg, respectively); however, this compound has been replaced with ammoniacal copper zinc arsenate (ACZA). Only one wood preservation plant in the Lower Mainland has reported using ACZA. In 1999, this facility used 16,488 kg of ACZA, compared to 2,214 kg in 2003 (ENKON 2002).

Some non-wood preservative pesticides used in BC also contain copper. Both the 1999 and 2003 inventories identified copper oxychloride to be among the top 20 reportable active ingredients in pesticides used in BC. Sales of copper oxychloride (on an “as copper basis”) in BC were 19,562 kg (19.6 t), compared to 14,699 kg (14.7 t) in 1999, 16,316 kg (16.3 t) in 1995, and 10,202 kg (10.2 t) in 1991. Sales of cupric hydroxide (a fungicide) were 6907 kg (6.9 t) in 1999 compared to 3524 kg (3.5 t) in 2003. The majority of these products were sold in the Lower Mainland (ENKON 2002).

A potentially significant source of copper to the aquatic environment of the Georgia Basin is the use of copper-based antifouling paints. The use of these products has increased in recent years as a replacement for the tributyltin-based paints whose use in Canada was discontinued in 2002. Copper-based grits have also been used as blasting material for the removal of paint from boat hulls and for cleaning boat hulls. Significant copper contamination can occur near tidal grids and in boatyards if this material is not properly contained (Liu 2003, personal communication). In addition, some aquaculture facilities use copper-based antifoulants to treat salmon net pens. Copper loading to the Georgia Basin from the use of copper-based antifouling paints has not been estimated.

Information on loading of copper to the Georgia Basin from atmospheric sources was not available. Copper and other metals have been detected in precipitation in the Georgia Basin and copper concentrations in rainfall collected in the Burnaby Lake area in 1995 were consistently higher than the Canadian Water Quality Guidelines for the protection of freshwater aquatic life (Belzer *et al.* 1996; Belzer *et al.* 1998a; Belzer and Petrov 1997).

Britannia Mines, a now closed copper mine located on Howe Sound, has been recognized as one of the largest metal pollution sources in North America. ARD was identified as the main source of metal pollution; however, other sources included waste rock disposal, concentrate spills, and tailings disposal. Loading of copper to Howe Sound was estimated to be more than 100,000 kg/day. Pollution prevention measures are now being implemented; however, metal-contaminated drainage will continue to be released until the treatment facility, which is currently under construction, is completed. For additional information, refer to the provincial government website on Britannia Mines (http://www.agf.gov.bc.ca/clad/britannia/index.html).

Elevated copper concentrations in the Georgia Basin were detected primarily in harbours and in the vicinity of wastewater discharges. In Vancouver, Esquimalt, and Victoria harbours, copper concentrations in the sediments commonly exceeded the Canadian ISQGs and, in some cases, the PEL values as well (Boyd *et al.* 1997; Boyd *et al.* 1998; Bright *et al.* 1993; Bright and Reimer 1996; ESG 1996; Garrett 1995; Johnson 1991; Transport Canada 2000). Copper concentrations in some aquatic organisms in Burrard Inlet and Victoria Harbour were also elevated. The hepatopancreas tissue of shrimp and crab from Burrard Inlet and Victoria Harbour contained high concentrations (several hundred to more than 1000 μg/g (dw)). Much lower concentrations (less than 100 μg/g (dw)) were detected in the muscle tissue. The concentrations of copper in mussels and crabs collected from Esquimalt Harbour were higher near the Department of National Defence facility in Constance Cove than in other areas of the harbour. Industrial releases, stormwater discharges, and antifoulant releases from boat hulls contribute to the elevated copper concentrations detected in these harbours (Bright *et al.* 1993; ESG 1996; Garrett 1995; Goyette and Boyd 1989; VEHEAP 1997).

Information on the effect of the recent increased usage of copper-based antifoulants on copper concentrations in the Georgia Basin environment is very limited. A study at one aquaculture facility in BC found that the concentrations of copper inside and outside net pens treated with copper-based antifoulants were similar and that concentrations in an area removed from the influence of the net pens were not significantly different (Lewis and Metaxas 1991). This finding is similar to that of a Norwegian study which found that copper concentrations in fish, invertebrates, and macro-algae collected near aquaculture facilities using copper-treated nets were not significantly different from copper concentrations in organisms from areas where copper-treated nets were not used (Borufsen Solberg *et al.* 2002). Brooks (2000) tested 117 sediment samples from 14 farms using copper treated nets and determined that concentrations in some samples were elevated compared to sediments collected from 10 reference sites and also compared to sediments from farms not using copper treated nets. In two of the samples, concentrations exceeded NOAA's Effects Range Median of 270 µg/g (dw) and the Washington State sediment quality criterion of 390 µg/g (dw). A total of 13 sediment samples exceeded the mean TEL and PEL used as a screening benchmark in British Columbia. However, the elevated concentrations occurred at farms where net washing on barges was conducted. Sediment copper concentrations at most farms using copper treated nets, but not conducting net washing, were much lower. Brooks (2000) also reported that copper levels in sediments from farms not using copper treated nets were well below any recognized effects benchmarks indicating that the small amount of copper micronutrients added to fish food did not pose an environmental risk. Several other studies have reported that both zinc and copper concentrations are elevated in sediments collected within fish farms relative to sediments from remote areas (Belias *et al*. 2003; Chou *et al.* 2004; Erikson *et al*. 2001; Kempf *et al.* 2002; Mendiguchia *et al.* 2006; Schendel *et al.* 2004; Uotila 1991; Yeats *et al.* 2005), including one study in the Broughton Archipelago of BC (Sutherland *et al.* 2007).

Elevated copper levels detected in sediments near the Iona Island WWTP were attributed to natural mineralization rather than to discharges from the WWTP (Gordon 1997; GVRD 2000; Thomas and Bendell-Young 1998). Copper concentrations in Fraser River sediments increased downstream toward urban areas (Swain *et al.* 1998). In Still Creek in Burnaby, the concentrations of copper in the sediments increased between 1973 and 1993, unlike the concentrations of many metals which have decreased in recent decades. This finding was attributed to increased traffic density in this area over the time period of the study (Hall *et al.* 1999). Elevated copper concentrations were also detected in the

Sumas River and were attributed to high natural background levels and/or the presence of copper in livestock feed supplements (Schreier *et al.* 1998).

Recent information on copper concentrations in aquatic species from the Georgia Basin is limited; however, historic data indicates that overall mean concentrations for molluscs, crustaceans, and fish from the south coast of BC were 5, 10, and 1.92 μg/g (ww), respectively. Copper concentrations were especially high in oysters (mean of 27.33 μg/g (ww)), compared to other mollusc species (Harbo *et al.* 1983). Oysters collected near the Britannia Mine on Howe Sound in 1975 contained 14,000 μg/g (dw) (Hagen 2001). This very high concentration was attributed to ARD from Britannia Mines which resulted in environmental contamination in the vicinity of the mine. Elevated copper concentrations have also been detected in water and sediments in the vicinity of the mine. Elevated copper concentrations detected in sediments near the mine were attributed to contamination with mine tailings (Drysdale 1990). Water concentrations of greater than 6.4 μg/L adversely affected algal growth and impacted phytoplankton populations near the mine. Surface waters of the Britannia Creek estuary were toxic to juvenile salmon during spring migration and mature salmon may have experienced sublethal toxic effects (Barry *et al.* 2000). In addition, Grout and Levings (2001) concluded that contamination resulting from ARD from the mine would cause reduced survival in mussels in an area extending 2.1 km north and 1.7 km south of the mine, while Levings *et al*. (2005) reported that the copper concentrations in the ARD could negatively affect both primary productivity and the standing stock of primary producers in Howe Sound.

ARD from the Mount Washington Mine on Vancouver Island also resulted in the release of copper to nearby waters and contributed to elevated copper concentrations in rainbow trout in Buttle Lake. However, the ARD issue at this mine was successfully addressed in 2003 and copper concentrations in rainbow trout have now declined (Deniseger and Erikson 1991).

Information on copper concentrations in wildlife and marine mammals in the Georgia Basin is very limited. A study of mink and river otter populations from the Lower Fraser River in 1990/91 found that mink and otter contained very low μg/g concentrations (up to 32 μg/g (dw)) in the liver and kidney (Harding *et al.* 1998), while Varanasi *et al.* (1994) reported that gray whales found stranded in the south coastal area of BC contained low μg/g (ww) concentrations of copper in the liver, kidney, and stomach contents.

4.3.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to copper include:

Obtain current information on environmental levels by:

- measuring environmental concentrations of copper in harbour areas, marinas, recreational boating areas, and aquaculture facilities to determine whether the replacement of tributyltin-based antifouling paints with copper-based products has resulted in unacceptable environmental concentrations of copper.

Obtain more information on non-point (and other) sources and loadings by:

- determining the adherence of marinas and the shipbuilding/repair industry with BMPs for these facilities;
- assessing the adequacy of the existing BMPs in reducing releases of antifouling compounds; and
- estimating the loadings of copper and other antifouling compounds to the Georgia Basin from these facilities.

4.3.4 Management Actions and Needs

The development of environmental codes of practice and the implementation of inspection and enforcement programs at BC wood preservation facilities has been effective in reducing contaminated stormwater discharges by more than 90%. New recommendations for the design and operation of wood preservation facilities were developed and agreement was reached with almost all of the wood preservation facilities in Canada to voluntarily implement these recommendations by 2005.

BMPs for shipbuilding/repair facilities and marinas were prepared in 1995 under the Fraser River Action Plan (FRAP) and were distributed to local shipyards and marinas (http://www.rem.sfu.ca/research/publications/frap_pdf_list/). The widespread implementation of these guidelines would help to decrease releases of antifouling chemicals to the environment. Inspections of ship and boatyards in 1998 by Environment Canada found that the implementation within this sector of the eight sections of the BMPs was variable and ranged from 2% for record keeping to 74% for waste fluids management. The average score was 42%. These BMPs have been updated and their implementation has been promoted widely among these facilities (refer to website http://www.pyr.ec.gc.ca/boatyards/index_e.htm).

Nationally, the Pest Management Regulatory Agency (PMRA) is reviewing the use of heavy duty wood preservatives (including CCA) in Canada. PMRA reached an agreement with the industry to move away from the use of CCA on lumber for residential use by December 31, 2003. This agreement was implemented due to concerns over the presence of arsenic in this product, but does not affect the use of CCA on wood for use on industrial sites.

Risk management strategies developed for several industry sectors include recommendations to reduce releases of various metals including cadmium, nickel, arsenic, and chromium. These metals have been assessed by Environment Canada and Health Canada and were determined to be toxic as defined under CEPA 1988. While copper has not been assessed under CEPA, it is expected that the implementation of recommendations to reduce the release of CEPA-toxic substances from the base metal smelting, fossil fuel power generation, metal finishing, and steel manufacturing sectors would also decrease copper loadings to the environment. For more information refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=C5039DE5-1.

No management actions to specifically address the presence of copper in the Georgia Basin have been implemented and no specific needs have been identified.

4.4 Manganese

4.4.1 Background Information

Manganese is released to the environment through natural weathering and from anthropogenic sources such as acid mine drainage from mines, emissions, and effluents from the iron and steel industry, municipal wastewater treatment plant (WWTP) discharges, and emissions from gasoline-powered motor vehicles. A manganese compound, methylcyclopentadienyl manganese tricarbonyl (MMT), has been used for more than 25 years to replace lead as an anti-knock agent in gasoline. In 1992, MMT use accounted for the release of approximately 650 t of manganese per year to the Canadian environment and it was estimated that releases were increasing at a rate of about 10% annually (Loranger and Zahed 1994).

Marine organisms readily bioconcentrate manganese and BCFs of 10^2 to 10^5 were reported for shellfish, algae, plants, and fish. Manganese is an essential element for plants and animals and occurs naturally in most organisms (CCME 1987). While, in some situations, the presence of manganese can reduce the toxicity of other metals, concentrations as low as 0.005 mg/L have been shown to have toxic effects on some algae and a 96-h LC_{50} of 2.4 mg/L was reported for coho salmon exposed to manganese in soft water. Water hardness is an important factor in determining the toxicity of manganese to aquatic life and the BC Ministry of Environment provincial water quality criteria for manganese in freshwater systems are based on local levels of water hardness. For example, at a water hardness of 25 mg/L $CaCO_3$, the acute (maximum) guideline is 0.8 mg/L and the chronic (30-day mean) guideline is 0.7 mg/L, while at 300 mg/L $CaCO_3$, the acute guideline is 3.8 mg/L and the chronic guideline is 1.9 mg/L (BC MELP 2001; BC MELP 2006). BC provincial guidelines are available on-line at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html. There are currently no Canadian water or sediment quality objectives for manganese for the protection of aquatic life (CCME 2006).

4.4.2 Georgia Basin

Manganese releases to the Georgia Basin have not been inventoried; however, loadings from select sources have been estimated. A report prepared for Environment Canada estimated that, based on data collected between 1990 and 1998, municipal WWTPs released approximately 34 t (33,941 kg) (based on plants for which information was available) and pulp and paper plants released approximately 26 t (26,173 kg) of manganese, respectively, to the Georgia Basin. Estimated manganese loadings to the Georgia Basin from other identified sources were 1.2 t (1,196 kg) from landfills, 1.1 t (1,111 kg) from metal mines, 12 kg from fabricated metal products, and 3.49 kg from transportation service industries (ENKON 2002).

Loadings of manganese to the Georgia Basin from atmospheric deposition have not been estimated; however, total manganese emissions to the atmosphere in BC in the late 1980s were estimated to be 31 t, with 27 t originating from gasoline-powered vehicles (Jaques 1987). Atmospheric deposition has been identified as a significant source of the elevated manganese concentrations detected in Still Creek and the Brunette River. It was estimated that the deposition rate of manganese for the entire Brunette River watershed was 6.4 t/yr (Brewer *et al.* 2000). Moss monitoring studies in the Lower Mainland indicated that the atmospheric deposition of manganese has increased significantly since MMT was first added to Canadian gasoline. Although the use of the gasoline additive MMT was thought to be a major source of manganese to the environment, the manganese concentrations in moss did not correlate with mobile emission sources (Pott 1995; Pott 1997; Pott and Turpin 1996). Similarly, while manganese concentrations in street and stream sediments in the Brunette River Basin have also increased since the introduction of MMT to gasoline, the increase was not correlated with traffic density (Hall *et al.* 1999).

Manganese concentrations in Burrard Inlet sediments ranged from 333 to 933 μg/g (dw), with an average concentration of 613 μg/g (dw) (Johnson 1991). Similar concentrations were detected in sediments from Victoria Harbour (up to 941 μg/g with a mean of 251 μg/g (dw)) (Transport Canada 2000). Higher manganese concentrations (701 to 6222 μg/g (dw)) have been detected in surface sediments from the Sturgeon Bank off Metro Vancouver's Iona Island WWTP. Manganese concentrations in Fraser River sediments ranged from 328 to 802 μg/g (dw) and it was concluded that the sediments were naturally enriched. Natural elevated manganese concentrations have been detected in coastal sediments in areas removed from known pollution sources. For example, manganese concentrations in sediments from Loughborough Inlet, a natural inlet on the BC coast, were 546 to 2650 μg/g (dw) (Goyette and Boyd 1989; Swain *et al*. 1998).

Recent information on manganese concentrations in BC aquatic species is limited. Manganese concentrations in fish collected in the Fraser River below Hope in the 1980s were generally similar to those detected in fish from uncontaminated lakes, with the exceptions of red shiner and stickleback which contained higher concentrations (Swain *et al.* 1998). A more recent Environment Canada survey concluded there was no obvious difference in the manganese concentrations in fish collected from the Fraser River upstream and downstream of Hope (Raymond *et al.* 1998a,b). Similarly, the limited data available for fish and invertebrates collected in coastal areas of BC did not indicate any areas of manganese contamination (Harding *et al.* 1988; Goyette and Boyd 1989; Swain and Walton 1994; VEHEAP 1997).

4.4.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to manganese include:

Develop a better understanding of environmental fate and distribution by:

- assessing the role of manganese in sequestering other metals in the aquatic environment; and

- investigating the reasons for the lack of correlation between elevated manganese levels in the environment and traffic density.

Obtain more information on non-point (and other) sources and loadings by:

- developing the ability to distinguish the difference in environmental samples between manganese originating from MMT releases and manganese originating from other sources. This is necessary to more accurately assess the concentrations and potential impacts of MMT in the aquatic environment.

4.4.4 Management Actions and Needs

No management actions to specifically address the presence of manganese in the Georgia Basin have been implemented and no specific needs have been identified.

4.5 Mercury

4.5.1 Background Information

Natural sources of mercury to the environment include volcanic emissions, weathering of soils and rocks, and vapourization from oceans. Emissions to the atmosphere are the major anthropogenic source of mercury to the aquatic environment. Sources of mercury to the atmosphere in Canada are metal mining and smelting, municipal waste incineration, sewage and medical waste incineration, coal-fired power plants, cement manufacturing facilities, ore processing, steel manufacturing, petroleum refining, and fossil-fuel combustion. In the past, chlor-alkali plants were major sources of mercury to the environment; however, process changes introduced in the 1980s substantially reduced mercury discharges. The use of mercury in a variety of consumer products such as fluorescent lamps, thermostats, thermometers, electrical switches, blood pressure reading devices, and dental amalgams has also resulted in the release of mercury to the environment. Although mercury is no longer used in the manufacture of many of these products, older items containing mercury are still in use and continue to be discarded to landfills. Mercury containing pesticides were once registered in Canada for use as fungicides and antimicrobials; however, the use of mercury-based pesticides in Canada has been discontinued (BC MELP 2001; Environment Canada 2006e).

Sediments can serve as a sink for mercury in both marine and freshwater systems; however, under some conditions, mercury in the environment can be converted to the more toxic and biologically available methylmercury. Rapid uptake of mercury into aquatic species, combined with a slow rate of depuration, results in high BCFs (10^4). Biomagnification through the food chain can occur and, as a result, organisms at the higher trophic levels often accumulate mercury to concentrations several orders of magnitude greater than the concentrations in ambient waters (Environment Canada 2006e).

Acute toxicity has been observed in various species of aquatic organisms exposed to inorganic and organic mercury compounds in the μg to mg/L concentration range. However, methylmercuric chloride is much more toxic to aquatic species than is mercuric chloride. Exposure to inorganic and organic mercury in the μg/L range can result in a variety of sublethal effects including impaired growth, development, and reproduction; inhibition of limb regeneration in crabs; and impaired immune responses. Concentrations in the ng/L to μg/L range can decrease growth, reproduction, and survival of plankton and diatoms. In contaminated areas, mercury concentrations in fish-eating birds can reach concentrations which are high enough to cause reproductive impairment and abnormal behaviour (CCME 1999). Mercury has been determined to be a toxic substance as defined under CEPA 1999 (Environment Canada 2006e).

The Canadian water quality guideline for the protection of freshwater aquatic life for inorganic mercury is 26 ng/L and the interim guideline for methylmercury is 4 ng/L. The interim guideline for inorganic mercury for the protection of marine aquatic life is 16 ng/L; however, a guideline for methylmercury in marine waters has not yet been developed. The Canadian ISQG for mercury in freshwater sediment is 0.174 μg/g (dw) (equivalent to a threshold effects level or TEL) and the PEL is 0.486 μg/g. The ISQG for marine sediments is 0.13 μg/g and the PEL is 0.70 μg/g (dw) (CCME 2006). Canadian environmental quality guidelines can be viewed on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. BC provincial guidelines for mercury can be viewed at http://www.env.gov.bc.ca/wat/wq/BCguidelines/mercury/mercury.html.

4.5.2 Georgia Basin

Total loadings of mercury to the Georgia Basin have not been estimated; however, loadings estimates are available for some sources. Based on available data for 1990 to 1998, a report prepared for Environment Canada estimated that 21.0 to 56.9 kg of mercury were released annually to the Georgia Basin from municipal wastewater treatment plants (based on information from plants for which data was available) and 3.30 kg of mercury were released annually from combined sewer overflows (CSOs) (ENKON 2002). Hall *et al*. (1999) reported that the mean deposition rate of mercury in precipitation in the Brunette River area was 0.01 $\mu g/m^2/d$; however, atmospheric loadings for other areas of the Georgia Basin have not been estimated.

Mercury concentrations in sediments from south coastal areas of BC were typically less than 0.10 μg/g (dw); however, historical data indicated elevated mercury concentrations in harbour areas and in the vicinity of several industrial facilities, with particularly high concentrations adjacent to CSOs and shipyards. Mercury concentrations exceeding 1.0 μg/g (dw) were detected in sediments collected in Vancouver, Victoria, and Esquimalt harbours; Point Grey; Sturgeon Bank; in the vicinity of a now closed chlor-alkali plant in Howe Sound. At False Creek; Coal Harbour; Roberts Bank; Ladysmith Harbour; Comox; in the vicinities of pulp mills at Harmac, Chemainus, and Powell River; and at various coastal marinas and government docks sediments contained mercury concentrations in the 0.1 to 1.0 μg/g (dw) range. Recent information on mercury concentrations in the Georgia Basin is limited and, for most of the areas identified above, information was not available on current mercury concentrations. However, samples collected from Vancouver Harbour, Sturgeon Bank, and Roberts Bank in the late 1990s indicated that, while concentrations were still elevated at some sites, overall mercury concentrations in sediments from these areas had decreased since the late 1980s (Boyd *et al*. 1997; Boyd *et al*. 1998; Bright *et al*. 1993; ESG 1996; Garrett 1995; Garrett 1985b; Goyette and Boyd 1989; Transport Canada 2000).

Health Canada recommends that mercury concentrations in fish for human consumption not exceed 0.5 μg/g (ww) in the edible portion[9]. Mercury concentrations in BC fish and shellfish generally do not exceed those considered safe for human consumption. Molluscs, crustaceans, salmon, and most ocean species of fish typically contained mercury concentrations of less than 0.5 μg/g. However, some species including shark, swordfish, halibut, and tuna commonly contain higher concentrations. A review of available data, up to 1980, reported that high mercury concentrations were also detected in large halibut (weight of more than 60 lbs), groundfish, and shark species caught in coastal BC waters. In these species, elevated concentrations are not uncommon and are thought to result from natural enrichment and the long life span of these species. In the 1980s, mercury concentrations in some species of fish collected from the lower Fraser River also exceeded the Health Canada recommended guideline of 0.5 μg/g (ww); however, maximum concentrations in Fraser River fish collected in 1994 to 1995 were well below this value (Garrett 1985b; Raymond *et al*. 1998b). Elevated levels of mercury have recently been detected in rockfishes collected near salmon farms situated in coastal BC (Debruyn *et al*. 2006). Mercury can be deposited to the bottom sediments at fish farms in both waste feed and fish feces, and the anoxic

[9] As of July 11, 2007 updated Health Canada standards (maximum limits) for total mercury in commercial fish sold at the retail level came into force. For some fish species (escolar, orange roughy, marlin, fresh and frozen tuna, shark and swordfish), the standard is now 1 ug/g (ww), rather than 0.5 ug/g (ww). In addition, Health Canada has issued consumption advice to Canadians. For more information on mercury standards and consumption advisories, visit the Health Canada website on mercury http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/environ/mercur/index-eng.php.

conditions in sediments at fish farms result in increased mobilization of mercury in the sediments as a result of methylation. The authors recommended ongoing monitoring at fish farms to ensure that wild species are safe to consume. Elevated levels of mercury have also been detected in freshwater bass from Vancouver Island and in rockfish collected from the west coast of Vancouver Island (Vancouver Sun 2007). Canadian Food Inspection Agency and Health Canada are responsible for determining the suitability of fish and shellfish for human consumption.

Fish-eating species of birds from south coastal areas of BC have also been shown to contain high mercury concentrations. Between 1987 and 1994, 82 eagles were found dead or dying in the vicinity of pulp and paper mills in the Georgia Basin. Fourteen of these eagles had sub-clinical levels of mercury in their tissues and one was determined to have died from mercury poisoning. This was the first documented case of mercury poisoning of a bald eagle. In addition, elevated mercury concentrations were detected in mergansers from the Squamish area in 2000 and in the feathers of dippers breeding in the Chilliwack watershed in 1999/2000. The potential biological impacts of these concentrations and the possible sources of the mercury to these birds are currently being investigated (Elliott *et al.* 1996b; Weech *et al.* 2003; Wilson 2002, personal communication).

Information on mercury concentrations in marine mammals is lacking; however, Varanasi *et al.* (1994) reported that gray whales stranded in the Strait of Georgia/Strait of Juan de Fuca contained mercury concentrations of 120, 60, and 85 ng/g (ww) in the liver, kidney, and stomach contents, respectively.

4.5.3 Data Gaps and Research/Monitoring Needs

Obtain current information on environmental levels by:

- investigating the presence of elevated concentrations of mercury in rockfish collected in the vicinity of BC salmon farms; and
- obtaining additional information on mercury concentrations in various species of both freshwater and marine species of fish in BC, in light of the fact that mercury concentrations exceeding the recommended health guidelines have recently been detected in freshwater bass from Vancouver Island and in rockfish from the west coast of Vancouver Island.

4.5.4 Management Actions and Needs

Numerous management actions have been taken nationally to reduce the release of mercury to the Canadian environment. These include the development of management strategies under CEPA 1999 for reducing the release of mercury, as well as other CEPA-toxic substances, from specific industry sectors including base metal smelting, steel manufacturing, and fossil fuel power generation. For additional information refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=C5039DE5-1. In addition, the CCME developed Canada-wide standards (CWSs) for significant mercury-emitting industry sectors and for certain products containing mercury. CWSs have been prepared for emissions from base metal smelters and waste incinerators, dental amalgams, mercury-containing lamps, and coal-fired power plants. For more information on CWSs, refer to the website http://www.ccme.ca/ourwork/environment.html?category_id=108. Other provisions under CEPA 1999 specifically control or inventory the release of mercury to the environment. For more information on actions implemented nationally to address mercury releases to the Canadian environment, refer to the Environment Canada mercury website (www.ec.gc.ca/mercury/).

No management actions to specifically address the presence of mercury in the Georgia Basin have been implemented and no specific needs have been identified.

4.6 Nickel

4.6.1 Background Information

Nickel is used primarily in nickel plating, the manufacture of stainless steel, the production of high-nickel alloys (for chemical, marine, electronic, nuclear, and aerospace applications), nuclear generating plants, gas turbine engines, cryogenic containers, pollution abatement equipment, oil refining, and as a catalyst in some industrial processes. Nickel enters the environment through both natural sources and anthropogenic sources. Natural sources include the weathering of rocks and minerals, volcanic activity, forest fires, soil dust and erosion, and sea salt. Anthropogenic activities such as mining, smelting, and refining; nickel plating; gold mining; iron and steel processing; municipal wastewater treatment discharge; fossil fuel combustion; and cement manufacturing can release nickel to the environment. Nickel-cadmium batteries are not manufactured in Canada, but are imported for use. Their improper disposal can result in nickel releases to the environment (Environment Canada/Health Canada 1994e).

The BCFs for nickel in aquatic organisms typically range from 100 to 5000. Biomagnification of nickel in aquatic food chains has not been observed (Environment Canada/Health Canada 1994e). A variety of freshwater aquatic organisms have exhibited adverse effects as a result of exposure to dissolved nickel in the 24 to 10,000 μg/L range. Most adult fish in soft water have LC_{50}s ranging from 4000 to 14,000 μg/L. In 1994, oxidic, sulphidic, and soluble inorganic nickel compounds were found to be "toxic" as defined under the CEPA 1988 (Environment Canada/Health Canada 1994e).

Canadian interim water quality guidelines for nickel in freshwater systems range from 25 to 150 μg/L, depending on local water hardness. There are currently no Canadian environmental quality guidelines for nickel in marine waters or in sediments (CCME 2006). Canadian environment quality guidelines can be viewed on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. BC provincial approved water quality guidelines have not yet been developed for nickel; however, some guidelines for nickel are contained in the BC provincial working water quality guidelines (BC MELP 2006), which can be viewed on-line at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html#working

4.6.2 Georgia Basin

Loadings of nickel to the Georgia Basin environment have been estimated for some sources. A report prepared for Environment Canada estimated that stormwater discharges contributed 16.7 t (16,664 kg) (based on information for the Lower Mainland Fraser Valley, the Capital Regional District, and the City of Nanaimo), while municipal wastewater treatment plants (WWTP) contributed 6.4 t (6,429 kg) (based on information from the plants for which data was available). Smaller contributions from combined sewer overflows (117 kg), the chemical products industry (45.4 kg), marine cargo handling (11.2 kg), and metal fabricators (1.77 kg) were also identified (ENKON 2002). Another study estimated annual loading of nickel to the Fraser Basin from urban runoff to be 12.6 t (12,600 kg). Loadings to the Lower Fraser River accounted for approximately 10.9 t (10,900 kg) of this amount (Stanley Associates 1992).

Atmospheric deposition also contributes nickel to the Georgia Basin environment; however, information on the loadings from this source is limited. Dry deposition contributed an estimated loading of 1.85 $\mu g/m^2/yr$ to the environment in Abbotsford, but nickel was not detected in wet deposition in this area (Belzer 2001, personal communication). Atmospheric deposition of nickel to the Brunette River watershed ranged from 0.0001 to 11.6 $mg/m^2/day$ (Belzer and Petrov 1997). Analysis of moss in the Lower Fraser Valley indicated that there was a significant decrease in nickel deposition between 1960 and 1993 (Pott and Turpin 1996).

Nickel concentrations in surface waters from most freshwater systems in BC ranged from <1 to 3 μg/L; however, information on concentrations in marine waters was not available (CCME 1987). Sediments collected throughout the Georgia Basin contained nickel in the low μg/g range. Although there are currently no Canadian sediment quality guidelines, concentrations in some sediment samples from the Georgia Basin exceeded the BC provincial "working guideline" values for marine sediments of 30 µg/g dw (for effects-range-low) and 50 µg/g (for effects-range-medium); however, in many instances nickel concentrations were within the range of natural enrichment. For example, while nickel concentrations in sediments from Sturgeon Bank ranged from 40 to 55 µg/g, no enrichment trends were observed which led researchers to conclude that nickel concentrations in the Georgia Basin were natural and not due to contamination from the Iona Island wastewater treatment plant deep-sea outfall (Bertold 2000; Gordon 1997; GVRD 2000; McPherson *et al.* 2001). Mean nickel concentrations in sediments collected from the Burrard Inlet in the 1980s ranged from 7 to 296 µg/g (dw), with the highest concentrations occurring in the Inner Harbour (Goyette and Boyd 1989). More recently, core samples collected in Burrard Inlet contained nickel concentrations of 27.6 to 57 µg/g (dw) in the surface sediment layer and 32.4 to 58.8 µg/g in sediments from the end of the core (Boyd *et al.* 1997). The range of natural nickel concentrations in this area is reported to be 4.5 to 130 µg/g (dw) (Johnson 1991). Nickel concentrations in sediments collected from some sites in Victoria and Esquimalt harbours in 1990 were also higher than the 30 µg/g effects-range-low provincial working guideline, but were generally lower than the 50 µg/g working guideline for effects-range-medium (Bright *et al.* 1993; Transport Canada 2000).

Sediments collected from several locations in the Fraser River contained nickel concentrations in excess of the provincial "working guideline" of 16 µg/g (effects-range-low) for freshwater sediments (Swain *et al.* 1998). In addition, high concentrations of nickel have been detected in the Sumas River sediments and fish, but were attributed to naturally elevated concentrations of nickel in the soils (Schreier 2005, personal communication).

Recent information on nickel concentrations in aquatic organisms within the Georgia Basin is lacking; however, historic information indicated that nickel concentrations in molluscs, crustaceans, and fish from the south coast of BC were typically in the very low µg/g range (<0.5 to 0.43 µg/g (ww)). Invertebrates and flatfish collected in Vancouver Harbour contained nickel concentrations less than or near the detection limit of 2 µg/g (dw). In Esquimalt Harbour, nickel concentrations in most fish and shellfish were below the detection limit; however, concentrations of up to 35 µg/g (dw) were detected in English sole (Bright *et al*. 1993; ESG 1996; Goyette and Boyd 1989; Harbo *et al.* 1983). In the Fraser River, fish from the upper reaches generally contained higher nickel concentrations than did fish collected from the lower reaches of the river. Whitefish collected in the Fraser River in 1994 contained lower nickel concentrations than did whitefish collected from BC lakes considered to be uncontaminated (Raymond *et al.* 1998a,b; Swain and Walton 1989; Swain *et al.* 1998).

Liver, kidney, and stomach content samples collected from stranded gray whales in the Strait of Georgia/Strait of Juan de Fuca contained nickel concentrations of 100, 210, and 900 ng/g (ww), respectively (Varanasi *et al.* 1994)

4.6.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to nickel include:

Develop a better understanding of biological effects of toxic substances by:

- assessing the bioavailability of naturally high levels of nickel in Sumas River bottom sediments and suspended solids.

4.6.4 Management Actions and Needs

Under the federal CEPA 1999, risk management options for the management of CEPA-toxic substances, including nickel, have been developed for the base metal smelting, steel manufacturing, and metal finishing sectors and for fossil fuel power generation. For additional information, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=C5039DE5-1.

No management actions to specifically address the presence of nickel in the Georgia Basin have been implemented and no specific needs have been identified.

4.7 Silver

4.7.1 Background Information

Silver enters the environment from both natural and anthropogenic sources. Natural sources include weathering, volcanic activity, and hot springs. Anthropogenic sources include the iron and steel industry, the cement industry, photo-processing, electronics manufacturing, metal plating, coal combustion, crude oil production, cloud seeding for weather modification, municipal waste treatment plant discharges, and runoff from landfills. In the past, the release of silver thiosulphate complexes in waste photo-processing solutions, originating from medical and dental x-rays and photographic development, was the main source of silver to the aquatic environment. These wastes were discharged primarily to municipal sewer systems. The photo-processing industry has now taken measures to reduce silver releases to the sewer systems, thus decreasing the release of silver to the aquatic environment. It has been estimated that approximately 11,000 tonnes (t) of silver enter the world's oceans annually as a result of weathering, compared to 2500 t from anthropogenic sources (BC MELP 1996; CCME 1987; Environment Canada 1999).

The highest BCFs for silver were reported for algae ($>10^5$) and have been attributed to the adsorption of silver onto the cell surface. Zooplankton and bivalves have BCFs of approximately 10^2 or lower. The bioaccumulation of silver in fish has not been well studied; however, it was reported that fish bioaccumulate silver to a lesser extent than do aquatic invertebrates. This is consistent with the fact that fish in the natural environment generally contain lower levels of silver than do invertebrate species. There is no evidence of biomagnification in the aquatic food chain (BC MELP 1996; CCME 1987; Ratte 1999; Wang *et al.* 1999).

Among the most sensitive aquatic organisms to the toxic effects of silver are phytoplankton and the embryonic and larval stages of invertebrates and fish. Fish embryos are much more sensitive to silver than are juvenile and adult fish. LC_{50} values of between 2.5 and 10 μg/L have been reported for sensitive freshwater fish species exposed to silver nitrate. Toxicity tests indicate that the embryos and larvae of flounders are as sensitive to silver as were the most sensitive species of marine invertebrates. However, in general, silver is less toxic to both juvenile and adult stages of marine fish than to freshwater fish and the LC_{50}s for marine fish are generally from 1 to 2 orders of magnitude higher than are those for freshwater fish. Sublethal effects can occur at concentrations far below the acutely lethal levels. For instance, exposure to silver at concentrations 1/500 and 1/400 of the LC_{50} values adversely impacted egg production in cladocerans and copepods, respectively (Ratte 1999; Wood *et al.* 1999).

The toxicity of silver is determined by the presence of active free Ag+ ions in the water. Silver in the natural environment tends to bind with particulates or complexing agents, thus reducing the available free Ag+ ions in the water column. For this reason, the toxicity of silver to aquatic organisms is typically lower in the natural environment than in laboratory tests. More information is needed on the toxicity of various forms of silver in the natural environment, particularly with respect to the early developmental stages of fish (Guadagnolo *et al.* 2001; Ratte 1999; Wood *et al.* 1999).

The Canadian water quality guideline for silver, for the protection of freshwater aquatic life, is 0.1 μg/L. There are currently no Canadian guidelines for silver in marine waters or in sediments (CCME 2006). The BC provincial water quality criteria for silver in freshwater and marine/estuarine systems vary according to local levels of water hardness (BC MELP 1996). Canadian environmental quality guidelines can be viewed on-line at http://www.ccme.ca/publications/ceqg_rcqe.html and BC provincial guidelines at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html.

4.7.2 Georgia Basin

Information on the sources and loading of silver to the Georgia Basin is lacking. A report prepared for Environment Canada estimated that municipal WWTPs in the Georgia Basin discharged annual loadings ranging from 715 to 1901 kg (0.72 to 1.9 t) between 1991 and 1998 (based on information from WWTPs for which data was available). Limited information was also available for silver releases to the Georgia Basin environment from combined sewer overflows (CSOs), urban runoff, landfill leachate, and industrial effluents. However, available information was not sufficient to estimate loadings from these sources. The report noted that the identification and characterization of silver sources to the environment in the Georgia Basin may be required in order to better control the release of silver to the environment (ENKON 2002).

Atmospheric deposition contributes an estimated 128 kg/yr of silver to the Brunette River (Brewer *et al.* 2000). A 1995 study in the Brunette Basin in Burnaby revealed that the concentrations of silver and several other metals in precipitation were sometimes higher than the Canadian water quality guidelines for the protection of aquatic life (Environment Canada 1998b).

Silver concentrations in south coastal BC surface waters were less than the detection limit of 0.10 μg/L (CCME 1999); however, concentrations in sediments collected from some nearshore south coastal areas were elevated in comparison to sediments collected from the deeper waters of the Strait of Georgia. The highest concentrations (>1000 ng/g (dw)) were detected near the Iona Island wastewater treatment plant on Sturgeon Bank. The study concluded that silver showed a pattern of deposition clearly related to the Iona discharge (GVRD 2000; Wilson 2000). Silver concentrations exceeding 1000 ng/g (dw) have also been detected in sediments from Vancouver Harbour (up to 3500 ng/g (dw)), Victoria Harbour (up to 6200 ng/g (dw)), and Esquimalt Harbour (up to 2800 ng/g (dw)) (VEHEAP 1997; Transport Canada 2000). Sediments collected near a large CSO discharge in Vancouver Harbour contained 3500 ng/g (dw) silver (Hall *et al.* 1999). Silver concentrations were elevated (1700 ng/g (dw)) in sediments collected within 1000 meters of the major Victoria area deepwater sewage discharge, compared to concentrations in sediments from the reference area (70 to 130 ng/g (dw)) (Chapman *et al.* 1996).

Little information was available on silver levels in biota in the Georgia Basin; however, Wilson (2000) reported that the mean silver concentrations in fish and shellfish near the Iona outfall off Sturgeon Bank were 790 and 1430 ng/g (ww) in crab muscle and hepatopancreas, respectively; 590 ng/g (ww) in shrimp muscle; and <50 and 510 ng/g (ww) in English sole muscle and liver, respectively. Histopathological effects were observed in Dungeness crab from the vicinity of the Iona WWTP and were positively correlated with the concentration of silver (Wilson 2000).

Gray whales found stranded along the coast of Strait of Georgia/Strait of Juan de Fuca contained low silver concentrations (20 ng/g (ww)) in the liver, kidney, and stomach contents (Varanasi *et al.* 1994).

4.7.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to silver include:

Obtain current information on environmental levels by:

- developing a means of measuring the biologically-available forms of silver (free monovalent silver ion), as most of the existing guidelines and criteria are based on total silver measurements, which include the less toxic forms, resulting in guidelines that are overprotective.

Develop a better understanding of biological effects by:

- determining if present criteria/guidelines are protective of both hatchery fry and wild fry by assessing the toxicity of silver to anadromous salmonids, particularly fry in soft freshwater habitats, as little is known about the mechanism of silver toxicity to the early developmental stages of fish;

- evaluating the biocidal properties of Ag^{2+} and Ag^{3+}, which are active ingredients in disinfectants used for water purification of drinking water and swimming pools; and
- investigating the effect of chemical speciation on the toxicity of silver chloride complexes in seawater to marine benthic organisms due to the high sensitivity of larval stages to silver.

Develop a better understanding of environmental fate and distribution by:

- developing a better understanding of the geochemistry and chemical speciation of silver in the aquatic environment of the Georgia Basin.

Obtain more information on non-point (and other) sources and loadings by:

- identifying and characterizing industries discharging silver to municipal sewers in order to better determine loadings and control sources of silver to the Georgia Basin environment.
  Note: This need was specifically identified by an Environment Canada report on wastewater sources of toxic substances to the Georgia Basin (ENKON 2002).

4.7.4 Management Actions and Needs

No management actions to specifically address silver in the Georgia Basin have been implemented; however, both Metro Vancouver and CRD sewer use bylaws set maximum limits on the concentration of silver in wastewaters discharged to sewer systems. In addition, the CRD has introduced Codes of Practice for both dental and photographic imaging operations. Dental wastewater contains restricted waste as defined in the CRD sewer use bylaw. Dental operations are, therefore, required to follow the Code of Practice for Dental Operations. Adherence of dental operations to the Code will decrease the release of silver to the environment through the proper handling and disposal of X-ray wastes and dental amalgams, which both contain silver. In addition, a Code of Practice for Photographic Imaging Operations in the CRD has been developed and is included under the CRD sewer use bylaw.

No specific needs for management actions to address the presence of silver in the Georgia Basin have been identified.

4.8 Zinc

4.8.1 Background Information

Like other metals, zinc can enter the environment through natural processes such as weathering and erosion and also from anthropogenic sources. Major uses of zinc include zinc coatings for the protection of iron and steel, die casting alloys, brass production, dry batteries, roofing and exterior fittings in construction, and some printing processes. Zinc is also used in the manufacture of a wide variety of products including cosmetics, ointments, medicinal products, tires, glass, electrical apparatus, cement and concrete, textiles, agricultural fertilizers, pesticides, linoleum, rubber, paints, varnishes, and wood preservatives. In the marine environment, zinc sacrificial anodes are used on vessels to prevent corrosion. Zinc enters the environment as a result of the use and application of these products and also from primary zinc production, iron and steel production, municipal treatment plant wastewater discharges, wood combustion, and waste incineration (BC MELP 1999; Bird *et al.* 1996; CCME 1987; Environment Canada 1999).

Zinc is readily bioaccumulated by aquatic organisms and reported BCFs are in the 10^3 range for freshwater plants and fish and in the 10^4 range for freshwater invertebrates. Zinc is an essential trace element and is important in biological systems; however, it can be toxic to aquatic biota at elevated concentrations in the environment. Elevated zinc levels in stormwater runoff entering the marine environment caused a significant reduction in taxa abundance and biomass. Acutely toxic concentrations of zinc vary widely and are influenced by both the species and age of the organism and by environmental characteristics. In soft water, the maximum acceptable tolerance concentrations (MATC) for rainbow trout (based on success of fry from unexposed eggs) ranged from 36 to 71 μg/L, and the MATC values for fathead minnow eggs ranged from 78 to 145 μg/L. Zinc has been reported to be toxic to aquatic species at concentrations ranging from approximately 90 to 58,000 μg/L. Exposure of aquatic organisms to sublethal concentrations of zinc in water and/or sediments can result in a variety of adverse effects including decreased growth, decreased fecundity, inhibition of microbial activity, changes in cell morphology, reduced size of offspring, delayed hatching, decreased diversity and abundance, impaired reproduction, and behavioural changes (Casper 1994; CCME 1987; CCME 1999).

The Canadian water quality guideline for zinc for the protection of freshwater aquatic life is 30 μg/L; however, a guideline has not yet been developed for marine/estuarine systems. High concentrations of zinc in sediments have been shown to cause adverse effects in both freshwater and marine species and Canadian ISQGs (equivalent to a threshold effects level or TEL) and PELs for zinc have been developed for freshwater and marine sediments. The ISQG and PEL for zinc in freshwater are 123 and 124 μg/g (dw), respectively, and the ISQG and PEL for zinc in marine/estuarine sediments are 315 and 271 μg/g (dw), respectively (CCME 2006). The BC provincial water quality guidelines for zinc in freshwater systems vary with local levels of water hardness. Freshwater guidelines were based on the lowest observed effect level (LOEL) of 15 μg/L for copepods and a 96-h LC_{50} value of 66 μg/L for rainbow trout. Guidelines for marine systems are 10 μg/L for chronic exposures (30-day averages) and 33 μg/L for acute exposures (maximum concentration) (BC MELP 1999). Canadian environmental quality guidelines can be viewed on-line at http://www.ccme.ca/publications/ceqg_rcqe.html and BC provincial water quality guidelines can be viewed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html.

4.8.2 Georgia Basin

Information on the sources of zinc to the Georgia Basin environment is limited; however, loadings from some sources have been estimated. A report prepared for Environment Canada estimated that more than 100 t (100,433 kg) of zinc enters the Georgia Basin annually in stormwater discharges (based on stormwater information for the Lower Mainland Fraser Valley, the Capital Regional District, and the City of Nanaimo). Municipal wastewater treatment plants in the Georgia Basin (based on information from plants for which data was available) discharged annual loadings of 37.2 to 38.7 t of zinc. Estimated loadings from other sources were 2.7 t from pulp and paper facilities, 2.3 t from metal mines, 1.75 t from CSOs, 0.5 t from marine cargo handling, 0.1 t from fabricated metal products, and 0.06 t (57 kg) from chemical products industries (ENKON 2002). Stanley Associates (1992) estimated that zinc loadings to the Fraser Basin were 75.3 t annually, with 65.5 t being released to the Lower Fraser River. Although not included in this study, the now closed Britannia Mines in Howe Sound has been recognized as one of the largest metal pollution sources in North America. Metal releases from this site resulted in the contamination of sediments in Howe Sound and elevated metal concentrations have also been detected in soil and groundwater in this area. ARD was identified as the main source of metal pollution; however, other sources included past waste rock disposal, concentrate spills, and tailings disposal. The estimated loading of zinc to Howe Sound was 82.5 t/day. Pollution prevention measures are now being implemented; however, metals-contaminated drainage continued until the completion of the wastewater treatment plant (Government of BC 2006). For additional information refer to the provincial government website on Britannia Mines (http://www.agf.gov.bc.ca/clad/britannia/index.html).

Atmospheric deposition accounts for the entry of approximately 14 t/yr of zinc annually to the Brunette River watershed in Burnaby. Atmospheric deposition of zinc in this region was attributed primarily to transportation sources and tire wear (Belzer and Petrov 1997; Brewer *et al.* 2000). Information to determine the total contribution of zinc to the Georgia Basin from atmospheric deposition was not available. However, the analysis of moss in the Lower Fraser Valley indicated that there was a significant decrease in nickel deposition between 1960 and 1993 (Pott and Turpin 1996).

Surface water zinc concentrations in the Georgia Basin ranged from 1 to 88 μg/L (Macdonald *et al.* 1991; Swain *et al.* 1998). In coastal sediments, the highest zinc concentrations were typically detected in the vicinity of historic mines, pulp mills, shipyards, and active harbours. Surveys conducted in the 1980s and the early 1990s, found that sediments in Vancouver, Victoria, and Esquimalt harbours contained zinc at concentrations in the 100 to several thousand µg/g (dw) range, likely due to extensive historical industrial activity and also to the release of sewer discharges in these harbours (Bright *et al.* 1993; ESG 1996; Garrett 1995; Goyette and Boyd 1989; Transport Canada 2000). Subsequent sediment sampling in Vancouver Harbour conducted in the late 1990s revealed lower zinc concentrations (Boyd *et al.* 1997; Boyd *et al.* 1998). Elevated zinc concentrations have also been detected in sediments off public port facilities in the Georgia Basin (Transport Canada 2000). Sediments from Jervis Inlet, a reference area along the BC coast, contained a mean concentration of 161 µg/g (dw) (Brothers 1990).

Elevated concentrations of zinc and some other metals have also been detected in the sediments and surface waters of some golf courses in the Fraser Basin. Possible sources included fertilizers, pesticides, road runoff, piping, and atmospheric deposition (Environment Canada 1996).

ARD from some BC mines has resulted in elevated concentrations of zinc and other metals in the environment. The long-term release of metals-contaminated drainage from the Britannia Mine on Howe Sound resulted in elevated zinc concentrations in water, sediments, and biota. Pollution control measures are now being implemented to address pollution from this source. ARD also resulted in elevated concentrations of zinc in surface waters in a mine near Buttle Lake on Vancouver Island. However, this pollution issue has now been resolved and recent data indicated that concentrations have decreased and now meet provincial guidelines in most samples. Similar decreases have not been observed in muscle tissue of rainbow trout from Buttle Lake (Deniseger and Erikson 1991).

Recent information on zinc concentrations in aquatic species from the BC coast is very limited. A DFO study published in the early 1980s reported that mean zinc concentrations were 30, <60, and <15 µg/g (ww), respectively, for molluscs, crustaceans, and fish from the south coast of BC. The mean concentration of zinc in oysters (642 µg/g) was very high in comparison to other aquatic species (Harbo *et al.* 1983). High zinc concentrations (541 to 1821 µg/g (dw)) were also detected in the digestive gland of oysters from the Crofton area (Colodey and Tyers 1987). Elevated zinc concentrations were also detected in some species of aquatic biota from Vancouver, Victoria, and Esquimalt harbours (Garrett 1995; Goyette and Boyd 1989; VEHEAP 1997). No obvious pattern in zinc concentrations was detected in the muscle or liver tissue of Fraser River fish collected upstream and downstream of Hope in 1994 and 1995. However, differences in muscle concentrations of zinc were apparent between species, with peamouth chub containing higher concentrations than whitefish from the same locations. The zinc concentrations in the liver of starry flounder were higher than those detected in the liver of chub or whitefish (Raymond *et al.* 1998a,b; Swain *et al.* 1997; Swain *et al.* 1998).

Limited information on zinc concentrations in wildlife species in the Georgia Basin is available. Environment Canada has monitored concentrations of metals, including zinc, in diving ducks along the BC coast and in harbours within the Georgia Basin (Barjaktarovic *et al.* 2002; Wilson and Elliott 2004). Harding *et al.* (1998) studied mink and otter populations in the Lower Fraser River and concluded that zinc contamination in this area does not currently pose a problem to mustelid populations. Gray whales found stranded along the west coast of BC contained zinc concentrations of 120, 69, and 52 µg/g (ww) in the liver, kidney, and stomach contents, respectively (Varanasi *et al.* 1994).

4.8.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to zinc include:

Develop a better understanding of biological effects by:

- assessing the relative contribution of zinc to the toxicity of stormwater runoff from wood treatment facilities in the Georgia Basin.

4.8.4 Management Actions and Needs

Nationally, risk management strategies have been developed under the CEPA 1999 for several industry sectors and include recommendations for actions to reduce releases of several metals including cadmium, nickel, arsenic, and chromium. Assessments of these metals, conducted by Environment Canada and Health Canada, found them to be toxic as defined under CEPA. It is expected that the implementation of recommendations to reduce the release of CEPA-toxic substances from the base metal smelting, fossil fuel power generation, metal finishing, and steel manufacturing sectors would also decrease zinc loadings to the environment. For more information, refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=C5039DE5-1.

No management actions to specifically address the presence of zinc in the Georgia Basin have been implemented and no specific needs have been identified.

5. Other Priority Substances of Concern

5.1 Nitrogen-based Nutrients (nitrates, nitrites, and ammonia)

5.1.1 Background Information

Nitrates are used in the production of chemical fertilizers and explosives and as oxidizing agents, nitrite salts are used as industrial corrosion inhibitors, and sodium and potassium nitrite are registered for use in food processing under the *Food and Drugs Act*. Approximately 95% of the synthetically produced ammonia in Canada is used for the production of agricultural products such as urea, nitric acid, ammonia sulphate, and fertilizers. Ammonia is also used in industrial processes such as mining, refining, pulp and paper, and in the production of amines and nitriles (CCME 1987).

Nitrogen-based nutrients enter the atmosphere and aquatic systems from both natural and anthropogenic sources. Natural sources include the transformation of nitrogenous matter in soil and water; production and release by biota; atmospheric gas exchange; nitrogen fixation of dissolved nitrogen gas in water; and releases from forest fires, igneous rocks, and volcanic eruptions. A global study on ammonia emissions indicated that animal waste was the main contributor of ammonia to the atmosphere in North America. In 1995, it was estimated that natural releases of ammonia to the atmosphere in Canada (>500,000 t) were approximately equal to the atmospheric releases from the animal husbandry industry, which has been identified as the largest anthropogenic atmospheric source. Atmospheric deposition contributes approximately 2.5 kilograms per hectare annually to the Canadian environment in the form of nitrate and ammonium (CCME 1987; Lauriente 1995; Vezina 1997).

Anthropogenic sources of nitrogen-based nutrients to aquatic systems include discharges from various industries, municipal WWTP discharges, septic systems, fertilizers and manure applied to agricultural lands, feedlots and dairies, and aquaculture facilities. A 1995 study estimated that more than 1,470,000 t of total nitrogen were released to the atmosphere and that 41.3% originated from the agricultural sector, 21.1% from fossil fuel combustion for transportation, and 22.4% from combustion-related emissions and process emissions from industry. Environment Canada's National Pollutant Release Inventory (NPRI) is a legislated national and publicly accessible inventory on annual releases to air, water, land, and disposal or recycling from all sectors, including industrial, government, and commercial. For 1996, NPRI identified ammonia as the industrial pollutant with the highest releases (more than 32,000 t across Canada). For 2005, it was reported that total ammonia releases in Canada were more than 73,000 t. For more information, refer to the NPRI website http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm.

Municipal WWTPs have been identified as the major quantifiable anthropogenic source of ammonia to Canadian aquatic systems. In 1999, it was estimated that Canadian WWTPs released approximately 82,750 t of total nitrogen to the environment. In 1996, septic systems, which were used by approximately one-quarter of the Canadian population, released more than 15,000 t of nitrogen (Chambers *et al.* 2001; Environment Canada 2001; Environment Canada/Health Canada 2002). Another important source of nutrients to the environment is the widespread use of chemical fertilizers and manure, which are applied to agricultural land to increase crop yields. Where the application of these products is in excess of crop uptake requirements, nitrogen can be transported to aquatic systems via the atmosphere and irrigation waters. Agricultural releases of nutrients to the aquatic environment cannot be accurately quantified because of their diffuse nature. Feedlots and dairies (or other intensive animal-rearing facilities) with direct runoff to watercourses have the potential to significantly contaminate local water systems; however, the many diffuse agricultural releases would contribute larger quantities of ammonia to the environment overall (Burkart and James 1999; Carpenter *et al.* 1998; Environment Canada/Health Canada 2002). Fish feces and unconsumed food release large amounts of nutrients to the environment at aquaculture facilities. Finfish aquaculture releases an estimated 2,276 t/yr of nitrogen to inland and coastal waters in Canada (Chambers *et al.* 2001; Environment Canada 2001). Other sources of nitrogen-based nutrients to the environment include forest management practices; landfills; various industries including pulp and paper mills, mines, food processors and fertilizer manufacturers; industrial cleaning operations using ammonia or ammonium salts; and the manufacture and use of explosives in mining and construction. The use of ammonia-based substances for forest fire control is a source of ammonia to select forest ecosystems; however, loadings from this source have not been estimated (CCME 1987; Environment Canada/Health Canada 2002).

Nutrients are essential to the survival of living organisms; however, human activity such as urbanization, industrialization, and agriculture can increase the release of biologically available forms of nitrogen and, ultimately, alter the natural nitrogen cycle. Human activities have more than doubled the rate of nitrogen fixation globally since pre-industrial times. The natural balance of species diversity can be disrupted by eutrophication, which is the over-supply of nutrients to a water system. Excessive amounts of nutrients can over-stimulate the production of plant species (such as algae) to the detriment of other species, and can cause a variety of direct and indirect toxic effects on aquatic organisms. Adverse impacts associated with nutrient releases occur most commonly in water bodies with little natural flushing; however, the effects of eutrophication have been observed in rivers, lakes, wetlands, coastal waters, and particularly in estuaries (Chambers *et al.* 2001; Environment Canada 2001). Excess nutrients entering aquatic systems have caused environmental impacts in some areas of Canada, including the Lower Fraser Valley in BC.

Ammonia is toxic to aquatic organisms over a wide range of concentrations. Toxicity is primarily associated with un-ionized rather than ionized ammonia. Total ammonia concentrations of about 2 mg/L cause adverse effects in some species and life stages of aquatic organisms. Exposure to sublethal levels of ammonia can cause adverse physiological effects and tissue damage in fish. Both ammonia and nitrite act as stressors by stimulating the release of corticosteroid hormones that are linked to impaired immune function, decreased disease resistance, and reduced survival and growth. Nitrate is often detected in relatively high concentrations in Canadian surface waters. Nitrate concentrations in the 1 to 10 mg/L range can be toxic to eggs and, to a lesser extent, fry of salmon and trout. Amphibian tadpoles exposed to concentrations as low as 11 mg/L suffered adverse effects including behavioural changes and reduced survival. Observed declines in some amphibian populations in Canada have been attributed, at least in part, to the presence of high concentrations of nitrates. Nitrate concentrations in the 13 to 40 mg/L range are acutely toxic to a number of amphibian species, while chronic effects can occur at concentrations as low as 2.5 mg/L. Nitrite is not considered to be of significant environmental concern as it is rapidly oxidized to nitrate in the environment and, therefore, does not normally occur in surface waters at concentrations high enough to cause adverse effects in aquatic organisms. However, nitrate and ammonia can both be transformed to nitrite under certain environmental conditions. In addition, high nitrite concentrations can occur in receiving waters near WWTP discharges, in aquaculture facilities, and in ponds or other natural areas where animal biomass is high. Numerous fish kills in Canada have been attributed to the discharge of materials containing nutrients, particularly nitrogen compounds. In most cases, fish kills were associated with agricultural activities (especially manure contamination of storm or flood runoff), leaking underground tanks, storage facility overflows, or field spraying (Chambers *et al.* 2001; Environment Canada 2001; Rouse *et al.* 1999; Sarda and Burton 1995; Tomasso 1994).

Canadian interim water quality guidelines for ammonia, nitrate, and nitrite for the protection of freshwater aquatic life were developed by the CCME and provincial criteria have been developed by the BC Ministry of Environment. Canadian guidelines for the protection of marine species have not yet been developed for ammonia, nitrate, and nitrite; however, BC MOE has developed criteria for ammonia concentrations in marine waters. There are no provincial or Canadian sediment quality criteria for nitrogen-based nutrients in sediments. Canadian environmental quality guidelines can be viewed on-line at http://www.ccme.ca/publications/ceqg_rcqe.html and BC provincial guidelines at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html.

5.1.2 Georgia Basin

Existing information is inadequate to determine total loadings of nitrogen-based nutrients to the Georgia Basin. Based on available information for the period 1990 to 1998, a report prepared for Environment Canada estimated that annual loadings of ammonia from municipal WWTPs were 6616 t (based on plants for which data was available). This report also estimated loadings of 100 t from stormwater (based on stormwater information from the Lower Mainland, the Fraser Valley, the Capital Regional District, and the City of Nanaimo), 92 t from pulp and paper industries (likely an underestimate as some mills did not report ammonia), 66 t from combined sewer overflows (CSOs), 7 t from metal mines, 0.33 t from refined petroleum and coal products, and 13 t from other miscellaneous sources. The annual loading of ammonia to the Fraser River Basin from landfills was estimated to be 115 t (ENKON 2002). Studies to determine the presence of nitrogen-based nutrients in stormwater in the Lower Fraser Valley area have been conducted by Hall *et al.* (1996, 1998, 1999). Stanley and Associates (1992) estimated that annual nutrient loadings to the Fraser Basin were 75.3 t of ammonia, 351.6 t of nitrate/nitrite, and 878.9 t of total nitrogen. Loadings to the Lower Fraser River were estimated to account for 65.5 t, 305.7 t, and 764.2 t, respectively.

The atmospheric deposition of nitrogen-based nutrients to the Georgia Basin has not been well studied; however, Environment Canada has conducted studies in some areas including the Brunette Basin watershed in the Lower Mainland and the Abbotsford area (Belzer 2001; Belzer and Petrov 1997). Atmospheric inputs of nitrogen oxides (NOx) into the Georgia Basin are dominated by contributions from Vancouver Island and the Lower Mainland. These regions contributed approximately 133,000 t of the 260,000 t estimated total release for the province (BC MELP 1995).

The aquaculture industry is another source of nutrients to coastal BC waters. Studies conducted by DFO at BC coastal salmon farming operations estimated that, for each tonne of fish produced, 43 kg (0.043 t) of nitrogen and 9.5 kg (0.0095 t) of phosphorus were released to the environment (Chambers *et al.* 2001; Environment Canada 2001).

Researchers have reported that the natural nitrogen inputs to Strait of Georgia/Puget Sound/Juan de Fuca Strait by estuarine circulation (2600 to 2900 t/day N) are far greater than all other sources combined including sewage inputs of <100 t/day, Fraser River input (including sewage, agriculture, and natural contributions) of <60 t/day, coastal groundwater discharges (<15 t/day), and atmospheric inputs (<10 t/day) (Mackas and Harrison 1997).

The total estuarine input of nitrogen to the Georgia Basin is estimated to be 2,500 to 2,800 t per day. About 75% of this, or 2,000 to 2,100 t, are exported through seaward advection resulting in a net nutrient input of 500 to 1,000 t per day. Researchers studying nitrogen loadings to the Georgia Basin in 1994 concluded that most of the nitrogen to the Georgia Basin was supplied by entrained seawater from the Strait of Juan de Fuca and that wastewater loading from the Metro Vancouver municipal WWTPs provided less than 1% of the total nitrogen loading to Georgia Strait (Mackas and Harrison 1997).

Elevated nutrient levels occur in surface and groundwaters in areas of intensive agricultural activity in the Lower Fraser Valley. This is a result of excess manure waste from increased numbers of livestock confined to smaller areas of agricultural activity. In addition, many farmers use commercial animal feed, which contains high nutrient concentrations, rather than producing their own feed crops which would help to reduce the excess nutrients in the soil. Maximum concentrations of ammonia and nitrate in surface waters of the Sumas River watershed were in the range known to impact amphibians. Increased nitrate levels in the surface waters of the Salmon River system were attributed to increased septic tank and animal production unit densities (Schreier *et al.* 1998).

Groundwater contamination problems associated with nutrients occur mainly in the south coastal region, an area of high rainfall and intensive agriculture. Nutrient concentrations in excess of the Canadian drinking water standards were found in private wells in the Abbotsford-Sumas, Hopington, and

Langley-Brookswood aquifers. In the mid-1990s, nitrate concentrations in the Abbotsford-Sumas aquifer exceeded the recommended drinking water maximum concentration of 10 mg/L in up to 80% of the study area. It was concluded that the main source of contamination was the poultry manure applied to raspberry fields as a fertilizer. High seasonal variability and concentrations exceeding drinking water standards for nitrate were reported for well-water samples in the Salmon River watershed between 1994 and 1996. Concentrations in excess of drinking water standards are of concern due to the large number of households which rely on domestic water supplies in the Salmon River Basin. A nitrogen budget for the area indicated that the surplus nitrogen was contributed by agriculture, hobby farms, and septic systems (Chambers *et al.* 2001; Environment Canada 2001; Liebscher *et al.* 1999; Schreier *et al.* 1998; Wassenaar 1995). A recent review of decadal trends (1991 to 2004) by Wassenaar *et al.* (2006) revealed that the voluntary agricultural beneficial management practices (BMPs), which have been promoted in the Abbotsford-Sumas aquifer since the 1990s, have not had a positive impact on reducing the aquifer-scale nitrate contamination in this area. The authors concluded that the BMPs should be better linked to groundwater nutrient monitoring programs in order to more quickly identify deficiencies in BMPs.

Some fish kills in BC have been attributed to accidental municipal wastewater discharge and ammonia releases from food processing (Chambers *et al.* 2001; Environment Canada 2001). However, a report prepared for Metro Vancouver concluded that ammonia levels in the Lower Fraser River were not toxic to aquatic life and were not causing other adverse effects in the Lower Fraser River. The report also stated that it is unlikely that nitrogen discharged by WWTPs would accumulate in the Georgia Basin due to nitrification and uptake by phytoplankton and bacteria, which remove ammonia-nitrogen from the surface water (ENKON 2001b). Another study concluded that sewage discharges to the Georgia Basin would not have a significant influence on either phytoplankton production or on eutrophication in the Georgia Basin (Mackas and Harrison 1997).

5.1.3 Data Gaps and Research/Monitoring Needs

Various research and monitoring needs have been identified for nutrients in the environment nationally. These include:

Develop a better understanding of biological effects by:

- assessing the role of nutrients in inducing algal blooms and toxin production; and
- determining the effect of long-term (decades) loadings of nitrogen (along with phosphorus) on freshwater, marine, and terrestrial ecosystems and of atmospheric nitrogen deposition on terrestrial ecosystems.

Obtain more information on non-point (and other) sources and loadings by:

- estimating nitrogen (and phosphorus) loadings from industries not connected to municipal wastewater treatment systems;
- ensuring consistency in loadings assessments reporting with respect to parameters measured;
- determining the potential impacts of climate change on nutrient loading; and
- examining the effects of forest management practices on nutrient losses from forests to aquatic ecosystems.

In addition to these, data gaps and research/monitoring needs specific to nutrients in the Georgia Basin have been identified and include:

Obtain current information on environmental levels by:

- identifying aquifers of concern by compiling information on areas where surface or groundwater concentrations of nitrite, nitrate, and ammonia reach unacceptable levels for either human consumption or for aquatic species in the Georgia Basin; and
- implementing or continuing monitoring to identify trends in nitrogen-based nutrients in ground and surface waters.

Develop a better understanding of biological effects by:

- employing consistency in documenting and reporting information on fish kills from accidental spills/discharges of nutrient-related compounds, as current information is not always reliable and reporting is done on a voluntary basis.

Obtain more information on non-point (and other) sources and loadings by:

- estimating atmospheric deposition of nutrients to the Georgia Basin, including deposition to coastal mountains and both aquatic and terrestrial ecosystems. This information would help to identify regional differences in atmospheric nitrogen contributions which have been identified as a limitation in attempts at nutrient modelling;
- estimating nutrient loading to surface and groundwaters from agricultural sources, including greenhouses; and
- determining the relationship between agricultural application of nutrients and levels of nitrate in groundwater.

5.1.4 Management Actions and Needs

National initiatives to address concerns associated with the presence of ammonia in the Canadian environment include the assessment of ammonia under the *Canadian Environmental Protection Act, 1999* (CEPA 1999). Ammonia, in the aquatic environment, was found to be 'toxic' as defined under Section 64 of the Act and, under the requirements of the Act, the federal government was required to prepare a risk management strategy to reduce the release of ammonia to the aquatic environment. For information on the federal risk management strategy refer to the Environment Canada website http://www.ec.gc.ca/toxiques-toxics/Default.asp?lang=En&n=98E80CC6-0&xml=E9537B48-E09B-4FCF-8A56-F1F44B97FAE4.

Management action needs specific to nitrogen-based nutrients in the Georgia Basin include:

Review, support and promote past and existing initiatives which have been successful by:

- participating, tracking, and evaluating measures implemented under the Agricultural Policy Framework (APF), in effect between 2003 and 2008 to address priority agricultural environmental issues throughout BC;
- coordinating support by all agencies of the initiatives and implementation strategy contained in the BC MOE Action Plan for NPS in BC;
- continuing encouragement and support of interagency cooperative measurement programs;
- continuing existing initiatives to decrease agricultural and urban runoff of nutrients (BAWMPs);
- continuing efforts to remove manure from areas with nutrient surpluses to areas with nutrient deficiencies; and
- implementing additional educational programs, promotion of pollution control measures, and regulatory enforcement where required.

Implement measures to address identified hotspots and priority watersheds by:

- examining the feasibility of treating nitrogen contaminated wastes from intensive livestock operations; and
- making mandatory the regular servicing of septic systems, as it has been shown that these systems tend to be poorly maintained. (*Note: as of May 31st, 2005 a new provincial regulation puts the onus on the homeowner to ensure that systems are designed, installed and maintained properly. Under the new regulation, a septic or sewage system must be installed by a Registered Onsite Wastewater Practitioner. However, there is widespread concern that this regulation is not sufficient and requires revision. For more information on the BC Sewerage System Regulation refer to the British Columbia Ministry of Health website http://www.healthlinkbc.ca/healthfiles/hfile21.stm and the CRD website http://www.crd.bc.ca/wastewater/septic/onsite.htm*).

Utilize voluntary pollution prevention and pollution control initiatives by:

- considering the use of limits on animal stocking densities (as is practiced in Europe) in order to better manage nutrients and track the development of animal production systems in the Fraser Valley;
- ensuring the implementation of existing best management practices (BMPs) for agricultural activities to control nutrient loading to the environment and developing new BMPs for demonstrated sources of nitrogen loss to the environment, where deemed necessary. For example, future BMPs or codes for the aquaculture industry should address nutrient concerns as studies indicate that 70-80% of the added nutrients at these facilities are lost to the environment; and
- implementing pollution prevention and pollution control initiatives for other demonstrated sources of nitrogen. (With respect to WWTPs, nitrogen-based nutrients (and other toxics) are being managed through all levels of government under different regulations and initiatives such as the BC LWMPs, the CCME wastewater strategy and CEPA.)

5.2. Wood Extractives (resin acids, tannins, and lignins)

5.2.1 Background Information

Wood extractives are natural compounds found in all types of wood. Resin acids are present in some softwood conifer species, while tannins and lignins are found in both softwoods and hardwoods. These substances are also found in tall oil, a resin-containing by-product of the Kraft pulping process. Resin acids are commonly found in freshwater streams from natural sources and can also enter the environment from sources such as pulping process waste streams, stormwater runoff from lumber milling, wood product storage, wood waste landfills, cranberry farm runoff, light-weight fill, and bulk log handling areas. In addition to forest industry generated sources of wood extractives, there are also industrial uses and sources of these materials. For example, oleoresins and tall oil contain resin acids and are used in the manufacture of products such as tar, turpentine, rubber, adhesives, coatings, and inks (Bailey *et al.* 1999; CCME 1987).

Toxicity to aquatic species has been associated with high levels of wood extractives released from wood handling and processing activities including logging, milling, and storage of all types of wood products along the coast and in the interior of BC. Resin acids are the major toxicants in pulp and paper mill effluents. In general, the acute toxicity of these compounds is lower in marine habitats than in fresh water. Approximately 70% of the acute toxicity of mechanical pulping effluents to fish has been attributed to the acidic fraction of the effluents. The major toxic constituent in the acidic fraction contained seven resin acids: dehydroabietic (DHAA), palustric, abietic, isopimaric, pimaric, sandaracopimaric, and neoabietic acids. The toxicities of pulp mill effluents and resin acids in ambient water are influenced by ambient pH, temperature, and dissolved oxygen concentrations. At neutral pH the acutely toxic concentrations of resin acids are in the 500 to 1500 μg/L range for rainbow trout. Although dehydroabietic, pimaric, and abietic acids have the lowest LC_{50} values, they are of concern due to their presence at high concentrations in many pulp mill effluents. Very low concentrations of pulp mill effluent in water and sediment can cause sublethal effects including increased induction of mixed function oxidases (MFO) in the liver of fish, decreased serum sex hormones, slower growth rates, smaller gonad and egg size, increased age to maturity, reduced blood and lymphocyte cell counts, and interrupted osmoregulatory function. Resin acids have been implicated in EROD induction and symptoms of chronic stress (Carey *et al.* 1993; Davis 1976; Servizi *et al.* 1993; Taylor and Yeager 1987; Yu and Mohn 2001). It is not known to what extent many of these effects are attributable to wood extractives in the effluent or to other bioactive compounds (such as plant sterols) originating from the pulpwood. Some studies have noted that the effluents containing the highest concentrations of chlorinated phenols and resins acids do not always induce the strongest biological responses in test organisms (Tana *et al.* 1994).

Resin acids can accumulate in aquatic biota near sources. For DHAA, bioaccumulation factors of 50 to 200 have been reported for aquatic organisms. However, the biological half-time for the elimination of resin acids in fish is quite short, usually about 24 hours. In one study, the DHAA bioconcentration factor in blood plasma and liver was more than 100 (Pritchard *et al.* 1991).

There are currently no approved Canadian or BC provincial environmental quality guidelines for wood extractives; however, the BC MOE working water quality guidelines include recommended maximum ambient water concentrations for resin acids for the protection of freshwater aquatic life (BC MELP 2006; CCME 2006). Canadian environmental quality guidelines are available on-line at http://www.ccme.ca/publications/ceqg_rcqe.html. BC provincial approved water quality guidelines can be viewed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html and working water quality guidelines can be viewed at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html#working.

5.2.2 Georgia Basin

Loadings of wood extractives to the Georgia Basin have not been estimated. However, weekly monitoring of resin acids is required under the provincial discharge permits for some pulp and paper mills in the Georgia Basin and information on total resin acid concentrations in releases from pulp and paper facilities is available. Estimated resin acid loadings to the Fraser River from a pulp mill at Prince George between 1990 and 1992 were 1.46 t (1460 kg) annually. The total resin acids concentration in the effluents during this period was 350 μg/L. Virtually no information is available on other sources of resin acids or other wood extractives to the Georgia Basin (Swain *et al.* 1997).

A variety of wood extractives have been detected in surface waters and sediments in the vicinity of pulp mills and wood products industries along the Fraser River and in coastal areas of BC. However, information on the concentrations of wood extractives in the Georgia Basin environment is very limited, especially for aquatic biota. In the Fraser and Thompson rivers, resin acid concentrations in peamouth chub bile, which is considered to be a sensitive indicator of exposure to water-borne resin acids, ranged from <0.0007 μg/L near pristine areas to 0.4204 μg/L near sawmill operations (Brewer *et al.* 1998; Colodey and Tyers 1987; Hatfield Consultants 1997; Swain *et al*. 1997; Swain *et al*. 1998).

5.2.3 Data Gaps and Research/Monitoring Needs

Data gaps and research/monitoring needs specific to wood extractives in the Georgia Basin include:

Obtain current information on environmental levels by:

- evaluating existing information on environmental levels of wood extractives in the Georgia Basin and obtaining current information on the presence of these compounds in both fresh and marine environs; and
- considering the development of techniques to monitor plant sterols extractives (such as the endocrine disruptor β-sitosterol)

Develop a better understanding of biological effects by:

- assessing potential sublethal effects in freshwater and marine nearshore and harbour environments where chronic exposure to extractives from wood handling and milling facilities occurs; and
- determining the contribution of plant sterols to the sublethal effects of pulp and paper effluents.

Develop a better understanding of the environmental fate and distribution by:

- examining the release of wood extractives from sediment disturbance in log pockets; and
- determining accumulation and degradation rates of wood extractives in marine sediments.

Obtain more information on sources and loadings to the Georgia Basin by:

- compiling existing information on sources of wood extractives (e.g., annual runoff volumes from suspected sources, volume and type of wood handled, type of handling and processing, estimates of waste wood thickness on the sea bed, and frequency of site dredging);
- measuring concentrations and loadings of resin acids, etc., in runoff from lumber mills, heavy duty wood preservation plants, wood chip storage areas, wood waste landfills, equestrian rings, and berms around cranberry fields; and
- obtaining information on pulp mills as sources of plant sterols.

5.2.4 Management Actions and Needs

Management actions implemented to address issues associated with wood extractives in the Georgia Basin include those initiated under the Fraser River Action Plan (FRAP) through both voluntary compliance and the implementation of innovative technologies. Pollution control improvements have also been accomplished through regulatory initiatives where significant reductions, measured in terms of biochemical oxygen demand (BOD) and total suspended solids (TSS), were achieved in pulp mill discharges after 1992 as a result of the amendment of the *Fisheries Act Pulp and Paper Effluent Regulations* and the promulgation of dioxin and furan regulations under CEPA 1999. In related work, the federal and provincial government agencies have developed best management practices, guidelines, and monitoring practices for log sorting and wood waste control. Whereas pulp mills have extensive treatment systems to break down the wood extractives, many of the wood processing industries do not have sophisticated waste treatment systems. The mills and log sorts have, however, developed stormwater runoff control systems through which wood residue laden water is retained in a sump to reduce wood residue discharges to the environment. While these measures reduce contaminant loading to the aquatic environment, wood extractives are not removed effectively and continue to enter the aquatic environment.

Management action needs specific to wood extractives in the Georgia Basin include:

Review existing controls and/or develop mandatory regulatory activities by:

- reviewing current monitoring programs for the wood industry and giving consideration to the inclusion of wood extractives in regular runoff and industrial process water testing (these programs should link to associated industrial environmental audit requirements).
- reviewing and, if necessary, revising existing regulations and guidelines to control non-point sources of wood extractives to the environment, particularly in wood processing areas; and
- developing water quality guidelines/criteria for resin and fatty acids prevalent in the Georgia Basin environment. Site-specific objectives should be based on toxicity information for local species and a standard suite of bioassays.

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