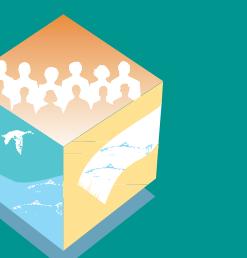


# Health of the Fraser River Aquatic Ecosystem Vol. I

Edited by Colin Gray and Taina Tuominen

DCE FRAP 1998-11



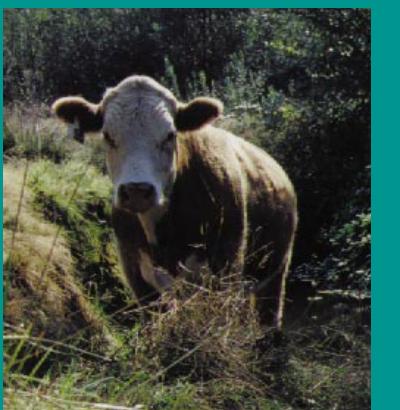
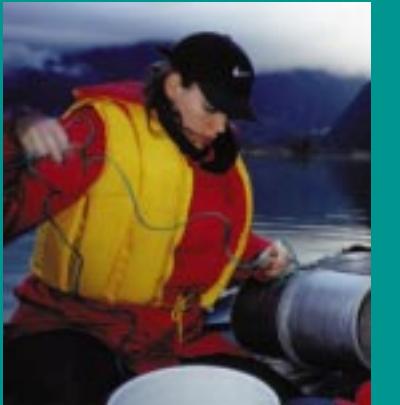
# Health of the Fraser River Aquatic Ecosystem Vol. I

A Synthesis of Research Conducted  
under the Fraser River Action Plan

*Edited by Colin Gray and Taina Tuominen*

DOE FRAP 1998-11

Canada



## Health of the Fraser River Aquatic Ecosystem Vol. II

*Edited by Colin Gray and Taina Tuominen*

DOE FRAP 1998-11



# Health of the Fraser River Aquatic Ecosystem Vol. II

A Synthesis of Research Conducted  
under the Fraser River Action Plan

*Edited by Colin Gray and Taina Tuominen*

DOE FRAP 1998-11

Canada

# THE FRASER RIVER BASIN

## PHYSICAL

Largest river in B.C. (on length, basin size and flow basis)  
3rd greatest mean annual flow in Canada

10<sup>th</sup> longest river in Canada

5<sup>th</sup> largest drainage basin in Canada

Basin size: 234,000 km<sup>2</sup> or 1/4 of the area of BC

River length: 1,375 km

Mean annual discharge at Port Mann: 3600 m<sup>3</sup>/s  
or 113x10<sup>9</sup> m<sup>3</sup>/yr (113 km<sup>3</sup>/yr)

### Fraser River at Hope



Maximum daily discharge recorded at Hope:  
15,200 m<sup>3</sup>/s (1948); higher discharge in 1894—  
however there are no discharge records for  
that period

Minimum daily discharge recorded at Hope:  
340 m<sup>3</sup>/s (1916)

21% of the total discharge at Port Mann is added  
by tributaries downstream of Agassiz (e.g., Harrison,  
Chehalis, Chilliwack, Pitt, Stave and Coquitlam rivers).

Suspended sediment dominated by silt to sand-  
sized particles

Mean suspended sediment concentration at Mission:  
165 mg/L—lower than other large rivers in Western  
Canada, e.g.:

- Mackenzie (327 mg/L)
- Liard (566 mg/L)
- Peace (753 mg/L)

Range of mean annual precipitation: 270 mm  
at Kamloops to 2,460 mm/year measured at  
Alouette Lake in the Lower Fraser Valley.

Range of river water temperatures:  

- 0 °C (December and January) to 22 °C (August)  
at Mission
- 0 °C (November to March) to 19 °C (August)  
at Marguerite

Range of mean daily high air temperatures:  

- January: -7.2 °C at Fort St James to 5.7 °C  
at Vancouver
- July: 21.7 °C at Vancouver to 28.3 °C  
at Kamloops

Headwater streams originate in three mountain  
ranges and a plateau:  

- Rocky Mountains
- Columbia Mountains
- Coastal Mountains
- Interior Plateau

Stream order of the Fraser River is 8 at mouth  
(based on a 1:250,000 scale map)

The bedrock geology can be split roughly into  
five types:  

- igneous intrusive rocks
- volcanic & sedimentary
- foliated metamorphic
- folded sedimentary
- flat lava with some sedimentary

Basin contains 11 biogeoclimatic zones of B.C.,  
which include alpine, interior forest, grasslands  
and coastal forest.

Basin occurs in 2 Canadian ecozones: montane  
cordillera and Pacific maritime.

To date, 210 aquifers (of 296 in B.C.) have been  
delineated in the basin  

- sizes range from 0.3 km<sup>2</sup> to >1660 km<sup>2</sup>
- 90% are used for drinking water

## BIOLOGICAL

Total fish species that use the river: 59

Native freshwater fish species in basin: 40

Basin has the world's most productive salmon river  
system, supporting 5 species of salmon.

Total species of birds that use the basin: over 300

Species of waterfowl that breed in the basin:  
estimated at 21

Water birds from 3 continents rely on the estuary  
as part of the Pacific Flyway

Number of vascular plant species in the lower  
Fraser basin: 1446

Vascular plant species that are introduced aliens to  
the lower Fraser Basin: 40%

Native plant species that are rare in the lower  
Fraser basin: nearly 25%

## POPULATION

Basin's population (1997): 2.5 million

By 2021, the basin's population is expected to  
increase by 50%

2/3 of the population of BC lives in the basin  
(54% in the lower Fraser area)

Greater Vancouver Regional District (GVRD)  
population (1996): 1.8 million

Population of the GVRD is expected to reach  
2.7 million in 20 years

First Nations in the basin: 8 linguistic groups  
in 96 communities

## LAND USE

Urban area (1996): 5,100 km<sup>2</sup>

Agricultural area (1996): 1,510 km<sup>2</sup>

Other land area (forest, park, etc.) (1996): 227,500 km<sup>2</sup>

About 50% of BC's arable land is in the basin.

Approximately 20% of the farmland is irrigated  
using water from the Fraser or its tributaries

Contains almost 50% of BC's sustainable yield  
of timber

Contains 90% of BC's gravel extraction operations,  
mostly in the Lower Fraser Valley

Unlogged watersheds >50 km<sup>2</sup> from Prince George  
to Vancouver:

- Stein River Valley
- Siswe Creek (near the Stein)

Contains 60% of BC's metal mines

Contains 8 pulp and paper mills

Contains 25 major (9m or greater in height) dams;  
all on tributaries

As of 1991, approximately 6% of the land area in  
the basin was provincial parkland

## REFERENCES:

Dorcey, A.H.J. and J.R. Griggs (editors). 1991. Water in Sustainable Development: *Exploring Our Common Future in the Fraser River Basin*. Westwater Research Centre, The University of British Columbia, Vancouver, B.C.

Bocking, Richard C. 1997. *A Portrait of the Fraser: Mighty River*. Douglas & McIntyre, Vancouver, B.C.

Fraser Basin Management Program (FBMP). 1995. *State of the Fraser Basin - Assessing Progress towards Sustainability*. Vancouver, B.C.

Greater Vancouver Regional District (GVRD). 1997. *Greater Vancouver Key Facts. A Statistical Profile of Greater Vancouver, Canada*. Greater Vancouver Regional District Strategic Planning Department, Vancouver, B.C.

Healey, M.C. 1997. *Fraser Basin Ecosystem Study Final Report: Prospects for Sustainability*. Westwater Research Centre, Vancouver, B.C.

## CANADIAN CATALOGUING IN PUBLICATION DATA

Health of the Fraser River aquatic ecosystem:  
a synthesis of research conducted under  
the Fraser River Action Plan.

État de l'écosystème aquatique du fleuve  
Fraser: synthèse d'une recherche réalisée dans  
le cadre du plan d'action du fleuve Fraser.

Complete in 2 volumes.

Includes French title and

French executive summary.

ISBN 0-662-27870-4

Cat. no. En47-119/1999E

1. Aquatic ecology  
—British Columbia—  
Fraser River Watershed.

2. Stream ecology  
—British Columbia—  
Fraser River Watershed.

3. Effluent quality  
—British Columbia—  
Fraser River Watershed.

4. Fraser River Watershed (B.C.)  
—Environmental aspects.

5. Environmental monitoring  
—British Columbia—  
Fraser River Watershed.

I. Gray, C.B.J. (Colin Butler  
James), 1947-

II. Tuominen, Taina Maria.

III. Fraser River Action Plan (Canada)

QH541.5.W3H42 1999

363.739'42'097113

C99-980191-0

# **HEALTH OF THE FRASER RIVER AQUATIC ECOSYSTEM**

A Synthesis of Research Conducted under the Fraser River Action Plan

*edited by Colin Gray and Taina Tuominen*  
Aquatic and Atmospheric Sciences Division  
Environment Canada, Vancouver, B.C.

1999

**Volume I**  
DOE FRAP 1998-11



Fraser River Action Plan



Environment  
Canada

Environnement  
Canada



# Table of Contents

## VOLUME I

|   |     |
|---|-----|
| Executive Summary   | iii |
| Sommaire  | vii |
| Acknowledgements  | xii |
| <b>1.0 Introduction</b>   | 1   |
| by Colin Gray and Taina Tuominen  |     |
| <b>2.0 Contaminant Sources</b>  | 7   |
| by Eric R. McGreer and Wayne Belzer   |     |
| <b>3.0 Basin-wide Contamination and Health Assessment</b>   |     |
| <b>3.1 Contaminants in Lake Sediments and Fish</b>  | 23  |
| by Robie W. Macdonald, D. Patrick Shaw and Colin Gray   |     |
| <b>3.2 Water Quality in the Fraser River Basin</b>  | 47  |
| by D. Patrick Shaw and Taina Tuominen   |     |
| <b>3.3 Sediment Sources, Transport Processes, and Modeling Approaches for the Fraser River</b>  | 63  |
| by Michael Church and Bommanna G. Krishnappan   |     |
| <b>3.4 Sediment Transport Patterns in the Lower Fraser River and Fraser Delta</b>   | 81  |
| by Patrick McLaren and Taina Tuominen   |     |
| <b>3.5 Sediment Quality in the Fraser River Basin</b>   | 93  |
| by Roxanne Brewer, Stephanie Sylvestre, Mark Sekela and Taina Tuominen  |     |
| <b>3.6 Benthic Invertebrate Community Structure</b>   | 109 |
| by Trefor B. Reynoldson and David M. Rosenberg  |     |
| <b>3.7 Fish Community Structure and Indicator Species</b>   | 123 |
| by J. Donald McPhail  |     |
| <b>3.8 Fish Health Assessment</b>   | 143 |
| by Beverley Raymond, D. Patrick Shaw and Kay Kim  |     |
| <b>3.9 Contaminants in Wildlife Indicator Species from the Fraser Basin</b>   | 161 |
| by Laurie Wilson, Megan Harris and John Elliott   |     |
| <b>3.10 The Delta Foreshore Ecosystem: Past and Present Status of Geochemistry, Benthic Community Production and Shorebird Utilization after Sewage Diversion</b>   | 189 |
| by Paul J. Harrison, Kedong Yin, Lauren Ross, Joseph Arvai, Katherine Gordon, Leah Bendell-Young, Christine Thomas, Robert Elner, Mary Sewell and Philippa Shepherd |     |

# Table of Contents

## VOLUME II

### 4.0 Pollution Source Impacts and Management

#### *Pulp Mills*

- |     |  |    |
|-----|--|----|
| 4.1 | The Interaction of Pulp Mill Discharges with the Fraser River and its Sediments<br>by Bommanna G. Krishnappan and Greg Lawrence  | 1  |
| 4.2 | Pulp Mill Effluent Impacts on Benthic Communities and Selected Fish Species<br>in the Fraser River Basin<br>by Joseph M. Culp and Richard B. Lowell  | 13 |
| 4.3 | Developing Water Quality Guidelines for Chemicals of Concern<br>from Pulp Mill Effluent<br>by Erika Szenasy, Colin Gray, Roxanne Brewer, Lars Juergensen, Robert Kent<br>and Pierre-Yves Caux  | 35 |
| 4.4 | Development and Field Validation of a Multi-Media Exposure Assessment Model<br>for Waste Load Allocation in the Fraser-Thompson River System:<br>Application to TCDD and TCDF Discharges by Pulp and Paper Mills<br>by Frank A.P.C. Gobas, John P. Pasternak, Kent Lien and Ramona K. Duncan | 45 |

#### *Lumber Antisapstain Facilities*

- |     |  |    |
|-----|--|----|
| 4.5 | Toxicity of the Antisapstain Fungicides, DDAC and IPBC, to Fishes and Aquatic<br>Invertebrates<br>by Anthony P. Farrell and Christopher J. Kennedy   | 57 |
| 4.6 | Assessing the Potential Impact of the Antisapstain Chemicals DDAC and IPBC<br>in the Fraser River<br>by Erika Szenasy, Colin Gray, Dennis Konasewich, Graham van Aggelen, Vesna Furtula,<br>Lars Juergensen and Pierre-Yves Caux | 69 |

#### *Agriculture*

- |     |  |     |
|-----|--|-----|
| 4.7 | Agriculture: an Important Non-point Source of Pollution<br>by Hans Schreier, Kenneth J. Hall, Sandra J. Brown, Barbara Wernick, Caroline Berka,<br>Wayne Belzer and Karen Pettit | 83  |
| 4.8 | Impact of Agricultural Pesticides on Birds of Prey in the Lower Fraser Valley<br>by Laurie Wilson, Megan Harris and John Elliott   | 101 |

#### *Urban runoff*

- |     |  |     |
|-----|--|-----|
| 4.9 | Non-Point Source Contamination in the Urban Environment of Greater Vancouver:<br>A Case Study of the Brunette River Watershed<br>by Kenneth J. Hall, Peter Kiffney, Ron Macdonald, Don McCallum, Gillian Larkin,<br>John Richardson, Hans Schreier, Jacqueline Smith, Paul Zandbergen, Patricia Keen,<br>Wayne Belzer, Roxanne Brewer, Mark Sekela and Bruce Thomson | 109 |
|-----|--|-----|

### 5.0 Research Results: Integration and Conclusions

by Taina Tuominen and Colin Gray

# Executive Summary

The purpose of the Fraser River Action Plan (FRAP) was to restore the environmental health and promote long term sustainability of the Fraser River watershed, in cooperation with all governments and stakeholders. This federal government initiative was undertaken by the Departments of Environment and Fisheries and Oceans from 1991 to 1998. A major thrust of FRAP was a program of research on the extent and severity of contamination in the Fraser Basin's aquatic ecosystem. The program was led by Environment Canada and conducted by scientists from universities, government and the business sector.

New methods and indicators, as well as existing tools, were used to assess the extent of basin contamination and its effect on the health of the aquatic system. Concentrations of contaminants in water, suspended and bed sediment and biological tissues (fish, birds and mammals) were used as one set of indicators of relative contamination. A smaller set of biological response indicators, including the structure of the benthic macroinvertebrate community, fish condition and health, detoxifying enzyme levels, and the reproductive success of selected wildlife species, was also used. The synthesis of information provided by these indicators records the status of the basin's aquatic-based ecosystem between 1992 and 1997.

The research program was focused on the main stem Fraser River from the Rocky Mountains to the estuary, and two major tributaries, the Thompson and Nechako rivers. The effects of effluents from point sources, such as pulp and paper mills, were evaluated in these rivers below Prince George, Quesnel and Kamloops. Non-point sources of contaminants and their effects were assessed in the Brunette River, an urbanized basin in the Greater Vancouver region, and the Sumas River, an agricultural basin in the Lower Fraser Valley. Headwater lakes were investigated for metals and persistent organic pollutants. Lastly, we examined the recovery of the delta foreshore ecosystem from exposure to effluent from a large municipal wastewater treatment plant (WWTP).

Our assessment revealed that smaller tributaries, arising in basins affected by urban or intense agricultural development, are showing many obvious signs of contaminant stress. These signs of stress from urban and agricultural runoff, or non-point source pollution, include: elevated levels of contaminants in water and sediment; the failure of eggs for some amphibian species to hatch; the poisoning of raptors by certain pesticides; and significant changes in the structure of the benthic macroinvertebrate community.

Contamination is also evident in the Fraser estuary and at some sites in the Thompson River where the levels of chemicals such as polycyclic aromatic hydrocarbons (PAHs) and some dioxin and furan congeners in sediment exceed guidelines or draft guidelines established for the protection of aquatic life. The effects of antisapstain chemicals accumulating in estuary sediments have not been fully evaluated. The source of these chemicals is stormwater runoff near sawmills. The recovery of Sturgeon Bank from past exposure to municipal WWTP effluent is evident from the return of benthic communities and decline in sediment metals after the large outfall at Iona Island was extended beyond the intertidal area. Two newly installed secondary WWTPs in the Vancouver area should further reduce the discharge of contaminants to the estuary. However, without preventative action, it is expected that non-point source pollution from urban and agricultural

development and effluent volume from WWTPs will continue to increase with the projected population growth for the Lower Mainland.

The main stem river upstream of the estuary and its major tributaries do not exhibit significant concentrations of contaminants at most locations. This is largely due to production changes in pulp mills in the early 1990s, which resulted in the significant reduction of dioxins and furans in the mills' effluents, and recent improvements in municipal WWTPs. Large reductions in the use of some chemicals, such as polychlorinated biphenyls (PCBs), lead, pentachlorophenol and some pesticides over the past two decades are also responsible for the low levels of contaminants observed. Toxicity data were developed for some chlorophenolic and PAH contaminants that are present at elevated levels downstream of pulp mills. The results indicate that the tested chemicals are not likely to cause effects on biota at the concentrations observed in the river outside of mixing zones. Although the main rivers generally have low levels of contaminants when compared to existing guidelines for the protection of water uses and aquatic biota, municipal WWTPs and pulp mills are still sources of many classes of chemicals.

Biota near these pollution sources show responses to these low levels of contaminant exposure. For example, analyses of fish and bird tissue show that there is greater induction of the detoxifying enzymes, mixed function oxygenases, in samples collected downstream of urban centres and pulp mill discharges than at other locations. While the two fish species surveyed have a relatively high incidence of abnormalities throughout the basin, highly pigmented livers and kidneys are commonly observed only at sites downstream of pulp mills on the Fraser River. Fish at these sites also have reduced gonad development, as do the fish downstream of Kamloops in the Thompson River. The significance of these effects on fish health are not known.

Artificial stream experiments conducted at Prince George and Kamloops demonstrate that pulp mill effluent, at dilution levels experienced in the river at low flow, can stimulate growth of benthic organisms. However, the experiments indicate that should effluent concentrations in the river increase signs of toxic effects will begin to appear.

Persistent organic pollutants were found in the river's headwaters. The likely source of PCBs, DDT and its metabolites, and toxaphene found in fish from these lakes, especially lakes at higher elevations, is long range atmospheric transport and deposition coupled with the release of historic deposits of contaminants from melting glaciers and permanent snowfields. In a warmer global climate the release of contaminants from glacial "storage" will continue.

These results have led to the following recommendations to help sustain the ecosystem in the Fraser River Basin.

Runoff from agricultural and urban areas is now a significant source of contaminants in the basin. Strategies for controlling contaminated runoff from urban and agricultural areas should be a priority in future urban planning and agricultural development programs. Such strategies should include: (1) minimizing impervious area; (2) maintaining riparian buffer zones along streams; (3) incorporating sedimentation basins along streams and in storm sewers; (4) promoting and enforcing best management practices for livestock densities, septic tank servicing, and fertilizer (such as manure) application; (5) and promoting public environmental stewardship.

To monitor progress in restoring and preserving the health of the Fraser Basin, the condition of the basin's aquatic ecosystem should be periodically reassessed. FRAP has provided a baseline of the basin's condition. The future use of the indicators and methods employed in FRAP will enable comparison to this baseline. Opportunities for integrating FRAP methods into programs, like the Environmental Effects Monitoring

and Canada-BC Water Quality Monitoring programs, are being explored. For example, environmental effects monitoring could include, under certain circumstances, the benthic macroinvertebrate reference condition approach, in combination with controlled mesocosm experiments, to assess the effects of effluents downstream of discharges. Incorporation of more biological and biochemical components into routine measurement programs will enhance the ability to maintain the health of the basin's ecosystem.

Many knowledge gaps were identified by the participating scientists and during the synthesis of the program results. Two general knowledge gaps and some basin-specific research needs are highlighted here. The first general gap is the lack of understanding of the cumulative impacts of chronic exposure to mixtures of many chemicals, all at low levels. The second is determining the amount of site-specific toxicity information required to complement guidelines developed with standard bioassays, when setting site-specific water quality objectives. Environmental management agencies in the basin should periodically review and apply advances in understanding resulting from future research on these questions.

Several basin-specific research needs were identified in the program. Some of these are: determining the presence and effects of endocrine disrupting chemicals; identifying the causes of abnormalities found in basin fish; assessing the impacts of the antisapstain chemicals on the estuary; and evaluating the contamination of food chains in headwater lakes by atmospheric pollutants. Some of this research has been included in the Georgia Basin Ecosystem Initiative.

# Sommaire

**Le Plan d'action du fleuve Fraser (PAFF) avait pour objectif de restaurer l'environnement du bassin hydrographique du fleuve Fraser et d'en favoriser la durabilité à long terme, en collaboration avec tous les gouvernements et partenaires. De 1991 à 1998, cette initiative du gouvernement fédéral a été menée par les ministères de l'Environnement et des Pêches et des Océans. Le plan d'action consistait principalement en un programme de recherche sur la gravité et l'étendue de la contamination de l'écosystème aquatique du bassin du Fraser. Ce programme était dirigé par Environnement Canada et mené par des scientifiques des universités, du gouvernement et du monde des affaires.**

Des méthodes et indicateurs nouveaux ainsi que des instruments existants ont servi à évaluer l'étendue de la contamination du bassin et son impact sur le milieu aquatique. Les concentrations de polluants dans l'eau, les sédiments benthiques et en suspension et les tissus biologiques (poissons, oiseaux et mammifères) ont été utilisés comme indicateurs de la contamination relative. On a également eu recours à un ensemble plus restreint d'indicateurs de la réponse biologique, notamment la structure de la communauté des macroinvertébrés benthiques, l'état et la santé des poissons, la concentration d'enzymes de détoxicification et le succès de reproduction de certaines espèces sauvages. La synthèse de l'information fournie par ces indicateurs permet de suivre l'état de l'écosystème aquatique du bassin entre 1992 et 1997.

Le programme de recherche était axé sur le cours principal du fleuve Fraser, des montagnes Rocheuses à son estuaire, et sur deux de ses principaux affluents, les rivières Thompson et Nechako. Les effets des effluents de sources ponctuelles, comme les usines de pâte et papiers, ont été évalués dans ces rivières en aval de Prince George, Quesnel et Kamloops. Les sources diffuses de contaminants et leurs incidences ont été évaluées dans la rivière Brunette, un bassin urbanisé de la région métropolitaine de Vancouver, et dans la rivière Sumas, un bassin agricole de la vallée inférieure du Fraser. On a effectué des recherches dans des lacs d'amont afin de déceler la présence de dépôts de métaux et de polluants organiques persistants. Enfin, nous avons examiné le rétablissement de l'écosystème riverain du delta, qui a été exposé aux effluents d'une grande station de traitement des eaux usées urbaines.

Notre évaluation a révélé que les affluents plus petits, issus de bassins urbanisés ou soumis à une agriculture intensive, montrent de nombreux signes évidents de perturbation occasionnée par des polluants. Ces signes de perturbation exercée par l'écoulement des eaux de ruissellement agricole et urbain ou par la pollution de source diffuse se manifestent notamment par des concentrations élevées de polluants dans l'eau et les sédiments, par la non-éclosion des oeufs de certaines espèces d'amphibiens, par l'empoisonnement de rapaces par des pesticides ainsi que par des modifications majeures de la structure de la communauté des macroinvertébrés benthiques.

La contamination se manifeste également dans l'estuaire du Fraser et certains endroits de la rivière Thompson où les concentrations de substances chimiques dans les sédiments, comme les hydrocarbures aromatiques polycycliques (HAP) et certains congénères des dioxines et des furanes dépassent les lignes directrices établies ou provisoires visant la protection de la vie aquatique. Les incidences de l'accumulation des substances chimiques anti-taches dans les sédiments n'ont pas encore été entièrement évaluées. Ces substances chimiques sont transportées par les eaux pluviales dans le voisinage des scieries. Le rétablissement du banc Sturgeon,

qui a été exposé aux effluents des stations de traitement des eaux usées urbaines, est évident quand on constate le retour des communautés benthiques et la baisse des concentrations de métaux dans les sédiments, après le prolongement du grand émissaire d'évacuation de l'île Iona au-delà de la zone intertidale. Les deux nouvelles usines de traitement secondaire installées dans la région de Vancouver réduiront encore davantage le rejet de contaminants dans l'estuaire. Mais, à défaut de mesures de prévention, la pollution de source diffuse occasionnée par le développement urbain et agricole et le volume des effluents des stations de traitement des eaux usées continueront d'augmenter au rythme de l'accroissement démographique prévu dans le Lower Mainland.

La plupart des secteurs du cours principal du fleuve en amont de l'estuaire et ses principaux affluents n'affichent pas des concentrations importantes de contaminants. Ce fait s'explique en grande partie par la modification des méthodes de production dans les usines de pâte qui a entraîné, au début des années 1990, une réduction importante des concentrations de dioxines et de furanes dans les effluents; les améliorations apportées récemment aux stations de traitement des eaux usées y ont également contribué. La baisse marquée de l'utilisation de certaines substances chimiques, comme les biphenyles polychlorés (BPC), le plomb, le pentachlorophénol et certains pesticides, qui a eu lieu au cours des deux dernières décennies, est également responsable des faibles taux de contamination observés. Des données toxicologiques ont été compilées sur certains polluants chlorophénoliques et les HAP qui sont présents en concentrations élevées en aval des usines de pâte. Les résultats indiquent que les substances testées n'ont probablement pas d'effets sur le biote aux concentrations observées dans le fleuve, à l'extérieur des zones de mélange. Les grands cours d'eau affichent généralement de faibles concentrations de polluants, si on les compare aux lignes directrices existantes concernant la protection des utilisations de l'eau et du biote aquatique, mais les usines de pâte et les stations de traitement des eaux usées sont encore à la source de nombreuses catégories de substances chimiques.

Le biote à proximité des sources de pollution réagit à ces faibles taux d'exposition aux polluants. Par exemple, des analyses de tissus de poisson et d'oiseau montrent une plus grande induction de l'enzyme de détoxicification, l'oxydase à fonction mixte, dans les échantillons prélevés en aval des centres urbains et des effluents des usines de pâte. Alors que les deux espèces de poisson étudiées présentaient une assez forte incidence d'anomalies dans tout le bassin, la pigmentation prononcée du foie et des reins n'est couramment observée qu'en aval des usines de pâte dans le fleuve Fraser. À ces endroits, le développement des gonades chez les poissons est réduit tout comme chez les poissons de la rivière Thompson, en aval de Kamloops. On ne sait pas si ce phénomène aura une incidence importante sur la santé des poissons.

Des expériences menées dans des cours d'eau artificiels à Prince George et Kamloops montrent que les effluents des usines de pâte, aux taux de dilution enregistrés dans la rivière en période d'étiage, peuvent stimuler la croissance des organismes benthiques. Mais, les expériences montrent que des concentrations un peu plus élevées dans le fleuve font apparaître des signes de toxicité.

Des polluants organiques persistants ont été trouvés dans les eaux d'amont du fleuve. La source probable des BPC, du DDT et de ses métabolites et de la toxaphène décelés dans les poissons de ces lacs, surtout ceux en altitude, est le transport atmosphérique à grande distance et le dépôt des polluants, combinés à la libération, par la fonte des glaciers et des champs de neige permanents, de sédiments accumulés. Dans le contexte d'un réchauffement climatique, le rejet de polluants stockés dans les glaciers se poursuivra.

Ces résultats ont donné lieu aux recommandations suivantes en vue d'aider à préserver l'écosystème du bassin du fleuve Fraser.

Le ruissellement urbain et agricole est maintenant une source importante de polluants dans le bassin. Des stratégies visant à limiter le ruissellement des polluants devraient figurer au nombre des priorités des futurs programmes d'urbanisme et de développement agricole. Mentionnons 1) la réduction des surfaces

imperméables, 2) l'aménagement de zones tampons en bordure des cours d'eau, 3) l'installation de bassins de décantation le long des cours d'eau et dans les égouts pluviaux, 4) la promotion et l'application de meilleures pratiques de gestion du bétail, d'entretien des fosses septiques et d'épandage des engrais (comme le fumier) et 5) la sensibilisation de la population à la gérance de l'environnement.

Afin de surveiller les progrès accomplis dans la restauration et la préservation du bassin du Fraser, il faut réévaluer périodiquement l'état de son écosystème aquatique. Le Plan d'action du fleuve Fraser a fourni un point de référence sur l'état du bassin. L'utilisation future des méthodes et des indicateurs issus du plan d'action permettra d'établir des comparaisons. On examine aussi la possibilité d'intégrer les méthodes du plan d'action dans les programmes de surveillance, comme le Programme de suivi des effets sur l'environnement et le programme conjoint Canada-Colombie-Britannique de surveillance de la qualité de l'eau. Par exemple, la surveillance des effets environnementaux pourrait comprendre le recours à la méthode des conditions de référence des macroinvertébrés benthiques, combiné à des expériences de contrôle dans le mésocosme, en vue d'évaluer les incidences des effluents en aval des points de rejet. L'intégration d'un plus grand nombre d'éléments biologiques et biochimiques dans les programmes de mesures périodiques facilitera le maintien de la santé de l'écosystème du bassin.

Les scientifiques qui ont participé à l'étude et compilé les résultats du programme ont décelé de nombreuses lacunes au niveau des connaissances. Deux lacunes dans les connaissances générales et certains besoins de recherche propres au bassin ont été soulignés. La première lacune concerne l'absence de compréhension des incidences cumulatives de l'exposition chronique à des mélanges de nombreuses substances chimiques, toutes à faible concentration. La seconde consiste à déterminer la quantité de données toxicologiques spécifiques à un milieu afin de compléter les lignes directrices élaborées à partir des essais biologiques habituels, lorsqu'on établit des objectifs de qualité de l'eau propres à des sites particuliers. Les organismes de gestion de l'environnement du bassin devraient examiner périodiquement les découvertes issues des recherches ultérieures sur ces questions et les appliquer.

Le programme a permis de cerner plusieurs besoins en matière de recherche qui sont particuliers au bassin. Il faut notamment déterminer la présence de perturbateurs endocriniens et leurs effets, établir les causes des anomalies observées chez les poissons du bassin, évaluer les incidences des substances chimiques anti-taches sur l'estuaire et évaluer la contamination de la chaîne alimentaire par les polluants atmosphériques dans les lacs d'amont. Certains de ces sujets de recherche ont été inclus dans l'initiative concernant l'écosystème du bassin de Géorgie.

# Acknowledgements

An undertaking of this dimension—both the program and the report—is not possible without the assistance of many committed people. We are grateful for their generous contributions of expertise, enthusiasm and time. Without their support, the Environmental Quality Program and this report would not have been completed.

First, we especially thank the researchers for enthusiastically participating in the planning and results workshops throughout the lifespan of the Fraser River Action Plan (FRAP), and for responding amiably to several review cycles on their chapters. We are also grateful to the following for their reviews of one or more of the chapters: *Donald Bernard, Roxanne Brewer, Leslie Churchland, George Derksen, John Elliott, Annie-France Gravel, Andrew Green, Kirk Johnstone, Kay Kim, Jean MacRae, Eric McGreer, Dan Millar, Mike Nassichuk, Bev Raymond, Mark Sekela, Pat Shaw, Stephanie Sylvestre, Erika Szenasy, Lisa Walls, Laurie Wilson, Phil Wong and Marielou Verge* of the Pacific and Yukon Region office of Environment Canada; *Joseph Culp, Bommanna Krishnappan and Richard Lowell* of the National Water Research Institute (NWRI), Environment Canada; *Richard Addison, Robie Macdonald and Steve Samis* of the Department of Fisheries and Oceans; *Michael Church* of the University of British Columbia; *Tony Farrell* of Simon Fraser University; *Kris Andrews and Les Swain* of the BC Ministry of Environment, Lands and Parks; and *Don McCallum* of the Greater Vancouver Regional District.

Second, many people with Environment Canada in Vancouver contributed to the Environmental Quality Program; its success is due to their support and efforts. They are *Roxanne Brewer, Kim Joslin, Janet Landucci, Fred Mah, Gail Moyle, Bev Raymond, Mark Sekela and Pat Shaw*. The following are acknowledged for their contributions at critical times in the program: from Environment Canada, Vancouver—*Bonnie Antcliffe, Cristina Baldazzi, Wayne Belzer, Maki Hanawa, Kay Kim, Eric McGreer, Melanie Sullivan, Stephanie Sylvestre, Erika Szenasy and Cecilia Wong*; from NWRI—*Craig Logan, Mike Mawhinney and Sherri Thompson*. As organizational changes have occurred several times over the last seven years, many managers have supported and lead us. Specifically, we acknowledge *Leslie Churchland, Gordon Tofte and Stephen Wetmore* who managed components of the Environmental Quality Program; and *Art Martell, Linda MacQueen, Dan Millar, Vic Niemela, Carolyn O'Neill, Chris Pharo and Brian Wilson* who made up the FRAP management team and provided us with insightful feedback and advice.

Our time commitment to the report was extensive, and without the continued support of our Manager, *Kirk Johnstone*, it would not have been completed amidst other high-priority concerns. Kirk not only provided valuable direction and advice to the program, he also ably deflected a sufficient quantity of “other issues” from our desks, enabling us to devote the time required to complete this report.

The final editing, graphics and table formatting, layout and cover design were done by Iris Communications. We thank *Pearl Roberts, Kiyoshi Yamamoto, Elena Rivera, Carri Toivanen and Elissa Schmidt* for their patience and perseverance. *Ramona Franzen* of Franzen Print Communications coordinated printing. We appreciate her understanding and patience during the protracted report editing process.