Fraser River Basin Strategic Water Quality Plan

Chilcotin Region:

Seton-Bridge, Chilcotin, and West Road
Habitat Management Areas

by

J.C. Nener[1] and B.G. Wernick[1]

[1] Fraser River Action Plan
Habitat and Enhancement Branch
Fisheries and Oceans Canada
Suite 320-555 West Hastings Street
Vancouver, B.C. V6B 5G3

Canadian Cataloguing in Publication Data

Nener, Jennifer C. (Jennifer C.), 1961-

Fraser River Basin Strategic Water Quality Plan,
Chilcotin Region: Seton-Bridge, Chilcotin,
and West Road habitat management areas

(Fisheries and Oceans Canada - Fraser River
Action Plan Water Quality Series: 02)
Includes bibliographical references.
ISBN 0-662-26887-3
Cat. no. Fs22-2/3E

1. Water quality -- British Columbia -- Fraser
River Watershed.
2. Water quality bioassay -- British Columbia --
Fraser River Watershed.
3. Salmon -- Effect of water quality on --
British Columbia -- Fraser River Watershed.
4. Environmental monitoring --
British Columbia -- Fraser River Watershed.
I. Wernick, B. G. (Barbara G.), 1969-
II. Fraser River Action Plan (Canada)
III. Title.
IV. Series

TD387.B7N46 1998 553.7’8’0971137 C98-980244-2

Executive Summary

The Seton-Bridge, Chilcotin, and West Road Habitat Management Areas collectively provide habitat for large runs of sockeye and chinook, and smaller runs of coho, and pink salmon. These HMAs support a relatively small number of salmon-bearing watersheds, however, the watersheds are quite large and support significant anadromous and resident fish populations.

Water quality data were extremely limited for the three HMAs addressed in this report. Data were available for a total of 14 sites, only four of which were sampled on more than two occasions. These limited data did not provide the opportunity to make meaningful assessments of water quality conditions in the HMAs.

Compared with other areas of the Fraser Basin the Seton-Bridge, Chilcotin, and West Road HMAs have experienced relatively little development. Urbanization is limited to a small number of communities. There is virtually no manufacturing and processing industry in the HMAs considered here. There are four permitted waste discharges to surface waters located in the three HMAs, all of which are sewage effluents. The dams on the Seton and Bridge River systems are probably the most significant legacy of human development in this area.

The potential for degradation of water quality from non-point sources of pollution associated with land uses was considered for each of the salmon-bearing systems in the three HMAs. Forestry and agriculture (primarily ranching) are the two most significant land uses in the HMAs, but appear to be of lesser intensity than in many other Fraser Basin HMAs. Consequently, one would expect to find relatively few impacts to water quality in these HMAs at present.

Development of cottages along lake shores is occurring. Although no specific problems were identified in existing information, there may be problems in the future if increasing numbers of recreational properties are developed. Such activities may result in riparian loss or damage, and if cottages are reliant upon septic systems for disposal of domestic wastes degraded water quality may also occur. Existing requirements for obtaining a permit for installing a septic system need to be altered to address highly permeable soils, housing density, and other local conditions.

Three of seventeen salmon-bearing watersheds in the three HMAs were considered to have impacts related to agriculture that may limit fish production. Spring runoff from feedlots and cattle overwintering areas can introduce large amounts of nutrients and BOD to streams each year. This runoff may contain concentrations of ammonia many times greater than the levels which will kill fish. Runoff often flows along stream banks after entering a stream, hence juvenile fish using shoreline habitat may be either physiologically affected by the effluent or displaced by it. Many Fraser Basin producers are adopting improved stewardship practices and are working to attain compliance with the Code of Agricultural Practices for Waste Management, but in general there is still room for improvement. Information specific to agricultural practices in the Seton-Bridge, Chilcotin, and West Road HMAs was limited for many of the watersheds.

Only one salmon-bearing watershed was considered to have impacts from forestry that would be likely to limit fish production. Timber harvesting rates will increase in these areas, however, as other wood sources become depleted. The Cariboo-Chilcotin Land Use Plan identifies the Province's plans for the uses of Crown lands in much of the West Road and Chilcotin HMAs. Areas identified for high intensity logging should be monitored closely by DFO before, during, and after logging, for impacts to hydrology and sediment regimes.

The recommendations provided in Chapter 7 identify options for addressing existing problems and preventing the deterioration of water quality in the Seton-Bridge, Chilcotin, and West Road HMAs. These recommendations should lead to increased protection of water quality and aquatic habitats from future impacts, however, effectiveness will fall short of the benefits that could be achieved by implementing comprehensive watershed management, and overcoming jurisdictional barriers to good management. Successfully protecting ecosystem integrity so that healthy fish populations are sustained will likely require a shift from resource-based management which typically seeks to maximize short-term economic benefits among various sectors, to ecosystem-based watershed management approaches.

Degradation of water quality results from a complex interaction of land uses and human activities. Unfortunately, the control of these uses and activities is broken into many jurisdictions. Agencies make decisions daily about matters that can have a direct influence on water quality and aquatic habitats, without adequate consideration being given to fisheries values and ecosystem sensitivity. In order to properly manage water quality, a long term and integrated approach is required. The structures necessary to implement such an approach are inadequate or non-existent.

Protecting the ecological integrity of streams to sustain healthy fish populations requires multi-agency co-operation and political will. It also requires strong public support to pressure governments for change i.e. a shift towards ecosystem management, and improved practices from all segments of the population in the HMAs. While the negative effects resulting from the actions and choices of individuals may be small, collectively the impacts of the population, especially riparian land owners, on water quality and fish habitat are large in many areas of the Fraser Basin. Significant efforts to educate the public about how to minimize individuals' impacts on water quality and aquatic habitats may be important in the long term to protecting, and where necessary improving water quality in the Seton-Bridge, Chilcotin, and West Road HMAs.

Acknowledgements

Many people made significant contributions to this document and their efforts served to greatly improve the final report. Advice on the methodology, the provision of up-to-date information, and thoughtful editorial input were greatly appreciated. The following people gave generously of their time:

- Bob Grace from MELP, Kamloops office;
- Kris Andrews from MELP, Williams Lake office;
- Lisa Walls and Phil Wong from DOE's Pollution Abatement Branch;
- Bev Raymond, Pat Shaw, and Taina Tuominen, from DOE's Environmental Quality Branch;
- Otto Langer, Don Lawrence, Bruce MacDonald, Steve Samis, and Sean Standing, from DFO.

In addition, Bruce Galbraith of Environment Canada patiently responded to numerous requests related to the Fraser River Point Source Inventory database.

Steward Nimmo and Tom Pinkerton provided advice and guidance which contributed to the successful completion of GIS work for this project.

Peri Mehling prepared a status report on mining issues in the Fraser Basin, which served as the basis for the section on Mining in Chapter 2. Darlene Boyle prepared overview reports on Urbanization and Forestry, which provided the foundations for respective sections of Chapter 2 in this report.

Linda Berg assisted with editing Chapter 2.

Raymond Bedard synthesized information from SISS catalogues and hydrology reports which was used in developing the stream summaries.

The following individuals are thanked for kindly contributing unpublished data:

- Timber Whitehouse from DFO;
- Taina Tuominen from DOE's Environmental Quality branch;

Many other people also contributed to the completion of this report. Their efforts are gratefully acknowledged.

The preparation and printing of this report was funded through the Fraser River Action Plan - Fisheries and Oceans Canada.

Table of Contents

CHAPTER 3 METHODOLOGY

CHAPTER 4 SETON-BRIDGE HABITAT MANAGEMENT AREA

CHAPTER 5 CHILCOTIN HABITAT MANAGEMENT AREA

CHAPTER 6 WEST ROAD HABITAT MANAGEMENT AREA

CHAPTER 7 KEY ISSUES AND RECOMMENDED ACTIONS

APPENDIX 1 GENERAL BACKGROUND INFORMATION ABOUT WATER QUALITY

List of Tables

List of Figures

List of Acronyms

ACA	ammoniacal copper arsenate
AEPC	Agriculture Environmental Protection Council
ALR	Agricultural Land Reserve
AOX	adsorbable organic halide
ARDSA	Agriculture and Rural Development Subsidiary Agreement
BACT	Best Achievable Control Technology
BCCA	B.C. Cattlemen's Association
BCFA	B.C. Federation of Agriculture
BIEAP	Burrard Inlet Environmental Action Program
BMP	best management plan
BOD	biological oxygen demand
CCA	chromated copper arsenate
CEAA	*Canadian Environmental Assessment Act*
CEPA	*Canadian Environmental Protection Act*
COD	chemical oxygen demand
CORE	Committee on Resources and the Environment
CSO	combined sewer overflow
DFO	Department of Fisheries and Oceans
DOE	Environment Canada
EEM	Environmental Effects Monitoring
EIA	Effective Impervious Area
EMS	Environmental Monitoring System
FPAO	Fraser Pollution Abatement Office (DOE)
FRAP	Fraser River Action Plan
FREMP	Fraser River Estuary Management Program
FRPSI	Fraser River Point Source Inventory database
GCM	global climate model
GIS	Geographic Information System
GVRD	Greater Vancouver Regional District
GVWD	Greater Vancouver Water District
HMA	Habitat Management Area
IC_{25}	Inhibition Concentrations causing a 25% reduction in the number of young produced relative to controls
IDZ	initial dilution zone
IPM	Integrated Pest Management
LC_{50}	Lethal Concentration causing 50% mortality
LRMP	Land Resource Management Plan
LRUP	Local Resource Use Plan
LWMP	Liquid Waste Management Plan
MAFF	B.C. Ministry of Agriculture, Fisheries and Foods
MDAA	*Mine Development Assessment Act*
MDRC	Mine Development Review Committee
MELP	B.C. Ministry of Environment, Lands and Parks
MEMPR	B.C. Ministry of Energy, Mines and Petroleum Resources
MMLER	*Metal Mining Liquid Effluent Regulations*
MOF	B.C. Ministry of Forests
MOH	B.C. Ministry of Health
MOTH	B.C. Ministry of Transportation and Highways
NFR	nonfilterable residues (total suspended solids)
NOEC	No Observed Effect Concentrations
PAH	polycyclic aromatic hydrocarbon
PCP	pentachlorophenol
PEAA	*Provincial Environmental Assessment Act*
PMCC	Placer Mining Coordinating Committees
PMRA	Pest Management Regulatory Agency
PFZ	pesticide free zone
SISS	Stream Information Summary System
STP	sewage treatment plant
TSS	total suspended solids (nonfilterable residues)
WMB	Water Management Branch, B.C. MELP

Index of Streams

Chapter 1 Introduction to the Fraser Basin Strategic Water Quality Plan

1.1 Background

The Fraser River is a major source of Canada's salmon production and produces more salmon than any other single river system in the world.[1] Historically, salmon production in the Fraser River watershed was approximately double present levels. Salmon habitat, including water quality, has been substantially degraded in parts of the basin over the past 100 years, contributing to the decline of salmon populations.

Concerns regarding declining salmon populations and other environmental issues led to the establishment of the Fraser River Action Plan (FRAP) in 1991, under the federal Green Plan program. FRAP was jointly administered by the Department of Fisheries and Oceans (DFO) and Environment Canada (DOE). The overall objectives of DFO's FRAP program were to:

1. Develop new partnerships with other agencies and the public to assist with achieving the goals of sustainable development;
2. Clean up pollution; and
3. Restore and protect the natural environment. DFO efforts focused on protecting existing fish habitat, and restoring and enhancing habitat in some areas of the Fraser Basin.

In order to identify and address pollution issues in the Fraser Basin, DFO undertook the development of a Strategic Water Quality Plan. The Plan was intended to:

1. Document and assess water quality conditions throughout the basin;
2. Identify areas where degradation of water quality may impact aquatic life, with a focus on salmon-bearing streams; and
3. Identify specific actions necessary to address the identified impacts to water quality, and where possible, implement programs to address these impacts.

The Water Quality Plan complements other DFO and FRAP initiatives which focus on physical fish habitat issues. In many cases the activities leading to impairment of water quality also result in impacts to fish habitat, and the solutions required to address both types of problems are the same.

To be compatible with these habitat management efforts and to make the task of developing this Plan more manageable, the Fraser Basin was addressed as fifteen Habitat Management Areas (HMAs) which largely reflect the watershed boundaries of significant Fraser River tributaries (Figure 1.1.1).

The Water Quality Plan is divided into four reports which contain the same introductory and background information and explanation of methodologies used to collect and interpret information, but address different groups of HMAs in detail and provide corresponding recommendations. Where recommendations address broad-based issues rather than problems specific to a watershed they are similar among the four reports.

The HMAs are grouped as follows:

Report 1: Lower Fraser River: Fraser Delta, Pitt-Stave, Chilliwack and Harrison-Lillooet HMAs;

Report 2: Thompson River Sub-basin: North Thompson, South Thompson, and Thompson-Nicola HMAs;

Report 3: Chilcotin Region: Seton-Bridge, Chilcotin, and West Road HMAs; and

Report 4: Middle and North Fraser: Middle Fraser, Nechako, Stuart-Takla, and Upper Fraser, and Quesnel HMAs.

❖❖❖

1.2 Developing the Plan

The Water Quality Plan is based on two types of information:

1. Actual water quality, as well as sediment and fish tissue contaminants data; and
2. Information about factors that may affect water quality including waste discharges, land uses, and stream flow information.

Water quality, sediment contaminant, and fish tissue contaminant data were obtained from the provincial SEAM database and Environment Canada's ENVIRODAT database as well as other limited data sources. All data were combined into one common geo-referenced database as part of a joint DFO-DOE FRAP project.[2]

Data were summarized and assessed on a stream-by-stream basis. Efforts focused on parameters commonly measured, often influenced by anthropogenic activities, and which have implications for aquatic life. The objectives of data assessments were to:

1. Identify the occurrence of water quality conditions which may be harmful to aquatic life;
2. Identify the disruption of natural levels of parameters in watercourses (e.g. pH, metals); and
3. Identify the presence of contaminants in watercourses which indicate pollution resulting from anthropogenic activities.

Contaminants may be substances that occur naturally, such as metals, and which may naturally exceed guideline levels considered to protect aquatic life. Some of these substances, such as zinc, copper and other trace metals, are actually required in small amounts by aquatic organisms for normal metabolism and development but are toxic at higher concentrations. These naturally occurring substances are only considered to be pollutants if anthropogenic sources cause levels in an aquatic system to exceed natural background levels, resulting in the potential for impacts to aquatic biota.

Other contaminants are chemicals which have only anthropogenic sources such as some of the complex chlorinated organic compounds.

Because many contaminants can become concentrated in different components of the environment, all available data pertaining to contaminant concentrations in sediments and fish tissues were addressed in addition to data characterizing conditions in the water column.

Water quality data are not available for many salmon-bearing streams in the Fraser Basin. Information about effluent discharges, land uses and stream flows was therefore used to assess the level of concern for water quality resulting from industrial, urban development, agricultural, and/or forestry activities in each salmon-bearing watershed. Information describing natural summer low flows and water withdrawals was included in stream assessments because stream flows can have a large influence on water quality and the sensitivity of streams to impacts. This approach facilitated assessment of the level of concern associated with both point and non-point sources of pollution, and also provided an explanation of the sources of some of the conditions measured in surface waters.

All of the information gathered was used to develop a sum-

Figure 1.1.1 Fraser River Habitat Management Areas

mary of water quality issues in each salmon-bearing watershed in the Fraser Basin. The use of geo-referenced databases and a Geographic Information System (GIS) allowed for all of the water quality, effluent discharge, and land use information to be mapped for the entire Fraser Basin. The use of GIS techniques provided a basin-wide perspective on water quality issues, and greatly facilitated identification of priority problems both within the Fraser Basin as a whole, and within individual HMAs.

Building on the information collected, interpreted, and mapped, the Plan identifies recommendations for actions needed to address existing problems. Recommendations fall into two general categories:

1. What government agencies need to do differently to address short-comings of present approaches to protecting water quality; and
2. On-the-ground actions which are required to address particular problems.

Recommendations are intended to serve as a starting point for addressing water quality problems from a strategic level. Developing a detailed implementation plan goes beyond the scope of this report.

Numerous programs have been developed to address water quality and fish habitat issues at the "hands on" level as part of the FRAP program, and are at varying stages of implementation. An example is the Stewardship series (e.g. *Watershed Stewardship: A Guide for Agriculture*,[3] and *Stream Stewardship: A Guide for Planners and Developers*[4]). While tools, partnerships, and site-specific projects have been developed and/or implemented as a starting point to addressing many problems, the time-frame of the FRAP program was not sufficient to fully address all of the issues identified. Therefore, while many efforts have been made and much has been achieved, we still need to make much more progress to ensure that water quality and fish habitat are adequately protected to support thriving salmon populations in the Fraser Basin.

❖❖❖

1.3 The Audience

This Strategic Water Quality Plan is primarily intended to address a technical audience of resource managers, including individuals who do not have a strong background in aquatic biology or water chemistry. It should serve as an important planning tool for a broad spectrum of agencies and industries in the Fraser River Basin by identifying the larger documented salmon-bearing streams in the basin and their current status with regard to water quality impacts and pressures from human activities. It should also inform the reader about the types of impacts which DFO strives to avoid with any new or established development.

The Strategic Water Quality Plan should also serve as a useful tool for DFO staff by identifying the existing impacts and pressures on each known salmon-bearing watershed in the Basin, and the scope of these impacts at the sub-basin and watershed-wide level.

In addition to the water quality assessments and summary data this Plan provides brief overviews of six general sources of anthropogenic impacts on water quality in the Fraser Basin:

- urban development;
- forestry;
- agriculture;
- mining;
- industry/manufacturing in general; and
- impacts resulting from global human influences on the atmosphere.

These overviews are included to provide some context for the water quality summaries and recommended actions that follow.

With regard to planning specific developments, users of this report should assume that all streams are important fish habitat, even if they are not identified in the present report, until further inventory and clarification is obtained from DFO and MELP. Streams often have significant ecological value even if salmonids are not present. Also, as more sampling is done we continue to learn more about fish distribution in the Fraser Basin and the biological needs of those fish stocks.

❖❖❖

1.4 References

1 Levy, D.A. 1992. Potential impacts of global warming on salmon production in the Fraser River watershed. Can. Tech. Rep. Fish. Aquat. Sci. 1889. 96 p.

2 Wainwright, P., B. Humphrey, W. Drinnan and M. Foy. 1995. Review of information on the environmental occurrence of chemical contaminants and conditions of environmental degradation in the aquatic environment of the Fraser River Basin, Volume 1, Final Report. Prepared for Environment Canada and the Department of Fisheries and Oceans - Fraser River Action Plan. DOE-FRAP 95-25.

3 Nener, J.C. 1997. Watershed Stewardship - A guide for agriculture. Department of Fisheries and Oceans and B.C. Ministry of Environment, Lands and Parks. 61 p.

4 Lanarc Consultants Ltd. 1994. Stream stewardship: A guide for planners and developers. Stream Stewardship Series. Department of Fisheries and

Oceans, B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Municipal Affairs. 48 p.

Chapter 2 Point and Non-point Sources of Pollution in the Fraser Basin

2.1 Introduction

This general introduction to how different types of activities can affect water quality provides some context for how the land use information is assessed in the stream summaries provided within each of the HMA chapters, and also for the recommendations which follow in Chapter 7. It addresses five main types of land uses or activities which can affect water quality: manufacturing and processing industries; urban development; agriculture; forestry; and mining. A brief overview of two main atmospheric issues which are of relevance to the Fraser Basin, global warming and acid precipitation, and how they can influence water quality, is also provided.

❖❖❖

2.2 Manufacturing and Processing Industries

2.2.1 *Introduction*

The water quality concerns associated with manufacturing and processing industries generally relate to the discharge of processing effluents or cooling water to the environment. There are a wide variety of industries located in the Fraser Basin that discharge wastes into either the Fraser mainstem or tributary rivers and streams. Industries such as pulp and paper manufacturing, cement manufacturing, dry cleaning, petroleum and natural gas industries, breweries, fish processing, and food processing, are located in various parts of the basin, usually near a major urban center. The greatest number of discharges and diversity of industries is located in the Fraser Delta HMA, while there are only one or two industrial discharges to surface waters in some of the more rural and remote HMAs of the northern and western Fraser Basin.

2.2.2. *Management of Discharges to Surface Waters*

2.2.2.1 Federal Legislation

The general provisions of the *Canadian Environmental Protection Act* (CEPA) that address the "cradle-to-grave" management of persistent toxic substances, and the general provisions of the *Fisheries Act* (in particular Section 36), which prohibit the deposition of deleterious substances, apply to all discharges.

The *Fisheries Act* provides a broad prohibition from polluting waters with substances which are detrimental to fish, their habitat, their consumability, and the quality of the water in which fish reside. This *Act* remains one of Canada's foremost pieces of environmental legislation.

A relatively small number of industries, including pulp and paper manufacturing, mining, and petroleum refineries, must comply with specific liquid effluent regulations under the *Fisheries Act.* These regulations establish industry-specific national effluent quality standards and regulate maximum concentrations of specific parameters which may be present in effluents discharged to surface waters, as well as effluent monitoring and reporting requirements which the proponent must meet. The Pulp and Paper Effluent Regulations are unique in that they require dischargers to undertake Environmental Effects Monitoring (EEM) of the receiving environment in addition to effluent monitoring. The Environmental Effects Monitoring program was designed to test whether or not the effluent regulations are adequately protecting the receiving environment and aquatic biota downstream from mill discharges.

Environment Canada (DOE) has the lead administrative authority for the pollution prevention provisions of the *Fisheries Act* (Section 36), and addresses discharges largely from the perspective of pollution prevention and in-plant waste treatment technology. DFO maintains a strong support role in implementing Section 36 of the *Fisheries Act* because water quality is inextricably linked to the protection of biophysical fish habitat. In this role DFO provides expertise in biology, ecology, and toxicology to discharge issues.

Failure to comply with the *Fisheries Act* can result in fines of up to $300,000 for a first offence and $1 million for a second indictable offence. In extreme cases jail terms are a possibility.

2.2.2.2 Provincial Legislation

The discharge of wastes to the environment is managed primarily via the provincial *Waste Management Act*. Dischargers are required to obtain and abide by a Waste Management Permit, which specifies conditions under which wastes may be discharged to the environment. This permitting process is administered by the B.C. Ministry of Environment, Lands, and Parks (MELP).

2.2.2.2.1 Provincial Waste Management Permits

Provincial Waste Management permits in British Columbia are managed by MELP through a referral system which involves consultation with other regulatory agencies and provides proponents with "one window" access to the relevant agencies. MELP circulates applications for new Waste Management Permits and for significant amendments to existing permits to DOE for review. DOE involves DFO in the referral process if they believe a proposed discharge could potentially harm fish or fish habitat. DFO seeks to obtain compliance with the *Fisheries Act* by participating in this referral process. This "one-window" approach is intended to provide co-ordination among agencies, however, proponents are free to approach any agency directly for information.

The Fraser River Point Source Inventory (FRPSI) database details the conditions specified in every Waste Management Permit for every permitted waste discharge in the Fraser Basin.[1] Although DOE continuously updates the database, the version used here was updated to May 1995 only. According to this database, there are a total of 474 Waste Management Permits covering 239 discharges to surface waters (lakes, rivers, streams, or the Fraser Estuary) and 374 discharges to ground in the Fraser Basin. Permitted discharge volumes of various effluent types to surface waters are summarized in Table 2.2.1

For discharges to surface waters, Waste Management Permits typically limit the volume of effluent which can be discharged over a given time frame, as well as the maximum concentrations of selected parameters in each effluent.

MELP policy states that environmental protection managers must use Best Achievable Control Technology (BACT) as a starting point when establishing permit limits.[137] BACT-based discharge criteria are developed using: 1) scientific review of technical information on control technologies; and 2) stakeholder consultation involving industry, the public, government agencies, and others. This assessment and consultation process leads to discharge criteria for specific types of effluents (e.g. sewage treatment plant effluents). Actual discharge limits which are incorporated into individual waste permits may be more lenient or more strict than limits established under BACT policy, depending upon site-specific factors.[137]

Dischargers are usually required to submit effluent quality and quantity data at defined time intervals to the Pollution Prevention and Environmental Remediation Management Branch in regional MELP offices. Most effluent monitoring by the permit holder will be conducted at times suitable to the permit holder and may result in sampling under optimal rather than typical conditions. Monitoring frequencies as required in permits are usually widely spaced in time and would not be likely to capture transient pollution events such as might occur during plant wash down and other short-term events. The net biological effect of such transient events on fish populations may therefore be underestimated.

Monitoring requirements can apply only to the effluent and not the receiving environment, although major permittees are usually required to monitor both. Permittees may be required to monitor parameters in addition to those with discharge criteria specified in Waste Management Permits. Until recently effluent monitoring data were retained in staff offices, however, they are now incorporated into the MELP Environmental Monitoring System (EMS) database.

While there is a discharge auditing process, inspectors sometimes phone ahead before visiting a facility. This practice may result in an overly positive compliance record. Failure to comply with permit specifications for a discharge can result in a range of enforcement actions under the *Waste Management Act*, and placement on the provincial Non-Compliance Report.

There has been some discussion of MELP replacing Waste Management Permits for certain industrial dischargers with industry-wide regulations to control effluent quality. While this could be viewed as a more efficient way of managing industries and would reduce work loads for staff, it would also result in a lack of consideration for the site-specific conditions existing at each discharge location. Furthermore, the direction taken with the recently introduced B.C. Petroleum Storage and Distribution Facilities Wastewater Regulation (1994), raises concerns. This regulation replaced Waste Management Permit requirements addressing contaminant levels in stormwater runoff and other discharges from petroleum storage and distribution facilities, and in many cases resulted in a significant relaxation of the conditions dischargers are required to meet. Similarly, MELP is currently developing a Municipal Sewage Regulation which will ultimately replace permits for STPs, and which may not address DFO's concerns with regard to ammonia toxicity in sewage effluent.

Table 2.2.1 Total volumes of permitted discharges of various effluent types to surface waters in the Fraser Basin.

Effluent type	Volume ($m^3 \cdot d^{-1}$)
Processing	1,028,694
Cooling water	124,466
Stormwater*	4,112
Sewage treatment plant	972,015
Leachate	12,542

* Only includes permitted stormwater discharges from industrial sites, not municipal stormwater discharges.

2.2.2.3 Guidelines and Best Management Practices

The DOE Fraser Pollution Abatement Office (FPAO) was established under FRAP to develop and implement a pollution abatement strategy for the Fraser Basin. This group studied a number of industries considered to be likely pollution sources, to determine how they operate and to characterize their discharges and effects on the environment. Guidelines for improved management practices were then developed in partnership with the industries of concern, the objective being to reduce loading of pollutants to the Fraser River. As of May 1996, guidelines or Codes of Practice were developed to address the following: fish processors; the ready mix concrete industry; marinas and small boat yards; ship and boat building and repair industry; bulk terminals (through the Burrard Inlet Environmental Action Program [BIEAP]); woodwaste management; wood preservation facilities; antisapstain facilities; auto recycling; and commercial car and truck washes. In addition, a guide to industrial stormwater Best Management Practices (BMPs) was developed.

As Codes of Practice and BMPs were completed, DOE implemented inspection programs to assess the level of compliance, and worked with industries to improve compliance where necessary. While compliance is voluntary, the desire to avoid a regulatory presence, to strive towards demonstrating due diligence, and to attain a favourable reputation with the public encourages many operators to follow existing codes and guidelines. It should also be emphasized that adherence to such BMPs, codes, and/or guidelines may prevent the acquisition of substantive environmental and economic liabilities through the creation of environmental problems such as contaminated sites.

The DOE inspection program addresses compliance with federal regulations such as the *Fisheries Act* and *CEPA,* in addition to BMPs and guidelines. Results of DOE inspections conducted in each fiscal year are published by Environment Canada as part of their FRAP series.[2, 3] To date, their inspections program has addressed antisapstain facilities, wood preservation facilities, woodwaste management, pesticide use, mining, petroleum refineries, pulp and paper mills, and municipal sewage treatment plants. Some enforcement efforts have resulted from these inspections, as discussed in the two DOE-FRAP reports.

2.2.3 *Effluent Discharge Quality - Case Studies*

2.2.3.1 Effluent Characterization - A Study of Ten Industrial Facilities

An effluent characterization study was completed by DOE-FRAP[4] to investigate the chemical character and toxicity of effluents relative to terms specified under the associated Waste Management Permits, to estimate contaminant loadings to receiving waters, and to assess the acute and chronic toxicity of effluents.

Seventeen discharges from ten industrial facilities located in the Fraser Estuary were analyzed to document their chemical composition. Ten of these effluents were also tested for acute lethal toxicity using the water flea, *Daphnia magna* (48 hour) and rainbow trout (*Oncorhynchus mykiss*) (96 hour), and for chronic lethal and sublethal toxicity by measuring effects on survival and reproduction of the daphnid *Ceriodaphnia dubia* in 7-day tests. Results must be considered as a “snap shot” as only two samples of each effluent were collected.

Results of the wastewater characterization work showed that of the seventeen discharges sampled, one effluent was not covered by a permit and four effluents exceeded permit limits (Table 2.2.2) for one of the following: discharge volume, pH, or TSS levels. Two additional discharges slightly exceeded permit limits specified for oil and grease, however, the measured levels were not considered to be statistically different from permitted levels.

Results of *D. magna* bioassays revealed that three of the ten effluents tested were acutely lethal at concentrations ranging from 35 to 71% in each of the two or three replicate tests, although one sample was contaminated with seawater. Only four of the ten discharges passed all replicated bioassay tests (passing requires that more than 50% of the test population survive in 100% effluent concentration for the prescribed time period). The remaining three discharges yielded inconsistent results, with some replicates passing and others not. For eight of the ten effluents, more than 50% of the test fish populations survived LC_{50} rainbow trout bioassays in replicate tests, while two effluents showed inconsistent results between replicates. Of the seventeen permitted effluents only Scott Paper was required to routinely test for acute toxicity as a condition of its waste management permit. Toxicity testing is a requirement of the Pulp and Paper Effluent Regulations under the *Fisheries Act*.

Chronic toxicity tests with *Ceriodaphnia dubia* showed that each of the ten primary effluents caused significant impairment of reproductive success at concentrations ranging from 1% to 80% effluent. Results are difficult to fully interpret because in some cases less than half of the *Ceriodaphnia dubia* died, yet No Observed Effect Concentrations (NOEC), and Inhibition Concentrations causing a 25% reduction in the number of young produced relative to controls (IC_{25}) were extremely low (1%). Regardless, the overall result is clear; a significant proportion of discharges had some level of toxicity.

Examination of permit requirements shows that the substances considered to possibly contribute to observed toxicity based on wastewater characterization results, such as copper, zinc, viscosity, and others,[4] were usually not restricted under conditions specified in Waste Management Permits.

2.2.3.2 Fish Processing Plant Effluent

Existing effluent chemistry data from four fish processing plants was assessed and effluent from an additional four fish processing plants in the Fraser Estuary was collected for chemical analyses and toxicity testing using rainbow trout and *Photobacterium phosphoreum* (used in the Microtox® test) as the test organisms.[5] Considerable variation was found among and within processing plants in terms of effluent characteristics. While the annual contaminant loading from fish processing plants which discharge directly to the Fraser estuary is relatively small, study results suggest that environmental impacts may occur in the vicinity of outfalls due to high levels of BOD, COD, and ammonia in the effluent. Effluent toxicity was demonstrated at all plants, with the degree of toxicity observed varying on different processing days. Only four of nine effluent samples passed the 96 hour rainbow trout LC_{50} bioassay.

Study findings resulted in development of Codes of Practice for the fish processing industry, through a co-operative effort between the industry and the Pollution Prevention and Assessment Division of DOE. The resulting Code describes ways for fish processors to greatly reduce water use and improve the quality of effluent discharged. If all processors followed the guide, pollutants discharged by this industry could be reduced by up to an estimated 50%.

Table 2.2.2 DOE-FRAP assessment of waste Management permit compliance and effluent toxicity: A case study of ten industries.

Industry	Discharge Sampled	WMP Compliance	Exceedance**	Acute Toxicity (LC_{50})		Chronic Toxicity - *C. dubia*		
				Daphnia magna	Rainbow Trout	LC_{50} (%)	NOEC[1] (%)	IC_{25} [2] (%)
Lafarge Cement (1)	Non-contact cooling water & stormwater	**No**	Flow 3,106 $m^3 \cdot d^{-1}$ (2,950 $m^3 \cdot d^{-1}$)	NA	NA	NA	NA	NA
Lafarge Cement (2)	Non-contact cooling water & surface runoff	Yes		**2/3 passed**	2/2 passed	>100	**25**	**51**
Scott Paper Ltd.	Paper mill effluent	Yes		3/3 passed	2/2 passed	**81**	**13**	**18**
IFP Fraser Mills Ltd.	Non-contact cooling water & stormwater	Yes		**0/2 passed**	**1/2 passed**	**55**	**25**	**38**
MacMillan Bloedel (1)	Cooling water, boiler blowdown & runoff	***No**	Oil & grease 6 $mg \cdot L^{-1}$ (<5 $mg \cdot L^{-1}$)	NA	NA	NA	NA	NA
MacMillan Bloedel (2)	Stormwater & kiln condensate	***No**	Oil & grease 5 $mg \cdot L^{-1}$ (<5 $mg \cdot L^{-1}$)	**2/3 passed**	2/2 passed	>100	**50**	**80**
IFP Ltd. Hammond Cedar	Non-contact cooling water	Yes		NA	NA	NA	NA	NA
IFP Ltd. Hammond Cedar	Kiln condensate	Yes		NA	NA	NA	NA	NA
IFP Ltd. Hammond Cedar	Boiler blowdown	**No**	pH 9.06 - 9.49 (pH 6.5-8.5)	3/3 passed	2/2 passed	>100	**1**	**2**
Tree Island Industries	Process effluent	Yes		NA	NA	NA	NA	NA
Tree Island Industries	Non-contact cooling water	Yes		3/3 passed	2/2 passed	**71**	**25**	**42**
Domtar Inc.	Steam condensate	Yes		3/3 passed	2/2 passed	100	**1**	**2**
Tilbury Cement Ltd.	Non-contact cooling water	Yes		**0/3 passed**	2/2 passed	**35**	**3**	**15**
Tilbury Cement Ltd.	Ditch discharge (non-permitted)	**No**	Not permitted	NA	NA	NA	NA	NA
Hilinex Packaging Inc.	Effluent	Yes		**0/2 passed**	**1/2 passed**	**59**	**13**	**16**
Westshore Terminals	Runoff	Yes		**1/3 passed**	2/2 passed	**71**	**<1**	**1**
Westshore Terminals	Septic	**No**	TSS 194 $mg \cdot L^{-1}$ (TSS < 130 $mg \cdot L^{-1}$)	NA	NA	NA	NA	NA

Notes:

NA = not assessed.

* measured levels not considered to be statistically different from permit value.

** bracketed values indicate permit limits

[1] NOEC = No Observed Effects Concentration

[2] IC_{25} = the effluent concentration estimated to cause a 25% reduction on the mean number of young *C. dubia* produced, relative to the number produced by control animals.

Source: McDevitt, *et al.* 1993. (See reference 4)

2.2.3.3 Wood Protection

2.2.3.3.1 Heavy Duty Wood Preservatives

Heavy duty wood preservatives are toxic substances applied to wood to protect it from a range of organisms (i.e. fungi, insects, marine borers). There are 19 wood preservation facilities in B.C. using approximately 4,500 metric tonnes of wood preservation chemicals annually,[2] including: chromated copper arsenate (CCA); ammoniacal copper arsenate (ACA); pentachlorophenol (PCP); and creosote - a distillate of coal-tar consisting of some 160 chemicals including many polycyclic aromatic hydrocarbons (PAHs).[9] Results of a pesticide use survey conducted in 1991[143] indicate that chemicals used for wood preservation amounted to 61% of the total pesticides used province-wide.

PCP is chemically and biologically persistent and even low concentrations of PCP interfere with the basic metabolism of fish, leading to both short-term and chronic effects.[6] Acute toxicity to fish has been demonstrated at higher concentrations (30-150 ppb).[7] CCA and ACA are "fixed" to the wood through factory treatment to reduce the leaching of toxic ammonia and metal salts to the aquatic environment, but improperly treated wood will leach significant amounts of chemical.[8]

In B.C. creosote is commonly used to treat wood exposed to the marine environment. Approximately 5,000 to 7,000 m^3 of creosoted structures are used annually in marine construction in this province.[9] The persistence of compounds leached from structures treated with creosote, and the subsequent effects on aquatic organisms, are of concern. Studies have shown strong associations between exposure to creosote-contaminated sediment and the presence of lesions in the livers of fish.[10,11]

Guidelines have been developed for the design and operation of facilities which apply ACA, CCA, creosote, PCP, and thermal PCP to wood.[6, 12-14] Inspection of five B.C. treatment facilities by DOE in 1992/93 showed good implementation of most of the recommendations, however, there were deficiencies in fire and spill contingency plans, and in covered storage areas for freshly treated lumber. In other cases, legal actions were pursued under the *Fisheries Act*.[2]

2.2.3.3.2 Antisapstain Agents

Softwood lumber (except cedar) is subject to attack by micro-organisms, resulting in stains and blemishes which reduce the value of lumber. Antisapstain chemicals are often applied to freshly cut lumber at sawmills and lumber export terminals to prevent damage. A Code of Good Practice was developed in 1983, with the objective of protecting both the environment and the health of workers. A study of province-wide pesticide use in 1991 shows that antisapstain chemicals accounted for 17% of the total provincial pesticide use.[143] Inspections conducted by DOE showed three main areas of non-compliance with the Code: 1) fire and spill contingencies; 2) lack of proper covered areas to store freshly treated wood; and 3) poor sludge and waste handling practices.[2]

2.2.3.4 Pulp & paper industry

Potential physical and chemical impacts of pulpmill effluent on the aquatic environment include:

- localized low dissolved oxygen levels due to the addition of material with a high BOD;
- increased water temperatures which may attract fish to effluent plumes where effluent concentrations are high, especially during the winter;
- eutrophication from the addition of nutrients;
- decreased light penetration due to the dark colour of the effluent and floating foam; and
- sublethal effects, such as increased susceptibility of fish to disease.[144]

There are ten pulp and/or paper mills in the Fraser River basin: three at Prince George, two at Quesnel, one at Kamloops and four in the Vancouver area. One of the Vancouver mills (Newstech) discharges via the Annacis sewage treatment plant. Pulp and paper mills collectively account for 35% of the total permitted volume of liquids (including industrial and STP effluents, cooling water, stormwater and leachate) discharged to the Fraser Basin each day and 72% of the total permitted discharge volume of processing effluent daily, based on calculations using the FRPSI database.

Provincial Waste Management Permits set allowable discharge levels for temperature, pH, total suspended solids (TSS) content, dissolved oxygen level, BOD, and colour of mill effluents. Under the Pulp and Paper Effluent Regulations (1992) of the *Fisheries Act*, the federal government regulates TSS and BOD and also requires that effluents be non-acutely lethal at the point of discharge, as defined by rainbow trout and *Daphnia magna* LC_{50} bioassays. The acute lethality of pulp mill effluents is attributable mostly to resin acids and, to a lesser extent, fatty acids.[16] Secondary treatment significantly reduces the acute toxicity of pulp mill effluent by removing resin and fatty acids[16] and is required for all mills with direct discharges to surface waters in Canada.[3]

In the 1980's it was discovered that chlorinated dioxins and furans discharged with pulp mill effluents were accumulating in the tissues of fish, and the birds and wildlife which rely on fish as a major food source. Chronic exposure to dioxins, furans, and other chlorinated organic compounds may impair reproductive success of aquatic organisms, disrupt metabolism, cause developmental abnormalities, or affect behavioural patterns.[17] Dioxins and furans were also accumulating in tissues of some fish species to levels which were of concern from a human health perspective. Consumption advisories were therefore established for several fish species in different areas of the Fraser Basin. Consequently, under CEPA in 1992, new regulations were introduced to limit the discharge of chlorinated dioxins and furans from pulp and paper mills (Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations [1992] and the Pulp and

Paper Mill Defoamer and Woodchips Regulations [1992]). Primarily in response to regulatory pressure, industry spent millions of dollars to make process changes. Mills reduced or eliminated chlorine bleaching, and stopped using contaminated feedstock and defoamers. Levels of chlorinated dioxins and furans in effluent have declined sharply since the late 1980s and early 1990s, and levels in fish tissues mirrored these changes. All consumption advisories which were in place on fish species in the Fraser River due to dioxins and furans have been lifted, as of January 1994.

2.2.4 *Evaluation of Processes and Tools for Managing Discharges to the Environment*

2.2.4.1 Waste Management Permit System

As part of the assessment of water quality issues in each Fraser Basin Habitat Management Area, the discharge criteria specified for each permitted discharge to surface waters in the Fraser Basin (obtained from the FRPSI database) were evaluated relative to the sensitivity of the receiving environment. Three types of issues emerged:

1. As observed in effluent characterization studies (Section 2.2.3), the loadings and concentrations of potentially harmful parameters likely to be present in specific effluents were not always restricted by permits and were not necessarily correlated with levels of other parameters that did have permit specifications. For example, several of the waste management permits for sewage discharges required chlorination and dechlorination, but did not specify a maximum concentration of total residual chlorine in effluent. Chlorine is highly toxic to fish, and the levels which may remain in improperly dechlorinated effluent can vary considerably. Also, the chlorine found in non-dechlorinated sewage effluent can be in the form of chloramines.[139] While these substances do not differ substantially in toxicity from free chlorine they are much more persistent. Other examples are provided in HMA overviews.
2. It appeared that the criteria specified for certain parameters in some waste management permits might not be restrictive enough to protect aquatic life in receiving waters. Summary tables are provided in HMA chapters indicating permits for which this type of concern exists. MELP is currently initiating amendments to some permits in order to better protect aquatic environments, however, limited staff resources mean that these changes will not happen immediately.
3. Provincial permits usually do not incorporate requirements that permit holders monitor their effluents to ensure that the effluents are non-acutely toxic. Of all authorized discharges to surface waters in the Fraser Basin only 42 (17.6%) are required to pass an acute toxicity test, according to the FRPSI database. Numerous effluents in the Fraser Basin may be in compliance with their Waste Management Permits but potentially in violation of the *Fisheries Act.*

These three types of issues reflect differences between the engineering perspective of MELP's Pollution Prevention and Environmental Remediation Branch, which has focused on pollution prevention from the perspective of best available technology, and DFO's approach as a resource management agency which seeks to prevent the degradation of water quality for the purpose of protecting aquatic biota.

Water Quality Objectives are normally established by MELP for surface waters of concern, as a means of protecting existing and future water uses, including use by aquatic life, in surface waters of concern. Where Objectives are being established for transboundary waters, Objectives are established jointly by MELP and DOE. For areas of the Fraser Basin for which Objectives were established between 1991 and 1997, DOE and DFO participated in this process as part of the FRAP program.

Agency policies on implementation of Water Quality Objectives demonstrate further differences in the approaches taken to protecting water quality by federal and provincial agencies. MELP's policy states that Water Quality Objectives do not have to be met in the Initial Dilution Zone (IDZ) of an effluent discharge, usually considered to be 100 m downstream from a discharge pipe and not exceeding 25% to 50% of the width of the water body.[18] Conversely, DFO and DOE do not accept reliance on the mixing capacity of receiving waters to dilute wastes to an "acceptable" level. DFO and DOE policy states that effluents should not be acutely toxic at the point of discharge, whereas MELP IDZ policy states only that acutely lethal conditions should not occur in the IDZ of a discharge. DFO and DOE have concerns about, and may oppose, any potential degradation of water quality which can harm fish or impair fish habitat. It is contrary to the *Fisheries Act* to deposit a deleterious substance into waters frequented by fish. Fish may not avoid degraded habitats and can actually be attracted into zones of effluent mixing, where they may be negatively affected.

An additional consideration for DFO in relation to "mixing zones" is that they often occur in the nearshore areas, which are preferentially utilized by juvenile salmon as nursery grounds. Accordingly, the actual exposure of fish to toxicants found in effluent discharges may be far greater than predicted by the use of anthropogenically defined "mixing zones".

2.2.4.2 Guidelines as Effective Tools for Protecting Water Quality

There has been increasing effort among federal agencies to work in partnership with industry to address environmental protection issues. Many of these efforts have resulted in development of non-enforceable "Best Management Practices" (BMPs) or guidelines. Results of DOE's Inspections Program show that good compliance often results from this type of approach.[2,3] Benefits include:

- industry gaining a better understanding of agency objectives; and
- agencies gaining a better understanding of industry constraints.

Increased communication has resulted in development of guidelines which are workable for industry and, if followed, reduce or eliminate impacts on the aquatic environment.

Results of follow-up inspections by DOE show generally good compliance with BMP-type guidelines. While a high level of voluntary compliance with BMPs is something to strive for, an enforcement role for regulatory agencies must be maintained.

Where follow-up work shows that industries are not complying with existing Codes, DOE and DFO generally initiate legal investigations leading to direct enforcement actions where warranted. DOE also works with MELP to ensure that performance objectives established in relevant Codes are incorporated into Waste Management Permits, so that they become legally enforceable.

2.2.5 *Summary*

Federal regulatory control over effluent discharges exists for a limited number of industries under the *Fisheries Act* and CEPA. In many cases, however, DFO and DOE rely on the general provisions of the *Fisheries Act* as a deterrence from polluting. This deterrence, and therefore the value of the *Fisheries Act* as a management tool, require that violations of the *Act* be diligently prosecuted.

Waste Management Permits are one of MELP's main tools for controlling effluent quality for the purpose of preventing pollution, however, in many cases they do not fully address the protection of aquatic biota. While staff from DFO, DOE, and MELP work together on permitting issues and have made considerable progress, there is still room to improve co-operation, and the level of protection achieved for the environment.

Cutbacks have resulted in agencies seeking to scale back their involvement in permit referral reviews. Work loads have increased in this area, but resources to address the demands have declined. While the *Fisheries Act* is largely "after-the-fact" legislation, the referral process affords DFO (and MELP) an opportunity to achieve pro-active control of pollution discharges.

The replacement of Waste Management Permits with industry-wide regulations should be considered with caution. Any new regulations should include provisions for addressing site-specific circumstances of discharge locations, and should not reduce the level of protection afforded to the environment by existing Waste Management Permits.

❖❖❖

2.3 Urbanization

2.3.1 *Introduction*

Water quality is affected by urbanization through the impacts of land clearing, the presence of numerous diffuse pollution sources, and the disposal of solid and liquid wastes. In addition, natural stream hydrology is disrupted by the replacement of natural areas with permeable soils with roads, buildings, parking lots, and other impermeable surfaces. The flow of surface and groundwaters is disrupted, and the potential for erosion, sedimentation and flooding is increased.

Less than 15% of the total area of the Fraser Basin is incorporated, with 48 municipalities. The population of the Fraser Basin was estimated to be 2.4 million in 1994, about 2 million of which lived in the Lower Fraser Valley. Approximately 76% of this population resides within the Greater Vancouver Regional District (GVRD). Of the 24 municipalities with populations of over 5,000 in 1991, 18 drain entirely into the Fraser Basin.[19] Four drain partly into the Fraser Basin and partly into Burrard Inlet (Burnaby, Coquitlam, Port Moody and Vancouver), and 2 (the City of Armstrong and the Resort Municipality of Whistler) discharge their sewage outside of the Basin while at least some of their stormwater runoff stays within the Fraser Basin.[20]

The population of B.C. is expected to increase dramatically during the next several decades, and in the Lower Fraser Valley is predicted to double by the year 2031. This anticipated population growth and urban development will be a significant source of impacts on water quality and aquatic habitat, particularly in the Lower Fraser Valley.

2.3.2 *Impacts Resulting from Physical Alteration of the Land Base*

Inadequate planning and precautions during land clearing and excavation associated with urban development can result in high sediment loads in surface runoff. Suspended sediment levels above background levels in streams will negatively affect all fish life stages, and can also have indirect effects on fish by reducing their food supply. Smothering of aquatic organisms and/or loss of aquatic habitat by sedimentation can occur where sediments settle out. Erosion of streambanks by increased volumes of runoff may not only add silt but can also alter channel morphology and destroy valuable habitat.

The clearing of streamside vegetation can result in increased summer water temperatures, which decreases the oxygen carrying capacity of water and increases the metabolic rate of aquatic organisms. An increased metabolic rate coupled with decreased oxygen concentrations in water can cause physical and physiological stress, possibly leading to death of aquatic organisms. Loss of riparian vegetation also affects physical fish habitat, and eliminates an important source of fish food - insects which drop from overhanging vegetation, and leaf litter, an important food source for many insects which in turn are consumed by fish.

The scale of these potential impacts is determined by the extent of land clearing, biophysical features of the land and the development practices used. Management practices recommended in the Federal/Provincial *Land Development Guidelines*[21] include a number of measures which are intended to benefit water quality such as detaining stormwater, minimizing exposure of disrupted soils to precipitation and runoff, retaining streamside vegetation, and the removal of sediment from runoff water prior to offsite discharge to the receiving waters.

2.3.3 Water Quality Issues Associated with Land Development

2.3.3.1 Hydrological Impacts

Urbanization has been described as the land use with the greatest impact per unit area on the hydrological regime of a watershed.[22] The replacement of the natural environment with impermeable surfaces such as roads, parking lots and buildings decreases water absorption by soils, the interception of precipitation by foliage, and evapo-transpiration from plants. This results in greatly accelerated surface runoff and increased peak flows during and following precipitation events. These changes in stream hydrology often lead to scouring of stream banks, bedload movement, and the destruction of fish eggs. Lower groundwater tables and stream levels in dry seasons also result and contribute to higher summer water temperatures.[23]

2.3.3.2 Contaminants in Urban Stormwater Runoff

The type and extent of runoff contamination is highly variable according to storm-specific conditions (i.e., rainfall duration, time between rainfall events, storm intensity).[23] Longer duration storms transport contaminants from more remote areas of the watershed, and higher storm intensities mobilize greater quantities of contaminants associated with particulates.

The intensity and type of land uses in a watershed (i.e., residential, commercial, industrial, open space) greatly influence the quality of runoff water. Runoff from residential, commercial and industrial areas usually has a high biochemical oxygen demand. Urban runoff typically contains nutrients and pesticides from lawn treatments, chemicals associated with petroleum products (components of car exhaust, oil), other fluids which leak from vehicles such as radiator fluid and windshield washer fluid, soaps and detergents from washing cars, and bacteria from animal feces (Table 2.3.1). During winter months runoff may also contain high concentrations of the salt applied to road surfaces to reduce slippery conditions.[138] Runoff from highways contains higher levels of lead and zinc than runoff from other urban areas.

Typically the runoff generated early on in a storm event and preceding the peak discharge will contain the highest concentration of contaminants, as accumulated contaminants are washed from land surfaces into stormwater.[22] Land development practices have traditionally included installation of stormwater infrastructure to quickly conduct stormwater to the nearest stream. Hence, this “first flush” phenomenon can result in extremely high contaminant concentrations in streams during the early part of a storm event.

Minimizing the impermeable surface area is key to addressing urban stormwater runoff problems, and should be the first step in managing stormwater. MELP has developed Urban Runoff Quality Control Guidelines to assist municipalities and regional districts in preparing management plans for stormwater.[23] The guidelines emphasize Best Management Practices for source control (i.e. modification of the polluting activity to eliminate production of the contaminants) and treatment of urban runoff (in cases where source control is unable to address environmental concerns). Stormwater treatment technologies include oil-water separators, extended detention dry basins, wet ponds, constructed wetlands, vegetated swale or filter strips, infiltration basins and trenches, porous pavement, porous storm drain lines, first-flush separators, and revegetation.[23]

In addition to stormwater runoff, storm sewers also carry short pulses of toxic substances which have been deposited illegally into storm lines, to sensitive aquatic environments. These substances can include chlorinated water from swimming pools and hot tubs, washwater from uncured concrete used to make exposed aggregate surfaces and improper wash-down of concrete delivery trucks, used motor oil, household pesticides, and many other substances. These transient events are rarely detected in routine surface water monitoring programs, however, they can have devastating effects on aquatic communities.

2.3.4 Water Quality Issues Associated with the Discharge of Sewage Effluent

2.3.4.1 Sewage Disposal in Urban Areas

Areas which have moderately or highly intensive urban development usually conduct sewage effluents to a central treatment facility, and subsequently discharge treated wastes into the environment.

2.3.4.2 Sewage Effluents

Polluting substances in urban wastewater include suspended solids, oxygen-consuming materials, metals and trace elements, organics, nutrients, ammonia, detergents and soaps, and micro-organisms. In industrialized centers, many operations discharge their process effluent to sanitary sewer systems. This can alter the chemical composition of sewage effluent to something quite different from that anticipated from domestic sewage alone. The use of chlorine to disinfect sewage effluent is relatively common, and chlorinated organic contaminants may be produced.

Table 2.3.1 Pollutants typically found in urban stormwater and potential sources of contamination.

Pollutant	Potential sources	
Bacteria	◆Animal feces, faulty septic fields, sewage overflows	
Suspended solids	◆Exposed soils ◆Organic & inorganic debris left on urban surfaces	
Nutrients - general ammonia	◆Fertilization (golf courses, cemeteries, lawns) ◆Landfill leachate	
Oxygen-demanding substances	◆Decaying vegetation ◆Animal wastes ◆Chemical wastes	◆Landfill and woodwaste leachate ◆Sewage seepage
Metals (dissolved & particulate)	◆Motor vehicle operation ◆Copper water pipes ◆Galvanized culverts ◆Landfill leachate ◆Pigments in paints	◆Road salt ◆Industrial discharges ◆Atmospheric deposition ◆Illicit dumping ◆Poor waste disposal practices
Oil & grease	◆Motor vehicle operation ◆Spills of oil and fuel	
PAH & other hydrocarbons	◆Motor vehicle operation ◆Burning of fossil fuels, and fuel spills ◆Leaking underground fuel tanks	◆Creosoted structures ◆Asphalt particles ◆Natural sources, combustion
Phthalate esters	◆Leaching of plastic products	
Polychlorinated biphenyls (PCB)	◆Stockpiled waste PCB ◆Transformer leakage	
Pesticides	◆Pest control (golf courses, cemeteries, lawns) ◆Illicit dumping	
Anti-sapstain chemicals & heavy-duty wood preservatives	◆Wood preservation and protection ◆Railway ties	
Chloroform & napthalene	◆Interaction between road salt, gasoline & asphalt	

Source: BC Research Corp. 1992. (See reference 23)

The potential effects of these contaminants in sewage effluent are described below:

1. **Suspended solids** can reduce light penetration through the water column, and when they settle, may smother benthic food-producing habitat, spawning habitat, and fish eggs.
2. **Oxygen-consuming** materials can reduce dissolved oxygen concentrations in the water column, which stresses or kills aquatic organisms. Organic solids consume oxygen from deposition zones where they settle and decompose.
3. Some **metal** and **organic contaminants** may be acutely lethal, depending upon their bioavailable concentrations. **Detergents** and **ammonia** may be present in toxic concentrations in effluent.
4. The addition of **nutrients** to aquatic habitats may result in excessive algal growth, which can smother benthic habitat and use up oxygen. Nutrients can also promote the growth of fungus in benthic environments.
5. **Bacteria** can be concentrated by filter-feeding shellfish, rendering them unfit for human consumption. Fish may be affected by efforts to kill bacteria via chlorination of the effluent, if adequate dechlorination is not achieved prior to effluent discharge.
6. **Residual chlorine** in chlorinated effluent can cause toxicity. Studies at two wastewater plants showed that dechlorination removes 87-98% of chlorine but the remainder is slowly reduced. Kinetic evidence suggests it may be present in the form of chlorinated organic amines and peptides. The hydrophobic nature of the remaining fraction suggests it may be harmful to aquatic biota.[139]

There are 33 municipal sewage treatment plants (STPs) which discharge into surface waters in the Fraser Basin serving approximately 83% of the Basin population (Table 2.3.2). The treatment technologies used are classified as primary, secondary, or tertiary based on the degree of removal of contaminants. Primary treatment facilities remove debris and floatables from wastewater. About 25-40% of 5-day Biochemical Oxygen Demand (BOD_5) is removed, and approximately 35-65% of suspended solids (sludge) settle in sedimentation tanks[24] resulting in the removal of some persistent contaminants which are associated with the solids.

The distinction between primary and secondary lies mainly in the degree of removal of biochemical oxygen demand (BOD) and total suspended solids (TSS).

Secondary treatment facilities utilize micro-organisms to remove additional amounts of these parameters.

Tertiary treatment targets the removal of a specific contaminant of concern, for example the removal of phosphorus from an effluent to protect a nutrient-sensitive receiving water body. Additional TSS may also be removed during the extended treatment, although it is not usually the focus of tertiary treatment.

The volume of sewage sludge produced increases with each level of treatment. Advances have been made in developing beneficial uses for sewage sludge, for example as a soil fertilizer and conditioner in reforestation efforts, and as a top soil in mine reclamation projects. If sludge contains high levels of potentially harmful substances such as heavy metals, sludge disposal can be problematic.

Wastewater treatment plants may treat effluents with chlorine to kill pathogens that may affect human use of the water receiving water course. Subsequent dechlorination is becoming a standard requirement to reduce effluent toxicity prior to discharge, however, some chlorine may persist as discussed above. The use of ultraviolet light to disinfect sewage effluent is gaining favour for STPs which have secondary treatment (the optical clarity of secondary effluent allows adequate light penetration). This approach eliminates concerns over malfunctioning dechlorination systems.

2.3.4.3 Industrial Discharges to Sewage Systems

Municipalities can accept or reject the discharge of industrial wastes to their sewage treatment facilities. Many municipalities in the Fraser Basin do receive industrial wastes and have implemented sewer use bylaws to define the quality of effluent which their sewage treatment system receives. These by-laws are considered generally ineffective due to inadequate enforcement.[26] Also, many of the industrial wastes discharged to sewage systems remain uncontrolled due to lack of regulation of specific industries or of the specific chemicals discharged.[26] The Annacis STP, operated by the GVRD, receives large volumes of liquid wastes from industry, however, it does have a relatively effective program to monitor the effluents received.

2.3.4.4 Combined Sewer Overflows

Combined sewer systems collect both urban stormwater runoff and sewage, and in some cases industrial effluent, and deliver this combination of liquid effluents to sewage treatment facilities. When there are large volumes of runoff the capacity of collection and/or treatment systems is exceeded and the combination of effluents overflow into the aquatic environment untreated. All fifty-three of the CSOs in the Fraser Basin are located in the GVRD.[26]

Contaminants from CSOs can affect the receiving environment in the vicinity of the outfall and can persist in the environment. Levels of bacteria and other pathogens are higher in the vicinity of these outfalls, especially during and shortly after precipitation events. Similarly, CSO discharges may add substantial quantities of solid material with high BOD levels, and persistent plastics.

2.3.4.5 Septic Tanks

Approximately 17% of the Basin population is not serviced by a municipal sewage treatment plant. Households and businesses in these unserviced areas discharge human wastes to on-site septic tanks and tile fields. Several types of conditions can result in septic systems impacting nearby streams. Problems are most likely to result when formerly rural areas experience significant population growth without establishing sewage treatment facilities. This is particularly true if soils are highly permeable, and facilitate the lateral movement of water and contaminants from tile fields to nearby streams. Similarly, septic discharges can result in contamination of unconfined aquifers in the long term. Many streams are fed by unconfined aquifers particularly during dry months, and contaminants from septic tanks are then released to streams via groundwater. Some areas serviced only by septic tanks have very high groundwater levels, which again facilitates the lateral transport of contaminants to nearby streams.

Septic systems receiving greater than 22.7 $m^3 \cdot d^{-1}$ (5,000 gallons) require a Waste Management Permit while installation of systems receiving a lesser amount of effluent only requires a permit from the Ministry of Health (MOH). To obtain a MOH permit the applicant must show that certain criteria are met. These criteria are intended to prevent septic tank effluents from becoming a threat to human health but do not adequately address potential environmental impacts. One criteria addresses the minimum percolation rate of soils, with the objective

Table 2.3.2 Sewage treatment statistics for the Lower Fraser region vs. the Fraser Interior, 1989. The data are derived from the 1989 Municipal Water Use Database.

Level of treatment	% population served		% volume treated	
	Lower Fraser	Fraser interior	Lower Fraser	Fraser interior
Discharge to septic system (ground)	10	27	-	-
Primary treatment	81	1	93.8	3.28
Stabilization ponds	5	10	6.2*	14.70
Secondary treatment	4	39	*	49.53
Tertiary treatment	0	23	*	32.49
Total population	1,500,574	211,712	-	-
Total volume ($m^3 \cdot d^{-1}$)	-	-	930,286	70,689

*6.2% of the volume treated receives a higher treatment level than primary.
Source: Environment Canada. 1989. (See reference 25)

of avoiding soil saturation. There are no criteria to address the extremely high percolation rates linked with impacts to groundwater and subsequently surface waters.

For systems permitted under the *Health Act*, there are no requirements to ensure the proper maintenance of septic systems, and in many cases people do not maintain their systems at all. Premature failure of the system often results. There are many reports of untreated sewage effluent from failed septic systems reaching streams in the Fraser Basin.[27]

Several brochures and a video on septic tank maintenance have recently been developed by DOE and volunteer organizations.

2.3.5 Water Quality Issues Associated With Disposal of Municipal Solid Wastes

Municipal solid wastes include residential, industrial, commercial and institutional garbage, and demolition, land clearing and construction debris. The Regional Districts have planning responsibility to address disposal of these materials under the *Waste Management Amendment Act* of 1989. In 1991, approximately 3.4 million tonnes of municipal solid wastes were generated in B.C. (Table 2.3.3). There are approximately 180 municipal waste landfill sites in the Fraser Basin according to a recently completed inventory.[28]

Landfills produce leachates containing contaminants that reflect the wide spectrum of wastes received. Leachate production can be controlled at landfills by diverting drainage waters around the site and by periodically covering wastes with impermeable materials.[29] Leachates may be collected and treated on-site before discharge to receiving waters or they may be discharged to a sewage treatment plant. There are some old landfills which still generate leachate that reaches surface waters untreated. DOE is currently developing a geo-referenced database of all closed and operating landfills in the Fraser Basin.

The B.C. *Waste Management Amendment Act* (1989) establishes regulatory authority to implement a range of policy tools at both the provincial and Regional District level. The *Act* requires Regional Districts (or municipalities outside of Regional Districts) to submit solid waste management plans to MELP for approval.

2.3.6 Other Sources of Water Quality Impacts

All water distribution systems experience some leakage and pipe breakage. Approximately 640 leaks and/or breaks occur in the Greater Vancouver Water District (GVWD) drinking water distribution system per year.[30] This results in the release of drinking water to numerous small streams near the supply lines for potable water. This is a concern if there are levels of disinfectants in drinking water that are toxic to aquatic life.

Chloramine, a drinking water disinfectant, is comparatively persistent and is toxic to fish. Water main breaks in Surrey resulted in fish kills when chloramine was used on a trial basis by the GVWD.[140] The GVWD has since discontinued the use of chloramine, and is establishing rechlorination systems which will have a reduced potential to negatively affect fish, while protecting public health. Chlorinated swimming pool or hot tub waters discharged into storm drains can be toxic to fish.[31]

Melt water from snow collected from highways and urban areas contains road salt, sand, metals, oils and assorted garbage. Snow is often dumped directly into the Fraser River or its tributaries and these contaminants can have adverse impacts upon aquatic organisms.

2.3.7 Regulation and Guidance of Land Development

Municipal governments have jurisdiction over land development within their boundaries. The *Municipal Act* also allows local governments to regulate stormwater disposal, cutting of trees, removal of soil and the placing of fill.[21] MELP developed the Urban Runoff Quality Control Guidelines[23] to assist municipal and Regional Districts in preparing stormwater management plans which would provide both effective drainage and protection of aquatic habitats.

At the same time, any projects that affect watercourses, whether fish bearing or not, require authorization from MELP, and activities which result in harmful alteration, disruption, or destruction of fish habitat can result in charges under the *Fisheries Act*, unless authorization has been granted by DFO.

Clearly there is considerable room for inter-jurisdictional conflicts with the present system as decisions pertaining to development of the land base often have impacts on streams in the watershed, yet agencies with responsibilities for managing the aquatic resources may not be provided the opportunity for input into land use decisions. While the *Municipal Act* enables municipal governments to pass bylaws addressing a broad range of environmental protection measures, most municipal governments have not developed bylaws which would

Table 2.3.3 Municipal wastes generated, recycled and residuals disposed of in British Columbia in 1991, by regional district.

Regional District	Population	Households	Waste disposed of			Waste recycled			Residual wastes		
			Total waste (tonne)	Per capita ($kg \cdot yr^{-1}$)	Per household ($kg \cdot yr^{-1}$)	Total waste (tonne)	Per capita ($kg \cdot yr^{-1}$)	Per household ($kg \cdot yr^{-1}$)	Total waste (tonne)	Per capita ($kg \cdot yr^{-1}$)	Per household ($kg \cdot yr^{-1}$)
Bulkley-Nechako	40,248	13,053	27,809	691	2,130	2,318	58	178	25,491	633	1,953
Cariboo	64,158	22,142	27,445	428	1,240	2,645	41	119	24,800	387	1,120
Central Fraser Valley	96,964	32,979	78,475	809	2,380	19,131	244	580	59,344	756	1,799
Columbia Shuswap	45,252	17,132	32,442	717	1,894	1,041	23	61	31,401	694	1,833
Dewdney-Alouette	99,307	33,692	49,151	495	1,459	13,420	135	398	35,729	360	1,060
Fraser-Fort George	95,171	32,803	73,439	772	2,239	4,629	49	141	68,810	723	2,098
Fraser Cheam	76,399	27,676	43,354	567	1,566	9,543	125	345	33,801	442	1,221
Greater Vancouver [1]	1,647,806	631,369	1,444,041	876	2,287	343,354	208	544	914,241	555	1,448
Squamish-Lillooet	26,922	9,685	39,327	1,461	4,061	978	36	101	38,349	1,424	3,960
Thompson-Nicola	112,131	41,127	106,782	952	2,596	12,030	107	293	94,752	845	2,304

Notes

[1] GVRD also reports - 1,016,250 DLC tonnes generated, 492,650 DLC tonnes recycled, 523,600 DLC residual tonnes. (DLC = demolition, land clearing and construction)

Adapted from: Resource Integration Systems. 1993 (See reference 32.) Population statistics from BC Stats, 1993 Municipal and regional district population estimates.

afford a significant level of protection to riparian zones, instream habitats, and water quality.

The DFO/MELP *Land Development Guidelines*[21] are designed to aid in the conservation of fish populations and fish habitat at pre-development levels by preventing impacts from occurring before, during, and after development.[21] The guidelines are not enforceable unless incorporated into municipal bylaws. Abiding by the guidelines greatly facilitates approval processes for developments near streams, which provides some incentive for compliance. A guide entitled *Stream Stewardship: A Guide For Planners and Developers,*[33] was jointly developed by DFO and MELP, and is complimentary to the *Land Development Guidelines.*[21] It promotes the protection of fish and fish habitat during urban development through the use of local government bylaws to protect environmentally sensitive areas, and by promoting stewardship values.

2.3.8 Summary

Urban development is a significant source of water quality degradation in developed areas, and unless preventative measures are taken, new developments will contribute further to existing impacts. There are opportunities to address existing water quality and quantity problems associated with urban stormwater via public education programs which focus on source control and minimizing or reducing impermeable surfaces on private property. There may also be limited opportunities to address impacts associated with existing infrastructure (e.g. separation of sewage and stormwater collection systems or the construction of overflow containment tanks) on an opportunistic basis with redevelopment activities.

Preventing impacts to water quality with new developments presents a major challenge to DFO because of the number of agencies with divergent views involved with land use and resource management decisions. Prevention of further water quality impacts with urban development is a key issue particularly in the Lower Fraser Valley where population growth is booming, resulting in increasing pressures on the watersheds which collectively support 65% and 85% of Fraser River coho and chum populations, respectively.

❖❖❖

2.4 Agriculture

2.4.1 Introduction

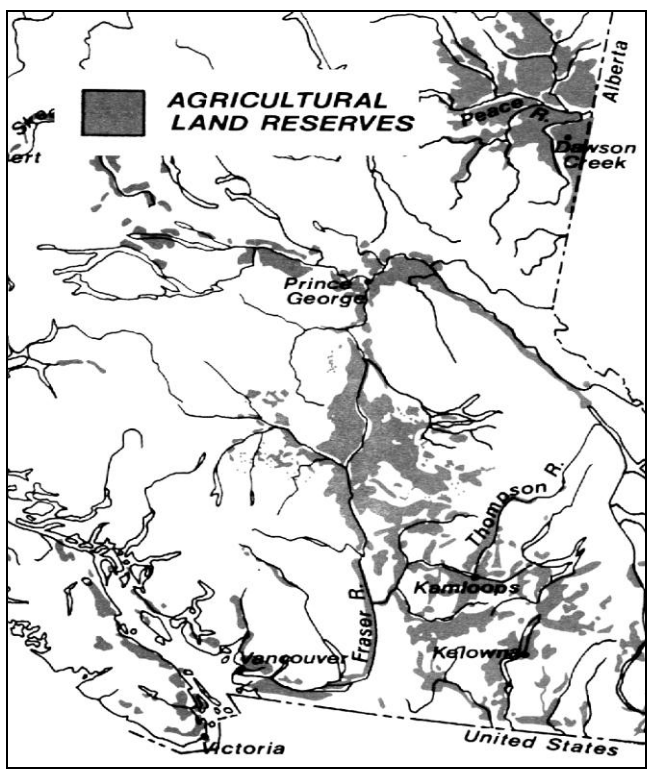
Agricultural activities are usually concentrated in valley bottoms where fertile soils are present and water is available for crop irrigation and livestock watering. The Agricultural Land Reserve (ALR) surrounds a substantial proportion of the Fraser River and tributary streams. This physical association between agriculture and surface waters (Figure 2.4.1) results in widespread potential for water pollution problems throughout farmed areas of the Fraser Basin unless precautions are taken to prevent impacts. Approximately 42% of the best arable lands and 69% of the best pasture lands in B.C. are located in the Fraser Basin, and about 50% of this land is fully utilized.[34] Despite the unfulfilled potential, agricultural development in the Basin is extensive, and has significant implications for water quality and quantity.

Most of the arable land is located in the Chilcotin and Middle Fraser areas, the Thompson sub-basin, and the Lower Fraser Valley. Cattle ranching is the predominant agricultural land use in the interior. Approximately 75% of B.C.'s 330,000 cattle are raised within the Kamloops and Cariboo Forest Regions.[133] Agricultural areas of the interior Fraser Basin also support production of a wide range of other products including ginseng, fruits, some vegetables, dairy, poultry, and ostriches.

Dairy, beef, hog, and poultry production are all significant industries in the Lower Fraser Valley. Fruit and vegetable crops are also produced in this area, including cranberries, raspberries, strawberries, cole crops, corn, potatoes, mushrooms, and turf. In general, agricultural practices in the Lower Fraser Valley are intensive in nature. Both pesticides and chemical fertilizers are used extensively in crop production.

Impacts to water quality from individual operations depend upon a range of factors including the type of crop, intensity of activity, physical features of the landscape, soil type, precipitation patterns, and precautions undertaken by the producer. Pollution generally results from non-point sources, which are difficult to monitor and quantify accurately because they vary widely with weather conditions and land-based activities such as spreading of fertilizer and manure. Impacts to aquatic systems are associated with erosion, excessive inputs of manure and/or fertilizer, and

Figure 2.4.1 Location of Agricultural Land Reserves in the Fraser Basin.



oxygen-consuming substances which result in low dissolved oxygen concentrations, and in some cases direct toxicity from substances such as ammonia from manure, and pesticides.

2.4.2 *Impacts of Agriculture on Water Quality*

The types of water quality problems commonly observed with different types of activities are described briefly below.

2.4.2.1 Ranching - northern and central areas of the Fraser Basin

Large areas of land are devoted to ranching in the central Fraser Basin, particularly in the Williams Lake and Thompson Basin areas. These areas are typically hot and dry during the summer, and cold with snow accumulation on frozen ground in the winter. There are a variety of impacts associated with ranching and the seasonal movement of cattle in these areas.

The most visible impacts on the aquatic environment are those associated with overwintering, when cattle are held in feedlots or seasonal feeding areas at fairly high densities, usually in valley bottoms in close proximity to streams. Significant amounts of animal waste accumulate on the frozen ground in these areas. During spring thaws, the wastes wash into nearby water courses, introducing large quantities of nutrients, fecal coliforms, biological oxygen demand (BOD), and toxic substances such as ammonia.

Spring runoff events which carry manure into streams can result in degraded water quality conditions that are harmful or lethal to fish. Although these severe conditions may be relatively short-lived (several hours or longer) or localized, they could potentially kill any fish present at the start of the runoff event. Runoff may stay in a relatively concentrated plume along the stream bank or shoreline, the areas most heavily utilized by juvenile fish. Dead salmon fry would not be easily seen in the fast-moving and murky waters; resulting fish kills would therefore likely go unreported.

The current Code of Agricultural Practice (1992) contains a number of specifications for confined livestock holding areas which aim to protect surface water quality from pollution. The Code addresses the location and management of these facilities, and prohibits livestock in confined holding areas from having direct access to a watercourse, with the exception of rangeland holding areas. Confined livestock areas are defined as outdoor, non-grazing areas where livestock, poultry, or farmed game are confined by topography, fences, or other structures (e.g. feedlots, paddocks, corrals, etc., but not including seasonal feeding areas).

Pollution problems can occur even when 30 m setbacks required under the Code for confined feeding areas are established, if runoff can reach a stream or lake. In a joint DFO-MELP study conducted in 1993,[35] runoff was found to contain 73.5 $mg \cdot L^{-1}$ ammonia near the point of entry to a creek, after flowing approximately 300 m over the ground. This concentration of ammonia is highly toxic to fish under the pH and temperature conditions measured in the receiving waters.

Under the Code, livestock in seasonal feeding areas are allowed access to a watercourse, provided that pollution does not occur. As defined by the Code, seasonal feeding areas are used for forage or other crop production during part of the year, and are used seasonally to feed livestock, poultry, or farmed game that is primarily sustained by supplemental feed. The Code states that the actual feeding site within a seasonal feeding area must be 30 m or more away from any watercourse. The amount or degree of livestock access to a stream which is acceptable is not defined (e.g. there are no requirements to limit the scope of access or livestock numbers) which has lead to problems with application of the Code.

Where seasonal feeding areas are located next to an unfenced watercourse, livestock tend to congregate along the shoreline where they trample stream banks and devegetate the riparian area. Degradation of the riparian zone results in increased summer stream temperatures due to loss of shading, increased suspended sediment loads, and sedimentation of stream bottoms. Animal wastes accumulate on the ground and can create spring runoff problems similar to those described for confined feeding areas.

The potential for problems associated with runoff events from both seasonal feeding areas and confined livestock areas has been documented in the Thompson sub-basin where cattle ranching is widespread. Helicopter surveys conducted in the spring of 1994 in the Thompson sub-basin revealed approximately 103 sites with potential environmental impacts from cattle overwintering areas, and approximately 50 of the sites required a follow-up inspection by MELP staff.[35]

During the late spring cattle are driven to outlying range lands where they graze through the summer at theoretically low densities. Calculated summer densities are misleading, as cattle tend to congregate in particular areas such as along streams or lake shores, where they can cause significant impacts.[36] Although the types of environmental damage caused by grazing have been extensively documented in the western U.S.[37] the actual extent of impacts in B.C. is poorly documented.

The Ministry of Forests (MOF) is responsible for managing Crown Lands which are used for grazing. MOF is developing a series of field guides to address grazing issues as they relate to riparian areas, community watersheds, and requirements for obtaining or renewing grazing tenures.

The B.C. Cattlemen's Association is currently revising their *Range Management Practices* manual which was first produced in 1978. The new manual will address the broad scope of range management issues within the context of ecosystem sustainability.

2.4.2.2 Fruit and Vegetable Production in Central Areas of the Fraser Basin

The relatively lengthy and warm summers of central areas of the Fraser Basin, in particular the Thompson River sub-basin, support production of some fruit and vegetable crops. Impacts to water quality from production of vegetable crops may arise from the use of fertilizers (including manure) and pesticides, in addition to suspended sediment problems associated with soil erosion. Removal of riparian vegetation can also cause significant increases in summer water temperatures. Potential impacts arising from the production of tree fruits are likely restricted to those associated with pesticide and possibly fertilizer use. Because soils are not tilled in fruit orchards erosion and suspended sediment problems are unlikely to be common. If precautions are taken and vegetated riparian buffer strips are undamaged, the chances of pesticides or excess nutrients reaching watercourses are greatly reduced.

2.4.2.3 Ginseng production in the Interior Fraser Basin

The ginseng industry is growing rapidly in the interior Fraser Basin, particularly in the Thompson sub-basin where this crop is grown in large plots, which are often located adjacent to watercourses. Typically, 4 to 5 years are required to produce one harvestable crop, therefore it is important for producers to ensure that pests do not damage their investment. As of 1995, four pesticides (all fungicides) were approved by the Pest Management Regulatory Agency (PMRA) of Health Canada (formerly Agriculture and Agri-food Canada) for use on ginseng crops: Dithane M45, Rovral, Dytene, and Quintozene. PMRA approval specifies that buffer zones be left around water courses. The risks associated with application of pesticides to this crop may be reduced compared with other crops because ginseng is usually covered with a canopy, which limits application methods to those least likely to cause drift. Also, because of the dry climate required by ginseng, pesticide runoff is less likely to be a concern than it would be in coastal areas. Both the PMRA and MELP are involved with field studies in the Okanagan area of B.C. to assess the movement of pesticides into aquatic habitats.

2.4.2.4 Animal and Vegetable Crop Production in the Lower Fraser

Agricultural production in the lower Fraser Basin by far exceeds production from all other areas of the Basin combined, in terms of product value per hectare of agricultural land. This is due to the relatively mild climate of the area, the proximity to markets, and the intensity of farming. In 1985, 25% of the B.C. gross income from agriculture was derived from the lower Fraser Basin and the average production value per hectare was more than 15 times the national average[38] for farm land. In 1995, Lower Fraser Valley agriculture generated gross farm receipts of $859 million.[134]

Practices are intensive and resulting impacts to water quality can be severe.[39-41] Common problems include: eutrophication from excessive or inappropriate use of chemical fertilizers and/or manure; potential toxicity from ammonia originating from manure; and low dissolved oxygen concentrations through the summer and into the fall months, resulting from eutrophication and BOD input. As well, damage to or elimination of riparian habitat causes sedimentation of stream beds, high suspended sediment levels, and elevated water temperatures. Salts and metals can also be introduced into aquatic systems by agricultural activities.[42] Low dissolved oxygen concentrations associated with runoff from farm lands resulted in pre-spawning mortality of over half of the Serpentine River coho run in October 1980, and October 1984.[43] Extremely low levels of dissolved oxygen have also been reported for the lowland Matsqui[39] and Sumas[40] systems, where intensive farming practices have developed.

2.4.2.4.1 Manure and Other Animal Wastes

There is a significant excess of nutrients applied to land on an annual basis in the Lower Fraser Valley. Each year feed is imported to support high densities of livestock, resulting in release of nutrients to the environment via manure, which is then spread locally. Nutrient applications from manure plus inorganic fertilizers spread on land in the Lower Fraser Valley greatly exceeds annual removal by crops, hence large imbalances have developed.[44] A nutrient balance modelling study of all agricultural areas in the Lower Fraser Valley showed that 17 of 20 management zones had a surplus of nutrients applied relative to what crops could take up, and 57% of the Lower Fraser Valley cropped area had an excess of more than 100 $kg\text{-}N\cdot ha^{-1}$ each year.[44]

The introduction of excessive amounts of phosphorus to aquatic environments is also of concern, as phosphorus is usually the nutrient which limits primary production in healthy B.C. streams. The same nutrient balance modelling study showed that the net application of phosphorus was at least twice the potential crop removal amount in 18 of 20 agricultural management zones. Phosphorus is normally readily bound by soils, however, the frequent and heavy rainfalls which are characteristic of the Lower Fraser Valley can result in the generation of nutrient-contaminated runoff which reaches streams.

2.4.2.4.2 Chemical Fertilizers

The use of chemical fertilizers in the Lower Fraser further compounds the nutrient excess problem. Chemical fertilizers are considered desirable by growers because the timing of nutrient release is very predictable. When properly applied, nutrients meet immediate crop requirements, resulting in maximum plant growth and nutrient uptake. In the Lower Fraser, however, more nutrients are available through manure alone than are required for crop production, without applying any chemical fertilizers.[44]

Experts in B.C. Ministry of Agriculture and Food (MAF) suggest that use of chemical fertilizers could be reduced as much as 75% without any reduction in crop production if manure was properly applied to the land as a fertilizer.[46] Similar reductions have been attained in European countries. Brisbin estimates that producers in the Lower Fraser Valley could save about $12 million per year collectively by relying more on manure as a nutrient source and reducing chemical fertilizer use.[44]

2.4.2.4.3 Pesticide Use

Pesticides are toxic substances designed to kill, repel, or control unwanted organisms including weeds, insects, rodents, fungi, nematodes, and others. They are also potentially toxic to non-target organisms, including aquatic biota if they enter streams. A study of pesticide use in 1991 covering all of B.C. showed that agriculture accounted for 13.7% of all pesticide use in the province, and 71% when wood preservatives, anti-sapstains, and slimicides were excluded.[143] Of the pesticides used on agricultural land, 71% was applied by farmers to their own land, and 4.7% was applied through commercial services.[143]

The best known and most common pesticide active ingredients are the organochlorines, organophosphates, and carbamates. Organochlorines are persistent and fat soluble. Since the 1970s the registration of most organochlorine pesticides has been cancelled, suspended, or restricted due to concerns associated with human health and environmental impacts. Residues can still be found in the environment, particularly in sediments and sometimes biota.[47] While concentrations are less than the range which would cause human health concerns, implications for fish are unknown.[48] Organophosphate pesticides are among the most commonly applied pesticides in B.C. They are not very persistent in the environment, however, they are water soluble and are among the most toxic pesticides used in Canada.

Census data from 1986 were examined by Schreier, *et al.*, who reported that 90% of all insecticides and 56% of all herbicides used in British Columbia are applied in the Lower Fraser.[34] Pesticide residues have been measured in ditch water in the Lower Fraser for up to one year after spraying, and at very high concentrations immediately after spraying.[48] Endosulfan was measured at a concentration of 1,530 $\mu g \cdot L^{-1}$ in ditch water, about 1,100 times the 96 hour LC_{50} concentration for rainbow trout.[48] Other substances detected included azinphosmethyl, diazinon, dinoseb, and fensulfothion. Drainage ditches in the Lower Fraser typically flow into fish-bearing streams or may directly support fish. The report stated that where set-back distances for tractor-mounted spray application were less than 3 m, pesticide contamination of ditch water and streams was likely.

Government agencies and industry have been working successfully to reduce pesticide use in agriculture by encouraging integrated pest management (IPM) programs. IPM involves the use of biological controls, cultural controls (crop rotation, etc.) and pest monitoring information to reduce the need for chemical pesticides. Approximately 8% of berry and 17% of vegetable hectarage in the Lower Mainland are managed with IPM techniques.[49] Significant proportions of particular vegetable crops such as carrots (66%), onions (74%), and potatoes (42%) are grown under integrated programs.[49] The amounts of pesticides used to manage 15 arthropod species were reduced on over 50% of the participating farms. In addition, IPM programs have resulted in economic gains for most participating producers.[49]

2.4.2.4.4 Urban-rural pressures on streams

A critical situation is now developing in the semi-rural areas of the Lower Fraser sub-basin. More than 65% of Fraser River coho production and 85% of Fraser River chum production originate from tributary streams located between Hope and the estuary. Many of these streams are severely impacted by the intensive agricultural activities described above. Adult coho and chum salmon typically return to spawning streams in the fall months and may be prevented from migrating upstream until fall rains flush badly contaminated or deoxygenated water out of these streams.[39]

The life cycle of the coho makes this species particularly vulnerable to degraded water quality relative to the other anadromous salmonids of the Pacific region. Coho spawn in relatively small streams and the juveniles rear in these same streams for a year or longer before migrating to sea. The poor water quality resulting from agriculture often confines rearing fish to refuge areas in the upper stream reaches, where the land is too hilly to farm. Lowland areas are protected for agricultural use by the Agricultural Land Reserve, and now the upper reaches of these watersheds are facing increasing pressure from urban development. This urban development threatens the limited year-round rearing habitat remaining in these Lower Fraser tributary streams.

There is an urgent need to improve water quality in the lower reaches and protect water quality in the upper reaches if these coho populations are to survive. Stormwater management in these urbanizing areas is also a key issue which needs to be addressed, as increasing stormwater runoff results in downstream flooding of agricultural lands, which impacts crop production and leads to further water quality problems when soils, manure, and agrochemicals are washed into streams.

2.4.2.5 Hobby Farms

Hobby farms can play a large role in degrading water quality. They are often owned by people who do not have training or experience in farm management and therefore lack knowledge about livestock management, and manure storage or application. Hobby farmers are usually not associated with any producer group and as a result are not linked with information networks available to larger scale commercial producers. Although each land owner may own only a small number of livestock, animal densities can be high because land parcels are relatively small. Where there are large numbers of hobby farms water quality problems may be exacerbated by seepage from improperly maintained septic systems in addition to manure runoff. Hobby farms contribute to environmental problems in both coastal,[41, 50] and interior areas of the Fraser Basin.

2.4.3 Legislation

2.4.3.1 Federal Legislation

With regard to federal legislation, the general provisions of the *Fisheries Act* are among the most powerful tools for protecting water quality. Other pieces of legislation provide indirect protection to water quality. For example, the federal *Fertilizer Act* specifies standards for composition, packaging, and labelling of fertilizers, and also prohibits the use of harmful ingredients. The *Canadian Environmental Protection Act* (CEPA) can also be used to restrict use of substances including pesticides, if they are considered to be persistent and toxic.

DOE-FRAP has developed an inspection program to address violations of the *Fisheries Act* by agricultural operations. This program will be implemented in the 1997-98 fiscal year, and targets farms in both the B.C. interior and the Lower Fraser Valley.

2.4.3.2 Provincial Legislation

Under the *Waste Management Act*, MELP enacted the Agricultural Waste Control Regulation in 1992, and the associated Code of Agricultural Practice for Waste Management, which describes appropriate waste management practices. A series of Environmental Guidelines documents has been prepared for specific producer groups (e.g. dairy, beef, poultry, mushroom, etc.), which provide "how to" information to help producers attain compliance with the Regulation and supporting Code. Producers who comply fully with the Code are exempt from the requirement to obtain a Waste Management Permit for discharging farm wastes. Producers who do not operate in compliance with the Code are required to obtain a Waste Management Permit from MELP, and abide by the conditions detailed within.

Enforcement of the Agricultural Waste Control Regulation has been phased in to allow producers time to bring their operations into compliance. While there are very few producers who actually have Waste Management Permits, there are still many producers who are not in compliance with the Regulation and supporting Code. This is likely due at least in part to limited enforcement capability which results from staff shortages. Two positions (1 in Kamloops and 1 in Surrey) were supported as part of DOE-FRAP/MELP regional initiatives to address agricultural issues and these positions are now supported by MELP.

Numerous other pieces of provincial legislation have indirect implications for water quality. The *Health Act*, for example, regulates farm practices which may cause health hazards, such as disposal of dead animals. The *Pesticide Control Act* applies to the sale, transportation, storage, preparation, application, and disposal of pesticides.

The *Water Act* requires the licensing of all surface water withdrawals in B.C. but does not require licensing of groundwater withdrawals. Water licenses are issued through the Water Management Branch of MELP. Provisions of the *Act* do not recognize instream water requirements for supporting aquatic life. MELP has been discussing revisions to the *Water Act* to address the needs of aquatic life, however, changes have yet to be made. While there is some degree of co-operation developing between the Water Management Branch and DFO in this regard, many streams are already over-licensed.

Most water licenses issued for irrigation withdrawals do not require anyone to monitor the amounts of water removed from a surface source, and actual withdrawals may exceed permitted volumes. In some areas of the Fraser Basin excessive water withdrawals result in very low stream flows, and may cause some streams to go dry during hot summer months. Other impacts from excessive withdrawals include increased water temperatures, reduced oxygenation, and increased concentrations of contaminants.

An overview of irrigation withdrawals for the Fraser Basin was provided by Schreier, *et al.*,[34] who indicated that about 27% of the 8,343 farms located in the Basin in 1986 were irrigating crops. In some sub-basins such as the Chilcotin, Bridge, Middle Fraser, Lillooet, and the North, South, and mainstem Thompson, the percentage using irrigation water varied between 41 and 76%. About 55% of the Fraser Basin farms which used irrigation water were obtaining it from the Fraser River or its tributaries. Lakes and rivers provide more than two thirds of all irrigation water in all sub-basins except for the Lower Fraser, where groundwater provides 47% of irrigation water. It should be recognized that groundwater withdrawals can detract from flows in streams which are groundwater fed.

Stream flow information and licensed water withdrawals have been summarized for most salmon-bearing streams in the Fraser Basin in a series of reports prepared by Rood and Hamilton,[51-62] on behalf of DFO-FRAP. The contents of these reports provided the basis of the stream summer low flow and water withdrawal information which is summarized in the HMA overviews provided in this report on a stream-by-stream basis.

2.4.3.3 Industry Initiatives

The Agriculture Environmental Protection Council (AEPC) is a joint partnership between industry and government, whose ultimate goal is to address environmental concerns within the farming community, without the necessity of regulatory action. To achieve this, the AEPC has developed a program under which volunteer peer advisors respond to and resolve nuisance and pollution complaints against farms. Under a co-operative agreement with MELP, advisors respond first unless there is an emergency situation, or a peer advisor is unable to respond within a reasonably short time period.

Ideally, peer advisors offer producers an educational opportunity, and MELP responds with regulatory tools only when other avenues have failed to bring about satisfactory results. Producers prefer to receive visits from fellow producers rather than enforcement officers. This approach aims to reduce the need for enforcement actions by government agencies, which reduces demands on staff. The peer advisor program has operated with varying degrees of success in different parts of the Fraser Basin.

A similar peer advisor program, Enviralert, has been implemented through the B.C. Cattlemen's Association (BCCA). The BCCA also fosters environmental protection and enhancement with its annual Environmental Stewardship Award. The Enviralert Program has been effective at increasing awareness among ranchers of the environmental issues associated with ranching, in some areas of the Fraser Basin. The BCCA is implementing training workshops for peer advisors, in co-operation with MAF, MELP, and DFO.

Numerous producer "conservation groups" have developed over the past several years with support from government programs such as the Agriculture Canada Green Plan. These groups have taken on leadership roles in developing new reduced-impact approaches to farming. Many of these groups have an impressive list of accomplishments in terms of identifying and promoting lower impact practices, modifying equipment to introduce new manure management options, developing markets for manure, to name a few. Many of these groups lacked sufficient funds to continue functioning in the same capacity following the end of the Green Plan (March 1997).

2.4.4 *DFO-FRAP Actions to Address Agricultural Issues*

A wide range of initiatives have focused on reducing the impacts of agriculture on water quality in the Fraser Basin. A Demonstration Project in the Fraser Basin on the Salmon River (Langley) has produced a large and valuable knowledge base to use in making land-use decisions, and provides a model for rural watershed management approaches. It has also highlighted the scale of problems which can be caused by hobby farms. A Demonstration Project on the Salmon River (Salmon Arm) is also addressing impacts from agriculture on aquatic systems, and has involved significant riparian restoration efforts. Both projects have raised awareness among local landowners of the importance of properly managing riparian areas.

A broad range of agencies and organizations including MELP, MAF, DOE, DFO, B.C. Federation of Agriculture, and Westwater-U.B.C., participated in developing a nutrient-flow model for agriculture in the Lower Fraser Valley. This model provided a tool for quantifying the scope of the nutrient management problem, identifying the "hot spot" areas, and estimating the potential effectiveness of different management tools at addressing identified problems. A summary report identifies the key findings from all component projects, and includes a recommended multi-agency management approach.[135]

An educational stewardship guide[147] has been developed via an inter-agency committee led by DFO and including representatives from DOE, MELP, MAF, and the BCFA. The purpose of the guide is to inform producers about the habitat requirements of healthy fish and wildlife populations, and how to make changes to their operations which will benefit these habitats, while often benefiting the farm as well. An education program based on the guide is now being implemented.

2.4.5 *Summary*

Agricultural land comprises a significant proportion of the Fraser Basin lowland areas which border on important fish-bearing streams. Unless precautions are taken agricultural activities have a significant likelihood of generating impacts to water quality, through basic activities such as tilling soil, removal of riparian vegetation, the generation and spreading of manure, and the use of chemical fertilizers and pesticides. Impacts to water quality from agriculture have been reported in many areas of the Fraser Basin, from Prince George to the estuary. While little new land is being brought into production, in many cases farming is becoming more intensive on existing farm land. While agriculture is a provincial responsibility, agencies such as DOE, DFO, MELP, and MAF need to expand upon existing co-operative efforts with producers if existing impacts on the environment and other resources are to be reversed and further impacts are to be prevented.

❖❖❖

2.5 Forestry

2.5.1 *Introduction*

Many aspects of wood harvesting and forest management have the potential to affect water quality and fish habitat. The Fraser Basin contains approximately 37% (9.6 million ha) of the productive forest on provincial crown land. The geographic scope of forested lands in the basin makes forestry a potentially dominant land use in many areas, and consequently good forest practices are key to protecting water quality throughout the Fraser Basin. The types of water quality impacts which can result from road building, logging, silvicultural activities, log handling, and the generation of woodwaste are briefly described here.

2.5.2 *Timber Harvesting*

2.5.2.1 Effects of Road Building and Timber Harvesting on Water Quality

Timber harvesting can affect the hydrology of a watershed through soil compaction and vegetation removal. The construction of logging roads and use of skid trails both cause soil compaction. Compaction reduces the rate of water infiltration into soils and the capacity of soils to store moisture, interrupts subsurface water flows, and increases the flow of water over compacted areas.[63, 64] Water is usually collected in ditches along logging roads, and is channelled under roads through culverts or across roads via water bars. While ditching and culverting may help to protect the integrity of roads, the channelling of runoff water also disrupts the natural hydrology of the watershed, and can generate considerable erosive force which leads to stream sedimentation. The improper sizing or location of culverts can cause road failures which often result in stream sedimentation. Poorly constructed roads and inadequate road drainage measures further contribute to stream sedimentation.

The removal of vegetation that occurs with logging (especially clear-cut logging) increases the amount of moisture that reaches the soil during precipitation events, and can also reduce evapo-transpiration rates,[65] resulting in increased rate and amount of runoff during and after precipitation events.[64] Canopy openings allow for greater snow accumulation and faster snow melt, again resulting in increased runoff.[66]

Increased runoff can promote erosion of surface soils, as well as streambank erosion and the scouring of streambed materials. Sediment deposition will then occur in lower-energy segments of streams, often infilling key habitat features. Mass soil movements such as landslides, earth flows, and slumps may also result from road and slope failures and contribute to stream sedimentation.

The Jones Creek watershed, near Hope, B.C., provides a sad example of the types of problems discussed above. Extensive logging of slopes with thin top soils over bedrock led to decreased soil strength (due to water-logged soils) and the destruction of root systems which effectively bound the soils together. Erosion problems have been ongoing since logging began in the watershed and culminated in huge debris torrents that filled the creek channel and destroyed the worlds first successful salmonid spawning channel in 1993-'95. Fish are no longer able to reach spawning grounds, and the genetically unique pink salmon run has virtually disappeared from this stream.[136]

When logging occurs right up to stream banks the loss of riparian vegetation results in an increased influence of solar radiation on streams, and removal of the insulating effect which riparian vegetation has on stream temperatures. The net result is higher summer daytime water temperatures and lower summer night time temperatures.[67] Loss of riparian vegetation can also lead to lower winter water temperatures, which increases the chances of anchor ice forming.

Increases in summer water temperature may place physiological stress upon aquatic organisms by increasing their metabolic rate while decreasing the capacity of water to hold dissolved oxygen. Other impacts to aquatic organisms associated with disruption of the thermal regime are discussed in Appendix 1.

While the loss of riparian vegetation with logging should be greatly reduced following introduction of the *Forest Practices Code of British Columbia Act* and supporting Code in 1995, there are thousands of kilometers of stream banks in the Fraser Basin that were cleared prior to introduction of the Code, and the problems described above will persist until riparian vegetation regenerates.

2.5.3 Silviculture

2.5.3.1 Site Preparation Effects on Erosion and Stream Sedimentation

The preparation of logged sites for replanting involves the removal of slash following scarifying or burning. These activities further disrupt exposed soils, and can increase the detachment and transport of sediment. They can also contribute to increased nutrient loading to streams.[68] Table 2.5.1. shows the scope of these activities in the Fraser Basin.

2.5.3.2 Pesticides

A variety of herbicides are used to control the growth of brush and tree species that may reduce growth or compete with the desired "crop" of trees. The herbicide glyphosate (trade names Roundup®, Vision®) is commonly used in B.C., while 2,4-D, hexazinone and triclopyr (trade names Garlon 4®, Release®) are used to a much lesser extent. Herbicide use in each of the Ministry of Forests (MOF) regions is summarized in Table 2.5.1. A study of pesticide use in B.C. for 1991 indicates that forestry is a relatively small user of pesticides, and accounted for 1.6% of total use, and 8% of use when wood preservatives, anti-sapstains, and slimicides were excluded.[143] Approximately 1,200 ha of the Vancouver Region area lies within the Fraser Basin.[70]

Insecticides are used to control defoliating insects and bark beetles. Insecticides commonly used in B.C. forests are Btk, monosodium methanearsonate and carbaryl (trade name Sevin®). Btk is a bacteria which is relatively harmless to non-target organisms, however, the chemical pesticides can be toxic to non-target species including aquatic organisms. Direct effects of silvicultural pesticide chemicals on the aquatic environment include acute and sublethal toxicity.[71-73] Over-spraying a stream with glyphosate resulted in increased invertebrate drift,[74] temporary signs of stress in caged coho fingerlings and avoidance of sprayed areas by resident coho.[75] Indirect effects of herbicides reaching riparian vegetation include short-term reductions in streamside vegetation, reduced leaf-litter fall, increased exposure to sunlight, warmer summer water temperatures, increased erosion, and increased nutrient concentrations in stream water.[76]

Pesticide use in B.C. is primarily regulated under the B.C. *Pesticide Control Act*. The Forest Practices Code establishes further restrictions on pesticide use on Crown forest lands, and builds on the MELP/DFO Coastal Fisheries/Forestry Guidelines[78] by requiring establishment of a "pesticide-free zone" (PFZ) around streams. A buffer zone between the treatment area and the PFZ helps to prevent movement of pesticides into the PFZ during or following treatment of an area.[77] The Forest Practices Code is the only legislation prescribing a PFZ.

Pesticides which are toxic to aquatic organisms would be considered deleterious substances as defined by Section 36(3) of the federal *Fisheries Act*, hence the introduction of pesticides into fish habitat could result in charges under the *Act*. Furthermore, buffer zones protect riparian vegetation from herbicide damage. Riparian vegetation is an integral part of fish habitat, and the loss of riparian habitat in B.C. has been equated with destruction of fish habitat in court cases.

2.5.3.3 Fertilization

Nitrogen is applied as a fertilizer to replanted areas to stimulate tree growth. Fertilizers are usually applied by aerial spraying on a site-specific basis depending upon needs of the tree species. Eutrophication or toxicity problems may result if excessive nitrogen enters water-bodies directly from aerial spraying and indirectly as a leachate from upland areas.[67]

The use of fertilizers in silviculture is administered by MOF through Silviculture Prescriptions. The Silviculture Practices Regulation of the Forest Practices Code only regulates broadcast fertilization in community water-sheds. The MOF Forest Fertilization Guidebook[69] recommends leaving a 10 m “no fertilizer application zone” around fish-bearing lakes, designated fisheries streams, and streams that flow into fisheries streams, to ensure that there is no direct deposition of fertilizer pellets and to minimize the leaching of fertilizer into a water body.[69] The guidelines are enforceable only when inserted into silviculture prescriptions. Fertilizer use in B.C. in 1992/93 is summarized in Table 2.5.1, but it varies greatly from year to year.[79, 80]

2.5.3.4 Forest Fire-Fighting

Forest fires cause considerable economic damage in British Columbia and loss of vegetation from fires can be detrimental to fish habitat. Forest fires are fought with a variety of methods, including the use of fire-retardant chemicals which are toxic to fish.[141] While it is necessary to extinguish some forest fires, the chemical industry should consider developing non-toxic fire-retardants, which would clearly have a market.

2.5.4 *Log handling, transportation and storage*

Log handling processes which can impact the aquatic environment include the dumping of cut timber into the water for sorting, the booming of logs as bundle booms or flat rafts, long-term storage of logs on land near watercourses, the storage of booms in fresh or marine water, and their transport from all areas of the province to processing facilities in the Lower Fraser Valley and on Vancouver Island.[81] The physical effects of log handling include scouring of soft substrates, smothering of natural benthic substrates by accumulation of bark and wood debris, shoreline erosion, sediment disturbance and re-distribution in aquatic habitats, and a decrease in light penetration.[82] The major effects on water chemistry are increased BOD, the release of soluble organic com-pounds from logs stored on land or in the water [81, 83, 84] and the production of toxic leachates during the decom-position of bark and woody debris.

2.5.5 *Woodwaste from forest product mills*

2.5.5.1 Leachate From Woodwaste Disposal Sites

Sawmills, shake and shingle mills, pole mills and re-manufacturing mills all produce woodwaste in the form of bark, shavings, sawdust, chips, edging, trim ends, rejects, breakages, and miscellaneous log yard debris.[85] Although much of this waste is utilized surplus residues are still incinerated or landfilled.[86] The most recent data

Table 2.5.1 Silvicultural activities on crown land in 1992/93, measured in hectares, classified by Ministry of Forests region.

Silvicultural Activity	Cariboo	Kamloops	Nelson	Prince George	Prince Rupert	Vancouver	Total
Surveying	134,128	146,461	126,692	181,916	103,847	117,538	810,582
Preparing sites							
Broadcast burn	3,246	1,600	2,263	588	535	784	9,016
Spot burn	3,537	2,177	501	6,412	479	1,577	14,683
Broadcast mechanical	14,402	18,802	6,492	40,556	8,244	176	88,672
Spot mechanical	1,305	1,138	996	3,924	650	1,054	9,067
Broadcast chemical	1,151	104	295	2,321	15	1,534	5,420
Spot chemical	-	3	907	13	-	149	1,072
Grass seeding [1]	3,991	205	251	43	343	109	4,942
Other treatments	1,289	1,506	1,004	206	1,534	27	5,566
Planting	17,990	30,426	17,600	62,346	27,215	25,015	180,592
Brushing [2]							-
Manual	2,219	5,514	7,821	5,649	3,992	4,349	29,544
Chemical (herbicides)	4,188	1,043	540	14,817	2,036	5,325	27,949
Spacing [3]	14,585	7,202	6,663	3,802	3,882	9,600	45,734
Fertilizing	822	720	1,043	679	-	4,565	7,829
Pruning	101	869	385	22	393	1,343	3,113
Other activities [4]	2,205	19	132	478	179	1,285	4,298

Notes:
[1] Includes grass seeding of roads, landings and cutblocks.
[2] A silvicultural activity done to control competing forest vegetation.
[3] The removal of undesirable trees within a young stand to control stocking, improve growth, or to increase wood quality.
[4] Includes commercial thinning, controlling mistletoe, and falling snags and residual trees.
Adapted from: B.C. Ministry of Forests, 1995. (See reference 69)

available for mill residue production, utilization and disposal in the Fraser Basin are summarized in Table 2.5.2.

Woodwaste from both old fill sites and new disposal operations can affect water quality and aquatic biota through several mechanisms. Woodwaste leachates may be acidic, have high BOD or chemical oxygen demand (resulting in reduced oxygen levels in the vicinity of the woodwastes), or contain toxic concentrations of dissolved metals or organic chemicals.[3] Among the organic chemicals contributing to the toxicity of wood leachates are resin acids, present in most softwoods, and phenols, which are present at high concentrations in aspen leachate.[83, 84] The chemical characteristics of woodwaste leachate are influenced by the tree species,[87] and by the age of the woodwaste. In addition to the chemicals which originate from the wood itself, woodwaste may also be contaminated with oils from forestry operations, as well as heavy duty wood preservatives and anti-sapstain chemicals.[3]

Hogfuel is wood residue that has been hogged or chipped. It has been used as landfill in construction sites in parts of the Fraser Basin, resulting in numerous leachate problems in some areas. Large volumes of woodwaste were deposited in Richmond to meet B.C.'s flood-proofing requirements for construction of residential developments in 1980's. Leachates are still released into the Fraser Estuary from these sites.[146] The volume of leachate generated from a woodwaste disposal site generally increases with the amount of water that infiltrates the site. Lower Mainland fill sites have a higher risk of leachate production than sites in the interior of the province, due to a higher precipitation rate.

The disposal of woodwaste in landfills requires a permit under the B.C. *Waste Management Act*, although in the past it was much less carefully managed than it is today. There are numerous old woodwaste landfills which continue to generate leachates throughout the Fraser Basin. The discharge of woodwaste leachates into aquatic or riparian environments may violate subsection 36(3) of the *Fisheries Act*. DFO and DOE recently published a guide to managing woodwastes.[88]

2.5.6 *Regulation of Forest Practices in B.C.*

The forest industry in B.C. is largely regulated by the *Forest Practices Code of British Columbia Act*, which specifies administrative arrangements, establishes requirements for harvesting and silviculture plans, guides road building and harvesting practices, and contains enforcement and penalty provisions. The *Act* applies only to forestry activities on Crown lands, and does not regulate any forestry activities on private lands, contrary to earlier plans announced by the provincial government.

The *Act* and supporting Code became law in 1995. Prior to this time there was no legislation which pro-actively restricted forest practices that impinged on fish-bearing streams. At best, charges could be laid under the *Fisheries Act* after the damage was already done. MELP and DFO had jointly developed the Coastal Fisheries/ Forestry Guidelines, however, there were no similar guidelines developed for the B.C. interior, and a detailed study showed that the Guidelines were seldom applied in Coastal areas.[89]

2.5.7 *Summary*

Forestry is a major land use in the Fraser Basin, and involves numerous types of activities which are potentially detrimental to water quality and biophysical fish habitat. While the Forest Practices Code should increase the level of protection afforded to streams in association with forestry activities, careful monitoring will be needed to determine whether the Code adequately protects physical stream habitats and water quality. The Code, as written, leaves much to the discretion of the MOF district managers, so the level of protection which streams receive may vary widely across the province. DFO must therefore continue to devote significant efforts to reviewing harvesting and silvicultural plans, and increase audit and enforcement efforts where forestry

Table 2.5.2 The production, utilization and disposal of mill residue in the Fraser River Basin.

Forest Region & District	**Bark (BDT)**			**Other Wastes (m^3 SWE)**		
	Production	**Utilization**	**Surplus**	**Production**	**Utilization**	**Surplus**
Vancouver Forest Region:						
Chilliwack (Forest District 1)	892,200	450,300	441,900	2,392,500	1,535,800	856,700
Kamloops Forest Region:						
Kamloops (Forest District 2)	80,100	43,200	36,900	281,000	245,000	36,000
Other districts (combined)	414,100	97,800	316,300	1,089,600	450,900	638,700
Prince George Forest Region:						
Prince George (Forest District 1)	375,000	9,200	365,800	843,200	142,500	700,700
Cariboo Forest Region:						
Quesnel (Forest District 1)	192,500	16,500	176,000	661,600	162,600	499,000
Williams Lake (Forest District 2)	159,800	5,500	154,300	642,400	126,500	515,900
100 Mile House (Forest District 4)	78,600	-	78,600	262,300	55,000	207,300

"BDT" - bone dry tonnes; "SWE" - solid wood equivalents.
Adapted from Stewart and Fraize Assoc. Ltd. *et al.* 1990 (See reference 86)

activities impact water quality or physical fish habitat.

❖❖❖

2.6 Mining Operations

This overview of mining issues in the Fraser Basin is based on an unpublished report was prepared for DFO.[142]

2.6.1 *Introduction*

Mining operations extract materials by simple excavation (rock, limestone, some industrial materials), sorting and washing after excavation (placer gold, sand, gravel, coal, some industrial materials), and chemical processing to separate product from host rock (metal and gold mines).

Numerous types of mines have extracted base metals (copper and molybdenum), precious metals (refined and placer gold), coal, industrial minerals (perlite, pumice, gypsum, silica, barite, magnesite, garnet, sodaspar), sand and gravel, limestone and quarried rock from the Fraser Basin.

2.6.1.1 Mining in the Fraser Basin

Metal production in the Fraser Basin comes mostly from four large copper/molybdenum operations. There are currently no gold mills or coal mines operating in the Fraser basin, and historic operations have been small relative to operations in other parts of the province. One new copper/gold mine is proposed in the Fraser Basin and has generated considerable controversy. The proposed Prosperity mine is located in the vicinity of Taseko Lake in the Chilcotin region of the Fraser Basin. The ore body is located beneath spawning habitat of a unique rainbow trout population, and the mine proponents planned to drain Fish Lake (considered to be among the top ten lakes in B.C. in terms of catch success rates), and convert it into a rock dump and tailings impoundment. The mining company is currently working on a new development proposal, as their first approach was rejected by DFO.

Gold is presently extracted in the Fraser Basin as a by-product of copper production, and from an estimated 750 placer gold mines. It is estimated that 65% to 75% of B.C. placer mining activity occurs in the Fraser Basin.

Up to 40 large mineral mines are operating in the Basin. There are approximately 1,000 commercial sand and gravel extraction operations in B.C., and an additional 3,000-4,000 gravel pits operated by the Provincial Ministry of Transportation and Highways (MOTH) and some forest companies. It was not possible to easily determine how many of these are located in the Fraser Basin but it is likely a significant proportion given that approximately 70% of the provincial sand and gravel demand is in the Fraser Basin. Operations are numerous but generally cover small areas of less than 2 to 3 hectares.

2.6.2 *Water Quality Issues Associated With Mining*

Some of the water quality issues associated with mining are common to all types of mines, while others are specific to the minerals present in parent materials and the processing methods used.

All types of mines have the potential to generate suspended sediment loads from both the access roads, and mine sites themselves. Most mines also have the potential to release nutrients to surface waters via suspended sediment loads. Explosives used at mine sites also release nutrients, especially nitrogen, to the environment; these nutrients can then be washed into surface waters with stormwater runoff.

Some mines are point sources of effluents which may contain a wide range of contaminants including suspended sediments, dissolved and particulate metals, and contaminants introduced via chemicals used for processing. These contaminants may affect fish directly through their toxicity, or indirectly by altering physical parameters of their environment (i.e. pH, alkalinity, oxygen saturation levels, sedimentation).

2.6.2.1 Exploration Activities

Water quality impacts from exploration activities (road building, drilling, trenching and small scale underground or surface mining) are largely related to sediment released by surface disturbances. Exploration also introduces the potential for fuel spills, as fuels are often stored onsite for equipment operation. When exploration camps are established, the generation of sewage and other camp wastes can cause water quality problems if adequate waste management practices are not implemented. The necessary approaches are usually specified in the terms of a provincial Waste Management Permit as they are for any other business which discharges a waste to the environment.

When mine exploration sites begin to look promising, underground exploration is often initiated, using quantities of water which are discharged into the aquatic environment after settling. These waters can contain metals.

2.6.2.2 Road Access

Water quality issues arising from the construction of mine site access roads are the same as those identified for forestry, and include sedimentation from road surfaces, as well as cut and fill slopes, altered surface water flows from culverts, and the potential for spills of transported materials. Roads also establish human access to remote areas which can encourage illegal dumping. Mitigation strategies include locating roads away from surface waters, following road building and de-activation standards established under the Forest Practices Code, adequately sizing culverts and surface water diversions, minimizing cut and fill slopes, re-vegetating slopes, and providing secure containers for potentially toxic supplies.

2.6.2.3 Base Metal Mines - Open Pit and Underground

Mineral-rich ores may be removed by surface excavations (large open pits) or underground tunnels, depending upon the location of the ore body. To access ore, rock containing uneconomic levels of minerals is removed and discarded as waste rock. Surface mining generates vastly greater amounts of waste rock compared with underground mining.

Ore with economically acceptable metal concentrations is extracted and transported to a mill, where it is crushed and ground to sand or silt sizes and mixed with water to form a slurry. Minerals containing desired metals such as copper, lead, zinc and molybdenum are removed from the slurry using chemicals which cause the minerals containing desired metals to preferentially attach to bubbles or 'float'. The float is skimmed off and dried, and the concentrated product is shipped to a smelter for further purification of metals. The remaining slurry ('tail') is discarded as waste to a tailings impoundment area.

Water quality issues associated with base metal mining include the potential release of:

- sediment from excavation activities, disturbed lands, and waste materials;
- flocculants and coagulants, used to lower suspended sediment levels (these substances can be toxic to fish);
- nutrients contained in the sediments or from the explosives used in excavations;
- particulate metals contained in the sediment, tailings, and waste rock;
- dissolved metals brought into solution during the milling process;
- acidic drainage resulting from an increased rate of sulfide oxidation in minerals exposed during excavation or road construction, and left as waste rock, tailings, open pit walls or underground tunnel walls;
- metals dissolved from waste material by the acid drainage (i.e., copper, cadmium, arsenic, zinc, iron);
- chemical reagents used in the milling process;
- alkaline drainage arising from an increased rate of carbonate dissolution in the minerals exposed during excavation, and left as waste rock, tailings, open pit walls or underground tunnel walls; and,
- metals associated with alkaline drainage (particularly molybdenum).

These potential water quality issues can often be satisfactorily resolved by good material handling practices, control of surface water and erosion, and containment and recycle of water associated with the tailings and milling process.

Most of the operating and potential metal mines in the Fraser Basin are low-grade with disseminated sulfides, and present a lower risk of generating acidic drainage compared with the massive sulfide deposits present in other areas of B.C. The relatively dry climate characteristic of much of the Fraser Basin reduces the generation of contaminated runoff from mine sites, and facilitates the effective management of surface water.

2.6.2.4 Gold Mill Operations

Coarse gold is recovered using simple gravity techniques. The ore is crushed, ground, and mixed with fresh water so that the gold can be separated due to its relatively high density. Water quality issues are related to the fine sediment left in wash water, possible particulate metals contained in the sediment, and potential residual nutrients from sediment and the explosives used to excavate gold ore. These issues can usually be managed by appropriate water handling procedures, settling ponds, water recycling, and the judicious use of chemical flocculants to enhance settling of very fine particles.

Gold contained in hard rock as minute particles is recovered by cyanidation. Rock is ground into fine silt and sand, and is then mixed in a slurry with cyanide to dissolve the gold. The fine rock waste is washed and discharged to a tailings impoundment, and the gold-rich cyanide solution is treated chemically to re-precipitate the gold and leave a barren cyanide solution that can be recycled.

As the cyanide solution becomes contaminated with other metals contained in the ore including copper, arsenic, iron and zinc, a portion must be discarded and replaced with fresh cyanide solution. Water quality issues unique to this process are related to the handling of rinsed tailings which may contain residual cyanide and unwanted metals, and the waste cyanide solution. The residual cyanide can be reduced to low concentrations using established methods of chemical oxidation. The waste streams are usually stored in a tailings impoundment, where further natural degradation of the cyanide and its by-products occur. If excess water is not contained on site for a sufficient length of time, a discharge containing low residual levels of contaminants occurs.

The present treatment technology cannot always guarantee a non-toxic effluent as determined by a static rainbow trout bioassay test. Cyanidation gold mills in the Fraser Basin have been small operations with effluent discharges containing elevated concentrations of copper, cyanide and ammonia, which have usually failed 96-hr LC_{50} static rainbow trout bioassays. Poor water management practices at a gold mine located on Ladner Creek, north of Hope, resulted in the release of cyanide-laced effluent from a tailings impoundment in the early 1980’s. A massive fish kill resulted and the company was successfully prosecuted under the *Fisheries Act*. The mine has been out of operation since shortly after the spill occurred.

2.6.2.5 Placer Gold

The extraction of gold by placer mining involves the excavation of gravels along the base of a river bed. Coarse materials are screened from gravels, and the finer material is washed through sluices to recover gold nuggets and dust. Lighter materials are washed away as waste. Water quality issues associated with placer mining include:

- the use of large quantities of water for washing;
- the discharge of this sediment-loaded waste water; and
- sediment from erosion and runoff from piles of waste boulders and cobbles left adjacent to the creek beds.

Historically, waste water with a high sediment load was discharged directly into the aquatic environment. Present practice requires settling and re-use of the waste water. Sedimentation continues to be an issue beyond mine closure if sites are inadequately reclaimed or revegetated. Diversions of river beds to access placer gravels are common in some historically active areas, resulting in a direct disruption of fish habitat and the elimination of stream side vegetation that helps to capture sediment.

Water quality impacts from each site are generally minimized by sediment control and reclamation practices, as long as mining is kept an adequate distance away from surface streams. Despite precautions, a large number of operations in a localized region can result in significant cumulative effects, and historic rights may allow some operations to continue mining close to, in, or under surface streams. In these cases, extreme care is required to avoid undercutting the creek, disrupting groundwater flows that feed the creek, or causing subsidence that might disrupt spawning beds in the creek.

An additional water quality issue arises from the historic use of mercury to recover very fine gold from placer gravels. The process, called amalgamation, involves mixing mercury with fine gravel containing nearly invisible flakes of gold. The gold is absorbed by the mercury, separated from the waste, and heated to drive off the mercury, leaving the gold behind. A substantial amount of mercury was likely lost with the waste in this process. The presence of mercury globules in river gravels is still reported in the sand bars of the Fraser River, as well as the Lillooet and Cariboo placer areas.[90,91] Environmental concerns are related to potential methylation of the mercury, and uptake by biota. Apart from fish in Pinchi Lake, the site of an old cinnabar mine, sturgeon in the Upper Fraser are the only fish in the Fraser River watershed known to have elevated mercury levels. The source of the mercury in sturgeon tissues is unknown.

2.6.2.6 Sand and Gravel

Sand and gravel extraction involves stripping the topsoil to reach deposits. The sand and gravel may then be crushed and sorted by screening and/or washing. The primary water quality issue arises from the potential discharge of sediment-laden wash waters, and runoff from the topsoil stockpiles and disturbed land. Sediment problems can be controlled by the recycling of wash-water and use of settling ponds, particularly as most gravel quarries are preferentially located at a considerable distance from surface streams and above natural groundwater tables for ease of operation. Problems arise when the sediment in the wash or runoff water is too fine to settle efficiently, the gravel operations are too close to surface streams, settling ponds are inadequate to treat the volume of runoff generated, or the settling systems are not operated in an optimal manner. Some gravel mining operations cause tremendous impacts to fish habitat by generating very high suspended sediment levels, and through sedimentation of spawning grounds and other areas.

Gravel extraction near streams can result in the loss of streamside vegetation which increases water temperatures, and eliminates cover and food sources (leaf litter and insect drop) for fish. Indirect impacts from gravel extraction occur through inadvertent alteration of groundwater and surface water flows that supply fish habitat. Poor operational practices may result in sediment releases or spills of fuel stored on site for trucks and gravel washing equipment.

2.6.2.7 Industrial Minerals, Quarries and 'Non - Mineral' Products

Water quality issues associated with the mining of industrial minerals and construction products include the control of sediment and nutrients released from residual explosives used in the quarrying process.

2.6.3 Environmental Management Mechanisms And Review Processes

2.6.3.1 *B.C. Environmental Assessment Act*

The *B.C. Environmental Assessment Act* was proclaimed in 1995. It places all major project reviews under the authority of the Provincial Environmental Assessment Agency, including projects previously addressed via the Mine Development Assessment Process. Projects which are too small to be captured by the *B.C. Environmental Assessment Act* or the federal *Canadian Environmental Assessment Act* (*CEAA* - section 3.3) are reviewed at the regional level.

2.6.3.2 *Canadian Environmental Assessment Act* (1995)

The *Canadian Environmental Assessment Act* (*CEAA*) generally captures larger projects than *BCEAA* (Table 2.6.1), and also covers construction, decommissioning and/or abandonment of mines (*BCEAA* does not cover mine decommissioning as reclamation plans are a prerequisite to start-up under the *Mines Act*).

The key triggers for CEAA with regard to mining projects include Coast Guard's decisions under the *Navigable Water Protection Act* (i.e., transportation to the mine site

Table 2.6.1 Size of mining projects captured by CEAA[1] and BCEAA.[2]

	CEAA	BCCEA
Mineral Mines	*see more specific definitions*	*≥ 25000 TPY*[3] *≥ approx. 75 TPD*[4]
Metal Mine	≥3000 TPD ore production capacity	"
Metal Mill	≥4000 TPD ore input capacity	"
Gold Mine	≥600 TPD ore production capacity	"
Asbestos Mine	All	"
Graphite	≥1500 TPD production capacity	"
Gypsum	≥4000 TPD production capacity	"
Magnetite	≥1500 TPD production capacity	"
Coal Mines	≥3000 TPD coal production capacity	≥100,000 TPY coal product. ≥ approx. 300 TPD
Non-'Mineral' Mines:	*see more specific definitions*	*>250,000 TPY product*
Limestone	≥12000 TPD production capacity	
Clay	≥20000 TPD production capacity	
Stone Quarry	≥1 million TPY production capacity	
Sand & Gravel	≥1 million TPY production capacity	≥500,000 TPY, or ≥1,000,000 T over ≤4 years

[1] CEAA = *Canadian Environmental Assessment Act*
[2] BCEAA = *British Columbia Environmental Assessment Act*
[3] TPY = metric tonnes per year.
[4] TPD = metric tonnes per day.
Adapted from: Mehling. 1995. (See reference 142)

by bridges or port facilities in navigable waters), DFO's decisions as to whether there is a harmful alteration or destruction of habitat, and Section 5.2 of the Metal Mining Liquid Effluent Regulations (MMLER) which allows the Minister to designate tailings impoundment areas for the deposit of prescribed deleterious substances in any quantity or concentration. When triggered, CEAA requires either a screening report or a comprehensive study report. Generally, only the larger mining projects are captured by CEAA but moderate sized metal and gold mines may also trigger CEAA. Production expansions of 50% or more that bring existing mines up to the stated size (Table 2.6.1) are included in the comprehensive study list, but placer gold mines are excluded.

2.6.4 *Provincial Legislation Pertaining to Water Quality*

2.6.4.1 Mines Act

The *Mines Act* provides the authority for approving work-plans for the exploration, development and operation of all mines, and to approve programs for the reclamation of the land and watercourses affected by a mine on mineral-tenured lands. The legislation indirectly influences the quality and quantity of effluent produced by a mine by defining the conditions under which the mine can operate, but it does not state any specific effluent criteria. Notices of Work submitted by mining proponents are reviewed by Regional MEMPR staff and circulated for comment to MDRC participants judged to have an interest in the project.

2.6.4.2 Waste Management Act

The *Waste Management Act* (1982) addresses the discharge of all business wastes to the environment. The permits issued under the *Act* normally specify maximum allowable concentrations of contaminants in effluent, the maximum volumes that can be discharged, effluent monitoring and reporting requirements, and may also establish requirements for non-acutely lethal effluents. Effluent criteria vary for each mine or exploration project, but are roughly governed by a range of concentrations for each contaminant identified in the 1979 Pollution Control Objectives for Mining, Smelting and Related Industries.

The permits allow the control of point source discharges which have a direct impact on water quality but they are not always successful in addressing non-point sources or groundwater contamination issues. A weakness of the permits is the easing of requirements as the operating mine demonstrates a need to discharge a greater effluent volume than originally anticipated, or an inability to meet originally targeted contaminant concentrations in effluent.

2.6.4.3 Water Act

The *Water Act* authorizes MELP to issue licenses for the use of water. This allows control of all water diversions and quantities of water withdrawn from the ground and from surface waters. These withdrawals can have an indirect influence on water quality.

2.6.4.4 Contaminated Sites Regulation

This regulation was introduced under the *Waste Management Act* and is intended to implement effective management of contaminated sites, develop a site registry, and implement the 'polluter pay' principle. In addition to protecting surface waters from leachates and runoff that can be generated at contaminated sites, this regulation will help to protect groundwater in the absence of groundwater legislation. Large volumes of stored waste solutions, contaminated soils, and discharges from exfiltration ponds can result in groundwater contamination over time.

2.6.5 *Federal Legislation and Initiatives*

2.6.5.1 Fisheries Act

The Federal *Fisheries Act* is the key legislative instrument for protecting water quality. Section 36(3) of the *Act* prohibits the deposit of deleterious substances into waters frequented by fish, or in any place or conditions that result in a deleterious substance reaching waters frequented by fish. The federal requirements under the *Fisheries Act* are usually incorporated in MELP's Waste Management Permits.

2.6.5.2 Metal Mining Liquid Effluent Regulations

The MMLER (1977) are regulations under the *Fisheries Act* which define maximum allowable concentrations of specific deleterious substances (arsenic, copper, lead, nickel, zinc, total suspended matter, radium 226 and low pH) which can be discharged from metal mines. They only apply to new, expanded, and re-opened metal mines (after 1977), and do not apply to gold mines using cyanidation processes. The MMLER do not cover discharges from closed or abandoned mines, or exploration projects, nor do they apply to the mining of coal, placer gold, industrial minerals, or sand and gravel. Only two mines in the Fraser Basin (Afton and Highland Valley Copper) are subject to the MMLER; neither has a direct discharge to the environment. The MMLER are somewhat out-dated, and established discharge limits are based more on treatment technologies which were available at the time the regulations were written, rather than needs of the receiving environment. DFO and DOE are leading a review of the MMLER and intend to require Environmental Effects Monitoring (EEM) programs for mines similar in intent to the Pulp and Paper EEM program.

2.6.6 *General Compliance with Regulations*

Metal mines operating in the Fraser Basin were in general compliance with the federal MMLER and MMLEG.[2]

With the exception of gravel operations on the Coquitlam River, little information on *Fisheries Act* compliance was available for gravel pits and perhaps an assessment of the gravel mining industry would be appropriate. Significant impacts from gravel removal operations on the Coquitlam River have been an ongoing issue with DFO for more than a decade, without satisfactory resolution.

Poor mine reclamation practices and numerous illegal placer mine effluent discharges have been reported by DFO staff, particularly in the Cariboo region. With regard to placer mining, individual sites may be in compliance, but in some areas numerous operations located in confined areas have reportedly led to significant cumulative water quality impacts.[91]

2.6.7 *Summary*

A review of available information suggests that impacts from metal and gold mining in the Fraser Basin are limited as there are few of these mines which are currently active in the Fraser Basin and they are closely regulated. Placer and gravel mining require an increased audit and enforcement effort.

❖❖❖

2.7 "Atmospheric" Effects

2.7.1 *Introduction*

Many contaminants are released to the atmosphere in the form of gases and fine particulates, which eventually make their way back to the land and surface waters through precipitation. Contaminants which are released to the atmosphere can affect surface waters locally and/or globally. The Lower Fraser Valley receives some industrial contaminants from Washington State. Sulfur oxides originating from four oil refineries along the Washington coast are considered to be significant sources. [94]

Airborne contaminants known to affect water quality in parts of the Fraser Basin include sulfur and nitrogen oxides from industry and automobile exhaust, which can cause acid precipitation, and carbon dioxide, which is a greenhouse gas believed to cause global warming.

Recent sampling of snow at Mount Seymour (Lower Fraser) shows copper levels as high as 0.007 $mg \cdot L^{-1}$, almost double the guideline for protection of aquatic life and four times the level measured in 1982.[145] In 1995, zinc levels of 0.037 $mg \cdot L^{-1}$, approximately 3 times the guideline for protection of aquatic life, were measured at the top of Mount Blanshard, east of Pitt Lake.[145] If these metal concentrations continue to increase, they may eventually affect aquatic life. Other substances such as pesticides and organic contaminants are also circulated via the atmosphere. They will not be addressed here because atmospheric sources in the Fraser Basin are small compared with point source discharges and stormwater runoff.

2.7.2 *Acid Precipitation*

2.7.2.1 Effects on Biota

Many physiological and biochemical processes are very sensitive to changes in acidity. Soils and soil microorganisms, vegetation, and surface waters, can all be affected by acid precipitation. Aquatic organisms are very sensitive to pH changes in their environment because many of the functions performed by gill tissues, including osmoregulation and uptake of oxygen, can be disrupted by pH changes. Studies on fish have shown that all life cycle phases can be adversely affected by acid precipitation although reproductive and early life stages are the most sensitive.[92] Salmon are reported to be very sensitive to low stream pH during smoltification, a period of physiological change in preparation for the marine phase of their life cycle, and during their spawning migration.[93]

2.7.2.2 Chemistry of Acid Precipitation

The largest sources of sulfur and nitrogen oxides in B.C. are automobile exhaust, pulp mills, and gas refineries, although other industries also discharge these substances to atmosphere. Agriculture is believed to be a significant source of nitrogen oxides, either directly, or indirectly from the oxidation of ammonia.[94] Sulfur and nitrogen compounds undergo a chemical reaction in the atmosphere to form sulfuric acid and nitric acid respectively, both of which can cause acid precipitation.

In addition to direct toxic effects on aquatic organisms, acid precipitation can reduce the pH of ground and surface waters, dissolving toxic heavy metals, thereby increasing their bioavailability.[95]

The potential impacts of acid precipitation on a water body are determined by two major factors:

1. the amount of acid inputs; and
2. the **alkalinity** of the receiving waters, which is a measure of the capacity of water to neutralize a specific amount of acid.

Waters with alkalinity in the range of 0-400 $Teq\cdot L^{-1}$, or 20 $mg\cdot L^{-1}$ $CaCO_3$ are considered to have inadequate buffering capacity to protect aquatic life from acid deposition,[96] as there is not enough capacity to resist pH change in response to acid deposition.

Alkalinity reflects the nature of the rocks in a drainage system, and the degree to which they are weathered. It largely results from carbon dioxide and water interacting with carbonate rocks, dissolving the carbonate to form bicarbonate. In polluted waters, organic ions and phosphate may contribute to total alkalinity. The influence of bedrock and soil on alkalinity and other water quality parameters is a function of duration of contact, types of rocks and soils to which water is exposed, among others.

Wiens[97] evaluated the geology and soils of B.C. for sensitivity to acid inputs using a range of parameters including: soil depth and texture; pH of soil and parent material; soil acidification; base saturation; cation exchange capacity; bedrock and soil type; and ability to dissolve aluminum. This information was summarized for the Fraser Basin by Hall*, et al.* (Table 2.7.1).[98] Of the six sub-basins that drain the western side of the Fraser Basin, two had low acid reduction potential in more than 60% of their area, and three of the remaining four had more than 70% of their areas in the low to moderately low categories. These sub-basins should therefore be considered as relatively susceptible to damage from acid inputs from any source.

The Nechako sub-basin was considered to have low to moderate-low buffering capacity. In the long term acid precipitation may become a concern if the population and level of industrial activity in the nearby City of Prince George increase greatly.

The Lower Fraser is particularly vulnerable to impacts from acid precipitation due to the large inputs of sulfur and nitrogen dioxides combined with relatively low capacity of many streams in the area to buffer acid inputs. Approximately 75% of the Lower Fraser Basin had a low to moderately low capacity to reduce acidity.[98] Sulfur dioxide levels are relatively low in the Lower Fraser compared with many other urban regions due to lower heating requirements, greater reliance on hydroelectricity instead of burning fossil fuels, and fewer industrial polluters. In contrast, nitrogen dioxide levels in the Lower Fraser Valley approach or exceed the Level A annual objective (30 ppb) on a continuous basis.[99]

2.7.2.2 Occurrence of Acid Precipitation in the Lower Fraser Basin.

Studies on rainfall pH in the Lower Fraser Valley indicate that acid precipitation is being generated in this area. Rain is naturally slightly acidic with a pH in the range of 5.5-6.0 as it dissolves some carbon dioxide from the atmosphere. Rainfall pH values less than 5.0 have been recorded in the Lower Fraser Basin.[100] Whitfield, *et al.* measured precipitation pHs as low as 4.5 near Kanaka Creek in the Lower Fraser Basin, which suggests the presence of strong acids in rainfall.[101]

2.7.2.3 The Effect of Acid Precipitation on Salmon Streams

Twenty-four salmon streams in the Lower Fraser Basin were sampled by DFO either weekly or monthly from January 1985 to July 1986, in order to determine sensitivity to acid depositions. An acidification index developed by Henriksen[102] was applied to data from thirteen of these streams. Results indicated that acidification may be ongoing.[103] The same study also determined that most Lower Mainland streams have a minimal capacity to withstand acidic inputs because of low buffer capacities, which are generally in the range of 0 to 50 $Teq\cdot L^{-1}$. Thus, for the Lower Fraser, field observations support predictions that the area is susceptible to impacts from acid precipitation. The mean pH values for the thirteen streams which were sampled ranged from 5.86 to 6.99, with short-term episodic declines to pH 5.30.

Using a continuous monitoring system, other researchers have measured short-term declines of up to 1.2 pH units in Kanaka Creek in the Lower Mainland in response to precipitation events.[104] All pH values measured in the creek were in the range of 5.2 to 6.2, below the minimum guideline of 6.5 which is considered to protect aquatic life.[105] A pH in the range of 5.0 to 6.0 is unlikely to be acutely lethal to aquatic organisms, however, there is a gradual deterioration of water quality as pH values go beyond the normal range. Also, sudden declines in pH can cause acid shock in fish, and potentially cause death at levels above those normally considered lethal.[106]

Whitfield and Dalley[104] found that the degree of pH depression which occurred with a rainfall event was strongly influenced by the base flow present in the stream - i.e. the largest pH depressions occurred when base flow was lowest. The authors hypothesized that this was because direct runoff becomes a larger proportion of the streamflow during a storm, and that this runoff has little time within the groundwater system, and hence remains unbuffered, or otherwise unmodified. This amplification of pH depression under low flow conditions is of concern, as one of the hydrological effects of urban development commonly observed is a decrease in stream flows between rainfalls. Thus, streams in the lower Fraser may become more susceptible to impacts from acid rain for two compounding reasons:

1. increasing amounts of acid-forming pollutants in the atmosphere; and
2. decreasing base flows due to hydrological changes which result from urban development.

Concentrations of dissolved heavy metals are known to increase with acidification of surface waters.[107] Furthermore, increasing acidity can enhance the toxicity of metals to aquatic organisms. Aluminum is considered to be the metal most likely to become problematic as waters become acidified because it is generally present at relatively high levels in forms which are not normally bio-available.[108] Of twenty-four streams monitored in the Lower Mainland by Sullivan and Samis,[103] eleven were found to periodically exhibit dissolved aluminum concentrations exceeding those reported to be acutely toxic to fish.[109, 110] Although the report did not specifically link elevated dissolved aluminum levels with precipitation events, acidic rain would likely be a contributing factor.

2.7.2.4 Summary of Acid Precipitation

Acid rain is a consequence of elevated sulfur dioxide and nitrogen dioxide levels in the atmosphere. In the Lower Fraser Valley most of the nitrogen oxides come from vehicle exhaust. The human population of the area is predicted to double from the present 1.8 million by about the year 2030. The number of trips per day per person is also increasing, and grew by 15.6% between 1985 and 1992.[111] An *Air Care* program was introduced to reduce air pollution from vehicles and has been successful to date, however, the growing numbers of cars and people will make it very difficult to prevent further degradation of air quality.

One recently identified issue of concern in the lower Fraser Valley is the large amount of nitrogen emitted to the atmosphere by agriculture.[112] In Holland the ammonia emitted from agricultural sources is known to be a major contributor to acid rain.[112] The ammonia emitted by agriculture in the Lower Fraser Valley appears to have a different chemical fate, and binds with sulfur compounds which effectively neutralizes the acid-generating capabilities of both the nitrogen and sulfur. This is a benefit from the perspective of acid rain, but is cause for concern with regard to human health, as the resulting small particulates are associated with respiratory ailments.[94]

Table 2.7.1 Potential in Fraser Basin HMAs to Reduce Acidity from Atmospheric Deposits.

HMA	Potential area (%) in HMA with capability to reduce acidity	
	Low to moderate	Moderate to High
Lower Fraser[1, 2]	74	19
Lillooet[1]	82	8
Middle Fraser	41	59
Thompson-Nicola	15	85
South Thompson-Shuswap	56	44
North Thompson[1]	36	62
Seton-Bridge	32	68
Chicotin[1]	71	27
Quesnel	23	77
West Road	79	21
Nechako	79	21
Stuart	37	63
Upper Fraser[1]	15	82

[1] Remaining percentage covered by permanent ice
[2] Includes the Fraser Delta, Pitt-Stave and Chilliwack HMAs.
Based on: Hall, *et al*. 1991. (See reference 98).

2.7.3 *Global Warming and Water Temperature*

Global warming has the potential to substantially alter ocean temperatures, surface water temperatures and stream hydrology, and is therefore considered to be a water quality issue. A detailed review of global warming, Global Climate Models (GCMs), and general implications for salmonids, was prepared on behalf of the Fraser River Action Plan by Levy.[113] Discussion here will be limited to a very brief overview of global warming summarized from Levy,[113] and will address the issue in the context of thermal impacts resulting from other activities.

Global warming, also known as the greenhouse effect, is a result of trace gases with heat-trapping properties in the Earth's atmosphere. These heat-trapping gases absorb infrared radiation causing the average surface temperature of the earth to be approximately 33°C warmer than it would be without absorption of infrared radiation.[114] Greenhouse gases include water vapour, carbon dioxide, nitrous oxide, ozone, methane, halocarbons, and others. There is strong evidence that concentrations of carbon dioxide and other greenhouse gases in the atmosphere have increased over the past several decades. These increasing concentrations are related to industrialization, present agricultural practices, deforestation, and the use of fossil fuels.

There are several different methods available for predicting the climatic and hydrological impacts of future increases in greenhouse gases. These include comparisons of climatic conditions during warm and cold periods, known as the Comparative Method, as well as computer simulation of future conditions with GCMs. Both methods lead to predictions about changes in temperature and precipitation. Each method has limitations which must be considered, as outlined in Moore[115] and different methods can generate discrepancies.

Models are capable of producing reasonable climatic predictions over large spatial scales, however, they can be misleading when applied on a regional scale.[116] Even if realistic local, regional-scale climate change predictions could be obtained, ecological responses may be difficult to predict accurately due to our generally poor understanding of climate-ecosystem interactions.

2.7.3.1 Effects of Global Warming on Hydrology and Biota of Freshwater Systems

Global warming will affect not only temperatures, but also the amounts and seasonal distribution of precipitation. In turn these changes will directly influence seasonal runoff timing and volume. Watersheds where there is currently a close balance between water demand and water supply will be the most vulnerable to impacts. For aquatic life, seasonal cycles in water availability and temperature can influence life history events and biological production.

One scenario modelled by Ripley[117] predicts a substantial increase in winter precipitation, coupled with possible reductions during the summer months for British Columbia. This would result in greater seasonal flow fluctuations, and potentially lower summer flows in the Fraser Basin.

The impacts of climate warming on groundwater, and the role of groundwater in salmonid stream ecology, was reviewed by Meisner*, et al.*[118] who predicted that groundwater temperatures will follow the projected increases in mean annual temperature from climate warming. Many of the streams used by coho and chinook for rearing in the Fraser Basin during summer months have borderline temperature conditions already, and benefit from cool groundwater inputs. As well, in some streams summer temperatures already exceed lethal limits, and fish survive by clustering around cool groundwater inputs which act as thermal refugia.[119] Reduction of the cooling effects from groundwater in these streams would put further pressure on salmon populations which rely on them for rearing habitat.

Global warming will likely have a direct impact on lake temperatures and heating processes. Juvenile sockeye rear in lakes, hence disruption of the normal thermal regime of lakes in the Fraser system is of particular concern. A possible preview of potential impacts of global warming on lake physics, chemistry, and biology is available in a recent report by Schindler, *et al*.,[120] who monitored a Northern Ontario lake for over 20 years. During that time, both air and lake temperatures increased by 2°C, the length of the ice-free season increased by three weeks, and available habitat for cold water species diminished.

2.7.3.2 Effects of Global Warming on Fish Populations

Overall, warming can be expected to influence fish populations and distribution both within and between systems. For example, some lakes and streams may become too warm to support some fish species. In other cases, fish species may become restricted to occupying particular parts of a lake such as deeper, cooler waters, provided that food, oxygen, and other conditions are amenable. Geographical distribution patterns suggest that the northern distribution of a large number of freshwater fish species is governed by temperature (for an example, see Meisner*, et al.*[118]). It therefore seems likely that climate warming will promote the northern range expansion of a broad spectrum of freshwater fish, and cause some species to disappear from the southern limits of their present ranges. An analysis by Meisner[121] concludes that stenothermic fish species (e.g., salmonids) may experience the greatest habitat effects of climate warming, and that such effects will likely become noticeable first in populations located at the southern margins of the species' geographic distributions. They may also become noticeable early on in areas which already have high summer water temperatures, such as in the Nechako, the Stuart-Takla system, and the Thompson sub-basin.

2.7.3.3 Prediction of Freshwater Habitat Changes for B.C.

There are three different climatic and hydrologic regions within the Fraser River watershed: the Coast Mountains, the Interior Plateau, and the Eastern Mountains. There is approximately one order of magnitude difference in the amount of annual precipitation throughout the watershed. This variation, together with differences in seasonal timing of precipitation, snowpack storage and glacier melt imply differences in water storage capacity and runoff patterns for the different sub-basins in the Fraser River.[122] Climate change will most likely affect the three hydrologic regions of the Fraser River watershed in different ways that are not presently easy to predict. Anticipated changes which may occur in freshwater habitats of the Fraser River with global warming as summarized in Levy[113] are outlined below:

1. **Streamflows:** It is likely that there will be higher winter runoffs due to a reduction in the amount of precipitation falling as snow, and an increase in winter precipitation levels, particularly in the Coast Mountains portion of the watershed. Winter streamflow increases and flooding are anticipated to be most severe in the Lower Fraser, Lillooet, and Bridge-Seton watersheds. It is likely that summer runoff will be reduced throughout the entire Fraser, and particularly in the Interior Plateau region, including the North Thompson, South Thompson, and Thompson-Nicola watersheds. The overall timing of the spring freshet of the Fraser will probably occur several weeks earlier than it does at present.
2. **Thermal characteristics:** Average stream and groundwater temperatures in the Fraser watershed will increase and generally follow the future alterations in atmospheric temperature. Reduced future snowpack and accompanying reduced summer discharges will create higher peak and average stream temperatures, due to an interaction between temperatures and flows. Similarly, stream temperatures may further increase if extraction requirements intensify, since a smaller water volume will warm faster than a larger volume. The duration of cold winter water temperatures (<4°C) will be reduced. Lakes within the Fraser watershed will experience increases in surface water and epilimnetic temperatures.

2.7.3.4 Possible Implications of Global Warming for Fraser River Salmon

Impacts of future climate change may have major implications for British Columbia's freshwater fisheries resource. A preliminary evaluation of potential climate warming impacts was undertaken by Northcote[123] who identified the possible consequences of climate change for freshwater fisheries in B.C. (Table 2.7.2).

Due to their life histories and distributions, Northcote[123] concluded that cutthroat trout, pink salmon, and chum salmon should be less affected by climatic change than rainbow trout, dolly varden, lake char, and coho, sockeye and chinook salmon.

There will likely be regional disparities in the impacts of global warming on salmon within the Fraser watershed. Salmon populations in the interior portion of the watershed (Thompson, Middle, and Upper Regions) that are highly dependent upon the freshwater environment for juvenile rearing are particularly vulnerable to future global warming effects. The latter includes most of the chinook and sockeye populations, and many of the coho salmon stocks within the Fraser River watershed. Coho are considered to be particularly vulnerable because they spawn and rear for a year or more in small streams, many of which already have problems with high summer water temperatures. Pink and chum salmon populations in the coastal portions of the watershed may be vulnerable to the negative effects of winter flooding, and subsequent reductions in egg-to-fry survival.

This analysis does not include effects of global warming on the oceans, and the thermal requirements of salmon while they are at sea. Some scientists predict that within 50 years, global warming will result in ocean temperatures which are high enough to cause the collapse of some B.C. salmon stocks.[136]

2.7.3.5 Existing Water Temperature Problems in the Fraser River Basin

The issue of global warming must be examined within the context of existing issues which are already causing critical water temperature and hydrology problems in the Fraser Basin. Disruption of natural thermal and hydrological conditions occurs in streams already as a result of extensive land clearing related to forestry, agriculture, and urban development.

Land-clearing activities often result in the loss of riparian vegetation, which normally provides shade and is therefore a cooling influence to streams during warm and dry months. Numerous studies have reported substantial increases in stream temperatures during the summer due to land clearing.[124-127] A study on Slim Creek in the central interior of B.C. showed that maximum summer daytime temperatures were up to 9°C warmer than upstream shaded sites, and diurnal temperature fluctuations doubled as a result of land clearing.[128] Fish are vulnerable both to high temperatures and large temperature fluctuations.

Results of recent work in the Fraser Basin indicate that losses of riparian vegetation along Fraser Basin streams are extensive, at least in some areas such as the Thompson sub-basin, and the Lower Fraser Basin.[129-131] These losses have resulted from urban and agricultural development, forestry activities and linear developments. Many of the tributaries with extensive

Table 2.7.2 Possible freshwater fisheries consequences of climate change in B.C.

Climate change impacts on:	Major concern:
◆migration	◆salmon stocks which presently experience high levels of pre-spawning mortality
◆spawning	◆early-fall spawners
◆development timing and emergence	◆premature emergence, reduced egg survival
◆feeding, growth, survival	◆reduced survival associated with oxygen depletion, increased frequency of “summer kill” events
◆distribution and community structure	◆altered fish distribution, invasions by exotics
◆fisheries management	◆greater variability and unpredictability

riparian losses are known to experience summer water temperatures which approach or exceed 20°C and are therefore potentially lethal to salmonids.

In addition to temperature problems in small streams, high water temperatures have recently been problematic in the Fraser mainstem. Record high water temperatures in the Fraser Basin during the summer of 1994 resulted from a combination of warm air temperatures and low precipitation. Temperatures recorded in the Fraser mainstem frequently exceeded 20°C, and likely had a significant role in the "missing fish" - salmon which were expected to reach spawning grounds but never arrived there.[132] Radio-tagging studies showed that salmon encountering the warm waters were actually swimming downstream rather than upstream. Fish which were swimming in the right direction had reduced chances of reaching their destinations due to increased susceptibility to infections, and increased energy requirements imposed by the warm waters. The summer of 1994 may provide some insight into the future of salmon runs, particularly those which migrate significant distances upstream to spawn, and those which spawn in the summer or early fall, when water temperatures are highest.

2.7.5 *Relevant Policies and Legislation*

Section V of the *Canadian Environmental Protection Act* contains provisions to control sources of air pollution in Canada where a violation of an international agreement would otherwise result, or where air pollution affects another country and reciprocal legislation exists to control the sources of pollution. Most efforts to address international concerns over air pollution have been focused on the acid rain issue in eastern Canada, and the north-eastern United States. Lakes in the area are typically poorly buffered and were being heavily impacted by long-term effects of acid rain.

Canadian initiatives to address the emission of greenhouse gases have fallen short of targets; inputs have increased significantly over the past 10 years instead of decreasing. Trends in British Columbia have mirrored the increases documented for the rest of Canada.

Issues such as acid rain and global warming are extremely complicated both politically, and in terms of chemical complexity. Countries are generally reluctant to invoke strict legislation to address emissions as they do not wish to "handicap" industry and consumers with expensive anti-pollution measures if the rest of the world is not willing to do the same. Consequently, remedial actions come about slowly at best. Often restrictions of emissions, such as the GVRD *Air Care Program*, are implemented to alleviate immediate human health impacts rather than environmental impacts.

2.7.6 *Summary*

Both local and global inputs of contaminants and greenhouse gases to the atmosphere can have potentially serious impacts on Fraser River salmon populations. These types of pollution problems are very difficult to manage, especially in the case of CO_2 concentrations, because of the global sources.

While acid rain is nowhere near the serious problem in B.C. as it is in eastern Canada, it is still a potentially serious problem in the Lower Fraser Basin. Controlling acid-generating substances such as nitrate and sulfate at source is the only viable long-term solution to addressing acid rain, and would have numerous benefits that extend beyond fish such as reducing damage to buildings, soils, and farm crops. Interim mitigative measures such as adding limestone to surface waters to help neutralize the pH have been successful in some cases and may be an option which DFO needs to explore in the future if rainfall becomes more acidic with the growing Lower Fraser population.

While there is considerable evidence to support the theory that increased emissions of greenhouse gases are resulting in a global warming trend, there appears to be little commitment among nations to address the problem.

Global warming may or may not prove to be a reality. What is a reality is the fact that there are already serious problems with high summer water temperatures in many salmon-bearing streams in the Fraser Basin. Temperature increases which occur due to extensive losses of riparian vegetation may exceed the increases predicted to occur due to global warming by several degrees. Temperature must be considered as an important water quality condition which needs to be protected. Actions need to be taken now to address existing problems and will at least provide some protection against additional temperature increases that may occur as a result of global warming effects. Two interim types of options exist for addressing existing large scale water temperature issues:

1. constructing water storage facilities for the purpose of providing cold water releases during hot summer months; and
2. restoring riparian vegetation in sub-basins which have experienced significant losses, and protecting existing riparian vegetation on all streams.

The first option is not desirable for numerous reasons including the additional problems that are typically created when a dam is constructed (loss of existing habitat, disruption of normal flow patterns). Furthermore, constructing dams is extremely expensive.

Riparian restoration may prove to be the best option for guarding against increasing water temperatures in the Fraser Basin, and would benefit numerous water quality and fish habitat issues in addition to temperature. Pilot projects to restore riparian vegetation on farm land and in urban areas are underway in a number of areas of the basin, and need to be encouraged on a broader scale. Large-scale riparian restoration could only be accomplished with the co-operation of land owners, which may prove to be an obstacle, as many land owners are unwilling to participate. Protection and restoration of riparian areas on agricultural land might be best addressed through education with the B.C. Federation of Agriculture, and the peer inspector program. Initiatives such as *Watershed Stewardship - A Guide for Agriculture*[147] can serve as effective educational tools, especially if they are backed up with training/education sessions. With regard to urban development, education of planners and developers (as per the *Stream Stewardship for Urban Planners and Developers* [33]), individual land owners, and municipal governments who have the power to pass bylaws, should all be effective means for protecting and restoring riparian areas.

With regard to forestry, the Forest Practices Code has provisions for the protection of riparian areas on Crown lands which are enforceable. These provisions should be monitored for effectiveness in protecting water temperatures, and buffer strips should be increased if necessary.

❖❖❖

2.8 References

1 Westwater Research Centre. 1994. Effluent point source inventory and database for the Fraser River Basin. Prepared for Environment Canada, Environmental Protection, Fraser Pollution Abatement Office, North Vancouver, B.C. DOE-FRAP 1993-05. 14 p + appendices.

2 Mendoza, E. and J. Gee. 1994. Compliance status summary report: Fiscal year 1992-1993 - British Columbia. Environment Canada, Environmental Protection Branch, Enforcement & Emergencies Division, Inspection Section. North Vancouver, B.C. DOE Report 1994-02. 85 p.

3 Paquet, M. 1994. Compliance status summary report - British Columbia: Fiscal year 1993-1994. Prepared for Environment Canada, Environmental Protection Branch, Enforcement & Emergencies Division, Inspection Section. North Vancouver, B.C. DOE Report 1994-04. 110 p.

4 McDevitt, C.A., D.J. McLeay, and A. Brown. 1993. Effluent characterization study. Prepared for FREMP Water Quality/Waste Management Committee. DOE-FRAP 1993-13. 182 p.

5 NovaTec and EVS Consultants. 1993. Wastewater characterization of fish processing plant effluents. Prepared for FREMP, Water Quality/Waste Management Committee. DOE-FRAP Report 1993-39.

6 Konasewich, D.E. and F.A. Henning. 1988. Pentachlorophenol (PCP) wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada, Conservation and Protection. Report EPS 2/WP/2. 90 p.

7 Davis, J.C. and R.A.W. Hoos. 1975. Use of sodium pentachlorophenate and dehydroabetic acid as reference toxicants for salmonid bioassays. J. Fish. Res. Bd. Can. 32:411.

8 S. Samis, Department of Fisheries and Oceans, Vancouver, B.C., personal communication.

9 EVS Consultants Ltd. 1994. Creosote evaluation project. Prepared for the Creosote Evaluation Project Steering Committee. Fraser River Estuary Management Program (FREMP) Technical Report No. WQWM-93-13. New Westminster, B.C. 49 p. + appendices.

10 Malins, D.C., M.M. Krahn, M.S. Myers, L.D. Rhodes, D.W. Brown, C.A. Krone, B.B. McCain and S. Chan. 1985. Toxic chemicals in sediments and biota from a creosote-polluted harbor: Relationships with hepatic neoplasms and other hepatic lesions in English sole (Parophrys vetukus). Carcinogenesis 6(10): 1463-1469.

11 Vogelbein, W.K., J.W. Fournie, P.A. Van Veld and R.J. Huggett. 1990. Hepatic neoplasms in the mummichog *Fundulus heteroclitus* from a creosote-contaminated site. Cancer Research 50:5978-5986.

12 Konasewich, D.E. and F.A. Henning. 1988. Ammoniacal copper arsenate (ACA) wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada, Conservation and Protection. Report EPS 2/WP/4. 88 p.

13 Konasewich, D.E. and F.A. Henning. 1988. Chromated copper arsenate (CCA) wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada, Conservation and Protection. Report EPS 2/WP/3. 81 p.

14 Konasewich, D.E. and F.A. Henning. 1988. Creosote wood preservation facilities: Recommendations

for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada. Report EPS 2/WP/1. 90 p.

15 Konasewich, D.E. and F.A. Henning. 1988. Pentachlorophenol (PCP) thermal wood preservation facilities: Recommendations for design and operation. Prepared by Envirochem Services, under the direction of the Wood Preservation Industry Technical Steering Committee, for Environment Canada, Conservation and Protection. Report EPS 2/WP/5. 88 p.

16 Sprague, J.B. and A.G. Colodey. 1989. Toxicity to aquatic organisms of organochlorine substances in kraft mill effluents. Unpublished background report for Environment Canada. IP-100. 53 p.

17 Environment Canada and Health and Welfare Canada. 1991. *Canadian Environmental Protection Act*, Priority Substances List assessment report no. 2: Effluents from pulp mills using bleaching. 60 p.

18 B.C. Water Management Branch. 1986. Principles for preparing Water Quality Objectives in British Columbia. Ministry of Environment and Parks, Province of B.C.

19 Stanley and Associates. 1993. Urban runoff quantification and contaminants loading in the Fraser River Basin and Burrard Inlet. DOE-FRAP 1993-19. Stanley Associates Engineering Ltd., Surrey, B.C.

20 Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.

21 Chilibeck, B., G. Chislett and G. Norris 1992. Land development guidelines for the protection of aquatic habitat. Department of Fisheries and Oceans, and B.C. Ministry of Environment, Lands and Parks. 128 p.

22 MacKenzie, F.B. 1987. Urbanization and the hydrological regime, p. 277-293. *In:* M.C. Healey and R.R. Wallace (ed.). 1987. Canadian aquatic resources. Can. Bull. Fish. Aquat. Sci. 215: 533 p.

23 British Columbia Research Corporation. Waste Management Group. 1992. Urban runoff quality control guidelines for the Province of British Columbia. Prepared for BC Environment, Environmental Protection Division, Municipal Waste Reduction Branch. 132 p.

24 U.S. Congress. Office of Technology Assessment. 1987. Wastes in marine environments. OTA-O-334. 313 p.

25 Boeckh, I., V.S. Christie, A.H.J. Dorcey, and H.I. Reggeberg. 1991. Water use in the Fraser Basin. *In:* Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development. Vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.

26 UMA Engineering Ltd. 1993. Sewer use control for Fraser River basin and Burrard Inlet drainage basin. Prepared for Environment Canada, Conservation and Protection, Fraser Pollution Abatement Office, North Vancouver, B.C. Report No. DOE FRAP 1993-20. 83 p. + appendices.

27 B. Locken, Ministry of the Environment, Lands and Parks, Surrey, B.C., personal communication.

28 Gartner Lee Ltd. 1997. Fraser Basin Landfill Inventory. DOE-FRAP 1997-19

29 Atwater, J.W. 1980. Fraser River Estuary Study - water quality: Impact of landfills. Fraser River Estuary Study, Vancouver, B.C. 285 p.

30 Greater Vancouver Water District. 1993. Environmental impact assessment of proposed secondary disinfection of drinking water: Stage II.

31 L. Nikl, Department of Fisheries and Oceans, New Westminster, B.C., personal communication.

32 Resource Integration Systems, CH2M HILL Engineering Ltd. and Peat Marwick Stevenson and Kellogg. 1993. Municipal reduction, reuse and recycling programs. GVRD solid waste management plan - stage 2: Technical memorandum 1. Prepared for the Greater Vancouver Regional District and the Ministry of Environment, Lands and Parks.

33 Lanarc Consultants Ltd. 1994. Stream stewardship: A guide for planners and developers. Stream Stewardship Series. Department of Fisheries and Oceans, and B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Municipal Affairs. 48 p.

34 Schreier, H., S.J. Brown and K.J. Hall. 1991. The land-water interface in the Fraser River Basin. *In:* Dorcey, A.H.J. and J.R. Griggs, eds. 1991. Water in Sustainable Development: Exploring Our Common Future in the Fraser River Basin. Vol. 2. Westwater Research Institute, University of British Columbia, Vancouver, B.C. 288 p.

35 John, B., and M. Geier. 1994. Survey of agricultural practices in the Thompson Basin - 1994. Prepared for Ministry of the Environment, Lands and Parks, and Fraser Pollution Abatement Office, Environmental Protection. DOE-FRAP 1994-26. 52 p.

36 M. Fairbarns, Range Ecologist, Range Branch, Ministry of Forests, Victoria, B.C. personal communication.

37 Platts, W.S. 1981. Influence of forest and rangeland management on anadromous fish habitat in western North America. Effects of livestock

grazing. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 25 p.

38 Statistics Canada. 1986. Agricultural census data for 1986. Statistics Canada, Ottawa.

39 IRC Integrated Resource Consultants, Inc. 1994. Agricultural land use survey in the Matsqui River Watershed - summary report. Prepared by IRC Integrated Resource Consultants, Inc. for B.C. Ministry of Environment, Environment Canada and Department of Fisheries and Oceans. DOE-FRAP 1994-22.

40 IRC Integrated Resource Consultants, Inc. 1994. Agricultural land use survey in the Sumas River Watershed - summary report. Prepared by IRC Integrated Resource Consultants, Inc. for B.C. Ministry of Environment, Environment Canada and Department of Fisheries and Oceans. DOE-FRAP 1994-21

41 Cook, K.E. 1994. An evaluation of water quality and land use in the Salmon River Watershed, Langley, B.C., using GIS techniques. M.Sc. Thesis, Department of Soil Science, University of British Columbia, Vancouver, B.C. 252 p.

42 B.C. Ministry of Agriculture, Fisheries and Foods, B.C. Association of Cattle Feeders, B.C. Cattlemen's Association and B.C. Federation of Agriculture. 1992. Environmental guidelines for beef cattle producers in British Columbia. B.C. Ministry of Agriculture, Fisheries and Food, Soils and Engineering Branch, Abbotsford, B.C. 78 p.

43 Moore, B. 1989. Partner or Policeman: It's Your Choice. *In:* South Coastal Dairy Education Association, 21st Annual Dairy Producers' Short Course, Proceedings, February 14 and 15, 1989. South coastal Dairy Education Association (Dairy Education Committee) and B.C. Ministry of Agriculture and Fisheries. p. 41-52.

44 Brisbin, P.E. 1995. Agricultural nutrient management in the Lower Fraser Valley. Component project of management of livestock and poultry manures in the Lower Fraser Valley. Report 4. Prepared for B.C. MELP, Environment Canada-FRAP, B.C. MAFF, and Fisheries and Oceans-FRAP. DOE-FRAP 1995-27.

45 Runka, G. 1995. Livestock waste management practices and legislation outside British Columbia July 1995. DOE FRAP 1995 - 26.

46 R. Van Kleek, Ministry of Agriculture Fisheries and Food, Abbotsford, B.C., personal communication.

47 Swain, L.G. and D.G. Walton. 1991. (Fraser River Estuary Monitoring.) Report on the 1990 Lower Fraser River and Boundary Bay Sediment Chemistry and Toxicity Program.

48 Wan, M.T. 1989. Levels of selected pesticides in farm ditches leading to rivers in the Lower Mainland of British Columbia. J. Environ. Sci. Health, 324(2):183-203.

49 Sirois, G. 1995. Survey of agricultural pesticide application practices & recommendations for protecting Lower Mainland riparian habitat from off-target pesticide deposit: a view to the future. Prepared for Habitat Protection Branch, Ministry of the Environment, Lands and Parks, and Commercial Chemicals Division, Environmental Protection, Environment Canada. 53 p.

50 Wernick, B.G. 1996. Land use and water quality dynamics on the urban-rural fringe: A GIS analysis of the Salmon River Watershed, Langley, B.C. M.Sc. Thesis, Resource Management and Environmental Studies, University of British Columbia, Vancouver, B.C. 217 p.

51 Rood, K.M. and R.E. Hamilton. 1994. Hydrology and water use for salmon streams in the Fraser Delta Habitat Management Area, British Columbia. Manuscrip. Rep. Fish. Aquat. Sci. 2238.

52 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilcotin Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2287.

53 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilliwack/ Lower Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2288.

54 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Harrison Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2293.

55 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Middle Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2292.

56 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Nechako Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2299.

57 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Pitt/Stave Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2289.

58 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Quesnel Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2296.

59 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Seton/ Bridge Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2298.

60 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Thompson

Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2297.

61 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Upper Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2294.

62 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the West Road Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2295.

63 Brown, George W. 1991. Forestry and water quality, 2nd ed. Oregon State University, College of Forestry, Corvallis, OR. 142 p.

64 MacDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific northwest and Alaska. U.S. Environmental Protection Agency, Region 10, Seattle, WA; and University of Washington, College of Forestry and College of Ocean and Fishery Sciences, Center for Streamside Studies, Seattle, WA. Report No. EPA/910/9-91-001. 166 p.

65 Chamberlin, T.W., R.D. Harr and F.H. Everest. 1991. Timber harvesting, silviculture, and watershed processes. American Fisheries Society Special Publication 19: 181-205.

66 Toews, D.A.A. and D.R. Gluns. 1986. Snow accumulation and ablation on adjacent forested and clearcut sites in southeastern British Columbia. *In:* Proceedings, western snow conference 54th annual meeting, Spokane, Washington. p. 101-111.

67 Toews, D.A.A. and M.J. Brownlee. 1981. A handbook for fish habitat protection on forest lands in British Columbia. Department of Fisheries and Oceans, Field Services Branch, Habitat Protection Division, Land Use Unit. 166 p.

68 Scrivener, C. 1982. Logging impacts on the concentration pattern of dissolved ions in Carnation Creek, British Columbia. *In:* G.F. Hartman (ed.). Proceedings of the Carnation creek workshop: A Ten-Year Review. Malaspina College, Nanaimo, B.C. February 24-26, 1982.

69 B.C. Ministry of Forests and B.C. Environment. 1995. Forest Practices Code of British Columbia: Silviculture prescription guidebook. 72 p.

70 L. Anderson, Ministry of Agriculture, Fisheries and Food, Rosedale, B.C., personal communication. *In:* Boyle, D.E. 1995. The impacts of forestry and wood processing industries on water quality in the Fraser River Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan, Vancouver, B.C. 48 p.

71 Norris, L.A., H.W. Lorz and S.V. Gregory. 1991. Forest chemicals. American Fisheries Society Special Publication 19:207-296.

72 Servizi, J.A. 1989. Protecting Fraser River salmon (*Oncorhynchus spp.*) from wastewaters: An assessment. Can. Spec. Publ. Fish. Aquat. Sci. 105:136-153.

73 Chapman, P.M. 1989. Salmonid toxicity studies with Roundup. *In:* P.E. Reynolds (ed.), Proceedings of the Carnation Creek Herbicide Workshop. FRDA Report No. 063. p. 257-262.

74 Kreutzweiser, D.P. and P.D. Kingsbury. 1989. Drift of aquatic invertebrates in a glyphosate contaminated watershed. *In:* P.E. Reynolds (ed.), Proceedings of the Carnation Creek Herbicide Workshop. FRDA Report No. 063. p. 250-256.

75 Holtby, L.B. and S.J. Baillie. 1989. Effects of the herbicide ROUNDUP on coho salmon fingerlings in an oversprayed tributary of Carnation Creek, British Columbia. *In:* P.E. Reynolds (ed.), Proceedings of the Carnation Creek Herbicide Workshop. FRDA Report No. 063. p. 273-285.

76 Reynolds, P.E., J.C. Scrivener, L.B. Holtby and P.D. Kingsbury. 1989. A summary of Carnation Creek herbicide study results. *In:* P.E. Reynolds (ed.), Proceedings of the Carnation Creek Herbicide Workshop. FRDA Report No. 063. p. 322-334.

77 Samis, S.C., S. von Schuckmann, M.T. Wan, G.D. McKellar and M. Scott. 1992. Guidelines for the protection of fish and fish habitat during use of glyphosate and other selected forestry herbicides in coastal British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2176. 9 p.

78 B.C. Ministry of Forests; B.C. Ministry of Environment, Lands and Parks; Canada, Department of Fisheries and Oceans; and Council of Forest Industries. 1993. British Columbia coastal fisheries/forestry guidelines. Revised third edition (July 1993). 133 p.

79 L. Herring, Ministry of Forestry, Prince George, B.C., personal communication. *In:* Boyle, D.E. 1995. The Impacts of Forestry and Wood Processing Industries on Water Quality in the Fraser River Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan, Vancouver, B.C. 48 p.

80 H. Yano, Ministry of Forests, Kamloops, B.C., personal communication. *In:* Boyle, D.E. 1995. The impacts of forestry and wood processing industries on water quality in the Fraser River Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan, Vancouver, B.C. 48 p.

81 Sedell, J.R., F.N. Leone and W.S. Duval. 1991. Water transportation and storage of logs. American Fisheries Society Special Publication 19: 325-368.

82 Fraser River Estuary Management Program (FREMP). 1991. Log management in the Fraser River estuary. Report of the Log Management Activity Working Group. 47 p.

83 Goudey J.S. and B.R. Taylor. 1992. Toxicity of aspen wood leachate to aquatic life. Part I: Laboratory studies. Prepared by Hydroqual Laboratories Ltd., Calgary, AB, for B.C. Ministry of Environment, Lands and Parks, Environmental Protection Branch, Northern Interior Region. 49 p. + appendices.

84 Taylor, B.R. 1994. Toxicity of aspen wood leachate to aquatic life, Part II: Field study. Prepared for B.C. Ministry of Environment, Northern Interior Branch, Environmental Protection Branch. 67 p.

85 Archibald, Craig. 1992. Woodwaste inventory 1992. B.C. Environment, Lower Mainland Region, Industrial Section. Surrey, B.C. 63 p. + appendices.

86 Stewart and Ewing Assoc. Ltd. (SEAFOR); F.B.M. Consulting Ent.; and J.F. McWilliams. 1990. British Columbia forest industry mill residues for calendar year 1989. Prepared for the B.C. Ministry of Forests Mill Residue Task Force.

87 Moore, K. 1992. Wood waste leachate characterization Study. Prepared for B.C. Environment, Lower Mainland Region, Industrial Section. 38 p. + appendices.

88 Liu, S.D., M.D. Nassichuk, and S.C. Samis. 1995. Guidelines on storage, use and disposal of wood residue for the protection of fish and fish habitat in British Columbia. DOE/DFO-FRAP 1995-18. 28 p.

89 Tripp, D., A. Nixon and R. Dunlop. 1992. The application and effectiveness of Coastal Fisheries Forestry Guidelines in selected cut blocks on Vancouver Island. Prepared by D. Tripp Biological Consultants Ltd. for B.C. MELP, Fish and Wildlife Division, Nanaimo, B.C. 25 p.

90 G. Ford, Ministry of the Environment, Lands and Parks, personal communication. *In:* Mehling, P. 1995. Review article for status of water quality issues pertaining to mining and gravel removal in the Fraser Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan. 33 p.

91 B. McDonald, Department of Fisheries and Oceans, Prince George office, personal communication.

92 Schofield, C. L. 1976. Acid precipitation: effects on fish. Ambio 5: 228-230.

93 Rosseland, B.O. 1986. Ecological effects of acidiication on tertiary consumers, fish population responses. Water, Air and Soil Pollution. 30: 451-460.

94 W. Belzer, Environment Canada, Vancouver, B.C., personal communication.

95 Baker, J.P. 1982. Effects of metals associated with acidification. *In:* Acid Rain/Fisheries. Proc. International Symposium on Acidic Rain and Fishery Impacts in Northeastern North America. R.E. Johnson (ed.). Cornell University, New York. 357 p.

96 Clark, M.J.R. and N. Bonham. 1982. Potential sensitivity of the British Columbia aquatic environment to acid rain. B.C. Ministry of Environment, Victoria, B.C. 12 p. + figures.

97 Wiens, J. 1985. Sensitivity of British Columbia Soils and Geology to Acidic Inputs. *In:* Baldwin, J.W. (ed.). Acid Rain in the Pacific Northwest, Proceedings of the Acid Rain Symposium, Annual Conference of the Northwest Association for Environmental Studies, Univ. of Victoria, Victoria, B.C.

98 Hall, K.J., H. Schreier, and S.J. Brown. 1991. Water quality conditions in the Fraser River Basin. *In:* Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.

99 BC MELP and Environment Canada. 1992. State of the environment for the Lower Fraser River Basin. Ministry of Supply and Services Canada. SOE Report No. 92-1. 79 p.

100 Nikleva, S. 1985. Acid rain over southwestern British Columbia. In J.H. Baldwin (ed.) Proceedings of the Acid Rain Symposium. Annual Conference of the Northwest Association for Environmental Studies. University of Victoria. p. 15-29.

101 Whitfield, P.H., N. Rousseau and E. Michnowsky. 1993. Rainfall Induced changes in Chemistry of a British Columbia Coastal Stream. Northwest Sci. 67(1): 1-6.

102 Henriksen, A. 1980. Acidification of freshwater - a large titration. *In:* D. Drablos and A. Tollan (eds.). Ecological impact of acid precipitation. Proc. Int. Conf. SNSF Proj. Rep. Norway. 383 p.

103 Sullivan, M.A. and S.C. Samis. 1988. Assessment of acidification potential of selected Lower Mainland and Vancouver Island, British Columbia streams. Can. Tech. Rep. Fish. Aquat. Sci. 1599: 113 p.

104 Whitfield, P.H. and N.E. Dalley. 1987. Rainfall driven pH depressions in a British Columbia coastal stream. Symposium on Monitoring, Modeling, and Mediating Water Quality. American Water Resources Association. p. 285-294.

105 Canadian Council of Resource and Environment Ministers. 1987. Canadian Water Quality Guidelines. Prepared by the Task Force on Water Quality Guidelines, Ottawa.

106 Bubenick, D.V. (ed.). 1984. Acid rain information book. 2nd edition. Noyes Publications, Park Ridge, New Jersey. 400 p.

107 Norton, S.A. 1982. The effects of acidification on the chemistry of ground and surface waters. *In:* R.E. Johnson (ed.). Acid Rain/Fisheries. Proc. International Symp. on Acidic Rain and Fishery Impacts in Northeastern North America. Cornell University, N.Y. 357 p.

108 Haines, T.A. 1981. Acidic precipitation and its consequences for aquatic ecosystems: a review. Trans. Am. Fish. Soc. 110(6): 690-707.

109 Baker, J.P. and C.L. Schofield. 1982. Aluminum toxicity to fish in acidic waters. Water, Air and Soil Pollution 18:289-309.

110 Cleveland, L., E.E. Little, S.J. Hamilton, D.R. Buckler and J.B. Hunn. 1986. Interactive toxicity of aluminum and acidity to early life stages of brook trout. Trans. Am. Fish. Soc. 115: 610-620.

111 Greater Vancouver Regional District. 1992. Greater Vancouver travel survey. Report No. 6. Comparison of 1985 and 1992 Travel Characteristics. Greater Vancouver Regional District, Burnaby, B.C.

112 B. Thompson, Environment Canada, Vancouver, B.C., personal communication.

113 Levy, D.A. 1992. Potential impacts of global warming on salmon production in the Fraser River watershed. Can. Tech. Rep. Fish. Aquat. Sci. 1889. 96 p.

114 Schneider, S.H. 1989. The changing climate. Sci. Am. 262: 70-79.

115 Moore, R.D. 1991. Hydrology and water supply in the Fraser River basin. *In:* Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.

116 Pitman, A.J., A. Henderson-Sellars, and Z.L. Yang. 1990. Sensitivity of regional climates to localized precipitation in global models. Nature 346: 734-737.

117 Ripley, E.A. 1987. Climatic change and the hydrological regime. Can. Bull. Fish. Aquat. Sci. 215:137-178.

118 Meisner, J.D., J.S. Rosenfeld, and H.A. Regier. 1988. The role of groundwater in the impact of climate warming on stream salmonines. Fisheries 13:2-8.

119 Walthers, L., and J.C. Nener. 1997. Continuous water temperature monitoring on the Nicola River, B.C., 1994: Implications of high measured temperatures for Pacific anadromous salmonids. Can. Tech. Rep. Fish. and Aquat. Sci. 2158: 65 p.

120 Schindler, D.W., K.G. Beaty, E.J. Fee, D.R. Cruikshank, E.R. DeBruyn, D.L. Findlay, G.A. Linsey, J.A. Shearer, M.P. Stainton and M.A. Turner. 1990. Effects of climate warming on lakes of the central boreal forest. Science 250: 967-970.

121 Meisner, J.D. 1990. Potential loss of thermal habitat for brook trout, due to climatic warming, in two Southern Ontario streams. Trans. Am. Fish. Soc. 119: 282-291.

122 Moore, R.D. 1991. Hydrology and water supply in the Fraser River basin. *In:* Dorcey, A.H.J. and J.R. Griggs (eds.). Water in sustainable development: Exploring our common future in the Fraser River basin. Research program on water in sustainable development; vol. 2. Vancouver: Westwater Research Centre, The University of British Columbia. 288 p.

123 Northcote, T.G. 1992. Prediction and assessment of potential effects of global environment change on freshwater sport fish habitat in British Columbia. GeoJounal 28: 39-49.

124 Hall, J.D. and R.L. Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. *In:* T.G. Northcote (ed.). Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries, U.B.C., Vancouver, B.C.

125 Holtby, L.B. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columbia, and associated impacts on the coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 45: 502-515.

126 Slaney, P.A., T.G. Halsey, and H.A. Smith. 1977. Physical alterations to small stream channels associated with streamside logging practices in the Central Interior of British Columbia. Province of British Columbia, Ministry of Recreation and Conservation. Fisheries Management Report No. 31. 22 p.

127 Slaney, P.A., T.G. Halsey, and H.A. Smith. 1977. Some effects of forest harvesting on salmonid rearing habitat in two streams in the central interior of British Columbia. Province of British Columbia, Ministry of Recreation and Conservation. Fisheries Management Report No. 71. 26 p.

128 Brownlee, M.J., B.G. Shepherd, and D.R. Bustard. 1988. Some effects of forest harvesting on water quality in the Slim Creek Watershed in the central interior of British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. No. 1613. 41 p.

129 Miles, M. 1995. Salmon river channel stability Analysis. Can. Man. Rep. Fish. Aquat. Sci. No. 2309. 121 p.

130 Miles, M. 1995. Deadman River channel stability analysis. Can. Man. Rep. Fish. Aquat. Sci. No. 2310. 145 p + maps.

131 Fisheries and Oceans Canada. In preparation. Strategic Review of Streams in the Lower Fraser Valley. Fraser River Action Plan - Fisheries and Oceans, Vancouver, B.C.

132 Fraser River Sockeye Public Review Board. 1994. Fraser River sockeye 1994: Problems & Discrepancies. Public Works and Government Services Canada, Ottawa, ON. 131 p.

133 Broersma, K., P. Webb, B. Roddan, and K. Wallach. 1995. Status report of projects in waste

management in the livestock industry in the interior of British Columbia. Prepared for Fraser River Action Plan, Fraser Pollution Abatement Office, Environmental Protection, Environment Canada, Pacific and Yukon Region, North Vancouver, B.C. DOE-FRAP 1995-30. 135 p.

134 B.C. MAFF. 1996. Mark Aiyaddurai. Senior Data Analyst. M.C. Ministry of Agriculture, Fisheries and Food. Victoria, B.C.

135 The Management of Agricultural Wastes in the Lower Fraser Valley Program Steering Committee. In preparation. Management of agricultural wastes in the Lower Fraser Valley: Summary report - a working report.

136 Hartman, G.F. and M. Miles. 1997. Jones Creek spawning/rearing channel project: Post failure analysis. Prepared for Fraser River Action Plan, Fisheries and Oceans Canada, Vancouver, B.C.

137 B.C. Environment Backgrounder: “What is BACT?” Ministry of Environment, Lands, and Parks, 1992.

138 Scott, W.S. 1979. Road de-icing salts in an urban stream and flood control reservoir. Water Res. Bull. 15(6): 1733-1742.

139 Helz, G.R., and A.C. Nweke. 1995. Incompleteness of dechlorination. Environ. Sci. Technol. 29:1018-1022.

140 Nikl, L. and D. Nikl. 1993. Environmental impacts associated with monochloramine-disinfected municipal potable water. *In:* W. Robertson, R. Tobin, and K. Kjartanson (eds.). Disinfect dilemma: Microbiological control versus by-products. American Water Works Association.

141 Gaikowski, M.P., S. J. Hamilton, K.J. Buhl, S.F. McDonald, and C.H. Summers. 1996. Acute toxicity of three fire-retardant and two fire suppressant foam formulations to the early life stages of rainbow trout (*Oncorhyncus mykiss*). Environmental Toxicology and Chemistry 15(8): 1365-1374.

142 Mehling, P. 1995. Review article for status of water quality issues pertaining to mining and gravel removal in the Fraser Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan. 33 p.

143 Norecol Environmental Consultants. 1993. A comprehensive survey of pesticide use in British Columbia: 1991. DOE-FRAP 1993-35.

144 G. Kruzynski, Department of Fisheries and Oceans, West Vancouver Laboratory, personal communication.

145 Environment Canada, unpublished data, W. Belzer. Science Division. Environmental Conservation, Vancouver, B.C.

146 O.E. Langer, Department of Fisheries and Oceans, Vancouver, personal communication.

147 Nener, J.C. 1997. Watershed Stewardship - A guide for agriculture. Department of Fisheries and Oceans and B.C. Ministry of Environment, Lands and Parks. 48 p.

Chapter 3 Methodology

3.1 Introduction

Data and information about land uses and summer low flow conditions were used to evaluate water quality and the potential for impaired water quality in each known salmon-bearing watershed in the Fraser Basin. Information used to evaluate water quality conditions and the potential for water quality concerns in all salmon-bearing streams of the Fraser Basin included:

- water quality, sediment, and fish tissue contaminant data collected between 1980 and 1995, compiled into a database for DFO and DOE-FRAP programs by LGL Consultants Ltd.;[1]
- fish tissue contaminant data collected at selected reaches by DOE in 1994;
- the quality and quantity of all effluent discharges to surface waters addressed via provincial Waste Management Permits, based on permit specifications for each discharge;[2]
- information about land uses which generate non-point source pollution, focusing on urban and agricultural uses, and forest harvesting;
- information on licensed water withdrawals and stream hydrology, particularly summer low flows; and
- input obtained from DFO and MELP staff with first-hand knowledge of streams, through circulation of a draft report and follow-up discussions.

The data sources and assessment criteria used are described in detail below.

Data and information have been organized on a stream-by-stream basis to provide an overall synopsis of measured water quality conditions, and any discharges or activities which may impair water quality in each watershed.

Where data were available an assessment of the measured conditions is provided. A series of hydrology reports prepared for DFO-FRAP [3-14] supplied land use information for most salmon-bearing streams identified in DFO Stream Information Summary System (SISS) catalogues,[15-26] and served as a basis for assessing the potential for land uses and summer low flow conditions to affect water quality. The types of water quality impacts which can result from different types of human activities are explained in Chapter 2.

Colour-coded icons are used in the stream summaries to provide a quick synopsis of the level of concern for water quality in each documented salmon-bearing stream in each HMA. In general, the colour-coding scheme applied to icons represents the following:

Red ◆Available information indicates that water quality conditions limiting to fish production are likely to occur in the watercourse.

Yellow ◆Available information indicates that there may be some impairment of water quality, with potential implications for fish.

Green ◆Information indicates that water quality is unimpaired and should not be limiting to fish production.

Blue ◆There was not enough information available to assess water quality conditions.

A more detailed explanation is provided below for each of the icons used in the report. A coloured symbol is not provided for land uses which are not present in a watershed.

A colour-coded map showing water quality sampling stations, and an assessment of measured conditions is provided for each HMA. Maps indicating the locations of all discharges to surface waters addressed by MELP Waste Management Permits, and tables summarizing permit discharge information are also provided for each HMA.

❖❖❖

3.2 Methodology

3.2.1 Evaluation of Water Quality and Contaminant Data

A database compiled on behalf of DFO and DOE FRAP programs[1] was the main source of data used to evaluate surface water, sediment and fish tissue quality for the Fraser River and tributaries. Where data from elsewhere are included, the sources are indicated.

The data in this FRAP database originate primarily from MELP's SEAM database and Environment Canada's ENVIRODAT database. Additional data obtained via the Continental and Oceanographic Data Information System (CODIS)[35] and several other limited sources were also incorporated into the FRAP database.[1]

The data initially downloaded from the above sources were screened in a number of ways. Only data collected after 1979 were included in the FRAP database. Data from sites located outside the Fraser Basin were eliminated, as were sites lacking geographical co-ordinates or other spatial information necessary for mapping the sampling site. Nutrient data collected prior to 1985 were not included in the FRAP database because analytical approaches have changed significantly since this time.

After compiling the data, Wainwright, *et al.*[1] standardized units of measure and parameter codings, and further screened the database for anomalous values. Values reported as zero were converted to the method detection limit. Extreme outliers and duplicated data were excluded.

3.2.1.1 Parameters

The parameters used to evaluate the condition of streams in this report include: physical measures, nutrients, metals, and microbes in surface water; metals and organic contaminants in sediments; and, chlorophenols, dioxins, furans, PCBs, pesticides and mercury in fish tissue (Table 3.2.1).

Specific parameters were selected for inclusion in this water quality assessment for a number of reasons:

- each has either a direct or indirect effect on aquatic life;
- the selected parameters are often affected by specific anthropogenic activities, therefore, management options for abatement may be implemented; and
- the parameters are commonly measured, so adequate data are likely to be available for site-specific assessment of water quality, and for between-site comparisons of the parameter.

3.2.1.2 Data Evaluation

Where possible water, sediment and fish tissue quality were evaluated in relation to existing relevant guidelines (Table 3.2.1). For water quality parameters, data were compared with available CCREM (subsequently re-named to CCME) guidelines[33] established for the protection of aquatic life. For some parameters included in this study CCME guidelines do not exist. Therefore MELP Approved and Working Criteria for Water Quality[27] were applied. Sediment

Table 3.2.1 Guidelines and 80th percentiles for parameters used in this study.[29]

	Parameter	SEAM code	Guideline	For the protection of:	Guideline Source
Surface Water					
Physical	Temperature	0013	15 °C	Salmonids	DFO-FRAP
	Dissolved oxygen	0014	9.5 mg·L^{-1}	Aquatic life	CCME
	pH	0004	6.5 - 9.0	Aquatic life	CCME
Nutrients	Total nitrate/nitrite nitrogen	0109	0.123 mg·L^{-1}	N/A	80th percentile
	Dissolved ammonia-N	1108	0.01 mg·L^{-1}	N/A	80th percentile
	Total phosphorus	P--T	15 µg·L^{-1}	Aquatic life[1]	B.C. MELP
	Total phosphorus	P--T	90 µg·L^{-1}	N/A	80th percentile
Microbes	Fecal coliforms	0450	200 MPN·100mL^{-1}	N/A	LGL[2]
	Total coliforms	0451	240 MPN·100mL^{-1}	N/A	80th percentile
Metals	Arsenic	As-T	0.05 mg·L^{-1}	Aquatic life	CCME
	Cadmium	Cd-T	0.17 µg·L^{-1}	Aquatic life	CCME
	Chromium	Cr-T	2.0 µg·L^{-1}	Aquatic life	CCME
	Copper	Cu-T	2.0 µg·L^{-1}	Aquatic life	CCME
	Mercury	Hg-T	0.1 µg·L^{-1}	Aquatic life	CCME
	Lead	Pb-T	2 µg·L^{-1}	Aquatic life	CCME
	Zinc	Zn-T	0.03 mg·L^{-1}	Aquatic life	CCME
Sediments					
Metals	Arsenic	As-T	6 µg·g^{-1}	Aquatic life	B.C. MELP
	Cadmium	Cd-T	0.6 µg·g^{-1}	Aquatic life	B.C. MELP
	Chromium	Cr-T	26 µg·g^{-1}	Aquatic life	B.C. MELP
	Copper	Cu-T	16 µg·g^{-1}	Aquatic life	B.C. MELP
	Mercury	Hg-T	0.2 µg·g^{-1}	Aquatic life	B.C. MELP
	Lead	Pb-T	31 µg·g^{-1}	Aquatic life	B.C. MELP
	Zinc	Zn-T	120 µg·g^{-1}	Aquatic life	B.C. MELP
Organics	PAHs	various		see Appendix 2	
	Organochlorine pesticides	various		see Appendix 2	
Fish Tissues					
Metals	Mercury	Hg-T	0.65 µg·g^{-1} wet wt.[4]	Humans[3]	Health Canada
Chlorophenols	2,4,6-Trichlorophenol	T042	64.6 µg·g^{-1} wet wt.[4]	Humans[3]	B.C. MELP
	Pentachlorophenol	P022	2.59 µg·g^{-1} wet wt.[4]	Wildlife	N.Y.
	Pentachlorophenol	P022	25.85 µg·g^{-1} wet wt.[4]	Humans[3]	B.C. MELP
Dioxins	2,3,7,8,-T4CDD	T061	25.86 pg·g^{-1} wet wt.[4]	Aquatic life/ humans[3]	Health Canada
PCBs	Total PCB		2 µg·g^{-1} dry wt.	Aquatic life	B.C. MELP
Pesticides	p,p'-DDE		5 µg·g^{-1} dry wt.	Humans	
	Total Toxaphene		0.1 µg·g^{-1} dry wt.	Humans	Environment Canada

Guideline established
1 Salmonid-bearing lakes
2 LGL Ltd., see reference 1
3 Human consumption
4 Converted from criteria established for dry weight, based on fish moisture content of

metal data were compared with MELP Approved and Working Criteria for Water Quality[27] which are similar to Threshold Effects Levels identified in CCME guidelines. Contaminants in fish tissue were evaluated using guidelines for the protection of aquatic life, and human health where applicable.

In some watercourses, one or more parameters may naturally exceed CCME and/or MELP guidelines due to local geology and soil types, hence, “high” levels of a parameter relative to guidelines do not necessary indicate anthropogenic impacts. Efforts have been made to identify the source of “high” levels of any parameter, natural or otherwise, in stream summaries.

For some parameters neither CCME nor MELP has established guidelines for the protection of aquatic life. In such cases the 80th percentile values, calculated using data for the entire Fraser Basin, were assumed to be a threshold above which the measured value indicates a deviation from naturally occurring conditions. Data collected during freshet (considered to be April to July) for metals were excluded from 80th percentile calculations because it was believed that high levels were associated with high suspended sediment loads.

Where the database permitted, upstream/downstream comparisons of water quality data were made to help distinguish between natural water quality conditions and degraded water quality. Inclusion of land use information in stream summaries enables the reader to place water quality data into some context.

There are several parameter-specific issues which require further discussion:

1) Surface Water Quality

A) *Dissolved Oxygen (DO)*

Percent saturation is more important in determining the availability of oxygen to aquatic organisms than is the absolute concentration of DO in the water column. However, percent saturation is temperature-dependent, and water temperature data were often not available in the database to accompany DO data. The measured DO concentrations were, therefore, compared with the CCME guideline for the minimum DO concentration considered to protect early life stages of cold water biota, including salmonids.

B) *Phosphorus*

There are no Canadian guidelines addressing concentrations of total phosphorus in rivers because many factors, such as temperature and turbidity, may influence the sensitivity of moving water to phosphorus inputs. Phosphorus is not directly harmful to aquatic organisms. Rather, negative effects from high phosphorus levels result from eutrophication. Water quality impacts associated with eutrophication relevant to fish include diurnal fluctuations in pH, low night-time DO concentrations, and low DO concentrations resulting from the die-off and decomposition of algal blooms.

The B.C. MELP guideline for phosphorous concentrations (15 $\mu g \cdot L^{-1}$), established to protect lakes containing salmonids, was used here to evaluate phosphorus concentrations in lake surface waters only. The 80th percentile phosphorus concentration calculated from the Fraser River database (90 $\mu g \cdot L^{-1}$) was used to evaluate concentrations of total phosphorous measured in streams and rivers. It should be noted, however, that the 80th percentile concentration is quite high and likely reflects particulate phosphorus associated with high turbidity in the Fraser River and some tributaries. Phosphorus is not readily bio-available until converted to ortho-phosphorus, however, this parameter has been seldom measured. Total phosphorus provides a measure of the maximum amount of the nutrient which may be available to aquatic biota.

C) *Ammonia*

As water temperature and pH increase, the percentage of ammonia in the toxic NH_3 state (rather than NH_4^+) increases. Unfortunately, temperature and/or pH data often do not accompany ammonia measurements in the database, making it impossible to assess whether or not measured ammonia concentrations are potentially harmful to aquatic life at the majority of sampling sites. Ammonia data were therefore always compared with the 80th percentile level; values which exceeded this level were considered to be a sign of contamination resulting from anthropogenic activities (e.g. sewage discharges, septic systems, agricultural runoff). Where temperature and pH data were available, ammonia concentrations were compared with MELP criteria for 30-day exposures and maximum concentrations in stream summaries.

There is some evidence that MELP ammonia measurements made between 1986 and 1994 are of poor precision and accuracy for low to medium concentrations, as determined from non-blind audit samples.[36] Data should therefore be considered with caution.

D) *Fecal Coliforms*

Levels of total coliforms and fecal coliforms are not considered to be a direct threat to fish, hence, criteria for the protection of aquatic life have not been established for these parameters. Coliform levels may be an indicator of pollution sources such as sewage discharges or seepages and manure runoff which contain other substances harmful to fish, so coliform data were included in water quality assessments.

E) *Metals*

Concentrations of total metals in surface water are influenced by geological conditions. There were not enough data at many sites to determine whether elevated concentrations of total metals were due to high suspended solid levels, local mineralization, or inputs from anthropogenic activities.

The effects of individual metals on aquatic organisms is influenced by a number of factors including ionic state of the metal, water hardness, and concentrations of other metals in the water.

MELP analyses of metals from 1986 to 1994 show poor precision and accuracy, particularly for low concentrations of chromium, copper, and zinc.[36] Where measured values are close to detection limits, confidence in the data is low. There have been numerous changes in analytical techniques and labs, and in detection limits over the time span from 1986 to 1994. Also, MELP no longer measures mercury in water as there is no appropriate sampling protocol for mercury in water. The few measurements reported should therefore be considered with caution.

2) Sediment Quality

Many factors, such as particle size distribution and levels of acid-volatile sulfides, influence both the types and levels of contaminants likely to accumulate in sediments and the bio-availability of contaminants to organisms living in or on sediments. These factors were usually not reported in the database, therefore conclusions regarding biological implications of sediment contaminants usually could not be made based on the database. Furthermore, the methods used to extract metals from sediment samples were unknown, and can significantly affect measured values. Comparisons of measured sediment contaminant levels with guidelines do, however, provide information about where potential problems may exist.

Freshwater sediment guidelines from the B.C. MELP *Approved and Working Criteria for Water Quality* were used to assess sediment quality data in this study.[27] These criteria usually correspond with a Lowest Effect Level, based on Screening Level Concentration,[27] and are slightly more stringent than the recently developed Canadian (CCME) *Interim Sediment Quality Assessment Values* (Table 3.2.2). The CCME guidelines were derived through an empirical approach which implies a relationship between biological effects on aquatic organisms and the co-occurring sediment contaminant levels, rather than proof of causal relationship.[28]

The CCME guidelines include two sets of criteria to evaluate sediment quality: the “Threshold Effects Level” (TEL) and the “Probable Effects Level” (PEL). TEL indicates the level below which biological effects resulting from the contaminant are extremely unlikely, while PEL is the level above which biological effects resulting from the contaminant are very likely.

Clearly there is a need for particular caution in evaluating the sediment data, because natural background concentrations may exceed the guidelines, and bioavailability of substances in sediments is greatly influenced by many factors. In addition, differences in the methods used to extract metals from sediment samples can have a large influence on the levels measured, and consistent techniques must be used if samples are to be compared with one another, or with criteria or guidelines established by government authorities.

3) Contaminants in Fish Tissue

Organic contaminants in fish tissues, specifically total PCBs, total dioxins and furans, and select pesticide residues, were assessed according to guidelines established to protect the health of humans who consume fish flesh. Effects of these low concentrations of contaminants on fish are not well documented. Furthermore, these contaminants are usually found in mixtures, and their combined effects on fish at low concentrations are unknown.

In 1992, the Federal government promulgated regulations controlling pulp mill effluent quality and the levels of dioxins and furans in discharges, and mills were required to comply by 1994. Many mills, however, actually began implementing major process changes in 1989. As a result, there was a substantial decrease in the loading of dioxins and furans to the aquatic environment between 1989 and the early 1990's, and concentrations of these substances in sediments and fish tissues have declined rapidly. Dioxin and furan concentrations measured in fish tissues collected since 1992 are therefore evaluated separately from data collected prior to introduction of the legislation.

All consumption advisories which were applied to Fraser River stocks due to accumulation of dioxins and furans in fish tissues have now been lifted.

Table 3.2.2 A Comparison of BC MELP and CCME freshwater sediment guidelines.

Metal	CCME (µg·g^{-1}) TEL	CCME (µg·g^{-1}) PEL	BC MELP (µg·g^{-1})
Arsenic	6	17	6
Cadmium	0.6	3.5	0.6
Chromium	37	90	26
Copper	36	197	16
Lead	35	91	31
Mercury	0.17	0.5	0.2
Zinc	123	315	120

TEL = Threshold Effects Level
PEL = Probable Effects Level

3.2.1.3 Evaluation Criteria applied to Water Quality Data

The objective of the data evaluation was to provide an indication of the level of concern for water quality in each watercourse, based upon available data. Evaluation criteria used to assess water quality, sediment, and fish tissue data were developed in an attempt to provide a meaningful assessment of available data despite a number of problems with the existing data.

Difficulties with the data include but are not limited to:

- numerous sites with few sampling events;
- few sites with numerous sampling events;
- lack of consistency in the parameters measured between sites, and within sites on different sampling days;
- data are often lacking for parameters which should be sampled together (e.g. when ammonia is measured, water temperature and pH should also be reported); and
- lack of Quality Control/Quality Assurance data, to assess data quality.

The evaluation criteria used to assess **surface water quality data** for each sampling site in the Fraser Basin were as follows:

Red ◆n ≥ 20 and >25% of samples for any parameter exceed the guideline or 80th percentile value as indicated in Table 3.2.1.

Yellow ◆n ≥ 20 and > 10% but < 25% of samples for any parameter exceed the guideline or 80th percentile level;

OR n < 20 and 2 or more samples exceed the guideline or 80th percentile for at least one parameter.

Green ◆n ≥ 20 and fewer than 10% of samples exceed the guideline for any parameters measured, or the natural background levels for the watercourse as determined from the database;

OR n ≥ 10 for 3 or more parameters, and none of the measured values exceed guidelines or 80th percentile levels, or natural background levels for the watercourse as determined from the database.

If the range of parameters measured was inadequate to support a conclusion about water quality (e.g. only pH measured), the icon colour would default to blue.

Blue

◆None of the above conditions are met.

Rationale:

A minimum sample size (n) of 20 for a parameter at a given site was selected as the basis for a reasonably certain conclusion of either good water quality (green) or impaired water quality (red). The category of green for n ≥ 10 for three parameters or more was introduced to address situations where data are limited but indicate good water quality.

Where a sample size of less than 20 for a given parameter was available and more than 2 measurements of a parameter exceeded guideline or 80th percentile levels (Table 3.2.1), it was considered that water quality conditions may exist that negatively affect fish (yellow) and further sampling is required before conclusions can be made.

The number of samples measured per parameter often varies at a given site. The water quality assessment for each site was therefore based on the worst-rated parameter according to the above criteria.

Where available information was inadequate to support an assessment of water quality, a blue colour was assigned to the icon.

For **sediment contaminant** and **fish tissue contaminant** data, the above criteria were adjusted because sediments and biota tend to accumulate contaminants of concern. Hence, smaller sample sizes were considered to provide a viable basis for drawing conclusions about contaminants and the following evaluation criteria were applied:

Red

◆n ≥ 10 and ≥30% of samples for any parameter exceed the guideline or 80th percentile value as indicated in Table 3.2.1.

Yellow

◆n ≥ 10 and > 10% but < 30% of samples for any parameter exceed the guideline or 80th percentile level;

OR n > 5 and < 10, and 2 or more samples exceed the guideline or 80th percentile for at least one parameter.

Green

◆n ≥ 10 and fewer than 10% of samples exceed the guideline for any parameters.

OR n ≥ 5 and <10, and none of the measured values exceed guidelines or 80 percentiles.

If data are inadequate to support an assessment of sediment or fish tissue quality (e.g. only three measurements of a parameter), the icon colour would default to blue.

Blue

◆None of the above conditions are met.

Assessments of water quality and contaminants in sediments and fish tissue have been made for each sampling site in the Fraser Basin, based on available data. Assessments are presented on HMA maps using three-part coloured icons to represent surface water quality condition, fish tissue contaminant levels and sediment quality:

Where application of the assessment criteria described above are considered to be inappropriate for a sampling site an asterisk (★) has been placed beside the water quality icon on the HMA map. An explanation of the discrepancy is provided with the stream summary information.

Occasionally data from a source other than the FRAP water quality database (e.g. DFO unpublished data) were used to assess water quality; in all such cases the data are included in the data summaries and the information source is indicated in both the stream summary and data tables.

All data used to evaluate surface water quality, sediment contaminant, and fish tissue contaminant levels are summarized in the HMA chapters, so readers have the opportunity to form their own assessments.

3.2.2 Evaluation of Waste Management Permit Specifications

The discharge conditions specified in each Waste Management permit addressing a discharge to surface waters were assessed in terms of the sensitivity of the receiving environment. This was a subjective assessment as monitoring data from the receiving environment are rarely available. However, permits of concern were discussed with field staff in an effort to confirm whether the permit conditions warranted review. Summary tables indicating the permits which should be re-visited (i.e. where specified conditions may need to be reconsidered) are provided for each HMA which contained permitted discharges of potential concern.

3.2.3 Evaluation of Land Uses and Hydrology Information

There are three main categories of land uses which are widespread in the Fraser Basin and cause characteristic water quality problems unless significant precautions are taken. These land uses are urban development, agriculture, and forestry, all of which can generate significant amounts of non-point source pollution. Indices were developed to evaluate the likelihood of water quality degradation in Fraser Basin salmon-bearing streams, based on these three categories of land uses. If a type of land use does not occur in a watershed, the relevant icon is omitted from the stream summary.

In addition, low flows and water demand were assessed for existing or potential concerns because of their influence on water quality. Low volumes of water in a stream can result in highly variable temperatures and dissolved oxygen concentrations, and can reduce the ability of a stream to moderate impacts from contaminant inputs.

The indices are based on information contained in DFO's SISS catalogues[15-26] and a series of hydrology and water use reports for each of the Habitat Management Areas in the Fraser Basin.[3-14]

These assessments of the level of concern for impacts to water quality arising from human activities in Fraser Basin watersheds are often based on imprecise information. Assessments were intended to provide some perspective of the predominant land uses in each watershed, and an idea of the major water quality issues likely to be present in each stream.

Impacts in a watershed may be disproportionate to the degree of a land use present, resulting in assessments which are not representative of actual conditions. It should be noted, however, that DFO and MELP field staff reviewed draft reports and their first-hand knowledge of streams was incorporated into assessments in an effort to address shortcomings of the approach taken here. Field staff who reviewed drafts of the HMA chapters were asked to identify what they considered to be misleading or missing information, and to add their first-hand knowledge to the summary information. Based on feedback received from field staff, it appears that assessments of effects of adjacent land uses on the water quality of a watercourse generally provided a realistic overview of land uses and water quality issues.

3.2.3.1 Urban development

Urban runoff contributes a variety of contaminants to streams. As well, the increased variability of stream flows resulting from runoff affects stream temperatures and suspended sediment loads.

The percentage of the total area in a watershed which is impermeable determines the potential for both alteration to stream hydrology, and the contribution of contaminated stormwater runoff. The Effective Impervious Area (EIA) for Lower Fraser salmon streams was provided by Rood and Hamilton,[3, 5, 9] and was used to assess the extent to which urban land use is likely to affect water quality in a watershed. For HMAs outside of the Lower Fraser Valley, assessment of the effects of urban development on water quality relied more on specific problems being reported.

Criteria:

Red

◆Greater than 9% of the watershed consists of EIA;

OR a specific problem pertaining to impacts from urban development (e.g. extensive removal of riparian vegetation, erosion, etc.) are identified in a hydrology report, SISS Catalogue, or another reliable source. Water quality deterioration was assumed to accompany significant habitat disruptions - an assumption generally supported by field measurements and assessments.

Yellow

◆The EIA for a watershed is between 2% and 9%;

OR a relatively small level of impact has been reported, or the potential for water quality/fish habitat problems to develop has been identified in a reliable information source.

Green

◆EIA is less than 2% for a watershed indicating minimal development;

OR urban development does exist in the stream, and reports specify that there are no impacts result from the urban development.

Blue

◆No EIA or land use information is available.

Rationale:

Rood and Hamilton[3, 5, 9] stated that an EIA of 10% in a watershed causes major stream channel enlargement due to higher peak flows resulting from stormwater runoff. Stormwater runoff carries significant contaminant loadings to urban streams, and can also cause scouring which leads to sedimentation. The hydrology reports and SISS catalogues consistently identified impacts to streams with more than 9% EIA.[3, 5, 9, 15-20] Therefore, an EIA greater than 9% was considered to present a high probability of water quality impacts resulting from urban stormwater runoff.

A lower limit of 2% EIA was assigned to the yellow ranking because almost all streams with less than 2% EIA had no reported impacts on fish habitat or water quality (green) resulting from urban development.

3.2.3.2 Agriculture

Agriculture can affect water quality in several ways. Loss of riparian vegetation and low water flows resulting from water withdrawals can affect stream temperatures and dissolved oxygen concentrations. Leaching and runoff from fields or animal holding areas can contribute nutrients that cause eutrophication, organic matter which consumes dissolved oxygen when it decomposes, as well as ammonia and/or pesticides which are highly toxic to fish. Livestock access to stream banks can lead to slumping and erosion of stream banks, contributing suspended sediments to a stream.

SISS catalogues and hydrology reports often indicate the extent of agricultural activity present in a watershed, or specifically identify fish habitat and water quality impacts. The intensity or extent of activity was considered to reflect the probability of impacts to water quality.

Criteria:

Red

◆Hydrology reports, SISS catalogues, or other reliable information sources identify extensive or intensive activities often associated with water quality impacts, or a specific agricultural impact on fish habitat or water quality resulting from widespread activities.

Yellow

◆Hydrology reports, SISS catalogues, or other reliable information sources identify localized negative effects on fish habitat or water quality, or the potential for agricultural land use to degrade water quality, but actual impacts are not documented.

Green

◆Agricultural activity exists but information indicates that it is not degrading water quality.

Blue

◆Agricultural activity exists but it is unknown whether or not it is degrading water quality.

Rationale:

The intensity and amount of agricultural activity in a watershed reflects the extent of resulting impacts to water quality and fish habitat. Where habitat impacts were identified in information sources, a similar degree of water quality degradation was assumed. Since significant impacts to fish habitat will be accompanied by degraded water quality, red, yellow, or green ratings were applied accordingly.

Impacts on water quality were considered unlikely for streams in which agricultural activity is very low, resulting in a green ranking.

3.2.3.3 Forestry

Forest harvesting can disrupt the normal thermal regime of a stream via disruption of the natural hydrology, and through the removal of extensive amounts of riparian vegetation. Extensive harvesting often results in decreased summer low flows and increased summer water temperatures. Loss of riparian vegetation can cause increased summer and decreased winter stream temperatures, and larger diurnal fluctuations. As well, extensive logging can increase nutrient leaching and the delivery of suspended and bedload sediment to streams.

Forestry-related water quality problems were assessed based on:

1. The extent of logging activity in a watershed as a percentage of the total watershed area cut, i.e. % cut, as determined by Rood and Hamilton[3-14] (this information usually dated back to the 1960s) ; plus
2. The percentage of the total watershed area proposed for logging in MOF Five Year Plans - this area (when available) was included in the 20% (see red criteria below) as most of this logging would have occurred by now given that 5 year plans dated from 1992 - 93.[3-14]

In addition, specific mention of water quality impacts related to forest activity in the SISS catalogues, hydrology reports, or other information sources, was considered in watershed assessments.

Criteria:

Red ◆Greater than or equal to 20% total and proposed cut area in a watershed;

OR impacts to fish habitat or water quality are identified in hydrology reports, SISS catalogues, or other reliable information sources.

Yellow ◆The total and proposed cut is less than 20% but greater than 3% of the watershed area;

OR localized impacts or possible concerns about logging activity are reported in hydrology reports, SISS catalogue, or other reliable sources.

Green ◆The total and proposed cut is equal to or less than 3% of the watershed area,

OR information indicates some logging activities with no impacts to water quality or fish habitat.

Blue ◆Logging activity exists but no information was available describing the extent or level of impacts.

Rationale:

The types of water quality impacts associated with logging (e.g. sedimentation) tend to accompany disruptions to hydrology and are therefore likely proportional to the disruption of hydrology. Rood and Hamilton[3-14] indicate that when total or recent harvesting has occurred over more than 20 percent of a watershed area, management concerns for fish habitat can be expected in association with disruption of the natural watershed hydrology, which is consistent with DFO's approach taken in negotiating on Ministry of Forests land use planning initiatives.[34] This approach does not directly address the fact that some hydrologic recovery would likely have occurred in older clearcuts due to forest regeneration. However, the estimates of percent cut provided in Rood and Hamilton[3-14] may be low because they only date back to the 1960's, while logging prior to this time may still have some effects on hydrology, and hence on water quality.

Rood and Hamilton[3-14] do not identify a minimum percent of logged area for which hydrology impacts are not likely. A value of 3% was used as a lower limit for a yellow ranking because neither the hydrology reports nor SISS catalogues mention forestry-related problems along streams if the cut was under 3% of the total

Blue

watershed area.

If less than 3% of the watershed area was the subject of recent and proposed logging it was considered likely that impacts to water quality would not occur. In reality, even the smallest cuts can degrade water quality if efforts are not made to avoid damage to sensitive or erosion-prone areas.

3.2.3.4 Summer 7-day mean low flow

Low water flows influence maximum and minimum stream temperatures, as well as daily temperature fluctuations. Streams with very low flows are also more easily affected by contaminant inputs. Low flows can further affect habitat by reducing the total area of wetted habitat available to fish in a stream and by preventing fish migration.

An index based on summer 7-day low flows was used to assess the potential for low-flow conditions to negatively affect water quality. The 7-day low flows reflect naturalized (i.e. prior to water withdrawals) conditions in streams, based either on existing hydrometric data for streams with gauges or estimations for ungauged streams, as calculated by Rood and Hamilton,[3-14] and are presented as a percentage of the mean annual flow.

Criteria:

Red

◆The naturalized summer 7-day mean low flow is less than 10% of a stream's annual flow;

OR low flow problems are reported and there are no licensed withdrawals.

Yellow

◆The naturalized summer 7-day mean low flow is 10% to 30% of the stream's annual flow;

OR information indicates that low flow problems may exist, and there are no licensed withdrawals.

Green

◆The naturalized summer 7-day mean low flow is greater than 30% of the stream's annual flow;

◆No information about stream flows was available in the hydrology reports or SISS catalogues.

Rationale:

The criteria are based on studies of water flow effects on fish habitat. It is assumed that where summer low-flow conditions negatively affect fish habitat, there are accompanying water quality problems such as high stream temperatures. Tennant[31] and Orth and Leonard[32] reported that summer habitat for fish was generally poor if flows were less than 10% of annual flow. Summer flows greater than 30% of the mean annual flow for a stream usually support healthy fish habitat, assuming that other types of impacts are not present.

3.2.3.5 Water demand

A high water demand may result in low stream flows, in turn creating habitat and water quality impacts similar to those described for the previous index.

Water demand was calculated from licenses issued for consumptive uses including domestic, waterworks, irrigation and industrial withdrawals.[3-14]

- **Domestic** licenses are issued to individuals for household usage on a single property. Individuals are not obligated by law to obtain a water license, so it is likely that the licensed domestic withdrawals reported by Rood and Hamilton do not account for the actual usage by individuals.
- Licenses for **waterworks** address withdrawals which service as few as five properties, or a local authority the size of the GVRD.
- **Irrigation** licenses may be issued to individuals or to local authorities.
- Licenses issued for **industrial** purposes include, but are not limited to, the following uses: processing (sawmills, food, manufacturing); cooling; enterprise (hotels, restaurants); ponds; watering; bottling for sale; and mineral water used in swimming pools.

The potential water demand for August and September was assessed as a percentage of a stream's naturalized summer 7-day mean low water flow, or as a percentage of the naturalized mean August or September monthly flow (whichever was lowest). The *naturalized flow* value represents the natural flow regime of the stream[3-14] prior to any withdrawals. The total licensed water demand is the sum of the maximum water withdrawals for all water licenses and may not reflect the actual demand. Actual demand is unknown for all streams as most licenses do not require metering.

The impact of water demands on a stream depend partly on natural low flow conditions (see previous index criteria). The lower the natural flow in a stream the greater the impacts from water withdrawals will be on fish habitat and water quality.

Criteria:

The following table is a matrix of the naturalized summer 7-day low flow and summer water demand. The naturalized summer 7-day low flow criteria across the top of the table indicate the degree to which low flows are already a problem (see explanation in the previous index). The summer water demand, along the left side of the table, is the total licensed withdrawals for August and September expressed as a percentage of the naturalized summer 7-day mean low flow or August/September mean monthly flow.

Summer water demand (% of naturalized summer low-flow)	Naturalized summer low-flow (% of mean annual flow)		
	>30	10 to 30	<10
>40	Red	Red	Red
>15 to 40	Yellow	Red	Red
>5-15	Yellow	Yellow	Red
≤5	Green	Green	Red

Blue

◆Streams without water demand information are given a blue symbol.

Rationale:

Water withdrawal information was considered with natural summer low flow information to determine the effect of withdrawals on stream flow. If the summer low-flow is already less than 10% of the mean annual flow (see low-flow index) or water withdrawals are greater than 40% of the summer low-flow (indicating a significant alteration of the natural flow regime), then the potential for water quality to be negatively affected was considered high. Withdrawal of less than 5% of the natural summer low flow was considered to be insignificant, given the natural variation which exists in every stream. Where withdrawals amounted to between 5% and 40% of natural low flows, red or yellow ratings were assigned based on % of summer low flows remaining.

If specific problems were reported for an individual stream which did not correspond with the criteria outlined above then a worse case ranking (for example red instead of yellow) was assigned to that stream, and the information source provided.

❖❖❖

3.3 References

1 Wainwright, P., B. Humphrey, W. Drinnan and M. Foy. 1995. Review of information on the environmental occurrence of chemical contaminants and conditions of environmental degradation in the aquatic environment of the Fraser River Basin, Volume 1, Final Report. Prepared for Environment Canada and the Department of Fisheries and Oceans-Fraser River Action Plan. DOE-FRAP 95-25.

2 Westwater Research Centre. 1994. Effluent point source inventory and database for the Fraser River Basin. Prepared by Westwater Research Centre, University of British Columbia for Environment Canada, Environmental Protection, Fraser Pollution Abatement Office, Vancouver, BC. DOE-FRAP 1993-05. 14 p. + appendices.

3 Rood, K.M. and R.E. Hamilton. 1994. Hydrology and water use for salmon streams in the Fraser Delta Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2238.

4 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilcotin Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2287.

5 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilliwack/Lower Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2288.

6 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Harrison Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2293.

7 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Middle Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2292.

8 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Nechako Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2299.

9 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Pitt/Stave Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2289.

10 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Quesnel Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2296.

11 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Seton/Bridge Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2298.

12 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Thompson Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2297.

13 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Upper Fraser Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2294.

14 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the West Road Habitat Management Area, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2295.

15 Department of Fisheries and Oceans. 1989. Fish Habitat Inventory and Information Program Stream Summary Catalogue, Subdistrict # 28A Vancouver. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

16 Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 28B Squamish. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and

Oceans.

17 Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29B Surrey. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

18 Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29C Coquitlam. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

19 Department of Fisheries and Oceans. 1989. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29D Mission. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

20 Department of Fisheries and Oceans. 1990. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29E Chilliwack. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

21 Department of Fisheries and Oceans. 1992. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29F Lillooet. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

22 Department of Fisheries and Oceans. 1991. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29G Williams Lake. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

23 Department of Fisheries and Oceans. 1990. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29H Quesnel. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

24 Department of Fisheries and Oceans. 1991. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29I Prince George. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

25 Department of Fisheries and Oceans. 1992. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29J Clearwater. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

26 Department of Fisheries and Oceans. 1990. Fish habitat inventory and information program stream summary catalogue, Subdistrict # 29K Salmon Arm. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

27 Nagpal, N.K., L.W. Pommen, and L.G. Swain. 1995. Approved and working criteria for water quality, 1995. Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands and Parks, Victoria, BC. 45 p.

28 Smith, S.L, D.D. MacDonald, K.A. Keenleyside, and C.L. Gaudet. 1995. Development and implementation of Canadian sediment quality guidelines. Ecovision World Monograph Series (in press).

29 Haines, M.L., K. Brydges, M.J. MacDonald, S.L. Smith, and D.D. MacDonald. 1994. A review of environmental quality criteria and guidelines for priority substances in the Fraser River Basin, Supporting Documentation. Prepared by MacDonald Environmental Sciences Limited for Environment Canada-Fraser River Action Plan, DOE FRAP 1994-31. 222 p.

30 FREMP. 1996. Environmental quality of the Fraser River Estuary. Fraser River Estuary Management Program, Vancouver, B.C. 164 p.

31 Tennant, D.L. 1976. Instream flow regimens for fish,

wildlife, recreation and related environmental resource. Fisheries. 1:6-10.

32 Orth, D.J. and P.M. Leonard. 1990. Comparison of discharge methods and habitat optimization for recommending instream flows to protect fish habitat. Regulated Rivers. 5:129-138.

33 Canadian Council of Resource and Environment Ministers (CCREM). 1987. Canadian Water Quality Guidelines Chapter 3 (Freshwater Aquatic Life). p. 3.1 - 3.54.

34 M. Romaine, Fisheries and Oceans Canada, Vancouver, B.C., personal communication.

35 Fyles, T.M., B. King and P.R. West. 1993. Continental and Oceanographic Data Information System CODIS version 1.0. Protocols, software, compilation and appraisal of meta-data of organic contaminants in the Fraser River Basin. Prepared for Environment Canada, Environmental Conservation Directorate. DOE-FRAP 1993-24.

36 Clark, Malcolm, J.R. 1994. A Preliminary Review of the Long Term Robustness of a Number of Water Quality Variables. QA Workshop, Nov. 2-3, 1994, White Rock, B.C.

Chapter 4 Seton-Bridge Habitat Management Area

4.1 Background

The 6,600 km^2 Seton-Bridge HMA extends from the crest of the Coast Mountains eastward to the Fraser River. It contains two major river systems, the Seton and Bridge River watersheds, which are largely regulated by dams and contain large lake impoundments.

4.1.1 Hydrology

The hydrology of the Seton-Bridge HMA is dominated by natural climatic conditions and the presence of dams operated by B.C. Hydro on both the Seton and Bridge systems.

There is considerable variation in climate from west to east within the HMA. The Coast Mountains to the west experience a high annual precipitation level of about 2,000 mm. This contributes to significant winter snowpacks, which help to maintain summer stream flows into the reservoirs.[1] The upper Bridge system drains an area of extensive ice fields, including the Bridge Glacier. Annual precipitation decreases moving eastward across the HMA, and is only about 300 to 400 mm in the town of Lillooet,[1] located at the confluence of the Seton and Fraser Rivers. Snowmelt is the main source of natural summer stream flows in eastern areas of the HMA.

B.C. Hydro operates two large dams in the Bridge system and one in the Seton system. A hydroelectric generating station is located at the Lajoie Dam in the upper Bridge River area. Further downstream, the Terzaghi Dam controls the outlet of Carpenter Lake and essentially eliminates flows into the lower Bridge River. Water is diverted from Carpenter Lake via two tunnels to a generating station at Shalath, and into Seton Lake. Water in Seton Lake either flows over the dam or passes through the Seton Generating Facility and into the Fraser River.[1] Storage in Seton Lake is limited, and floods on the Gates and Portage Rivers result in spill over the dam and into the Seton River.[1]

Spills from the Terzaghi and Seton Dams have caused damage to salmon spawning habitat downstream. B.C. Hydro has been charged with two counts of harming fish and fish habitat through operation of the dams.[2]

The Walden Power Partnership Dam on Cayoosh Creek, located 1.6 km upstream from the confluence with the Seton River, seasonally diverts water to the Seton Dam fishway.

4.1.2 Fish

There are seven salmon bearing streams in the Seton-Bridge HMA.[1] Coho, chinook, sockeye, and pink salmon spawn and rear in the HMA. Very large runs of pink salmon return to Cayoosh Creek and the Bridge and Seton River systems.[3]

90 km of salmon habitat was destroyed when the Terzaghi Dam was constructed in 1948 and subsequently raised in 1960, flooding a huge portion of the Bridge River watershed.[3] The Terzaghi Dam and low flow conditions downstream are barriers to migrating anadromous salmon. The Seton hydroelectric generating facilities cause significant mortality of adult pink and sockeye salmon.

Other fish species present in the HMA include the anadromous steelhead trout, and resident kokanee, rainbow trout, Dolly Varden, and mountain whitefish.[3]

4.1.3 Predominant Land Uses

Land uses within the HMA include some logging, agriculture, hard rock and placer mining, although all activities are much less intensive than in many other Fraser Basin HMAs. A former gold mine is located at Bralorne, slightly south of the Bridge River. This mine may be re-opened in the future.[4] Mineral exploration is prevalent throughout the Gold Bridge and Bralorne area. Manufacturing and processing industries are almost absent from the HMA.

Recreational opportunities such as hiking, back country skiing and horseback riding draw many visitors to the area. A proposal to develop a ski resort near Melvin Creek, a tributary to Cayoosh Creek, has been put forward. This proposed resort would provide a total of 16,800 beds and would greatly increase the level of human activity in the area.

❖❖❖

4.2 Point Sources of Contaminants

Two STPs within the Bridge-Seton HMA are permitted to discharge wastes to surface waters (Table 4.2.1). There are no other permitted waste discharges to surface waters in the HMA.

4.2.1 Urban/Industrial Point Source Discharges to Surface Water

There are two permitted discharges of STP effluent to surface water in the Seton-Bridge HMA (Table 4.2.1, Figure 4.6.1), both of which are small (123 and 1000 $m^3 \cdot d^{-1}$). BOD and nonfilterable residue discharges are minor (Tables 4.2.2 a & b). The Lillooet STP is the largest single source of effluent generated within the HMA, and it discharges to the Fraser mainstem, outside of the HMA.

Drainage from the old Bralorne gold mine adit enters Cadwallader Creek, a tributary in the Bridge River watershed. The mine closed down in 1971 without ever having a Waste Management Permit. It may re-open in the future if economic conditions become more favourable. Plans developed to re-open the mine indicate that the drainage water could be collected and used in the milling process.[5]

There may be additional discharges to surface waters from federal lands, such as Indian Reserves, which usually do not have provincial Waste Management Permits.

4.2.2 Permitted Discharges to Ground

Provincial Waste Management Permits address several discharges to ground, including effluent from three STPs, and landfills associated with small towns such as Gold Bridge, Shalath, and Lillooet. No information was available about the potential for these discharges to impact surface water quality.

❖❖❖

4.3 Non-Point Sources of Contaminants

The potential for diffuse, non-point sources of contaminants to adversely affect water quality in the Seton-Bridge HMA is related to the intensity and extent of land uses. The primary land use is timber harvesting, with some ranching, and a few placer mining operations.

4.3.1 Urban Development

Of the 4,000 people who live in the Seton-Bridge HMA, over half live in the community of Lillooet on the banks of the Fraser River. Ionson[2] did not identify the need for any habitat enforcement actions as a result of urban development. However, there may be localized problems associated with land clearing and seepage from private septic systems affecting surface water quality.

4.3.2 Agriculture

There is very little agricultural activity in the HMA compared with other areas of the Fraser Basin, due to the mountainous nature of the terrain. Ionson[2] did not identify any agricultural issues requiring enforcement actions under the *Fisheries Act*.

4.3.3 Timber Harvesting

Logging occurs throughout the HMA and is intensive in some areas. Poor road building practices and inadequate cleanup of debris are problems on the Yalakom and Bridge Rivers.[2] Poor logging practices also cause increased sedimentation in Portage Creek.[2] Logging along Cayoosh Creek has been particularly intensive, and most of the side valleys have experienced significant logging pressure.

There are licensed water withdrawals on many of the small tributaries to the Bridge River and some licensees have complained that logging has affected stream flows, although watersheds in the HMA have experienced relatively low levels of harvest compared with elsewhere in the Fraser Basin.[1]

4.3.4 Mining

Placer mining occurs mainly along the Bridge and Fraser Rivers, and Churn Creek. Placer and gravel removal operations are often located in remote areas, making monitoring difficult. Most of these operations are far enough upstream of salmon habitat that little or no damage to fish-bearing areas is expected,[2] however sediment release and damage to riparian areas are potential problems.

❖❖❖

4.4 Factors Modifying Contaminant Behavior

Large lakes and reservoirs in the Bridge and Seton systems act as settling ponds, and also moderate peak and low flows. The Terzaghi Dam at the east end of Carpenter Lake greatly reduces flows to the Bridge River, and consequently the river channel has been narrowed by sediment deposition and establishment of riparian vegetation.

❖❖❖

4.5 General Water Quality Conditions

Water chemistry in the Bridge River is strongly influenced by a volcanic eruption which occurred about 2,000 years ago. Large quantities of volcanic ash from this eruption now form a significant portion of the soils in the sub-basin, and may be a source of the high sulphate concentrations which are characteristic of the river water. Calcium and magnesium silicates are prevalent in bedrock materials in the watershed, and likely account for the concentrations of silicon dioxide and calcium which are notably high compared with other Fraser River tributaries.[6]

❖❖❖

4.6 Measured Water Quality Conditions and Stream Assessments

This section provides an overview of measured water quality conditions, land uses, and stream flow issues on a stream-by-stream basis for each salmon-bearing watershed in the Seton-Bridge HMA. Site-specific water quality assessments, and influencing factors and supporting data (Table 4.6.1) are provided in Section 4.6 on a stream-by-stream basis. Evaluations of water quality conditions based on available data are presented in Figure 4.6.1.

Summary tables of:

- land use areas, stream flow, and water demand information for each salmon stream (Table 4.6.2)
- identified impacts for each salmon stream (Table 4.6.3)

are provided for quick reference.

All assessments of impacts from urban development, agriculture, forestry, low stream flows, and water withdrawals were based upon information provided in a series of hydrology reports which were prepared by Rood and Hamilton,[1] and/or SISS catalogues[3] unless otherwise indicated. Assessment criteria are explained in the Methodology section of this report.

Fraser River at Lillooet

◆Fish tissue samples were collected prior to 1991. One of ten measurements had a 2,3,7,8-T_4CDD value that exceeded the guideline establish for the protection of human health. Due to process changes and improvements to effluent treatment systems at pulp mills located at Prince George and Quesnel body burdens of these contaminants have likely declined.

❖❖❖

Seton River (00-1800-000-000-000-000-992)

◆The Town of Lillooet relies on the Seton River for its domestic water supply, and may wish to increase withdrawals in the future.[1] No further information was available regarding potential impacts of urban development on the Seton River.

◆Irrigation licenses suggest that some agricultural activity may be present in the watershed. There was not enough information to assess the implications for water quality.

◆6% of the total watershed has been logged, including 3% which has been recently harvested ('83-'92). Another 1% of the watershed area was proposed for harvesting before 1998.[1]

◆The naturalized summer 7-day average low flow is 45% of the mean annual flow. (Regulated releases have been treated as natural flows and adjusted by adding water extractions. Naturalized flows were calculated from releases between 1981 and 1990).[1]

◆The potential August water demand for domestic, irrigation, waterworks and industrial uses is 3% of the naturalized summer 7-day average low flow, calculated as described above.

◆**Other:** B.C. Hydro operates a large dam at the outlet of Seton Lake with a fishway that allows fish access to spawning areas upstream.[3] Habitat downstream of the dam is affected by wide fluctuations in flows, temperature and turbidity, resulting from highly variable water releases from the dam. Occasional large releases from the dam have caused scouring of spawning gravel and a build up of sediment near the confluence of Seton and Fraser Rivers.

The Ainsworth mill on the north side of the Seton River (near the Fraser confluence) deposits silty runoff and debris into the river. The facility also has a water intake which has experienced aggradation problems.[7]

❖❖❖

Cayoosh Creek (00-1800-050)

◆Irrigation licenses suggest that there is some agricultural activity in the watershed. The level of activity is likely very low.

◆9% of the total watershed has been logged, including 5% which has been recently harvested. An additional 2% of the watershed area was proposed for harvesting prior to 1998. Logging in several tributaries has been intensive, and has resulted in sedimentation problems and disruption of the natural hydrology.[1] Site-specific impacts including slope failures, increased siltation, and disruption of hydrology have been noted in Gott, Blowdown, and Downton Creeks.[7]

◆The naturalized summer 7-day average low flow is 6% of the mean annual flow.

◆The potential August water demand is <1% of the naturalized summer 7-day average low flow for domestic and irrigation use.

◆**Other:** Water from Cayoosh Creek is diverted to the Seton River spawning channel each year during the sockeye migration to provide adequate flows.[3] A small powerhouse located immediately upstream of the diversion tunnel to the Seton system was causing erosion. Work was completed to reduce erosion and improve downstream flows in Cayoosh Creek.[1]

A proposed placer mine would divert flows from the main creek, drying up about 1 km of streambed.[1] DFO is opposed to this application.[7]

There are six recreation sites located along the Duffey Lake Road between Duffey Lake and Cinnamon Creek and recreational activity is increasing in the Cayoosh Creek watershed.

❖❖❖

Portage River (00-1800-000-000-000-000-991)

◆The town of Seton Portage is located adjacent to the river. Summer cabins are located around Anderson and Seton Lakes. Foreshore development has occurred in sockeye spawning habitat near tributary mouths, and development of private land has damaged riparian vegetation along the mainstem. Four Indian Reserves are located near the Portage River.[7]

◆Irrigation licenses suggest that there is some agricultural activity in the watershed. Not enough information was available to assess potential effects on water quality.

◆3% of the total watershed has been logged, including 2% which was recently harvested ('83 - '92). No additional logging was proposed prior to 1998. Logging has been concentrated in tributary watersheds including Whitecap and McGillvary Creeks, where slides and channel stability problems are noted.[7] Poor logging practices have been noted to cause increased suspended sediment levels in the watershed.[2]

◆The naturalized summer 7-day average low flow is 34% of mean annual flow.[1]

◆The potential August water demand for domestic, irrigation, waterworks and industrial uses is 3% of the naturalized summer 7-day average low flow.[1]

◆**Other:** Major slides in the Whitecap Creek tributary have created a fan of coarse material which extends into Portage Creek, narrowing the channel and causing failure of a revetment opposite the mouth of Whitecap Creek.[1]

Upstream of the River, a mainline forestry road and power lines parallel the north shore of Anderson Lake. Associated problems include sidecasting of ditch materials, rock slides which deposit tracks and ties into the lake, and numerous culverted stream crossings which restrict fish access to tributaries.[7]

❖❖❖

Whitecap Creek (no SISS #)

◆No information was available to assess urban development.

◆No information was available to assess agricultural activity.

◆8% of the total watershed has been logged, including 5% which was recently harvested ('82 - '93). DFO is concerned that logging in the watershed is causing sedimentation which degrades Whitecap Creek and the Portage River.[1] Cross-stream skidding has degraded riparian habitat.[7]

◆No information was available to assess stream flow.

◆No information was available to assess water demand.

◆**Other:** B.C. Rail has diverted Whitecap Creek, causing bank erosion at Portage Bend.[1]

❖❖❖

Gates River (00-1800-650)

◆The community of D'Arcy and five Indian Reserves are located adjacent to the river. Development of private land has resulted in channelization and loss of rearing habitat, and accompanying impacts to water quality are likely.

◆Agriculture is extensive in the floodplain area, and small farms are concentrated along the Gates River mainstem. Barns and grazing cattle encroach on fish habitat and cause siltation. Riparian areas have been riprapped. Wetland complexes have been drained.[7]

◆2% of the total watershed has been recently logged ('82 - '93), and another 1% was proposed for harvesting prior to 1998. Harvesting has been concentrated in tributary watersheds. Halymore and Blackwater Creeks are tributaries which have experienced significant timber removal, and hydrologic impacts are suspected.[7]

◆The naturalized summer 7-day average low flow is 40% of mean annual flow.[1]

◆The potential August water demand for domestic, irrigation, waterworks and industrial uses is 4% of the naturalized summer 7-day average low flow.[1]

◆**Other:** Considerable bedload movement is reported.[1] Landowners have been repairing damage to stream banks and removing log jams in the river caused by several years of above average floods.

Highway 99 and B.C. Rail run parallel to the river. In some places the channel has been riprapped and the railway confines the river, reducing riparian vegetation. Ditch maintenance practices cause some problems.[7]

Historical logging and sawmilling damaged spawning substrates.[5]

❖❖❖

Bridge River (00-1900)

◆The community of Yalakom (population estimated at 200-300) is located at the confluence of the Yalakom and Bridge Rivers. A Native Reserve is located downstream of the confluence on the south bank of the Bridge River. Not enough information was available to assess the potential for effects on water quality.

◆Irrigation licenses suggest that there is some agricultural activity in the watershed.[1] There was not enough information to assess the effect it may have on water quality.

◆6% of the total watershed has been logged, including 4% which was recently harvested ('82 - '93). An additional 2% of the watershed area was proposed for harvesting prior to 1998. Sidecasting off steep roads is noted to have caused riparian damage and siltation. Endhauling should be enforced.[7] Problems with poor road building practices and inadequate clean-up of debris have been noted.[2]

◆The naturalized summer 7-day average low flow is 53% of mean annual flow (calculated from regulated releases between 1981 and 1990), however, the river is often dewatered for 3 km downstream from the Terzaghi Dam.

◆The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 9% of the naturalized (regulated) summer 7-day average low flow. Upstream from the confluence with the Yalakom River, flows in the Bridge River are maintained by springs and small tributaries only. Water withdrawals for irrigation removes a significant proportion of summer low flows from the lower Bridge River.[1]

◆**Other:** B.C. Hydro operates the Terzaghi Dam at the outlet of Carpenter Lake, which diverts water into Seton Lake and essentially eliminates flows into the lower Bridge River. Large water releases from the dam have eroded riparian vegetation and spawning gravels, and deposited sediment further downstream. B.C. Hydro is examining opportunities to better manage flood spills and to release a guaranteed flow to improve fish habitat below the dam.

Two or three placer mines operate along the river. The Hurley River mining development has impaired water quality and damaged riparian habitat.[7] Sidecasting of scree and ditch debris along the highway to Gold Bridge causes problems, and extensive use of CaCl on the road is killing riparian vegetation.[7]

Recreation values are high, with 22 recreation sites and numerous hiking trails in tributary watersheds drawing visitors to the area.[7]

❖❖❖

Yalakom River (00-1900-150)

◆Of the one to three measurements reported for pH, nonfilterable residue, dissolved ammonia,total phosphorus, arsenic and lead, only one each of the ammonia and phosphorus values exceeded the 80th percentile.

◆No information was available to assess urban development.

◆Irrigation licenses suggest that there is some agricultural activity in the watershed. There was not enough information to assess the effect it may have on water quality.

◆6% of the total watershed has been logged including 2% which was recently harvested (‘82 - ‘93). An additional 5% was proposed for harvesting prior to 1998. Problems with poor road building practices and inadequate clean up of debris have been noted.[2]

◆The naturalized summer 7-day average low flow is 53% of mean annual flow.[1] Flows are consistent throughout much of the summer.

◆The potential August water demand for domestic and irrigation uses is 2% of the naturalized summer 7-day average low flow.[1]

◆**Other:** There has been some placer mining activity since 1960 but no significant conflicts have been reported.

❖❖❖

4.7 References

1 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Seton/Bridge Habitat Management Area, British Columbia. Manuscr. Rep. Fish. Aquat. Sci. 2298.

2 Ionson, B. 1995. Habitat enforcement report for the Fraser River: A report outlining chronic habitat concerns in the Fraser River Basin and recommendations to achieve compliance. Department of Fisheries and Oceans, Fraser River Action Plan, Vancouver, B.C. 56 p. + appendices.

3 Department of Fisheries and Oceans. 1992. Fish Habitat Inventory and Information Program stream summary catalogue, Subdistrict # 29F Lillooet. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

4 Mehling, P. 1995. Review article for status of water quality issues pertaining to mining and gravel removal in the Fraser Basin. Prepared for Department of Fisheries and Oceans Fraser River Action Plan. 33 p.

5 B. Grace, B.C. Ministry of Environment, Lands and Parks, Kamloops, personal communication.

6 Hall, K, H. Schreier, and S.J. Brown. 1991. Water quality in the Fraser River Basin. *In:* Dorcey, A.H.J. and J.R. Griggs (eds.) 1991. Water in sustainable development: Exploring our common future in the Fraser River Basin. Westwater Research Institute, University of British Columbia, Vancouver, B.C.

7 Komori, V. 1997. Salmon watershed planning profiles for the Bridge/Seton Habitat Management Area. Fraser River Action Plan, Department of Fisheries and Oceans, Vancouver, B.C. 44 p. + maps.

Table 4.2.1 Summary of Permitted Discharges to Surface Water in the Seton-Bridge HMA.

Record Id	Facility	Waste Type	Waste Num	Maximum Flow	Receiving Water Body
P00092*	LILLOOET	STP	01	1000 $m^3 \cdot d^{-1}$	FRASER RIVER
P03157	BRALORNE STP	STP	01	61.5 $m^3 \cdot d^{-1}$	CADWALLADER CREEK
P03157	BRALORNE STP	STP	02	61.5 $m^3 \cdot d^{-1}$	CADWALLADER CREEK

*Permitted discharge limits for BOD and NFR are both 130 $mg \cdot L^{-1}$, far in excess of limits which can be achieved with standard effluent treatment technology.

Chapter 5 Chilcotin Habitat Management Area

5.1 Background

The Chilcotin HMA encompasses the entire Chilcotin River watershed, which is about 19,300 km^2 in area. The headwaters of the Chilcotin River are located west of the Fraser River in the Coast Mountains. Numerous tributaries draining the Chilcotin Plateau also contribute to mainstem flows.

5.1.1 Hydrology

The hydrology of streams in the Chilcotin HMA is determined by natural climatic conditions, which vary widely in the HMA.[1] The Chilcotin Plateau experiences a normal annual precipitation of 350 to 450 mm, while annual precipitation in the Coast Mountains likely exceeds 1000 mm.[1] Snow accumulation in the Coast Mountains results in peak flows in early summer. Glacier melt and attenuation by the numerous lakes in the HMA contribute to stable summer stream discharges. Smaller tributaries which begin near the Fraser mainstem are more reliant upon groundwater inputs and precipitation to support flows, and may experience extreme low flows in late summer.

5.1.2 Fish

Sockeye and chinook salmon, and steelhead trout are the most prevalent species of anadromous salmonids in the Chilcotin HMA, however, small numbers of coho also spawn here. Some pink salmon migrate up the Fraser River past the confluence of the Chilcotin River, but no pinks have been recorded in the Chilcotin watershed. The Chilcotin River is primarily a migration corridor for coho, chinook and sockeye salmon, and a rearing area for juvenile chinook.[2] The Chilko Lake sockeye stock is one of the largest in the Fraser Basin.[3] Other species found in the HMA include the anadromous steelhead trout and the resident Dolly Varden, rainbow trout, mountain whitefish, dace, suckers, chubs and lamprey.

5.1.3 Predominant Land Uses

There is significant logging and agricultural activity (mostly ranching/range land) ongoing in the HMA. The future may bring increases in logging activity, while urban development and agriculture are unlikely to grow significantly in the foreseeable future.[1]

❖❖❖

5.2 Point Sources of Contaminants

There is only one relatively small permitted waste discharge to surface water in the Chilcotin HMA, which is from a sewage treatment plant.

5.2.1 Urban/Industrial Point Source Discharges to Surface Water

The only permitted waste discharge in the HMA addresses effluent from a small sewage treatment plant which services an Indian Reserve and discharges to the Chilcotin River (Table 5.2.1). The STP is permitted to discharge 6,000 $kg \cdot yr^{-1}$ each of BOD and nonfilterable residues (Table 5.2.2 a & b). The location of the discharge is shown in Figure 5.5.1. There may be additional discharges to surface waters from federal lands, such as Indian Reserves, which usually do not have provincial Waste Management permits.

5.2.2 Permitted Discharges to Ground

There is only one permitted discharge to ground in the Chilcotin HMA; a STP at Alexis Creek discharges a minor amount of effluent.[10]

❖❖❖

5.3 Non-Point Sources of Contaminants

Various land uses can generate diffuse, non-point sources of contaminants which can degrade water quality in some salmon-bearing streams of the Chilcotin HMA. In general, due to the relatively low population and level of human activity, the threat of non-point source pollution is low in this HMA compared with other areas of the Fraser Basin.

5.3.1 Urban Development

The Chilcotin HMA is sparsely populated. Less than 2,500 people live in the HMA, generally in small settlements which are scattered throughout the area. There are numerous recreational properties in the Chilcotin and Chilko River watersheds.[4] Major problems associated with urban development have not been identified,[5] but land clearing, loss of riparian vegetation, and seepage from private septic systems may cause localized impacts to salmon bearing streams.[4]

5.3.2 Agriculture

Cattle grazing, winter feeding, forage production and feedlots in the area raise few concerns for water quality compared with similar activities in other HMAs.[5] This is in part due to a lower intensity of activities. Localized impacts to riparian areas in some of the smaller tributaries of the HMA have been noted.[4]

5.3.3 Timber Harvesting

Logging in the Chilcotin HMA began in the mid-1960's, however, a majority of the harvesting has occurred since about 1982.[1] The total cut in the salmon-bearing watersheds is generally less than 4% of the total watershed areas. Because the terrain is relatively flat, most operations are located away from salmon-bearing streams,[5] and there is little evidence of sedimentation or alteration of hydrology due to forest harvesting along the larger streams.[4] Large areas of lodge pole pine have been logged to control a pine beetle infestation and more is expected.[4]

5.3.4 *Mining*

Placer mining in the Chilcotin area has produced more than 2.5 million ounces of gold since the 1860's, which is more than any other placer area in B.C.[6] Placer operations in the area today are rarely monitored. Significant problems were occurring in 1990, and resulted in charges under the *Fisheries Act*.[11] Sediment release, water withdrawals, and damage to riparian areas are all potential problems and have been documented in the past.

❖❖❖

5.4 An Overview of Water Quality Conditions

Very little water sampling has been conducted in the Chilcotin HMA, likely a reflection of the relatively low level of human activity in the area. Streams draining from glaciers of the Coast Mountains tend to be cold and high in suspended sediment levels, though downstream lakes often provide significant settling. In general, nutrient (ammonia and phosphorus) concentrations tend to be low in the streams studied, while phosphorus tends to be slightly elevated in some of the lakes. Elevated phosphorus levels in this area are often associated with suspended glacial flours, and most of the phosphorus is not biologically available.

The Cariboo-Chilcotin plateau area contains many small pothole lakes, with no surface outlets. These lakes are very alkaline, and have high dissolved solids concentrations. They contain hard water and are eutrophic or hyper-eutrophic.[7] While these lakes do not contribute directly to salmon production, they provide ideal nesting habitat for waterfowl.

Buffer capacity tends to be moderate to high in lakes in the upper Chilcotin area, and is lower in the Chilko and Taseko sub-basins.[8]

Site-specific water quality assessments, and influencing factors and supporting data (Table 5.4.1) are provided in Section 5.5 on a stream-by-stream basis.

❖❖❖

5.5 Measured Water Quality Conditions and Stream Assessments

This section provides an overview of measured water quality conditions, land uses, and stream flow issues on a stream-by-stream basis for each salmon-bearing watershed in the Chilcotin HMA.

Summary tables of:

- land use areas, stream flow, and water demand information for each salmon stream (Table 5.5.1)
- identified impacts for each salmon stream (Table 5.5.2)

are provided for quick reference.

All assessments of impacts from urban development, agriculture, forestry, low stream flows, and water withdrawals were based upon information provided in a series of hydrology reports prepared by Rood and Hamilton,[1] and/or in SISS catalogues[2] unless otherwise indicated. Assessment criteria are explained in the Methodology section of this report.

❖❖❖

Chilcotin River (05-0000)

◆Between one and five measurements were reported for various parameters at two stations. All of the pH, nonfilterable residue, dissolved ammonia, total phosphorus, and coliform values were below guidelines or 80th percentile levels.

◆There is some sparse residential development.

◆There is some agricultural activity, primarily ranching, throughout the watershed. Riparian vegetation has been removed from localized areas downstream from Chilcotin Lake.[4] Lack of screens on irrigation ditches may result in fish being trapped.[2] Localized bank instability has been noted in association with cattle access.[4]

◆3% of the total watershed has been recently logged ('82 - '92), and an additional 2% was proposed for harvesting prior to 1997.[1]

◆The naturalized summer 7-day mean low flow is 43% of the mean annual flow. Lakes stabilize the flow regime.[1]

◆The potential August and September water demand for domestic, irrigation, waterworks and industrial uses is 11% of the naturalized summer 7-day mean low flow.[1] Storage accounts for 18% of the total irrigation demand.[1]

◆**Other:** High summer flows in the mainstem are maintained by glacial and snowpack melt. Low summer flows have been reported in some tributaries such as Alexis Creek.[1] The Taseko River is the main source of glacial flour which causes the characteristic high turbidity of the Chilcotin River.[2] Historic placer mining occurred in the Chilcotin area.

The Chilcotin River was illegally diverted in 1975 so that it enters Chilcotin Lake much nearer the lake outlet. This reduces circulation in the lake and has caused concerns about increased weed growth in the lake.[1] DFO has agreed to study the options available for addressing concerns.[4]

❖❖❖

Upper Chilcotin River, above Chilcotin Lake (no SISS #)

◆Water licenses indicate that some development is present but no problems have been reported. Development is sparse.

◆ Some ranching is present but there was not enough information to assess the implications for water quality. Irrigation withdrawals may consume up to 30% of the summer 7-day mean low flow.[1]

◆4% of the total watershed has been recently logged ('82-'92), and an additional 3% was proposed for harvesting by 1998.[1]

◆The naturalized summer 7-day mean low flow is 28% of the mean annual flow.[1]

◆The potential August and September water demand for domestic, irrigation, waterworks and industrial use is 27% of the naturalized summer 7-day mean low flow.[1] DFO should resist further licensing until actual water use is quantified and management options are reviewed.[1]

❖❖❖

Fletcher Lake

◆Results are reported for one sample. The dissolved ammonia value was above the 80th percentile but did not exceed the 30-day criteria for total ammonia. The total phosphorus value exceeded the guideline established to protect lakes containing anadromous salmon.

❖❖❖

Beaver Lake

◆Results are reported for one sample only. Total phosphorus is almost ten times greater than the guideline.

❖❖❖

Alexis Lake

◆The result for one sample is reported. The total phosphorus value exceeded the guideline.

❖❖❖

Chilko River (05-3835)

◆Data from only one sample was reported. None of the measured parameters, pH, dissolved ammonia and total phosphorus, exceeded the guidelines or 80th percentiles.

◆**Other Water Quality Data**: Continuous temperature data near the mouth of Chilko Lake from 1986 to 1994 show that maximum stream water temperatures can exceed 15°C in July and August.[9]

◆Recreational properties may impact the area about 7 - 8 km downstream from Chilko Lake.[4]

◆Ranching activity, including grazing on open range and some feedlots, is present.[4] There was not enough information to assess the extent or intensity of activity.

◆1% of the total watershed has been recently logged ('82 - '92), and an additional 2.5% was proposed for harvesting prior to 1997.[1]

◆The naturalized summer 7-day mean low flow is 33% of the mean annual flow.[1] This is a lake-fed system with relatively stable flows.

◆The potential August demand for domestic, irrigation, waterworks and industrial uses is 1% of the naturalized summer 7-day mean low flow.

◆**Other:** A provincial park has been established on Chilko Lake. There is a development corridor plan for the river from Brittany Creek to Chilko Lake that would control development.[4]

Chilko Lake is nutrient poor and there has been some experimentation with lake fertilization to increase fish production.[8]

❖❖❖

Taseko River (05-3835-115)

◆Ranching activity, primarily summer ranging, is present.[4] There was not enough information to assess its effect on water quality.

◆2% of the total watershed has been recently logged, and an additional 3% was proposed for harvesting prior to 1997.

◆The naturalized summer 7-day mean low flow is 31% of the mean annual flow.[1] Strong freshets are reported.[2]

◆The potential August water demand for domestic, irrigation and industrial uses is 1% of the naturalized summer 7-day mean low flow.[1]

◆**Other:** The river carries a heavy load of glacial silt.

Development of a controversial gold mine at Fish Lake in the Taseko watershed has been proposed. Several creeks, and the Taseko River itself, could all potentially be affected by the project. The mine development proposal is currently being reviewed under the harmonized *B.C. Environmental Assessment Act* and *Canadian Environmental Assessment Act* project review process.

❖❖❖

Elkin Creek (05-3835-115-290)

◆The primary agricultural activity is ranching, with considerable summer range use. There has been localized damage to riparian vegetation[4] and irrigation withdrawals consume up to 40% of the summer low flow.[1]

◆2% of the watershed is proposed for harvest.[1]

◆The naturalized summer 7-day mean low flow is 12% of the mean annual flow. Low flow problems upstream of Elkin Lake are reported.[1]

◆The potential August and September water demand is 41% of the naturalized summer 7-day mean low flow for domestic, irrigation, and industrial uses. Further licensing should be opposed until actual water use is established and management options reviewed.[1]

◆**Other:** Elkin Creek upstream of Elkin Lake is unstable and actively transports large bedloads.[1] Several kilometres of the creek above Nemimiah Valley Road have been channelized.

❖❖❖

Eagle Lake

◆Two measurements were reported for pH, dissolved ammonia, and total phosphorus. One ammonia measurement exceeded the 80th percentile level but not the 30-day criteria for total ammonia.

❖❖❖

Puntzi Lake

◆One sample was reported for each of two stations. Both the total phosphorus and the dissolved ammonia values exceeded the guideline or 80th percentile. The ammonia did not exceed the 30-day criteria for total ammonia.

There is some cabin development and agricultural activity around the lake.[11]

❖❖❖

5.6 References

1 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the Chilcotin Habitat Management Area, British Columbia. Manuscr. Rep. Fish. Aquat. Sci. 2287. 47 p. + appendices.

2 Department of Fisheries and Oceans. 1991. Fish Habitat Inventory and Information Program stream summary catalogue, Subdistrict # 29G Williams Lake. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

3 Department of Fisheries and Oceans. 1995. Fraser River sockeye salmon. Prep. by Fraser River Action Plan, Fishery Management Group. Vancouver, B.C. 55 p.

4 Rowland, D.E. and L.B. MacDonald. 1996. Salmon watershed planning profiles for the Fraser River Basin within the Cariboo-Chilcotin Land Use Plan (CCLUP) Area. Fraser River Action Plan, Vancouver, B.C., and Habitat Management Unit, Prince George, B.C., Department of Fisheries and Oceans. 375 p. + maps.

5 Ionson, B. 1995. Habitat enforcement report for the Fraser River: A report outlining chronic habitat concerns in the Fraser River Basin and recommendations to achieve compliance. Department of Fisheries and Oceans, Fraser River Action Plan, Vancouver, B.C. 56 p. + appendices.

6 Levson et al. 1990. *Cited in*: Dorcey, A.H.J. and J.R. Griggs, eds. 1991. Water in sustainable development: Exploring our common future in the Fraser River Basin. Westwater Research Institute, University of British Columbia, Vancouver, B.C. 288 p.

7 Boyd, W.S. and J-P.L. Savard. 1987. Abiotic and biotic characteristics of wetlands at Riske Creek, British Columbia - A data report. Tech. Report Series No. 16, Canadian Wildlife Service, Pacific and Yukon Region, B.C. *Cited in*: Dorcey, A.H.J. and J.R. Griggs, eds. 1991. Water in sustainable development: Exploring our common future in the Fraser River Basin. Westwater Research Institute, University of British Columbia, Vancouver, B.C. 288 p.

8 Hall, K.J., H. Schreier, and S.J. Brown. 1991. Water Quality in the Fraser River Basin. *In*: Dorcey, A.H.J. and J.R. Griggs, eds. 1991. Water in sustainable development: Exploring our common future in the Fraser River Basin. Westwater Research Institute, University of British Columbia, Vancouver, B.C. 288 p.

9 Department of Fisheries and Oceans, unpublished data. T. Whitehouse, Vancouver, B.C.

10 Fraser River Point Source Inventory Database, Environment Canada, 1995, Version 3.02 (May 23, 1995).

11 Otto Langer, Department of Fisheries and Oceans, Vancouver, B.C., personal communication.

Table 5.2.1 Summary of Permitted Discharges to Surface Water in the Chilcotin HMA

Record Id	Facility	Waste Type	Waste Num	Maximum Flow	Receiving Water Body
P07648	STONE INDIAN BAND RESERVE #1 STP, HANCEVILLE	STP	01	55 $m^3 \cdot d^{-1}$	CHILCOTIN RIVER
P07648	STONE INDIAN BAND RESERVE #1 STP, HANCEVILLE	STP	02	110 $m^3 \cdot d^{-1}$	CHILCOTIN RIVER

Chapter 6 West Road Habitat Management Area

6.1 Background

The West Road HMA encompasses about 12,800 km^2, or 6%, of the Fraser River Basin and includes the entire West Road River watershed. The West Road River originates in the Nechako Plateau and flows eastward through the Chilcotin Plateau. The river is joined by several large tributaries including the Nazko River prior to its confluence with the Fraser River, between Quesnel and Prince George.

6.1.1 Hydrology

Flows are highest in early summer, in response to snow-melt or rain on melting snow. Sometimes peak flows are delayed until July, reflecting snow pack conditions and showmelt.[3] Lakes and wetlands help to maintain flows into late summer in some tributaries, when there is little precipitation. On the Chilcotin Plateau, flows slowly decline through the summer months following freshet.

6.1.2 Fish

The West Road HMA provides spawning and rearing habitat for sockeye and chinook salmon. Large numbers of chinook are produced here, while sockeye are mostly limited to the Euchiniko River.[1] A total of five salmon bearing streams have been documented in the West Road HMA.[2]

In addition to anadromous species, the West Road River supports an important rainbow trout sport fishery, and contains a variety of other species including Dolly Varden, lake trout, kokanee salmon, and burbot.

6.1.3 Predominant Land Uses

The West Road HMA has relatively little activity occurring in it, compared to HMAs to the north and east. The area is sparsely populated and supports little, if any, manufacturing or processing industrial activity. Mining exploration is scattered throughout the HMA. Forestry is the main sector, and timber harvesting pressure is likely to increase as more accessible sources are depleted. Agriculture is limited to the eastern and southern areas of the HMA. Some placer mining occurred in the West Road River in the past, but there is no placer mining at the present time.

A Land Resource Use Plan (LRUP) has been developed for the upper West Road River, and covers an area of 68,000 ha of land along the river upstream of Kluskus Lake. The Plan includes protection of the Alexander MacKenzie Heritage Trail and the high sports fishing values associated with the river.[3] Timber harvesting in this area will be done within the context of other objectives such as retaining limited access, visual quality, and water quality.[3]

A LRUP has also been developed for the lower West Road River, with a focus on protecting the Alexander MacKenzie Trail.[1]

❖❖❖

6.2 Point Sources of Contaminants

6.2.1 Urban/Industrial Point Source Discharges to Surface Water

There are no discharges to surface water in the West Road HMA which are addressed via the provincial Waste Management Permitting process. There may be some discharges to surface waters from federal lands, such as Indian Reserves, which usually do not have provincial Waste Management Permits.

6.2.2 Permitted Discharges to Ground

There are three permitted discharges of wastes to ground within the HMA, from a sewage treatment plant, a veneer plant, and an acetylene plant, all located at Prince George. All of the discharges are small - from 7.3 $m^3 \cdot d^{-1}$ to 118 $m^3 \cdot d^{-1}$.

❖❖❖

6.3 Non-Point Sources of Contaminants

Non-point sources of contaminants in the West Road HMA may result from local land use issues, as discussed below.

6.3.1 *Urban Development*

The West Road HMA is sparsely populated and contains few residential settlements, primarily Indian Reserves. Riparian vegetation in the Nazko area has been affected by residential development in localized areas.[1]

6.3.2 *Agriculture*

There is some ranching scattered throughout the HMA, with most in the lower reaches of the river valleys. Cattle access to river banks causes bank erosion and sedimentation in some areas.[3]

Charges have recently been laid against private land owners who removed riparian vegetation adjacent to fish habitat.[4]

6.3.3 *Timber Harvesting*

Logging began in the mid-1960's, while most of the forest harvesting has occurred since 1982.[3] The harves-ted area amounts to less than 11% of the watershed area in each of the salmon-bearing watersheds of this HMA,.[3] There are some impacts, however, as clear-cut logging has removed substantial amounts of riparian vegetation in some large tributaries, and logging on private land has damaged fish habitat.[4]

❖❖❖

6.4 An Overview of Water Quality Conditions

Little recent data was available in the database to assess water quality conditions in the West Road River HMA. Older water quality data indicate relatively high levels of dissolved solids, reflecting major ions such as Ca^{++} and HCO_3^-, in West Road River water.[5] Stratified lavas, sandstones, and shales of the Central Plateau are believed to be the sources of these ions.[6]

Many of the tributaries to the West Road River drain muskegs or swamps so the water tends to be stained with humic acid, hence the commonly used alternate name of Blackwater River.[1]

In general, water courses in the HMA are prone to high water temperatures during hot summer months, par-ticularly if rainfall levels are low.[1]

Site-specific water quality assessments, influencing factors and supporting data (Table 6.4.1) are provided in Section 6.5 on a stream-by-stream basis.

❖❖❖

6.5 Measured Water Quality Conditions and Stream Assessments

This section provides an overview of measured water quality conditions, land uses, and stream flow issues on a stream-by-stream basis for each salmon-bearing watershed in the West Road HMA.

Summary tables of:

- land use areas, stream flow, and water demand information for each salmon stream (Table 6.5.1)
- identified impacts for each salmon stream (Table 6.5.2)

are provided for quick reference.

All assessments of impacts from urban development, agriculture, forestry, low stream flows, and water with-drawals were based upon information provided in a series of hydrology reports prepared by Rood and Hamilton,[3] and/or SISS catalogues[2] unless otherwise indicated. Assessment criteria are explained in the Methodology section of this report.

❖❖❖

West Road River (07)

◆Cattle grazing is damaging banks and causing sedimentation along the middle reaches between the Baezaeko and Euchiniko Rivers.[3] Flood irrigation is practiced along some reaches.

◆5% of the total watershed has been logged, including 3% which has been recently harvested ('82 - '93). Another 2% was planned for harvest prior to 1997.[3] Beetle infestations from 1984-89 resulted in increased timber harvest efforts. Significant road and bridge construction is associated with logging.[2] MELP staff indicated concern over slope failures and road encroachments on streams.[3]

◆The naturalized summer 7-day mean low flow is

45% of the mean annual flow.[3]

◆The potential August water demand for domestic, irrigation and industrial uses is 5% of the naturalized summer 7-day mean low flow. Storage accounts for 9% of the total irrigation demand.[3]

◆**Other:** A LRUP has been completed for upper watershed, which will guide management of the timber harvest.[3] The river has been placer mined in past years.

❖❖❖

Euchiniko River (07-2450)

◆Ranching occurs throughout the watershed creating some localized problems. There is some fording of the river in spawning areas by cattle.[1]

◆2% of the total watershed was classified as older logging, and an additional 4% was recently logged ('82 - '93). An additional 3% was proposed for harvesting prior to 1998.[3]

◆The naturalized summer 7-day mean low flow is 44% of the mean annual flow. Very low summer flows have been reported.[3]

◆The potential August water demand for domestic, irrigation and industrial uses is 2% of the naturalized summer 7-day mean low flow.[3]

◆**Other:** Two LRUPs guide the use of Crown lands in the West Road River watershed - both focus on the Alexander MacKenzie Heritage Trail. Low summer flows are associated with high water temperatures which may limit salmon production.

❖❖❖

Nazko River (07-3200)

◆Ranching occurs throughout the watershed from the mouth to upstream of the Nazko Indian Reserve.[1] Cattle access to the river is causing bank erosion and sedimentation, especially in the lower 30 km.[3]

◆7% of the total watershed has been logged, including 6% from recent activity. An additional 1% was proposed for harvest prior to 1998.[3] A pine beetle infestation from 1984-89 lead to increased logging efforts.[2] There is extensive logging in some tributaries e.g. the Snaking River.[1]

◆The naturalized summer 7-day mean low flow is 29% of the mean annual flow.[3] Very low summer flows have been reported.[3] The system has a relatively flashy hydrograph.[1]

◆The potential August and September water demand for domestic, irrigation and industrial use is 10% of the naturalized summer 7-day mean low flow. Storage accounts for 30% of irrigation demand.

◆**Other:** The stream water is stained with humic acid. Beaver dams may sometimes restrict access by salmon. There is some mineral exploration in the upper watershed near the Clisbako River.[1] Extremely high water temperatures have been reported during hot and dry summers.[1] The headwaters of the Nazko River are located in the Nazko Lakes Protected Area, which is about 12,500 ha in area.[1]

❖❖❖

Clisbako River (07-3200-365)

◆There is some ranching in the watershed, largely confined to the lower 2 or 3 km.[1] No further information was available.

◆There has been some logging due to a pine beetle infestation. Older cut blocks in the watershed encroach on stream banks in the lower river reaches.[1]

◆Very low summer flows are considered to be of concern.[1]

◆**Other:** Water temperatures can get very high during hot, dry weather. There is some mineral exploration in the upper watershed.

❖❖❖

MacKill Lake

◆There is not enough data to assess water or sediment quality. One of two total phosphorus values exceeded the guideline, and the single measurements of cadmium and copper in sediments exceeded the guidelines.

❖❖❖

eko River (07-3650)

◆There is some localized use of range lands in the HMA,[1] but effects on water quality are unknown.

◆Older logging accounts for 2% of the watershed area, and an additional 5% was recently logged ('82 - '93).[3] A further 4% was proposed for harvest prior to 1998.[3] There has been intensive harvesting in some tributaries with localized impacts to riparian areas.[1]

◆The naturalized summer 7-day mean low flow is 52% of the mean annual flow[3]

◆No licenses have been issued.

❖❖❖

Coglistiko River (07-3650-280)

◆There is very little agricultural activity in the watershed, and no information was available to assess the potential for impacts on water quality.

◆Older logging accounts for 0.6% of the watershed, and an additional 4% was categorized as recent logging.[3] An additional 5% of the watershed was proposed for harvest prior to 1998.[3]

◆The naturalized summer 7-day mean low flow is 50% of the mean annual flow.[3]

◆No licenses have been issued.[3]

◆**Other:** Low summer flows are often associated with high water temperatures.[1]

❖❖❖

6.6 References

1 Rowland, D.E. and L.B. MacDonald. 1996. Salmon watershed planning profiles for the Fraser River Basin within the Cariboo-Chilcotin Land Use Plan (CCLUP) Area. Fraser River Action Plan, Vancouver, B.C., and Habitat Managmeent Unit, Prince George, B.C., Department of Fisheries and Oceans. 375 pp. + maps.

2 Department of Fisheries and Oceans. 1990. Fish Habitat Inventory and Information Program stream summary catalogue, Subdistrict # 29H Quesnel. Fraser River Northern BC and Yukon Division, Fisheries Branch, Department of Fisheries and Oceans.

3 Rood, K.M. and R.E. Hamilton. 1995. Hydrology and water use for salmon streams in the West Road Habitat Management Area, British Columbia. Manuscr. Rep. Fish. Aquat. Sci. 2295.

4 Ionson, B. 1995. Habitat enforcement report for the Fraser River: A report outlining chronic habitat concerns in the Fraser River Basin and recommendations to achieve compliance. Department of Fisheries and Oceans, Fraser River Action Plan, Vancouver, B.C. 56 p. + appendices.

5 Northcote, T.G. and P.A. Larkin. 1989. The Fraser River: A major salmonine production system. *In*: Dodge, D.P. (ed.). Proceedings of the International Large River Symposium. Can. Spec. Pub. Fish. Aquat. Sci. 106: 172-204. *Cited in*: Dorcey, A.H.J. and J.R. Griggs, eds. 1991. Water in sustainable development: Exploring our common future in the Fraser River Basin. Westwater Research Institute, University of British Columbia, Vancouver, B.C.

6 Hall, K.J., H. Schreier, and S.J. Brown. 1991. Water quality in the Fraser River Basin. *In*: Dorcey, A.H.J. and J.R. Griggs, eds. 1991. Water in sustainable development: Exploring our common future in the Fraser River Basin. Westwater Research Institute, University of British Columbia, Vancouver, B.C. 288 p.

Table 6.5.2 Summary of Red-coded Indicators for Streams in the West Road HMA. (Streams are ordered from downstream to upstream.)

Stream Name	**Indicator**				
	Urban	Agriculture	Logging	Stream Flow	Demand
West Road River		*			
Euchiniko River				*	
Nazko River		*			
Clisbako River				*	
Baezaeko River					
Coglistiko River					

Chapter 7 Key Issues and Recommended Actions

The issues and recommended actions outlined here address water quality issues identified in the Seton-Bridge, Chilcotin, and West Road Habitat Management Areas, in Chapters 4-6. Many of the issues and recommended actions are also relevant to other areas of the Fraser Basin, and the Province of B.C. as a whole. The agencies and/or levels of government which are well positioned to take a leadership role in implementing recommendations, based on existing jurisdictions, are usually identified. Issues are addressed in the same order as they are presented in Chapter 2.

The Seton-Bridge, Chilcotin, and West Road HMAs are relatively undeveloped compared with the Lower Fraser and the Thompson River HMAs. Very little water quality data were available for these HMAs, however, the low levels of human activity should result in little impairment of water quality. Much of the Chilcotin HMAs still offer the opportunity to ensure that development occurs in a way that is compatible with the preservation of fish habitat and good water quality. Hence, the recommendations provided below apply largely to problem prevention, rather than addressing existing problems.

❖❖❖

7.1 Urban Development

7.1.1 Land Clearing and Excavation: Preventing Impacts to Water Quality

The Issues:

A. Although there is relatively little urban development established or ongoing in the Seton-Bridge, Chilcotin, and West Road HMAs, this may change in the future, with the most likely pressure coming from recreational properties and cottage development. Unless precautions are taken development inevitably results in incremental damage from erosion due to exposure of soils, and impacts to stream banks and riparian vegetation. Increased suspended sediment levels in stream water result in sedimentation of the stream bottom.

B. The province has jurisdiction over land use decisions, but does not have legislation to address common issues such as erosion control, riparian protection, etc. This absence of legislation creates an excessive workload for environmental agencies, who work with many local governments and developers in attempts to pro-actively address these issues.

Recommended Actions:

1. Municipal governments should adopt the *Land Development Guidelines*[1] as minimum standards of environmental protection associated with land development. Where riparian vegetation is still intact, and in remote areas where much of the land base is still undeveloped, stream setbacks should be wider than those promoted in the *Land Development Guidelines*,[1] and should reflect the 30-50 m required to preserve ecological functions of the riparian zone.[9] Municipalities have the jurisdiction of granting development permits and are therefore well positioned to require that developers comply with sediment control approaches recommended in the *Land Development Guidelines.*[1]

2. Presently, there is a significant duplication of effort as DFO and MELP lobby dozens of municipal governments throughout the Fraser Basin (and the rest of B.C.) to establish sediment control bylaws. Given the province's stated interest in protecting fish and the fact that they produced the *Land Development Guidelines*[1] in partnership with DFO, it is a logical progression that B.C. should act on this recommendation. Adoption of *Land Development Guidelines*[1] in habitat protection legislation as a minimum standard for protection of aquatic habitats during development would be a significant step forward in environmental protection. It would also streamline agency efforts by reducing referral workloads, and reduce administrative costs.

3. Development around any surface waters, particularly lakes, in the Seton-Bridge, Chilcotin, and West Road HMAs should be carefully controlled to ensure protection of riparian vegetation and water quality. There are numerous examples in B.C. already of uncontrolled cottage development leading to degraded surface water quality, especially in lakes.

4. DFO and MELP need to develop and promote environmental education programs for construction workers and heavy equipment operators, who can only comply with guidelines and regulations if they are aware of and understand them.

7.1.2 Preventing Impacts from Urban Development on Stream Hydrology

The Issues:

A. In the Seton-Bridge, Chilcotin, and West Road HMAs impervious surfaces are not yet causing notable problems, however, efforts should be made to ensure that conditions do not deteriorate. Replacement of vegetation with impermeable surfaces disrupts natural stream hydrology resulting in increased “flashiness” of stream flows. Increased high flows damage instream habitat and decreased low flows lead to higher summer water temperatures, and possibly other water quality impacts.

B. Stormwater outfalls often discharge to sensitive environments, such as small streams and near-shore areas, which provide important fish habitat and are easily damaged.

Recommended Actions:

1. For large development proposals and development areas, master drainage plans should be required in advance of development. Plans would address the effects of development on both surface and groundwater regimes, and provide stormwater management approaches that ensure the reasonable maintenance of stream base flows. Plans would include tree retention and some form of stormwater detention (e.g. artificial wetland, underground storage, etc.), with controlled release either to ground or surface waters.
2. The provincial government, given their jurisdiction for managing land and water use, should provide leadership on stormwater management and detention issues, and establish minimum requirements that would protect healthy aquatic environments and hydrology. Objectives for providing adequate protection for stream hydrology should be developed by DFO and MELP. Establishing province-wide standards would provide an improved level of environmental protection and reduce demands on agency staff. Until an agreement is reached DFO and MELP should require stormwater detention for all new subdivisions, unless it is shown that runoff quality and quantity can be adequately addressed in other ways. Municipal governments should ensure that impermeable surfaces are minimized as a means of minimizing their stormwater management costs.
3. DFO must persevere with efforts to educate planners, developers, and municipal governments about the community, financial, and environmental benefits from improved stormwater management practices (e.g. *Land Development Guidelines,*[1] and *Stream Stewardship: A Guide for Urban Planners and Developers* [2]).

7.1.3 Contaminants in Urban Stormwater Runoff

The Issues:

A. Contaminants released from many routine human activities accumulate on street, parking lot, and lawn surfaces. They are washed into storm sewers and ultimately streams during precipitation and thaw events, often at concentrations which are harmful to aquatic life. Similar stormwater problems exist to some degree in all urbanized areas, and will be an increasing problem as population growth occurs.

B. Stormwater outfalls often discharge to sensitive environments, such as small streams and near-shore areas, which provide important fish habitat and are easily damaged.

Recommended Actions:

1. For urban centres and along major roads, implementing recommendations which pertain to addressing hydrology concerns above, such as installation of artificial wetlands and stormwater detention ponds with new developments, would also lead to improved storm water quality. DFO, DOE and MELP should encourage the installation of stormwater detention facilities which are at least designed to capture the most highly contaminated “first flush” and to provide treatment, with all new developments. Stormwater should be directed to detention and treatment facilities which provide a controlled release to the environment, rather than being discharged directly to fish-bearing streams or other sensitive habitats.
2. Widespread adoption of development approaches recommended in *Land Development Guidelines*[1] and *Stream Stewardship: A Guide for Urban Planners and Developers*[2] is key to avoiding impacts from stormwater quantity and quality.
3. Guidelines for the design and construction of stormwater treatment methods such as artificial wetlands, bio-filtration swales, etc. need to be developed and implemented.

7.1.4 *Municipal Sewage Discharges*

The Issues:

A. To date, municipalities have not been required to plan for sewage discharges in anticipation of population growth, resulting in facilities being pushed beyond their capacity, and causing compromised effluent quality. There are numerous examples in the Fraser Basin of STPs being out of compliance with their Permits for years, while the population of the serviced area continued to grow rapidly. Many STPs discharge acutely toxic effluents to the environment at various times.[3, 4] STPs in the Seton-Bridge, Chilcotin, and West Road HMAs generally service small populations and therefore generate only small volumes of effluent. It should be noted, however, that the Lillooet STP in the Seton-Bridge HMA had the poorest record of ten STP facilities tested in a series of four 96-hour LC_{50} rainbow trout bioassays which were performed in 1992-'93.[3]

B. Many of the permits for STP discharges restrict the loadings and concentrations of only a few parameters such as BOD and TSS, yet effluents contain significant concentrations of numerous potentially harmful substances such as ammonia, residual chlorine, detergents, heavy metals, and other contaminants.

Recommended Action:

1. The Waste Management Permit for the Lillooet STP (P00092) restricts only two parameters (BOD and NFR), and permitted discharge concentrations of both parameters in the permit are much higher than can be achieved with modern treatment technology. The permit should be re-visited by regulatory agencies.
2. Municipal governments must plan growth and development in a manner that recognizes limitations of existing infrastructure in place to protect environmental quality. Adequate infrastructure should precede rather than follow new development. This type of issue should be addressed in the future through growth management strategies under the *Municipal Act*, and liquid waste management plans under the *Waste Management Act.* British Columbia's planning system (as per *Growth Strategies for the 1990s and Beyond*[7]) does not address these real growth issues and should be upgraded to adequately address environmental protection.
3. Regulatory agencies including MELP, DOE, and DFO should continue working with municipal governments to achieve non-acutely lethal sewage discharges. Where co-operation is lacking, enforcement actions may be necessary.

7.1.5 *Septic Tanks*

The Issues:

A. Recreational developments such as cottages are not uncommon around some lakes within the Seton-Bridge, Chilcotin, and West Road HMAs. Cottage development often occurs in areas that are not incorporated and therefore have no zoning bylaws, building regulations, or community water or sewage systems. This can lead to a large number of cottages in a relatively small area, which collectively can generate significant amounts of septic system effluents, saturating the ground and ultimately reaching surface waters.

B. The Ministry of Health (MOH) permitting process for septic systems does not impose more stringent requirements for septic systems installed in highly permeable soils, which may allow contaminated seepage to reach nearby surface waters or unconfined aquifers. In fact, MOH favours the installation of systems in highly permeable soils (i.e. soils must meet a minimum percolation rate but not a maximum percolation rate).

C. Substandard construction of septic tank systems results in a significant percentage of failures.

D. The MOH permitting process for septic systems does not include any maintenance requirements. When septic systems are not maintained they will eventually fail, potentially resulting in effluents flowing virtually untreated through permeable soils into nearby surface waters. In general they should be pumped out at least once every 3 years.

Recommended Actions:

1. Environmental regulatory agencies must encourage the upgrading of permitting requirements for septic systems to ensure protection of surface water quality. Measures could include relating required setbacks from surface waters to the permeability of soils in the area with more permeable soils requiring wider setbacks.
2. The Ministry of Health needs to consider certification of contractors involved with construction and maintenance of septic systems. This is already happening in the Capital Regional District (Victoria) and is being considered by Fraser Valley Health Units.
3. Existence of a septic system should be indicated on property titles.

4. When reviewing development proposals in urbanizing areas regulatory agencies need to consider the presence of septic tanks, and either ensure that new development will not impair the function of existing septic systems, or connect the new and existing buildings to municipal sewage treatment systems.
5. The provincial government should establish a regulation requiring regular septic tank maintenance. This could be enforced by requiring property owners to submit proof of septic system maintenance every three years with their property taxes, with failure to do so resulting in the local government doing the maintenance work for a fee and a fine.

❖❖❖

7.2 Addressing Permitted Waste Discharges

There are very few permitted waste discharges to surface waters in the Seton-Bridge, Chilcotin, and West Road HMAs. The only problem noted was for the Lillooet STP, as discussed above (section 7.1.4). The general issues pertaining to Waste Management Permits are discussed below, and apply to the province of B.C. as a whole.

The Issues:

A. The Waste Management Permit process has a strong engineering and pollution control emphasis (i.e. BACT). DFO's emphasis is based on a risk-averse strategy so as to prevent the discharge of toxic effluents, as fish will not necessarily avoid, and may even be attracted to harmful effluent plumes.

B. MELP does audit effluent discharges, however, they sometimes notify the discharger ahead of time. This allows the discharger to prepare their facility for an inspection. Maintaining viable aquatic life requires facilities to always be diligent in maintaining effluent quality.

C. Effluent quality data submitted to MELP by proponents will soon be incorporated into the new provincial Environmental Monitoring System database, however, it will not be directly accessible to other regulatory agencies.

Recommended Actions:

1. Requirements for toxicity-testing bioassays should be incorporated into most Waste Management Permits which address the discharge of an effluent to a sensitive or fish-bearing water body.
2. Where toxicity is identified, proponents should be required to control toxic components of effluent within agreed-upon time frames. Where persistent harmful substances are found in an effluent, the facility releasing these substances should be placed on a compliance schedule to remove the substances.
3. MELP and DOE should continue to promote pollution prevention as a preferred method of pollution control.
4. Where Codes of Practice, Best Management Practices (BMPs) etc. have been developed, MELP and DOE should work with industry to ensure implementation and improve compliance. Biological assessments should be conducted to ensure BMPs are adequately protective of aquatic resources.
5. Waste Management inspectors should be empowered with full rights of trespass so that they may undertake audits without having to notify proponents ahead of time.
6. DFO needs to conduct audits of effluent quality from a biological perspective. Where problematic discharges are identified DFO should work with MELP and DOE to ensure that effluent quality is satisfactorily improved.
7. Effluent quality data submitted to MELP by proponents needs to be checked for Quality Assurance and Quality Control, and made electronically accessible to all resource management agencies within an established time frame after collection. Many commercial laboratories now provide direct electronic reporting.

❖❖❖

7.3 Addressing Impacts from Agriculture

The Issues:

A. Spring runoff from livestock overwintering areas can be highly contaminated by manure and carry large amounts of nutrients, oxygen-demanding substances, and ammonia into fish-bearing streams. The scope of this type of problem is not well documented in the three HMAs addressed here, but is usually present to some extent where ranching is a prevalent land use. Many producers are working to improve practices, however, there are still numerous farms and ranches in B.C. where problems persist. Small-scale "hobby" farms are becoming an increasing source of problems throughout B.C., as land owners often do not have much background in good livestock management.

B. Cattle access to surface waters in overwintering areas often results in damage to riparian areas and impacts to water quality.

C. Exposed soils on fields erode, resulting in stream sedimentation and an increased need for ditch cleaning.

D. Water withdrawals in general do not create problems of low stream flows in the HMAs addressed here, however, efforts should be made to ensure that low flow problems are not created in the future.

E. In general in B.C. there is an inadequate stewardship education and enforcement effort at both federal and provincial levels to address impacts from farming on water quality (and fish habitat).

Recommended Actions:

1. Agencies including DFO, DOE, MELP, and MAF must continue working co-operatively to promote the use of Best Management Practices on farms, to address environmental problems, and avoid giving producers mixed or conflicting messages. An education program complementary to the *Water Stewardship: A Guide for Agriculture* [5] should be implemented in co-operation with MELP and MAF. DFO should continue to support "fish and farm" educational initiatives.

2. Agencies should continue to work with producers to develop alternative practices which benefit the environment and producers. DFO should persevere in supporting this type of positive initiative and publicizing the results. DFO needs to monitor the results of stewardship initiatives completed in the Fraser Basin and elsewhere. Results of alternative approaches must be publicized so that other producers and agency staff can learn from one another, and to promote interest in improved practices within the farming community.

3. DFO, MELP, and MAF must increase stream bank setbacks and bio-engineered restoration efforts on farm land with severe erosion problems, as this would address both habitat and water quality impacts, and improve relations with the farming community.

4. Protection of aquatic life needs to be given a higher priority under the *Water Act*, and Water Managers need to ensure that adequate flows for fish are always retained. Where summer low flows are already problematic for fish watershed assessments should be completed before any further licenses for withdrawals are issued, with the objective of determining how stakeholder needs can be met after water requirements for fish are accounted for.

5. MELP should increase the number of staff who address enforcement of the Agricultural Waste Control Regulation. DFO and DOE should pursue legal actions under the *Fisheries Act* when the Agricultural Waste Control Regulation fails to adequately protect fish habitat and water quality.

6. Government policies which promote farming practices that are detrimental to fish must be discouraged (e.g. higher taxes for unfarmed ALR land discourages establishment of leave strips on farm land). This will likely require high-level negotiations between environmental regulatory agencies and others such as the Agricultural Land Commission, as well as the public.

❖❖❖

7.4 Addressing Impacts from Forestry Activities on Water Quality

The Issues:

A. DFO-FRAP actively participated in the provincially-led process of developing the Cariboo-Chilcotin LRMP, however, it is uncertain to what extent the fisheries resource benefited, as the resulting plans are open to interpretation by end users during implementation.

B. Impacts to salmon-bearing streams in the Seton-Bridge, Chilcotin, and West Road HMAs as a result of logging appear to be less than in other HMAs to date, however, poor practices have been noted to cause sedimentation of streams and other problems in a number of watersheds. Also, the pressure for timber harvesting will increase in these HMAs as timber supplies elsewhere are depleted.

C. The Forest Practices Code has recently been amended, resulting in procedural changes which reduce the amount of pro-active inventory and planning work required, and therefore increase the likelihood of damage to streams. DFO was not consulted prior to the amendments being announced.

Recommended Actions:

1. DFO must re-evaluate its continued participation in provincially-lead planning processes. The department should assess the benefits which have resulted from input to CORE, LRMP, and LRUP processes in the Chilcotin area relative to the resources expended, and determine how the process can be improved or how DFO can best use its resources to protect water quality and fish habitat.

2. DFO must establish an auditing process to assess the adequacy of protection afforded to water quality and fish habitat in association with forestry activities. This might best be accomplished through a partnership with MELP, and should be an ongoing activity. Where forest harvesting leads to water quality and/or fish habitat impacts, DFO

should pursue enforcement of the *Fisheries Act*. Where intensive forest harvesting activities are planned hydrology studies should be done prior to logging to establish normal hydrological conditions as a baseline for measuring changes.

❖❖❖

7.5 Water Quality Issues Associated with Mining

The Issues:

A. No water quality problems resulting from mining were identified in the Seton-Bridge, Chilcotin, and West Road HMAs. There is some placer mining in several salmon-bearing systems, however, there is very little compliance monitoring done by regulatory agencies.[6]

Recommended Actions:

1. There should be increased monitoring of placer mining operations to ascertain that fish-bearing streams are being adequately protected. Mine exploration works should be monitored (e.g. road building etc.) to ensure that fish habitat is not impacted by these activities.

❖❖❖

7.6 Addressing Atmosphere-Sourced Impacts on Water Quality

The Issues:

A. Soils in the Seton-Bridge, Chilcotin, and West Road HMAs have a high ability to reduce acidity in some areas (mostly in the Seton-Bridge HMA), however, the majority of soils have a low to moderately-low ability to reduce acidity. At present acidification is not likely affecting water quality because atmospheric sources of acidity are minor. The West Road HMA near Prince George is the main potential problem area, as pulp mill emissions and automobile exhaust from this urban and industrial centre could be sources of acid precipitation. No data were available to support or refute the possibility.

B. Evidence suggests that the theory of global climate warming may be a reality. Global warming would likely result in increased stream temperatures during summer months, and could result in lower summer stream flows, higher summer temperatures, and increased demand for irrigation water. While global warming might not result in lethal summer water temperatures, it could result in earlier freshet, and lower summer flows.[8] Chinook and sockeye, the main anadromous species utilizing these HMAs, are vulnerable to global warming because of their prolonged freshwater juvenile residency.

Recommended Actions:

1. DFO should support and encourage monitoring of rainfall pH and pH of selected poorly buffered streams near Prince George in the West Road HMA. Such a monitoring program would be inexpensive, and results could guide a variety of environmental management programs. Monitoring could be taken on by Streamkeeper groups where interest exists, if DFO were able to provide equipment and training.

2. Environment Canada should devote increased effort to studying air quality issues, and should liaise with DFO in establishing monitoring and research programs so that opportunities for collaboration are identified early on.

3. DFO and provincial agencies (MAF, MELP, and MOF) should pursue the protection and restoration of riparian vegetation along all stream banks. This would help to address existing problems of sedimentation, erosion, and high summer water temperatures. Salmon-bearing streams in these HMAs are still relatively intact, and the opportunity remains to ensure that development does not impair water quality or fish habitat.

   Riparian protection and restoration would also minimize the effects of future global warming on the salmon stocks which rely upon streams in this area.

❖❖❖

7.7 Additional General Issues and Recommended Actions

The Issues:

A. Section 37(2) of the *Fisheries Act* enables the Minister of Fisheries and Oceans to request plans of works that may harm fish habitat, however, an Order in Council is necessary to adjust, revise, or shut down works that threaten to contravene the fish habitat and/or water quality protection provisions of the *Fisheries Act*. This section of the *Act* is not often utilized because it requires a cabinet-level decision and is therefore too cumbersome to implement effectively.

B. Development is increasing rapidly in the Fraser Basin (and elsewhere in B.C.), while budgets for habitat management (and DFO in general) are decreasing. Staff simply do not have enough resources for site visits to out-of-the-way places where logging and mining activities are often ongoing.

C. Existing legislative tools do not adequately protect streams and riparian areas from urban development and land uses such as agriculture.

Recommended Actions:

1. Amend the *Fisheries Act* so that Section 37 can be acted upon at a delegated level on behalf of the Minister. This would greatly facilitate the use of this section to prevent degradation of water quality and fish habitat, whereas Sections 35 and 36 enable DFO to address impacts once they have already occurred.

2. Programs need to be developed and implemented which would provide training for biological consultants and other professionals, with regard to standards acceptable to DFO. Presumably DFO-trained professionals would likely develop approaches to development, etc., which are more agreeable to DFO, and therefore require a reduced amount of staff time for review. This would also benefit proponents, as they would likely receive quicker responses from DFO regarding their projects.

3. Taking the training idea above a step further, the concept of DFO developing a certification program for professionals needs to be further explored. Such an approach would have to offer clear benefits to both DFO and the professionals. Certification would have be revocable for certified professionals who fail to consistently achieve DFO standards. Project proposals from DFO-certified professionals would presumably require a lower level of review effort from DFO than is currently often involved, and should free up more staff time for auditing of proposals, and field inspections. This should speed up to response time, resulting in a shorter waiting period for proponents.

4. In that *Fisheries Act* enforcement is best suited to larger cases, enforcement staff must have greater access to a universal ticketing system to address the numerous less serious violations which are presently under-enforced.

❖❖❖

7.8 References

1 Chilibeck, B., G. Chislett and G. Norris 1992. Land development guidelines for the protection of aquatic habitat. Department of Fisheries and Oceans, and B.C. Ministry of Environment, Lands and Parks. 128 p.

2 Lanarc Consultants Ltd. 1994. Stream stewardship: A guide for planners and developers. Stream Stewardship Series. Department of Fisheries and Oceans, B.C. Ministry of Environment, Lands and Parks, and B.C. Ministry of Municipal Affairs. 48 p.

3 Mendoza, E.C. and J. Gee. 1994. Compliance status summary report for the Fraser River Basin, British Columbia. Fiscal year 1992-1993. Environment Canada, Pacific Region. DOE-FRAP 1994-03

4 Paquet, M.M. 1994. Compliance status summary report for the Fraser River Basin 1993-1994. Environment Canada, Pacific Region. DOE-FRAP 1994-05

5 Nener, J.C. 1997. Watershed Stewardship - A guide for agriculture. Department of Fisheries and Oceans and B.C. Ministry of Environment, Lands and Parks. 61 p.

6 Ionson, B. 1995. Habitat Enforcement Report for the Fraser River: A report outlining chronic habitat concerns in the Fraser River Basin and recommendations to achieve compliance. Department of Fisheries and Oceans, Fraser River Action Plan, Vancouver, B.C. 56 p. + appendices.

7 Province of B.C. - Ministry of Municipal Affairs. 1994. Growth strategies for the 1990s and beyond. 22p. + appendices.

8 Levy, D.A. 1992. Potential impacts of global warming on salmon production in the Fraser River watershed. Can. Tech. Rep. Fish. Aquat. Sci. 1889.

9 Millar, J., N. Page, M. Farrell, B. Chillibeck, and M. Child. 1997. Establishing fisheries management and reserve zones in settlement areas of coastal British Columbia. Can. Manuscr. Rep. Fish./ Aquat. Sci. 2351:62 pp.

Appendix 1 General Background Information About Water Quality

Both physical and chemical parameters affect water quality. Most of these parameters interact with one another in determining the ability of water to support aquatic life. These parameters and the mechanisms by which they affect aquatic life are discussed briefly in this appendix.

❖❖❖

1 Suspended Sediment

All streams naturally carry loads of sediments, and levels fluctuate with stream flow. Disruption of natural sediment levels in aquatic systems is a common consequence of land-based activities that damage the integrity of riparian zones or alter runoff characteristics and hydrological patterns. Examples of such activities include urban development, agriculture, logging, placer mining, gravel removal, and many others.

Altering sediment inputs often has impacts on both habitat and water quality. Smothering of the natural substrate is the major impact on habitat and occurs when suspended sediments settle. Alterations to substrate materials can negatively affect populations of fish food organisms. Settling of fine sediments degrades fish spawning habitat, and impairs survival of fish eggs by reducing the amount of oxygen which reaches eggs during the incubation period.

Suspended solids reduce the penetration of light through the water column, thereby impacting primary production and reducing production of fish foods. Any changes in seasonal levels of suspended sediments in a system can impact the entire food chain. CCME Guidelines for the Protection of Aquatic Life are based on this potential impact, and state that suspended sediment should not be added to a system in amounts exceeding 10% of natural background levels which are greater than 100 $mg \cdot L^{-1}$, or 10 $mg \cdot L^{-1}$ where natural levels are less than 100 $mg \cdot L^{-1}$.

Very high suspended sediment levels may cause physical damage to fish gills. Fish species which rely heavily on vision for feeding may experience reduced efficiency of food capture if suspended sediment levels increase. Fish may avoid waters with high suspended sediment levels, resulting in effective reduction of available habitat.[1]

❖❖❖

2 Hardness

Hardness is a term used to describe the level of dissolved calcium and magnesium salts present in water. When hardness is in the range of 0 $mg \cdot L^{-1}$ to 60 $mg \cdot L^{-1}$ (expressed as $CaCO_3$) water is generally considered to be "soft". When hardness is in the range of 60 - 120 $mg \cdot L^{-1}$ it is considered moderate, and in the range of 120 - 180 $mg \cdot L^{-1}$ it is considered to be hard. Greater than 180 $mg \cdot L^{-1}$ is very hard. The global mean hardness of river waters is about 50 $mg \cdot L^{-1}$. When hardness is very low (20 $mg \cdot L^{-1}$) aquatic productivity is usually also low, due to a lack of nutrient minerals which are required for primary production. Such low levels of dissolved ions may also cause fish to experience osmotic stress. In addition to supporting higher levels of primary production, water with moderate to high hardness provides opportunities for contaminants to bind with ions and precipitate out of solution, thereby reducing bioavailability of non-desirable substances.

❖❖❖

3 Temperature

A thorough review of water temperature issues pertaining to fish was recently prepared by Levy, and forms the basis of the following discussion.[2] Water temperature is an extremely important component of water quality as it affects aquatic life through a variety of mechanisms. Water temperature is critical to survival of eggs, rearing juvenile fish, and adult salmon returning to spawning grounds. It also controls developmental times for fish eggs and benthic invertebrates. The two are usually synchronized in streams such that timing of alevin emergence is linked with food availability. In lakes, temperature conditions can affect thermal stratification and turn-over, which in turn can have a large effect on productivity. The assemblages of fish in the Fraser River are generally adapted to cold water conditions and are therefore very sensitive to warm waters.

Land-use activities that involve land clearing such as agriculture, forestry, and urban development have significant impacts on temperatures of surface waters.[3-5] Loss of riparian vegetation can increase both daily water temperature fluctuations, and average water temperature. An average increase in stream temperature of 6.7°C is reported for a stream section without riparian vegetation compared with an upstream shaded section.[6] Brownlee, *et al*. report daily temperature fluctuations of up to 8°C compared with 2°C at the upstream reference site.[7] The discharge of effluents from industrial processing, and industrial cooling waters can also have measurable localized effects on water temperature.

Theories about global warming lead to additional concerns regarding the warming of surface waters. Many tributaries of the Fraser River experience critically high temperatures during hot summer months, sometimes resulting in fish mortalities. The temperature of the Fraser mainstem has also reached very high levels in recent years (> 20°C in the summers of 1992 and 1994), causing concern with regard to pre-spawning mortality of all returning salmon species.

Virtually all fish, except a few marine species, are ectothermic animals and their body temperature is determined by the temperature of the surrounding water. Behavioural mechanisms provide the major means of body temperature regulation available to fish and other ectotherms (i.e. swimming to warmer or cooler water).[15] Altered temperature regimes are believed to have two types of impacts of fish, those being direct effects on metabolism and behaviour,[8] and exacerbation of impacts resulting from other stresses such as contaminants and disease.[4] Temperature effects upon acute toxicity of chemicals appear to depend both on the fish species and pollutant involved.[2]

Juvenile salmonids generally prefer and tolerate slightly higher water temperatures in comparison with adults of the same species. Mortality of juvenile pacific salmon species occurs when temperatures reach 20 - 25 °C. Preferred temperatures are in the range of 8 - 15 °C. A number of variables can influence thermal tolerance, including thermal history, seasonal and photoperiodic effects, geographical distribution, and ontogeny.[4] Studies have demonstrated that the preferred temperatures of fish often coincide with temperatures which optimize physiological function.[8]

Other ecological factors may potentially override the importance of temperature in determining fish distribution in the environment. For example, predation pressure may strongly influence salmon behaviour in freshwater, overriding physiological selection pressures, and causing salmon to occupy waters where the temperature is higher or lower than optimal.

Predation by freshwater piscivores is believed to exert an important structuring influence on fish communities in both lakes [9, 10] and streams.[11] With higher aquatic temperatures, prey fish have more opportunities to encounter "hungry" predators (rather than satiated ones) because, other things being equal, all ectotherms need to consume more food in warmer water in order to satisfy their metabolic requirements.[12] Thus, piscivore-induced mortality rates could conceivably increase under higher temperature conditions. Empirical studies on northern squawfish *(Ptychocheilus oregonensis)*, an abundant predator of juvenile salmon in the Fraser River watershed, suggest that stomach evacuation rates are directly related to environmental temperature.[13] Thus higher aquatic temperatures might serve to increase salmon mortality rates through increased piscivore predation.

It is evident that warming of aquatic systems could potentially affect salmon populations in the Fraser River watershed in several ways. First, extreme high temperatures can cause mortality directly where salmon encounter high temperatures at or above their limits of thermal tolerance. Secondly, shifts could occur in the thermal structure of aquatic habitats such that physiological performance of fish is compromised (e.g., growth rate). Thirdly, there are a number of indirect ecological changes with increased temperature (e.g., increased predation, increased susceptibility to parasites and pathogens, increased food abundance) that could profoundly affect salmon populations. Such ecological responses are difficult to predict, and might be positive or negative from a fish production standpoint.

It is crucial to protect the thermal integrity of the many small streams and larger tributaries of the Fraser as these provide much of the habitat used by salmonids for spawning and rearing, and also ultimately contribute to regulating the temperature of the Fraser mainstem. Small streams are very vulnerable to altered temperature regimes as a result of land clearing and loss of riparian vegetation.

❖❖❖

4 pH

The hydrogen ion concentration of water is typically presented as a pH measurement (-log 10 $[H^+]$). The pH range of 6.5 - 9.0 is considered adequate to protect aquatic life.[14] The pH range which is not acutely lethal to fish is 5.0 - 9.0, and different species have different optimum pHs within this range.

A gradual deterioration of water quality occurs as pH strays from the normal range for an aquatic system. In addition to direct effects on aquatic organisms such as affecting osmoregulation, changing pH can exert indirect effects by altering the bioavailability of toxic substances. Many metals, for example, are toxic at fairly low concentrations, and most metals become more soluble as pH declines. Altering pH will also affect speciation of ions, and some ionic species are much more toxic than others. Ammonia toxicity is strongly pH dependent for this reason, toxicity increasing with pH. The sensitivity of aquatic systems to changes in pH is determined by their buffering capacity. Acidic inputs from industrial effluents, non-point source runoff, and acidic rainfall can all affect pH of receiving waters.

❖❖❖

5 Contaminants

The fate and effect of different chemicals in the environment is largely determined by their physical and chemical properties, and the physical, chemical, and biological properties of the receiving environment.

The two general categories of contaminants are organic contaminants consisting primarily of carbon, hydrogen and oxygen, such as dioxins, furans, resin acids, PCBs, and PAHs, and inorganic contaminants such as metals, and nutrients like various forms of nitrogen and phosphorous. Some substances such as trace metals are required in low concentrations by aquatic organisms for normal growth and development, as they are components of particular enzymes, but have negative impacts at higher concentrations. Nutrients are essential for all levels of every food chain, but high levels in aquatic systems cause eutrophication. For the purpose of this report, the term contaminant is defined as a substance occurring in the environment at levels which exceed natural background concentrations for the aquatic system.

Factors to consider in assessing the potential of a substance to harm aquatic biota include:

5.1 *Acute toxicity*

Acute toxicity is measured with standard laboratory assays (bioassays) known generically as LC_{50}s, which measure the concentration of a substance that kills 50% of test organisms in a specific time period.

5.2 *Non-genetic sublethal effects*

This category includes changes in growth, development, reproduction, pharmacokinetic responses, pathology, biochemistry, physiology, and behaviour. Any of these sublethal effects can cause lethality indirectly through increased susceptibility to predation and disease.

5.3 *Genotoxicity*

Genotoxicity is a measure of the ability of a chemical to produce any of the three following effects, which all reflect damage to DNA:

a. **Carcinogenicity:** the ability of a substance to cause cancer as ascertained with experimental tests or human exposure data;

b. **Mutagenicity:** the ability to cause hereditary changes in cells, determined by tests on bacteria, cell lines, or whole organisms;

c. **Teratogenicity:** the ability to cause abnormal development of a fetus, determined with experimental tests or exposure data.

5.4 *Persistence in the environment*

This is measured by half-life, or the time required for 50% of the initial concentration to be eliminated. Substances are removed by a combination of mechanisms including biodegradation, volatilization, and photo-degradation. Persistent substances can accumulate in biota to toxic levels, even with relatively low loading to the environment. Dioxins and furans are well known examples of chemicals which bioaccumulate to harmful levels in aquatic biota.

5.5 Bioaccumulation

Substances which bioaccumulate can be present at very low concentrations in water and sediments, but reach harmful levels within biota. The potential for a substance to bioaccumulate can be measured directly in the laboratory, estimated from field measurements, or inferred from the

octanol/water partitioning coefficient. The half-life of a substance in aquatic biota provides a measure of the potential for tissue contamination to persist after organisms are no longer exposed to the substance of concern.

The fate of chemicals in aquatic systems determines to some extent their bioavailability. Highly soluble substances will dissolve and remain in the water column until removed or degraded by biota, or other processes such as precipitation, photolysis, hydrolysis, or oxidation. Many dissolved chemicals are freely available to organisms in the water column, as they will pass readily across gills and other permeable body surfaces.

Strongly hydrophobic substances may float in a layer on the surface of the water, or bind to particulates (suspended sediments) and hence be not directly available to biota. Particulates with their bound contaminants may eventually settle out in sediment depositional zones, and be taken up by biota either through incidental ingestion of sediment particles, or through direct uptake from interstitial water, where contaminant concentrations can be high (contaminants will reach a dynamic equilibrium between bound and dissolved state, depending upon their chemical properties and environmental conditions).

The fates and mechanisms of action of contaminants on organisms varies widely among contaminants, and species exposed to substances of concern. Contaminants which are not chemically reactive and not lipid soluble may be simply be excreted. Non-polar substances which are persistent such as dioxins, furans, and PCBs, may accumulate in various tissues or organs, usually fat or liver. Some chemicals such as PAHs will be metabolized into other compounds that can be more or less toxic than the parent compound. Contaminants may have more than one mechanism of toxic action, depending upon the concentrations organisms are exposed to. The same substance may exert lethal effects through one mechanism at high concentrations, and long-term sublethal effects at lower concentrations. In addition, consequences of exposure to contaminants may depend upon other environmental conditions such as dissolved oxygen levels, water temperature, pH, and the presence of other contaminants leading to synergistic effects. Detailed explanations regarding the mechanisms of action of specific contaminants are beyond the scope of this report, however, appropriate references will be provided.

❖❖❖

6 References:

1 McLeay, K.J., G.L. Ennis, I.K. Birtwell, and G.F. Hartman. 1984. Effects on arctic grayling (*Thymallus arcticus*) of prolonged exposure to Yukon placer mining sediment: A laboratory study. Can. Tech. Rep. Fish. Aquat. Sci. No 1241. West Vancouver, B.C. 96 p.

2 Levy, D.A. 1992. Potential impacts of global warming on salmon production in the Fraser River watershed. Can. Tech. Rep. Fish. Aquat. Sci. No 1889. 96 p.

3 Richards, F.P., W.W. Reynolds, and R.W. McCauley. 1977. Temperature preference studies in environmental impact assessments: and overview with procedural recommendations. J. Fish. Re. Board Can. 34:729-761.

4 Houston, A.H. 1982. Thermal effects upon fishes. NRCC Associate Committee on Scientific Criteria for Environmental Quality. Publ. No. NRCC 18566, Ottawa, Canada. 200 p.

5 Coutant, C.C. 1987. Thermal preference: when does an asset become a liability? Env. Biol. Fish 18:161-172.

6 Claire, E. and R. Storch. 1977. Streamside management and livestock grazing: An objective look at the situation. Paper presented at symposium on livestock interactions wit wildlife, fish and their environments, Sparks, Nev., May 1977. On file at University of California.

7 Brownlee, M.J., B.G. Shepherd, and D.R. Bustard. 1988. Some effects of forest harvesting on water quality in the Slim Creek watershed in the central interior of British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1613. 41p.

8 Brett, J.R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon *(Onchorynchus nerka)*. Am. Zool. 11:99-113.

9 Evans, D.O., B.A. Henderson, N.J. Bax, T.R. Marshall, R.T. Oglesby, and W.J. Christie. 1987. Concepts and methods of community ecology applied to freshwater fisheries management. Can. J. Fish. Aquat. Sci. 44 (suppl. 2):448-470.

10 Robinson, C.L.K. and W.M. Tonn. 1989. Influence of environmental factors and piscivory in structuring fish assemblages of small Alberta lakes. Can. J. Fish. Aquat. Sci. 46:81-89.

11 Brown, L.R. and P.B. Moyle. 1991. Changes in habitat and microhabitat partitioning within an assemblage of stream fishes in response to predation by Sacramento squawfish *(Ptychocheilus grandis)*. Can. J. Fish. Aquat. Sci. 48:849-856.

12 Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal du Conseil, Conseil International pour l'Exploration de la Mer 39:175-192.

13 Beyer, J.M., G. Lucchetti, and G. Gray. 1986. Digestive tract evacuation in northern squawfish *(Ptychocheilus oregonensis*). Can. J. Fish. Aquat. Sci. 45:548-553.

Parameter	SEAM code	Guideline		For the Protection of:	Guideline Source
Sediments					
PAHs					
Acenaphthelene	PA01	0.01	$\mu g \cdot g^{-1}$	Aquatic life	Environment Canada
Acenaphthylene	PA02	0.01	$\mu g \cdot g^{-1}$	Aquatic life	BC MELP
Anthracene	PA03	0.02	$\mu g \cdot g^{-1}$	Aquatic life	Environment Canada/St. Lawrence Action Plan
Benzo(a)anthracene	PA04	0.05	$\mu g \cdot g^{-1}$	Aquatic life	Environment Canada
Benzo(a)pyrene	PA05	1.0	$\mu g \cdot g^{-1}$	Aquatic life	BC MELP
Benzo(ghi)perylene	PA07	0.1	$\mu g \cdot g^{-1}$	Aquatic life	BC MELP
Benzo(k)fluoranthene	PA08	0.24	$\mu g \cdot g^{-1}$	Aquatic life	BC MELP
Crysene	PA09	0.1	$\mu g \cdot g^{-1}$	Aquatic life	BC MELP
Fluoranthene	PA11	0.02	$\mu g \cdot g^{-1}$	Aquatic life	Environment Canada
Fluorene	PA12	0.01	$\mu g \cdot g^{-1}$	Aquatic life	Environment Canada
Indeno(1,2,3-cd)pyrene	PA13	0.07	$\mu g \cdot g^{-1}$	Aquatic life	BC MELP
Naphthalene	PA14	0.02	$\mu g \cdot g^{-1}$	Aquatic life	Environment Canada
Phenanthrene	PA15	0.03	$\mu g \cdot g^{-1}$	Aquatic life	Environment Canada
Pyrene	PA16	0.49	$\mu g \cdot g^{-1}$	Aquatic life	BC MELP
Organochlorine pesticides					
Aldrin	A002	2	$ng \cdot g^{-1}$	Aquatic life	Environment Canada/St. Lawrence Action Plan
alpha-Chlordane	C011	na			no guideline/80th %ile not calc.
gamma-Chlordane	C012	na			no guideline/80th %ile not calc.
DDD	D025	8	$ng \cdot g^{-1}$	Aquatic life	BC MELP
DDE	D023	5	$ng \cdot g^{-1}$	Aquatic life	BC MELP
DDT	D026	8	$ng \cdot g^{-1}$	Aquatic life	BC MELP
Endosulfan I	E040	na			no guideline/80th %ile not calc.
Endosulfan II	E041	<0.001	$ng \cdot g^{-1}$		80th percentile
Endosulfan Sulphate	E042	na			no guideline/80th %ile not calc.
Endrin	E007	1	$ng \cdot g^{-1}$	Aquatic life	Environment Canada
Methoxychlor	M016	na			no guideline/80th %ile not calc.
Toxaphene	T014	na			no guideline/80th %ile not calc.
Fish Tissue					
PCBs					
Total PCB		2	$\mu g \cdot g^{-1}$	Aquatic life	BC MELP
Dioxins, Furans					
Total T4CDD	T060	na			no guideline/80th %ile not calc.
Total O8CDD	O101	na			no guideline/80th %ile not calc.
Total T4CDF	T062	na			no guideline/80th %ile not calc.
Total O4CDF	O102	na			no guideline/80th %ile not calc.
Pesticides					
p,p'-DDE (246)		5	$\mu g \cdot g^{-1}$	Humans	Environment Canada

Total Toxaphene	0.1	$\mu g \cdot g^{-1}$	Humans	Environment Canada
Coplanar PCBs				
PCB #77	na			no guideline/80th %ile not calc.
PCB # 126	na			no guideline/80th %ile not calc.
PCB #169	na			no guideline/80th %ile not calc.