The Cohen Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River

February 2011

TECHNICAL REPORT 2

Potential Effects of Contaminants on Fraser River Sockeye Salmon

Don MacDonald, Jesse Sinclair, Meara Crawford, Heather Prencipe and Melissa Meneghetti

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Preface

Fraser River sockeye salmon are vitally important for Canadians. Aboriginal and non-Aboriginal communities depend on sockeye for their food, social, and ceremonial purposes; recreational pursuits; and livelihood needs. They are key components of freshwater and marine aquatic ecosystems. Events over the past century have shown that the Fraser sockeye resource is fragile and vulnerable to human impacts such as rock slides, industrial activities, climatic change, fisheries policies and fishing. Fraser sockeye are also subject to natural environmental variations and population cycles that strongly influence survival and production.

In 2009, the decline of sockeye salmon stocks in the Fraser River in British Columbia led to the closure of the fishery for the third consecutive year, despite favourable pre-season estimates of the number of sockeye salmon expected to return to the river. The 2009 return marked a steady decline that could be traced back two decades. In November 2009, the Governor General in Council appointed Justice Bruce Cohen as a Commissioner under Part I of the *Inquiries Act* to investigate this decline of sockeye salmon in the Fraser River. Although the two-decade decline in Fraser sockeye stocks has been steady and profound, in 2010 Fraser sockeye experienced an extraordinary rebound, demonstrating their capacity to produce at historic levels. The extreme year-to-year variability in Fraser sockeye returns bears directly on the scientific work of the Commission.

The scientific research work of the inquiry will inform the Commissioner of the role of relevant fisheries and ecosystem factors in the Fraser sockeye decline. Twelve scientific projects were undertaken, including:

Project	
1	Diseases and parasites
2	Effects of contaminants on Fraser River sockeye salmon
3	Fraser River freshwater ecology and status of sockeye Conservation Units
4	Marine ecology
5	Impacts of salmon farms on Fraser River sockeye salmon
6	Data synthesis and cumulative impact analysis
7	Fraser River sockeye fisheries harvesting and fisheries management
8	Effects of predators on Fraser River sockeye salmon
9	Effects of climate change on Fraser River sockeye salmon
10	Fraser River sockeye production dynamics
11	Fraser River sockeye salmon – status of DFO science and management
12	Sockeye habitat analysis in the Lower Fraser River and the Strait of Georgia

Experts were engaged to undertake the projects and to analyse the contribution of their topic area to the decline in Fraser sockeye production. The researchers' draft reports were peer-reviewed and were finalized in early 2011. Reviewer comments are appended to the present report, one of the reports in the Cohen Commission Technical Report Series.

Executive Summary

ES1.0 Introduction

This study was conducted to develop an Inventory of Aquatic Contaminants for the Fraser River Basin and to evaluate the potential effects of those contaminants on Fraser River sockeye salmon. A risk-based approach was used to determine if the contaminants that have been released into freshwater ecosystems within the watershed have caused or substantially contributed to the decline of Fraser River sockeye salmon over the past 20 years or to the poor returns of sockeye salmon that were observed in 2009. Implementation of this approach involved the following steps:

- Developing an Inventory of Aquatic Contaminants (which are also referred to as chemicals of potential concern or COPCs);
- Conducting a preliminary evaluation of chemicals of potential concern to identify the substances that pose potential risks to sockeye salmon (which are termed contaminants of concern or COCs) and, hence, required further evaluation;
- Conducting a detailed evaluation of the contaminants of concern to determine if their concentrations in surface water, sediment, or fish tissues were sufficient to adversely affect the survival, growth, or reproduction of sockeye salmon;
- Conducting a qualitative evaluation of the potential effects on sockeye salmon associated with exposure to endocrine disrupting chemicals and other contaminants of emerging concern; and,
- Identifying uncertainties in the assessment and key data gaps.

ES1.1 Inventory of Aquatic Contaminants

To support the development of an Inventory of Aquatic Contaminants, the available information on land and water uses within the Fraser River Basin was compiled. In addition, the substances that have been, or may have been, released to aquatic ecosystems in conjunction with these land and water uses were identified. Subsequent integration of this information facilitated identification of over 200 substances that may have been released into aquatic ecosystems within the study area. All of the substances included in the Inventory of Aquatic Contaminants were considered to be chemicals of potential concern.

ES1.2 Preliminary Evaluation of Chemicals of Potential Concern

In the preliminary evaluation, the maximum concentrations of chemicals of potential concern in water and sediment were compared to toxicity screening values, which were intended to represent no observed effect levels for aquatic organisms. The results of the preliminary assessment indicated that a number of chemicals of potential concern exceeded the toxicity screening values in one or more environmental samples and, hence were identified as contaminants of concern. The water-borne contaminants of concern included conventional variables (total suspended solids, turbidity, pH), nutrients (nitrate, nitrite, phosphorus), major ions (chloride, fluoride, sulfate), metals (aluminum, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, silver); and, phenols. The sediment-associated contaminants of concern included metals (arsenic, cadmium, chromium, copper, iron, lead, and nickel), phthalates [bis(2-ethylhexyl)phthalate] and, polycyclic aromatic hydrocarbons [acenaphthalene, benz(a)anthracene, and dibenz(a,h)anthracene]. These substances were retained for further evaluation in the detailed assessment of risks to sockeye salmon in the Fraser River Basin.

Many other substances in the Inventory of Aquatic Contaminants have the potential to adversely affect Fraser River sockeye salmon, including organometals, cyanides, monoaromatic hydrocarbons, chlorinated and non-chlorinated phenolic compounds, resin and fatty acids, polybrominated diphenyl ethers, hormone mimicking substances, pharmaceuticals, personal care products, wood preservation chemicals and nanoparticles. However, insufficient information was available to evaluate the hazards posed to sockeye salmon in the Fraser River associated with exposure to these contaminants. Accordingly, these substances were identified as uncertain contaminants of concern and addressed in the qualitative evaluation of endocrine disrupting chemicals and contaminants of emerging concern.

ES1.3 Detailed Evaluation of the Potential Effects of Contaminants of Concern

In the next step of the process, the list of contaminants of concern was refined to eliminate those substances that were unlikely to be risk drivers. Then, a detailed evaluation was conducted to determine if the concentrations of any of the contaminants of concern in surface water, sediment, or fish tissues in the Fraser River or its tributaries were sufficient to adversely affect the survival, growth, or reproduction of sockeye salmon. In this evaluation, more realistic estimates of exposure to contaminants of concern (i.e., 95^{th} percentile concentrations) were compared to toxicity reference values (toxicity thresholds), which represent lowest observed effect levels of contaminants of concern for sockeye salmon or other salmonid fishes. The results of this assessment indicated that exposure to contaminated surface water and sediment or accumulation of contaminants in fish tissues pose potential hazards to sockeye salmon utilizing spawning, rearing, or migration habitats within the Fraser River Basin. The substances that occurred in water at concentrations sufficient to adversely affect the survival, growth, or reproduction of Fraser River sockeye salmon included total suspended solids, six metals (aluminum, chromium, copper, iron, mercury and silver), and phenols. However, analyses of water quality index scores and measures of productivity (i.e., Ricker residuals) suggested that declines in sockeye salmon abundance over the past 20 years or in 2009 were not likely caused by the substances considered in the water quality index. While the results of the sediment risk assessment showed that the concentrations of iron and nickel were elevated at various locations within the basin, exposure to these contaminants of concern in sediment is unlikely to be sufficient to adversely affect the survival, growth or reproduction of sockeye salmon. Nevertheless, the concentrations of selenium, and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalents, occurred or are likely to have occurred in salmon eggs at concentrations sufficient to adversely affect sockeye salmon reproduction.

ES1.4 Evaluation of Effects of Endocrine Disrupting Chemicals and Contaminants of Emerging Concern

Due to limitations on the availability of exposure data and/or toxicity thresholds, a qualitative evaluation was conducted to assess the potential effects on Fraser River sockeye salmon associated with exposure to endocrine disruption chemicals and contaminants of emerging concern. The results of this eco-epidemiological evaluation indicate that it is unlikely that exposure to these contaminants is the sole cause of the observed patterns in sockeye salmon abundance, either over the past 20 years or in 2009. However, contaminant exposures cannot be ruled out as a potential contributing factor for responses of Fraser River sockeye salmon over the past two decades and/or for the low returns of sockeye salmon to the river in 2009.

ES1.5 Uncertainty and Data Gap Analysis

There are a number of sources of uncertainty in assessments of risk to the sockeye salmon associated with exposure to contaminants in the Fraser River Basin, including uncertainties in the conceptual model, uncertainties in the effects assessment, and uncertainties in the exposure assessment. The results of the uncertainty analysis indicated that there are a number of key data gaps that substantively affect the confidence that can be placed in the evaluation of the potential effects of contaminants on Fraser River sockeye salmon. The most important of these uncertainties is the general absence of data that describe the nature and extent (both spatial and temporal) of contamination by total suspended solids, major ions, nutrients, metals, and other chemicals of potential concern in spawning and rearing habitats within the watershed. In addition, data on the concentrations of endocrine disrupting chemicals and other contaminants of emerging concern are generally lacking throughout the study area.

ES1.6 Conclusions and Recommendations

This study was conducted to determine if aquatic contaminants caused or substantially contributed to declines in the abundance of sockeye salmon over the past two decades and/or the low returns of sockeye salmon to the Fraser River in 2009. While limitations on the available data make it difficult to answer this question conclusively, the results of this study suggest that:

- Exposure to contaminants in surface water, sediments, or fish tissues is not the primary factor influencing the productivity or abundance of Fraser River sockeye salmon over the past 20 years or in 2009.
- There is a strong possibility that exposure to contaminants of concern, endocrine disrupting chemicals, and/or contaminants of emerging concern has contributed to the decline of sockeye salmon abundance in the Fraser River Basin over the past 20 years.

This evaluation of the effects of contaminants on Fraser River sockeye salmon was constrained by a number of key data gaps. As insufficient data were available to fully assess the role of contaminant exposures in the declines of sockeye salmon over the past two decades or the low returns of sockeye salmon to the Fraser River in 2009, a number of recommendations are offered to enhance the probability that the data and information required to conduct a more comprehensive evaluation are available in the future.

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2,4-D	-	2,4,-dichlorophenoxyacetic acid
ACA	-	ammoniacal copper arsenate
ACZA	-	ammoniacal copper zinc arsenate
AoI	-	area of interest
AOX	-	absorbable organic halide
APEO	-	alkylphenol ethoxylate
BAP	-	benzo(a)pyrene
BEHP	-	bis(2-ethylhexyl)phthalate
BBP	-	butylbenzyl phthalate
BOD	-	biological oxygen demand
BTEX	-	benzene, toluene, ethylbenzene, and xylene
BW	-	body weight
CABIN	-	Canadian Aquatic Biomonitoring Network
CCA	-	chromated copper arsenate
COC	-	contaminant of concern
COD	-	chemical oxygen demand
COPC	-	chemical of potential concern
Cu-8	-	copper-8-quinolinolate
CU	-	conservation unit
d	-	day
DBP	-	di-n-butyl phthalate
DDAC	-	didecyldimethyl ammonium chloride
DGIR	-	Director General of Investigation
EC_{25}	-	effective concentration affecting 25% of the population
EDC	-	endocrine disrupting compound
EPC	-	exposure point concentration
ER	-	estrogen-receptors
EROD	-	ethoxyresorufin-O-deethylase
FAV	-	final acute value
FRB	-	Fraser River Basin
GIS	-	geographic information system
GSI	-	gonadosomatic index scores
hr	-	hour
HQ	-	hazard quotient
IPBC	-	3-iodo-2-propynyl butyl carbamate
ISQG	-	interim sediment quality guideline
LC_{50}	-	lethal concentration affecting 50% of the population
LD_{50}	-	lethal dose affecting 50% of the population
LOAEL	-	lowest observed adverse effect level
LOECs	-	lowest observed effect concentration
log K_{ow}s	-	octanol-water partition coefficients
LRAT	-	long-range atmospheric transport
MATC	-	maximum acceptable toxicant concentration
MEC	-	median effect concentration

MeHg	-	methyl mercury
MS	-	Microsoft
MSMA	-	methanearsonate
NOAEL	-	no observed adverse effect level
PAH	-	polycyclic aromatic hydrocarbon
PBB	-	polybrominated biphenyls
PBDE	-	polybrominated diphenyl ether
PCB	-	polychlorinated biphenyl
PCDD/PCDF	-	dibenzo-*p*-dioxins and polychlorinated dibenzofuran
PCP	-	pentachlorophenol
PEC	-	probable effect concentration
PEC-Q	-	mean probable effect concentration quotient mean
PEL	-	probable effect level
PFOA	-	perfluorooctanoic acid
PFOS	-	perfluorooctane sulphonic acid
PPCP	-	pharmaceuticals and personal care product
PPM	-	pulp and paper mill
RET	-	residue effect threshold
SEV	-	screening ecotoxicity value
SVOC	-	semi-volatile organic compound
TBC	-	Treasury Board of Canada
TCDD	-	tetrachlorodibenzo-*p*-dioxin
TCMTB	-	2-(thiocyanomethylthio) benzothiazole
TEC	-	threshold effect concentration
TEQ	-	toxic equivalent
TRV	-	toxicity reference value
TSS	-	total suspended solid
TSV	-	toxicity screening value
TT	-	toxicity threshold
WAD	-	weak acid dissociable
wk	-	week
WQG	-	water quality guideline
WQI	-	water quality index
WW	-	wet weight
WWTP	-	wastewater treatment plants

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Chapter 1 Introduction

1.0 Background

On the west coast of North America, sockeye salmon utilize freshwater habitats from the Sacramento River in California to Kotzebue Sound in Alaska (Burgner 1991). Their unique life history means that sockeye salmon distribution and abundance are, for the most part, related to the availability of watersheds that contain linked riverine (for spawning) and lacustrine (for juvenile rearing) habitats. As a result of this unique habitat use, the two largest spawning complexes of sockeye salmon are found within the Bristol Bay watershed of southwestern Alaska and the Fraser River drainage basin of British Columbia (Burgner 1991). These populations of sockeye salmon have supported substantial aboriginal, commercial, and recreational fisheries for thousands of years.

While the productivity of Bristol Bay sockeye salmon populations has varied over the past 20 years, catches over this period have typically exceeded long-term averages (Eggers and Irvine 2007). In contrast, the productivity of sockeye salmon utilizing habitats within the Fraser River Basin has declined markedly over the past 20 years (Figure 1.1). Concerns over the productivity of Fraser River sockeye salmon intensified in 2007 and 2008, when low returns severely curtailed the fisheries on this species (McKinnell *et al.* 2011). The return of only 1.5 million adult sockeye salmon in 2009 - the lowest number since 1947, about 10% of the pre-season forecast of 10.5 million fish (Peterman *et al.* 2010) - reinforced these concerns and prompted the Governor General in Council to establish a Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (i.e., Cohen Commission). In accordance with its terms of reference, the Cohen Commission is required to:

- Consider the policies and practices of Fisheries and Oceans Canada with respect to the sockeye salmon fishery in the Fraser River;
- Evaluate the causes for the decline of Fraser River sockeye salmon;
- Investigate the current state of Fraser River sockeye salmon and the long-term projections for those stocks; and,
- Develop recommendations for improving the future sustainability of the sockeye salmon fishery in the Fraser River.

To assist it in fulfilling this mandate, the Cohen Commission engaged a team of scientists to evaluate the potential causes of the decline of Fraser River sockeye salmon. The topics addressed by these scientists include:

- Diseases and parasites;
- Effects of contaminants on Fraser River sockeye salmon;
- Fraser River freshwater ecology and status of sockeye salmon conservation units;
- Marine ecology;
- Impacts of salmon farms on Fraser River sockeye salmon;
- Fraser River sockeye fisheries and fisheries management;
- Effects of predators on Fraser River sockeye salmon;
- Effects of climate change on Fraser River sockeye salmon: literature compilation and analysis;
- Fraser River sockeye salmon production dynamics - data compilation, literature review, and reporting; and,
- Fraser River sockeye salmon: Status of Fisheries and Oceans Canada science and management.

It is anticipated that the series of scientific reports produced by the science team will assist the Commissioner during his deliberations on the decline of sockeye salmon in the Fraser River.

1.1 Study Objectives

This study was conducted to develop an Inventory of Aquatic Contaminants for the Fraser River Basin and to evaluate the potential effects of those contaminants on Fraser River sockeye salmon (See Appendix 1 for information on the Statement of Work for this project). To achieve these objectives, a work plan was developed that consisted of four distinct tasks, including:

- Prepare an Inventory of Aquatic Contaminants in the Fraser River in relation to the distribution of sockeye salmon conservation units;

- Compare data on water quality conditions in the Fraser River to toxicity data for sockeye salmon;
- Develop an overall assessment of the suite of contaminants (e.g., metals, pesticides) and natural substances (e.g., total suspended solids; TSS) that are encountered by juvenile and adult sockeye salmon; and,
- Evaluate the extent to which reductions in Fraser River sockeye salmon abundance are associated with contaminant conditions in the Fraser River.

1.2 Study Approach

A step-wise approach was developed to evaluate the potential effects on Fraser River sockeye salmon associated with exposure to contaminants. Implementation of the approach necessitated completion of the following steps:

- Identification of the areas and times that sockeye salmon could be exposed to aquatic contaminants in the Fraser River Basin (this information was used to define the geographic and temporal scope of the study);
- Identification of the chemical substances and natural variables that have been released into the Fraser River or its tributaries due to human activities (this list of substances was termed the Inventory of Aquatic Contaminants, which are also referred to as chemicals of potential concern);
- Determination of whether any of the chemicals of potential concern have occurred in surface water, sediment, or fish tissues at levels sufficient to pose potential threats to aquatic organisms (this assessment was termed the preliminary evaluation of chemicals of potential concern and resulted in identification of contaminants of concern that required further evaluation);
- Determination of whether the concentrations of any of the contaminants of concern in surface water, sediment, or fish tissues in the Fraser River or its tributaries were sufficient to adversely affect the survival, growth, or reproduction of sockeye salmon (this assessment was termed the evaluation of contaminants of concern);
- Evaluation of the potential effects of endocrine disrupting chemicals and other contaminants of emerging concern on sockeye salmon;
- Identification of uncertainties in the assessment and key data gaps; and,

- Development of conclusions and recommendations relative to the effects of contaminants on Fraser River sockeye salmon.

The methods that were used to conduct this evaluation, and the associated results, are described in the applicable sections of this report.

1.3 Organization of this Report

The primary objective of this investigation is to provide the Cohen Commission with an Inventory of Aquatic Contaminants in the Fraser River Basin (study area) and an evaluation of the potential effects of those contaminants on sockeye salmon. This report has been organized as follows:

- *Chapter 1* - Introduction;
- *Chapter 2* - Geographic and Temporal Scope of the Investigation: This chapter provides a brief description of the life history of Fraser River sockeye salmon, identifies the areas of interest that were investigated, and describes the temporal scope of the study;
- *Chapter 3* - Inventory of Aquatic Contaminants: This chapter provides descriptions of point source discharges, non-point source discharges, and atmospheric sources that release contaminants into aquatic ecosystems within the Fraser River Basin. The contaminants that are typically associated with each of these sources are also identified to support development of the Inventory of Aquatic Contaminants;
- *Chapter 4* - Preliminary Evaluation of Chemicals of Potential Concern: This chapter describes the procedures that were used to evaluate the potential risks to sockeye salmon associated with exposure to aquatic contaminants, including the effects assessment, the exposure assessment, and the hazard assessment. Contaminants of concern are also identified in this chapter;
- *Chapter 5* - Evaluation of Contaminants of Concern: This chapter describes the procedures that were used to evaluate the effects on sockeye salmon associated with exposure to contaminants of concern, including the effects assessment, the exposure assessment, and the hazard assessment. The spatial and temporal extent of conditions sufficient to adversely affect Fraser River sockeye salmon are also described in this chapter;

- *Chapter 6* - Evaluation of the Potential Effects of Endocrine Disrupting Chemicals and Other Contaminants of Emerging Concern on Fraser River Sockeye Salmon: This chapter describes the procedures that were used to evaluate the potential effects of endocrine disrupting chemicals and other contaminants of emerging concern on sockeye salmon in the Fraser River Basin. The results of that evaluation are also presented;
- *Chapter 7* - Uncertainty and Key Data Gaps: This chapter describes the uncertainties in the assessments of the potential effects of aquatic contaminants on sockeye salmon in the Fraser River Basin. Key data gaps are also identified in this chapter; and,
- *Chapter 8* - Summary and Conclusions: This chapter presents a summary of the study results and offers a series of recommendations to address the data gaps identified earlier in the document.
- *Chapter 9* - References Cited: A list of reference citations for references used int his report.
- Appendices - Appendix 1, Statement of Work; Appendix 2, Reviewer's comments on the first draft and response to comments; Appendix 3, Data Acquisition Plan; Appendix 4 - Data Methodology and Treatment; Appendix 5 - Data Description and Sources for all Maps.

Chapter 2 Geographic and Temporal Scope of the Investigation

2.0 Introduction

This investigation was conducted to evaluate the potential effects of contaminants on sockeye salmon utilizing habitats within the Fraser River Basin (Figure 2.1). Evaluation of the effects of contaminants requires an understanding of the life history of the sockeye salmon that utilize habitats within the Fraser River basin for key elements of their life cycles. Such information is needed to identify where and when sockeye salmon could be exposed to environmental contaminants. This chapter provides a brief overview of the life history of Fraser River sockeye salmon and conservation units that have been identified for managing these salmon stocks. In turn, this information was used to identify the geographic and temporal scope of the investigation.

2.1 Life History of Fraser River Sockeye Salmon

Sockeye salmon utilizing habitats in the Fraser River Basin (Figure 2.2) exhibit a diverse array of life history patterns. The life cycle of sockeye salmon begins when the females return to their natal streams to spawn. The timing of arrival at the mouth of the Fraser River varies considerably among sockeye salmon stocks, generally ranging from early June to early September (Burgner 1991; Lapointe 2010). Upon arrival, sockeye salmon can mill at the river mouth for a period of up to six weeks prior to initiating their ascent up the river (Johannessen and Ross 2002). Once in the river, sockeye salmon cover distances of up to 1000 km over a period of up to 24 days (averaging 35 to 50 km/day; Burgner 1991). Hence, migrating sockeye salmon can be in the Fraser River between about the middle of June and the middle of September each year.

Spawning generally occurs in the late summer and early fall (i.e., about mid-August to mid-October), with northern stocks typically spawning earliest and lower Fraser River tributary stocks spawning latest (McPhail 2007). These differences in spawning timing are directly related to the temperature regime of the spawning site and appear to be an adaptation to synchronize emergence timing in the spring (Brannon 1987). Spawning typically takes place in tributaries to lakes, within lakes, or in outlet streams from lakes in habitats dominated by gravel and cobbles. After digging a nest (or redd), female sockeye salmon typically deposit about 2000 to 4000 eggs into the stream-bed or lake-bed substrate, which are simultaneously fertilized by one or more males (Burgner 1991). Adult sockeye salmon die after spawning.

The eggs of sockeye salmon incubate within the stream-bed or lake-bed substrate for extended periods of time. Time to hatching is variable, depending primarily on the temperature regime at the spawning location. Data from several sources indicate that sockeye salmon eggs require between 350 and 720 temperature units (i.e., degree days, in ºC) and up to 170 days to hatch (Foerster 1968; Velsen 1980). After hatching, alevins (or yolk-sac fry) may remain in the gravel for several months, with emergence usually occurring 140 to 225 days following fertilization of the eggs (i.e., at 1000 to 1150 temperature units; Mead and Woodall 1968).

Emergent sockeye salmon fry exhibit a variety of migratory behaviours, depending on the stock and the spawning location under consideration. For example, fry emerging from tributaries located upstream of the nursery lake move downstream with the current, while those emerging from downstream spawning locations initially move laterally to the streambanks (to avoid being swept downstream) and then migrate upstream to the nursery lake (Burgner 1991). Fry emerging from lakeshore spawning sites tend to move offshore to deeper water. Upon arrival in the nursery lake, sockeye salmon fry rear for one to two years before migrating to the ocean. At least one stock (Harrison River) does not utilize rearing habitats within a freshwater nursery lake, but instead rears within the Harrison River, Lower Fraser River, and/or Fraser Estuary before migrating to the ocean (Johannessen and Ross 2002). Accordingly, most stocks of sockeye salmon utilize freshwater rearing habitats for at least one year prior to downstream migration.

In their second year of life, most sockeye salmon in the Fraser River Basin undergo a number of morphological, physiological, and behavioural alterations to prepare for migration to the ocean. This process, termed smoltification, usually occurs in the spring when break-up (i.e., ice melt) and spring overturn occur in the nursery lake. Sockeye salmon smolts typically initiate downstream migration in late April to late June, depending on the stock (Hartman *et al.* 1967). Downstream migrants may average 40 km/day, possibly requiring up to 30 days to reach the estuary. Some sockeye salmon reside in the estuary or nearshore areas for some time after outmigration, but most stocks enter the Strait of Georgia by the end of May (Burgner 1991). Distribution of sockeye salmon to offshore waters is usually complete by autumn. Sockeye salmon reside in the marine environment for one to four years, with most fish returning to the Fraser River after two to three years of ocean residence (Burgner 1991).

Adverse effects on ecological receptors can occur when stressors and receptors are present in the same place and at the same time. As such, determination of exposure of sockeye salmon to contaminants in the Fraser River Basin requires an understanding of the life history of this species. The foregoing review of life history characteristics provides a basis for generally identifying the time periods when Fraser River sockeye salmon utilize the three types of freshwater habitats. This information is essential for organizing water quality data in a manner that facilitates an evaluation of exposure to environmental contaminants. In this evaluation, the key time periods for sockeye salmon in freshwater habitats are considered to include:

- Spawning and incubation of sockeye salmon eggs and alevins in stream and lakeshore habitats - August 1 to May 31 (Burgner 1991; McPhail 2007);
- Early rearing of sockeye salmon fry in nursery lakes - April 1 to March 31 (Burgner 1991);
- Downstream migration of sockeye salmon smolts through riverine (i.e., Fraser River and tributaries) and estuarine habitats - May 1 to June 30 (Burgner 1991); and,
- Upstream migration of sockeye salmon adults through estuarine and riverine (i.e., Fraser River and tributaries) habitats - June 1 to September 30 (Burgner 1991; LaPointe 2010).

In developing these generalizations, it is understood that each stock of sockeye salmon in the Fraser River Basin has acquired life history characteristics that reflect adaptations to the specific conditions in their natal stream. Accordingly, the time periods that individual stocks use each habitat type is variable. Nevertheless, these time periods were used to compile water quality data that would be generally reflective of exposure periods for key life stages of Fraser River sockeye salmon and would facilitate comparisons of conditions within and among the various geographic areas to determine if the presence of contaminants in freshwater habitats has caused or substantially contributed to declines of sockeye salmon in the watershed.

2.2 Sockeye Salmon Conservation Units

Assessment of exposure of Fraser River sockeye salmon to contaminants requires an understanding of habitat use, in both time and space. Sockeye salmon utilize spawning, rearing, and migration habitats throughout much of the Fraser River Basin. In the past, individual populations of sockeye salmon were identified based on the location on their natal stream and each population was termed a “stock.” While the stock concept acknowledged the diversity of salmon populations, it is not consistent with the approach that is used to manage the use of sockeye salmon by commercial fishers, recreational anglers, and aboriginal groups (i.e., it is not practical to manage each stock of sockeye salmon in the Fraser River independently because they are difficult to distinguish in approach and riverine fisheries).

To address the limitations associated with the stock concept, salmon managers have developed the concept of sockeye salmon conservation units to provide a more practical basis for managing stocks that originate within a common geographic area. A conservation unit is defined as "Groups of wild salmon living in an area sufficiently isolated from other groups that, if extirpated, the area is very unlikely to be recolonized naturally within an acceptable time frame" (Holtby and Ciruna 2007). For Fraser River sockeye salmon, a total of 36 conservation units have been identified, based on data from 275 sampling sites in the basin (Table 2.1, 2.2, 2.3, and 2.4; Pestal and Cass 2009). These sockeye salmon conservation units were examined to identify key exposure areas (i.e., termed Areas of Interest in this study) for sockeye salmon in the Fraser River Basin. These areas of interest describe the geographic scope of the study area.

2.3 Areas of Interest

Sockeye salmon utilize spawning and rearing habitats throughout much of the Fraser River Basin. In addition, juvenile and adult sockeye salmon utilize migration corridors within the basin. Sockeye salmon can be exposed to aquatic contaminants in spawning habitats, rearing habitats, and/or migration corridors. Therefore, it is necessary to identify key exposure areas within the Fraser River Basin that are relevant to the various sockeye salmon conservation units. These exposure areas are referred to as areas of interest in this study.

In this study, areas of interest were identified using information on the distribution of sockeye salmon within the Fraser River Basin. More specifically, the sampling sites for early Stuart, early summer, summer, late, and river-type conservation units (Pestal and Cass 2009) were reviewed to identify a total of 15 exposure areas within the river basin (Figure 2.3), including:

- Lower Fraser River Area of Interest (i.e., from river mouth to Hope);
- Upper Fraser River Area of Interest (i.e., from Hope to Red Pass);

- Pitt River Area of Interest (i.e., headwaters to the confluence with the Fraser River);
- Harrison River Area of Interest (i.e., headwaters to the confluence with the Fraser River, including the Lillooet River, Birkenhead River, and Gates Creek basins);
- Cultus Lake Area of Interest (i.e., Chilliwack River headwaters to the confluence of the Vedder Canal and the Fraser River);
- Kakawa Lake Area of Interest (i.e., headwaters of Kakawa Lake to the confluence of the Coquihalla and Fraser rivers);
- Nahatlatch River Area of Interest (i.e., headwaters to the confluence with the Fraser River);
- Seton-Portage Area of Interest (i.e., headwaters to the mouth);
- Lower Thompson River Area of Interest (i.e., from inlet of Kamloops Lake to the confluence of the Thompson and Fraser rivers, including the Nicola, Coldwater, and Deadman river basins);
- North Thompson River Area of Interest (i.e., from the headwaters of the Barriere River to the confluence with the South Thompson River);
- South Thompson River Area of Interest (i.e., from the headwaters to the confluence with the North Thompson River, including the Adams River, Momich River, Eagle River, Scotch Creek, Upper Shushwap River, Middle Shuswap, Lower Shuswap, and Salmon rivers basins);
- Chilko River Area of Interest (i.e., from the headwaters of the Chilcotin, Chilko, and Taseko rivers to the confluence with the Fraser River);
- Quesnel River Area of Interest (i.e., from the headwaters to the confluence with the Fraser River, including the Mitchell River, McKinley Creek, Horsefly River, Little Horsefly River, and Cariboo River basins);
- Nechako River Area of Interest (i.e., from the headwaters to the confluence with the Fraser River, including, the Driftwood River, Middle River, Tachie River, Nadina River, and Stellako River basins); and
- Bowron River Area of Interest (i.e., from the headwaters to the confluence with the Fraser River).

Each of these areas of interest, was further examined to identify key exposure areas for sockeye salmon, including spawning areas, rearing areas, and migration routes. This latter information is essential for selecting water quality monitoring stations that can be used to characterize exposure of sockeye salmon to contaminants during each of their life history stages (i.e., eggs and alevins, fry, smolts, and adults).

2.4 Temporal Scope of Study

The escapement of sockeye salmon to the Fraser River has varied substantially over the period of record and has generally trended downward since the early 1990's (average escapement for each area of interest are shown in Figure 2.4, while temporal trends in sockeye salmon productivity for all stocks is presented in Figure 1.1). To determine if exposure to contaminants represents a causative or contributing factor in the decline of Fraser River sockeye salmon, it is necessary to compare current conditions in the watershed to those that have existed historically in the Fraser River and its tributary watersheds. Accordingly, the temporal scope of this study has been broadly defined to include the entire period of record for which reliable water quality data are available (i.e., 1965 - 2010).

Chapter 3 Inventory of Aquatic Contaminants

3.0 Introduction

There are a wide variety of land and water use activities that have the potential to adversely affect aquatic habitats within the Fraser River Basin. Such anthropogenic activities have the potential to release a diversity of contaminants into the Fraser River and its tributaries. To identify the substances that could be causing or substantially contributing to the declines of sockeye salmon in the study area, a review of the literature was conducted to document land and water use activities and to identify the contaminants that are typically associated with each land and water use. This information was then integrated to identify the substances that could be adversely affecting the survival, growth, or reproduction of sockeye salmon in the Fraser River Basin. The resultant compilation of chemicals that pose potential threats to sockeye salmon was termed the Inventory of Aquatic Contaminants for the watershed. This chapter describes the sources and releases of contaminants to the aquatic ecosystems contained within the basin and integrates the relevant information to develop the Inventory of Aquatic Contaminants.

3.1 Sources and Releases of Contaminants to Aquatic Ecosystems

There are a number of natural and anthropogenic sources of toxic and bioaccumulative substances in the Fraser River Basin. Natural sources of such substances include weathering and erosion of terrestrial soils, bacterial decomposition of vegetation and animal matter, and long-range transport of substances originating from forest fires or other natural combustion sources. In addition to these natural sources, there are a number of anthropogenic point and non-point sources of toxic and/or bioaccumulative substances within the Fraser River Basin, including:

<u>Point Sources</u>

- Pulp and paper mills;
- Sawmills, plywood mills, and particle board mills;
- Wood preservation facilities;
- Cement and concrete plants;
- Seafood processing facilities;
- Operating and abandoned mines;

- Oil and gas developments;
- Bulk storage and shipping facilities;
- Other manufacturing facilities;
- Contaminated sites and contaminant spills;
- Municipal wastewater treatment facilities;
- Municipal and industrial landfills; and,
- Salmonid enhancement facilities (including lake fertilization projects).

Non-Point Sources
- Runoff from forest management areas;
- Runoff from agricultural operations;
- Runoff of municipal stormwater; and,
- Runoff from linear developments.

Atmospheric Sources
- Natural sources of atmospheric pollutants (forest fires and volcanoes); and,
- Anthropogenic sources of atmospheric pollutants (i.e., vehicle emissions, industrial emissions, agricultural emissions, and long-range transport of atmospheric pollutants).

Each of these potential sources of toxic and/or bioaccumulative substances is briefly discussed in the following sections.

3.1.1 Point Sources
There are a number of point sources of contaminants that collectively discharge substantial volumes of wastewater into receiving waters within the Fraser River Basin. This section of the report describes point source discharges from municipal wastewater treatment plants, pulp mills, mines, and other facilities that are located within the study area.

3.1.1.1 Pulp and Paper Mills
There are a total of ten pulp and paper mills operating within the Fraser River Basin, including two located near Prince George (Northwood Pulp Mill and Prince George Pulp

and Paper Mills - Canfor Pulp Limited partnership), two located near Quesnel (Quesnel River Pulp and Cariboo Pulp and Paper Company - West Fraser Mills Ltd.), one located near Kamloops (Kamloops Cellulose Fibres - Domtar Pulp and Paper Products Inc.), and five located near Vancouver (Norampac Burnaby - Cascades Canada Inc.; Buckeye Canada - Delta Division; Kruger Products L.P - three locations; Figure 3.1, Table 3.1).

The chemical characteristics of pulp mill effluents are variable depending on the type of wood fibre that is available, the bleaching process that is used, and the level of treatment that is applied. Unbleached pulp mill effluents contain resin acids and soaps, fatty acids, diterpene alcohols, and phytosterols (Environment Canada and Health Canada 1991). In addition to these substances, effluents generated by pulp mills utilizing a chlorine bleaching process contain chlorinated acids, alcohols, aldehydes, ketones, sugars, aliphatic hydrocarbons, aromatic hydrocarbons, chlorophenols, chloroguaiacols, chlorocatechols, chlorovanallins, chlorosyringols, and chlorinated syringaldehydes (Suntio *et al.* 1988; Walden *et al.* 1986). The latter two groups of compounds are primarily associated with effluents from pulp mills utilizing hard wood as the fibre source (Fleming *et al.* 1990). Table 3.2 provides a listing of many of the substances that are typically found in bleached-kraft pulp mill effluent.

In Canada, the Pulp and Paper Effluent Regulations section of the Fisheries Act provides the legislative authority for regulating discharges from pulp and paper mills to the environment. These regulations explicitly identify three prescribed deleterious substances, including biological oxygen demand (BOD) matter, total suspended solids (TSS), and acutely lethal effluent. The first two variables are regulated under the Fisheries Act, with maximum daily and monthly discharges established for each mill based on its production rate (expressed in tonnes/day). In addition, all pulp mill effluent must be not acutely toxic, based on the results of 96-hr effluent toxicity tests with rainbow trout, *Onchorynchus mykiss* and/or 48-hr effluent toxicity tests with the cladoceran, *Daphnia magna*. Furthermore, dischargers are required to conduct a number of environmental monitoring studies to evaluate the potential effects of the effluent on fish populations, on fish tissues, and on the benthic invertebrate community. Such environmental effects monitoring may also include sub-lethal toxicity testing (i.e., 7-d effluent toxicity tests with the cladoceran, *Ceriodaphnia dubia*). The levels of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDFs) in the effluent are also typically reported as part of this monitoring program.

Since 1992, discharges of absorbable organic halides (AOX) have been regulated by the provincial government to reduce releases of organochlorines into aquatic environments (i.e., with regulations initially targeted on reducing AOX discharges to zero by 2002, and subsequently amended to be in line with those established in the United States). Data from various sources indicate that biological treatment tends to reduce diversity and mass of chlorinated compounds in the effluent from bleached kraft pulp mills (Bjorseth *et al.* 1976; McKague 1988; Kringstad and Lindstrom 1984). Janz *et al.* (2001) also reported that the concentrations of endocrine disrupting compounds in pulp mill effluent declined with secondary treatment. However, the extent to which the changes in pulp production processes, implemented in the 1990s, have reduced releases of endocrine disrupting compounds and/or other contaminants to the environment has not been fully evaluated (Johannessen and Ross 2002). In summary, the substances of greatest concern relative to contamination of aquatic habitats by pulp and paper effluents include:

- Conventional variables (such as pH, BOD and TSS; Samis *et al.* 1999);
- Nutrients (such as ammonia and phosphorus; Johannessen and Ross 2002);
- Major ions (such as chlorides; Hakeem and Bhatnager 2010);
- Metals (such as cadmium, copper, and mercury; Hakeem and Bhatnager 2010);
- Mono-aromatic hydrocarbons (such as benzene and toluene; Suntio *et al.* 1988);
- Polycyclic aromatic hydrocarbons (PAHs; such as parent and alkylated PAHs; Engwall *et al.* 2009);
- Chlorinated phenolics (chlorophenols, chloroguaiacols, and chlorocatechols; Suntio *et al.* 1988);
- Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (such as 2,3,7,8-TCDD; Mah *et al.* 1989);
- Resin acids (abietic acid, neoabietic acid, dehydroabietic acid, palustric acid, levopimaric acid, pimaric acid, and isopimaric acid; Suntio *et al.* 1988);
- Fatty acids (such as palmitic acid, stearic acid, lignoceric acid, oleic acid, linoleic acid, and linolenic acid; Suntio *et al.* 1988);
- Surfactants [such as alkylphenol ethoxylates (APEOs); Johannessen and Ross 2002]; and,
- Natural plant hormones (Johannessen and Ross 2002).

3.1.1.2 Sawmills, Plywood Mills and Particle Board Mills

There are numerous sawmills (including shake and shingle mills), veneer and plywood mills, and waferboard, particleboard, and fibreboard mills located throughout the Fraser River Basin (Figure 3.2; Table 3.3). For sawmills that produce raw or kiln-dried lumber, concerns relative to contamination of receiving water systems are primarily associated with releases of leachates from wood waste. According to Samis *et al.* (1999), wood-waste leachates contain a variety of chemical substances, including carbohydrates (i.e., long-chain water-insoluble polysaccharides and water-soluble wood sugars; e.g., cellulose, hemicellulose, starch, pectin), phenolics (e.g., lignins, tannins, lignans, para-hydroxybenzoic acid, tropolones), terpenes (e.g., non-volatile acids, such as resin acids; volatile terpenes, such as mono-terpenes and terpenoids), alphatic acids (i.e., saturated fatty acids, such as palmitic, stearic, and lignoceric acids; unsaturated fatty acids, such as oleic, linoleic, and linolenic acids), and alcohols (such as aliphatic alcohols and sterols). Based on the review of the literature, Samis *et al.* (1999) identified the following analytes as the most relevant for evaluating the potential effects of wood-waste leachate on aquatic organisms: pH, colour, dissolved oxygen, total organic carbon, BOD, chemical oxygen demand (COD), and toxicity. Other substances that have been measured to characterize wood-residue leachates include ammonia, total phosphorus, sulphide, tannin and lignin, and metals (Birkbeck *et al.* 1990). Wood-waste leachate concentrations as low as 25 mg/L were demonstrated to be toxic to pink salmon (*Onchorynchus gorbuscha*) fry (Samis *et al.* 1999).

For plywood mills, most of the water used in the production of plywoods and veneers is used to soak the logs (Jokela and Keskitalo 1999). Hence, wastewater generated from such facilities are likely to contain many or all of the substances that are associated with woodwaste leachates. Therefore, pH, colour, dissolved oxygen, total organic carbon, BOD, COD, and toxicity are likely to be the key issues that need to be addressed when evaluating the potential effects of effluents from such mills on aquatic organisms. In addition, production of plywoods, veneers, particleboard, waferboard, and/or fibreboard requires substantial quantities of synthetic phenol- and urea-formaldehyde resins, proteinaceous grain flour extender, and ligno-cellulose and clay filler (Sellers 1977). Therefore, effluents from such mills may also contain elevated levels of phenols, urea, and/or formaldehyde. Soto *et al.* (1991) reported that fibreboard mill effluents were enriched with sulphates, phosphates, ammonia, phenol, and *p*-cresol. In summary, the substances of greatest concern relative to contamination of aquatic habitats by discharges from sawmills and other wood product manufacturing facilities include:

- Conventional variables (such as pH, BOD and TSS; Samis *et al.* 1999);

- Nutrients (such as ammonia and phosphorus; Birkbeck *et al.* 1990);
- Major ions (such as sulphides and sulphates; Birkbeck *et al.* 1990; Soto *et al.* 1991);
- Metals (Birkbeck *et al.* 1990);
- Phenolic compounds (such as phenol; Sellers 1977);
- Resin acids (abietic acid, neoabietic acid, dehydroabietic acid, palustric acid, levopimaric acid, pimaric acid, and isopimaric acid; Samis *et al.* 1999);
- Fatty acids (such as palmitic acid, stearic acid, lignoceric acid, oleic acid, linoleic acid, and linolenic acid; Samis *et al.* 1999);
- Other chemicals (such as formaldehyde; Sellers 1977); and,
- Natural plant hormones (Johannessen and Ross 2002).

3.1.1.3 Wood Preservation Facilities

There are at least 15 operating wood preservation facilities located within the Fraser River Basin. Five of these facilities are located within the Lower Fraser River Area of Interest, four are located within the Upper Fraser River Area of Interest, three are located within the South Thompson River Area of Interest, two are located within the Lower Thompson River Area of Interest, and one is located within the Nechako River Area of Interest. The locations of these facilities are shown in Figure 3.3 and the facility names and principal products produced are presented in Table 3.4.

Freshly-cut softwood lumber is susceptible to attack by moulds and fungi that can discolour the wood or promote decomposition. For this reason, lumber and other forest products (e.g., poles) are frequently treated with various chemicals prior to transport and sale. Such wood preservation and anti-sapstain chemicals include a variety of products that contain one or more of the following active ingredients: creosote (and associated PAHs); chromated copper arsenate (CCA); pentachlorophenol (PCP; which may contain PCDFs); ammoniacal copper arsenate (ACA); ammoniacal copper zinc arsenate (ACZA); chlorophenol; 2-(thiocyanomethylthio) benzothiazole (TCMTB); copper-8-quinolinolate (Cu-8); 3-iodo-2-propynyl butyl carbamate (IPBC); didecyldimethyl ammonium chloride (DDAC); sodium carbonate; borate (disodium octaborate tetrahydrate and disodium tetraborate decahydrate); and/or, azaconazole (Johannessen and Ross 2002). The quantities of these chemicals that are used in British Columbia each year (primarily in the Fraser River Basin) ranges from 0.0 kg for ACA (i.e., use was halted in 1999) to 5,390,000 kg for creosote, based on the 1999 Survey of Pesticide Use in British Columbia

(ENKON Environmental Ltd. 2001). Considering the quantities used, the highest priority wood preservation and anti-sapstain chemicals in the study area include:

- Creosote;
- Chromated copper arsenate (CCA);
- Ammoniacal copper zinc arsenate (ACZA);
- Pentachlorophenol (PCP);
- Didecyldimethyl ammonium chloride (DDAC); and,
- 3-iodo-2-propynyl butyl carbamate (IPBC).

3.1.1.4 Cement and Concrete Plants

According to Environment Canada (1998), there were two major cement plants operating in the lower mainland in 1993, including the Lafarge Canada Inc. (located in Richmond) and Tilbury Cement Ltd. (located in Delta; Figure 3.4). These plants are permitted to discharge up to 6,100 and 18,200 m^3/d of effluent to the Fraser River, respectively. However, there are numerous other cement and concrete plants located throughout the study area, including one in the South Thompson River Area of Interest and 14 others in the lower Fraser River Area of Interest. Collectively, these other cement and concrete plants are permitted to discharge up to 775 m^3/d of effluent to the Fraser River or its tributaries (Table 3.5).

The information needed to fully characterize the effluents associated with cement and concrete plants was not located in the literature. However, Environment Canada (1998) reported that cement plant effluents typically contain elevated levels of TSS and metals (arsenic, copper, lead, and zinc). Information from other sources indicate that such effluents may also contain potassium, sodium hydroxide, chlorides, sulphates, calcium carbonate, aluminum, and chromium (EEAA 2005). Effluent discharges from these plants also tend to have elevated levels of pH, which can influence the toxicity of ammonia to freshwater fish and other aquatic organisms (USEPA 2009b). The effluent discharge permits that have been established for the facilities in the Fraser River Basin include monitoring requirements for effluent. The variables identified in these permits include oil and grease, TSS, pH, BOD, and/or toxicity. Therefore, the contaminants of greatest interest with respect to effluent discharges from cement plants include:

- Conventional variables (i.e., pH, BOD, and TSS);

- Major ions (sodium, potassium, chlorine, and sulfates);
- Oil and grease; and,
- Metals (aluminum, arsenic, copper, chromium, lead, and zinc).

3.1.1.5 Seafood Processing Facilities

According to Environment Canada (1998), there were eight fish processing plants that discharged effluent to the Fraser River in 1993. Data compiled more recently (2008-2010) indicate that there are at least 10 seafood processing operations that are permitted to discharge effluent into the lower Fraser River, including Aero Trading Co. Ltd. (Vancouver), Bella Coola Fisheries Ltd. (Delta), British Columbia Packers Ltd. (Now Weston Foods Canada; Richmond), Delta Pacific Seafoods Ltd. (Delta), Lions Gate Fisheries Ltd. (Delta), New West Net Co. Ltd. (New Westminster), Ocean Fisheries Ltd. (Richmond), S.M. Products (B.C.) Ltd. (Delta), Seven Seas Fish Co. (2005) Ltd. (Delta), Shearer Seafood Products Ltd. (Delta; Table 3.6; Figure 3.5; Source; Nova Tec Consultants Inc. and EVS Consultants 1993). Another 27 seafood processing facilities were identified in the lower mainland (Table 3.6; Figure 3.5); however, effluent permits were not located for these operations. One facility, which is operated by the Siska Traditions Society, is located in the Upper Fraser River Area of Interest.

Issues and concerns relative to the discharge of fish processing wastewaters into the Fraser River are primarily associated with total dissolved solids, TSS, BOD and COD, nitrate, nitrite, ammonia, and faecal coliforms. In addition, a least one of the effluent samples from each of three facilities tested were found to be acutely toxic to rainbow trout and toxic to the cladoceran, *Ceriodaphnia dubia*, the alga, *Selenastrum capricornutum*, and to bacteria, *Photobacterium phosphoreum* (Nova Tec Consultants Inc. and EVS Consultants 1993). Based on the variables that must be measured in effluents discharged from these facilities and other information, the priority contaminants for seafood processing facilities include:

- Conventional variables (i.e., temperature, pH, BOD, and TSS);
- Residual chlorine,
- Nutrients (nitrate, nitrite, and ammonia); and,
- Oil and grease.

Effluent toxicity was also included as a variable that must be monitored for a subset of the seafood processing facilities in the Fraser River Basin. Seafood processing facilities also represent potential sources of native bacterial and viral diseases that are harboured in processed fish. In the future, the effluent of seafood processing facilities should be tested for the presence of fish disease agents.

3.1.1.6 Operating and Abandoned Mines

There are numerous operating and abandoned mines located within the Fraser River Basin that have the potential to release contaminants into the Fraser River or its tributaries. The locations of the 28 operating metal and mineral mines within the study area are shown in Figure 3.6 (Table 3.7). The numbers and locations of abandoned mines or exploration sites were not determined as part of this investigation (see Nelitz *et al.* 2011 for more information on these facilities). There are seven operating mines in the Upper Fraser River Area of Interest, including the Anderson River (East Anderson) Mine (granite, dimension stone, and building stone, Dome Creek Mine (slate, flagstone, dimension stone, and building stone), the Giscome mine (limestone), the Gibraltar Mine (copper, molybdenum, gold, and silver), the Island Mount Mine (gold), the Nazko Mine (aggregate and pumice), and the Wingdam Mine (gold).

Within the Quesnel River Area of Interest, there are three operating or inactive mines including the Mount Polley Mine (copper, gold, and silver), the Keithley Creek Mine (gold), and the Quesnel River Mine and Mill (gold). Three mines are located within the Nechako/Stuart/Trembleur Area of Interest, including the Huckleberry Mine (copper, molybdenum, zinc, gold), the Endako mine (molybdenum, copper, zinc, tungsten, and bismuth), and the Dahl Lake Quarry (limestone, aggregate). The Prosperity Mine (gold and copper), which was proposed for development in the Chilko River watershed, has not been approved based on the results of an environmental assessment.

The Lower Thompson River Area of Interest has the highest density of mining operations in the study area. Two metal mines are located within this geographic area, including the Craigmont Mine (magnetite, copper, iron, gold, and silver) and the Highland Valley Copper Mine (copper, molybdenum, silver, gold, lead, and zinc). The Ashton Mine (gold and copper) recently completed the permitting phase of the regulatory process and will become the third operating metal mine in this area. There are four non-metal mines located within the Lower Thompson River Area of Interest, including the Ashcroft Mine (aggregate), the Pavilion Lime Plant (limestone and aggregate), the Ranchlands Mine (zeolite), and the Walhachin Quarry (railroad ballast).

Absorbent Products Ltd. operates the only mine in the North Thompson River Area of Interest, which produces bentonite for use in a variety of consumer products. In the South Thompson River Area of Interest, there are three non-metal mines in operation including a gypsum/anhydite producers near Falkland (Falkland Mine), a limestone producer near Kamloops (Harper Ranch Mine), and a volcanic ash/silica/kaolinite producer near Buse Lake (Buse Lake Mine).

The Mount Meager Mine, located in the Harrison/Lillooet River Area of Interest, produces pumice and pozzolan. In the Chilliwack/Cultus Lake area of interest, two facilities are producing shale and clay. These include the Richmix Fireclay facility and the Sumas Mountain facility.

The development and operation of metal mines and other mining facilities has the potential to influence water quality conditions in receiving water systems. Such effects on water quality can be associated with the construction and/or operation of the following mine components:

- Camp facilities, including buildings and equipment;
- Sewage treatment facilities;
- Wastewater treatment facilities;
- Tailings containment areas;
- Open pits;
- Waste rock piles;
- Roads and storage yards;
- Airstrip; and,
- Quarries and soil borrow areas.

In addition, unintentional releases of wastewater, waste materials, or contaminants (i.e., fuel, oil, etc.) can adversely affect water quality conditions. The substances that may have been released from operating mines in the Fraser River Basin include suspended solids, metals, nutrients (i.e., ammonia, nitrate, and nitrite from blasting; phosphorus from sewage), TSS, oil and grease, and diesel (i.e., PAHs and alkanes). Mercury releases likely occurred from the abandoned Pinchi Lake Mine in the Nechako River Area of Interest and, possibly, from the placer mining facility in the Quesnel River Area of Interest. Other abandoned mines could have released metals to receiving water systems in the study area, in association with acid rock drainage and/or other wastewater sources (see Nelitz *et al.*

2011 for more information on the locations of past producing mines in the study area). In summary, the contaminants that are typically associated with wastewater effluent discharges and other activities conducted at mine sites include:

- Conventional variables (i.e., alkalinity, conductivity, hardness, pH, and TSS);
- Microbiological variables (i.e., faecal coliforms and enterococci);
- Major ions (potassium, sodium, and sulphate);
- Nutrients (i.e., nitrate, nitrite, ammonia, and phosphorus);
- Metals (aluminum, arsenic, boron, barium, cadmium, copper, copper, chromium, iron, lead, mercury, manganese, molybdenum, nickel, antimony, selenium, strontium, silver, and zinc);
- Cyanides (strong acid dissociable and weak acid dissociable);
- Petroleum hydrocarbons (oil and grease, alkanes, diesel-range organics);
- Monoaromatic hydrocarbons (i.e., benzene, toluene, ethylbenzene, and xylene); and,
- Polycyclic aromatic hydrocarbons (i.e., parent PAHs, alkylated PAHs, total PAHs).

3.1.1.7 Oil and Gas Developments

Based on the information available, there is no active oil or gas production in the Fraser River Basin (Hannigan *et al.* 1998). However, exploration activities have revealed significant oil and gas potential in the Nechako Basin, the Quesnel trough, and the Georgia Basin (Hannigan *et al.* 1998).

There are several important oil and gas pipelines that are being operated within the study area (Figure 3.7; Table 3.8). First, Duke Energy operates a pipeline that transports natural gas from the Fort St. John area to various distribution points within the basin. Kinder Morgan Inc. and Pacific Northern Gas Ltd. operate pipelines that transport natural gas to end users throughout portions of the watershed and destinations located outside the Fraser River Basin. In addition, Kinder Morgan Inc. and Pembina Pipeline Corp. operate pipelines that transport oil from Alberta and Fort St. John to a refinery located in the lower mainland area. The gas plants, transmission facilities, and delivery points located in the study area are listed in Table 3.9 and shown in Figure 3.7. Abandoned and cancelled well heads located within the watershed are listed in Table 3.10.

Oil and gas developments can be associated with releases of a variety of chemical substances into aquatic ecosystems. The substances that may be released in association with oil and gas developments include (Haggarty *et al.* 2003):

- Metals (barium, cadmium, copper, lead, nickel, strontium, vanadium, and zinc);
- Petroleum hydrocarbons (lube oils, diesel range organics, alkanes, extractable petroleum hydrocarbons)
- Monoaromatic hydrocarbons (i.e., benzene, toluene, ethylbenzene, and xylene); and,
- Polycyclic aromatic hydrocarbons (i.e., parent PAHs, alkylated PAHs, total PAHs).

As exploration and development activities have been limited within the study area, it is anticipated that releases of contaminants from oil and gas developments have been largely associated with spills associated with oil transmission facilities. No information was located on spills of oil or other materials from oil pipelines or related facilities in the Fraser River Basin. Therefore, the extent to which oil and gas-related contaminants have been released to aquatic ecosystems within the study area is unknown.

3.1.1.8 Bulk Storage and Shipping Facilities

There are a total of 24 bulk storage and/or shipping facilities located within the Fraser River Basin, with the majority of these facilities located within the Lower Fraser River Area of Interest (Figure 3.8; Table 3.11). Many of these facilities are refrigerated storage and shipping operations (7) or warehousing and shipping operations (12). However, manufacturing, warehousing, storage, and shipping is conducted at one of these facilities (i.e., Exel Global Logistics Canada Inc.). In addition, import and export of freight, cargo, and/or containers by ship is conducted at three of these facilities (i.e., Fraser-Surrey Docks LP, Hutchinson Cargo Terminal Inc., and Locher Evers International). One of these facilities is a fuel storage site that is operated by Terasen Pipelines (Trans Mountain) Inc. Finally, there are four in-river log storage areas located in the Lower Fraser River Area of Interest (see Nelitz *et al.* 2011 for more information).

The contaminants that could be released into the aquatic ecosystem from bulk storage and shipping facilities depend on the types of products that are stored on site, the mode of transport utilized, the number and quantity of spills that occur, and the proximity to the river or other drainage pathways. No information was located to determine if any of the facilities identified in Table 3.11 have permitted discharges to the Fraser River or its tributaries. In addition, detailed information of the types of products stored at or shipped from these facilities was located only for a subset of the operations. Therefore, it is difficult to develop a detailed list of contaminants that have been released into aquatic ecosystems in the vicinity of these facilities. Nevertheless, the following provides a list of substances that could be released from one or more of the facilities located within the Fraser River Basin include:

- Metals (arsenic, cadmium, copper, chromium, lead, mercury, nickel, and zinc);
- Organotins (tributyltin and other antifouling agents);
- Petroleum hydrocarbons (oil and grease, diesel range organics, alkanes, extractable petroleum hydrocarbons)
- Monoaromatic hydrocarbons (i.e., benzene, toluene, ethylbenzene, and xylene); and,
- Polycyclic aromatic hydrocarbons (i.e., parent PAHs, alkylated PAHs, total PAHs).

Such contaminants would primarily be associated with spills of oil or other fuels and/or sloughing of antifouling paints from seagoing vessels.

3.1.1.9 Other Manufacturing Facilities

Although manufacturing is not typically considered to be a major industrial sector in British Columbia, there are numerous facilities located throughout the Fraser River Basin (Figure 3.9; Table 3.12). For example, there are five wood-pellet manufacturing facilities located in the Upper Fraser River Area of Interest (i.e., between Williams Lake and Prince George) that are operated by Pacific Bioenergy Corp. and Pinnacle Pellet Inc. In addition, Brink Forest Products Ltd. operates a finger-jointed lumber manufacturing facility in the Nechako River Area of Interest. It is anticipated that effluent discharged from these facilities and/or runoff from these sites could have chemical characteristics similar to those identified for sawmills and/or plywood mills (see Section 3.1.1.2 for further information).

Within the Thompson River watershed, at least three manufacturing facilities are located in the South Thompson River Area of Interest and at least one facility is located in the Lower Thompson River Area of Interest. In the South Thompson Area of Interest, rubber product manufacturing (Dinoflex Manufacturing Ltd.), truck trailer manufacturing (Doepker Industries Ltd.), and printing-related manufacturing (Pollard Banknote Ltd.)

facilities were identified (Figure 3.9). In addition, a non-metallic mineral product manufacturing facility (I.G. Machine and Fibers) is located in the Lower Thompson River Area of Interest. The information needed to document the chemical characteristics of discharges or runoff from these facilities was not located. Therefore, the contaminants that could be released from such facilities were not explicitly identified.

Three manufacturing facilities were identified in the Pitt River Area of Interest. These included a chemical manufacturing facility (Advance Chemicals Ltd.), an electrical equipment and component manufacturing facility [i.e., battery manufacturing; E-One Moli Energy (Canada) Ltd.], and a steel foundry (Esco Ltd.). While permit information was not located for any of these facilities, effluent discharges or spills could result in releases of a variety of contaminants into surface waters, including: cleaning and disinfectant products and/or precursors (e.g., various alcohols, chlorine, hydrochloric acid, phosphoric acid, potassium hydroxide, triclosan, triclocarban, etc.), electrolytes (e.g., ethylene carbonate, diethyl carbonate), metals (e.g., cadmium, copper, chromium, iron, lead, lithium, nickel, zinc), and petroleum hydrocarbons [e.g., benzene, toluene, ethylbenzene, and xylenes (BTEX), oil, diesel, and PAHs].

Three manufacturing facilities were identified within the Cultus Lake Area of Interest. Two of these facilities are involved in dairy product manufacturing (Armstrong Cheese Company Ltd. and Saputo Foods Ltd.), while the other is involved in the production of pesticides, fertilizers, and other agricultural chemicals (Sure-Gro Inc.). No information was located on the chemical composition of wastewaters from these facilities. However, information from other sources suggests that wastewaters from dairy product manufacturing facilities can have elevated levels of BOD and COD (Zin *et al.* 2008), microbiological variables, nutrients (nitrogen and phosphorus), hormones (17α-estradiol, 17ß-estradiol, and estrone; Zheng *et al.* 2008), and metals (iron, magnesium, and strontium; Hussain and Gondal 2008). The contaminants that could be released to the environment from the Sur-Gro Inc. mixed fertilizer manufacturing facility include: nutrients (nitrogen and phosphorus) and metals (arsenic and lead; Zeller *et al.* 2003).

The density of manufacturing facilities in the Lower Fraser River Area of Interest is higher than that elsewhere in the basin. The food and food products manufacturing sector includes bakeries (Canada Bread, Gourmet Baker Inc.; Weston Bakeries Ltd.), flour milling operations (Rogers Foods Ltd.), soft drink manufacturers (Coco-Cola Bottling Company; Pepsicola Bottling Group), flavouring syrup producers (Sensient Flavours Canada Inc.), breweries (Labatt Breweries of Canada), dairies and daily product facilities (Dairyland Fluid Division Ltd., Happy Days Dairies Ltd., Saputo Foods Ltd., Soyaworld

Inc.), poultry processing facilities (J.D. Sweid Ltd.), frozen foods producers (B.C. Frozen Foods Ltd.), and animal feed production facilities (Mastefeeds Inc., Unifeed Ltd., Viterra Inc.). While effluent permits were not located for most of these facilities, some of the variables that are typically measured in effluents to evaluate the effects of these types of industries on water quality conditions include: temperature, pH, BOD, COD, TSS, oil and grease, total residue chlorine, and nutrients (nitrogen and phosphorus).

Foundries and steel products manufacturing facilities also operate within the Lower Fraser River Area of Interest. Some of the metal product-based operations in this area include steel product manufacturing (Ahoy Industrial Corp. Ltd., Canadian Autoparts Toyota Inc., Tital Steel and Wire Co. Ltd., Western Steel Ltd.), metal fabrication businesses (Canada Metal Ltd.), coating, engraving and heat treating facilities (Ebco Metal Finishing LP; Enigma Interconnect Inc.; Molestro Plating Inc.; Silver City Galvanizing), foundries (Highland Foundry Ltd.), machine shops (Vae Nortrak Ltd.), heating and refrigeration equipment manufacturers (Zer-O-Loc Enterprises Ltd.), and metal recycling facilities (ABC Recycling Ltd.). The contaminants that could be released to aquatic ecosystems via effluent discharge, overland runoff, or spills from these facilities include: conventional variables (temperature, pH, alkalinity, TSS), metals (e.g., aluminum, barium, boron, cadmium, copper, chromium, iron, lead, manganese nickel, zinc), nutrients (phosphorus), and petroleum hydrocarbons (e.g., BTEX, oil and grease, diesel, and PAHs).

Plastics, glass, and other container and packaging operations are also located throughout the Lower Fraser Area of Interest. There are at least 12 plastics, resins, and foams manufacturing facilities in this area of interest, including Ampacet Canada Company, A-Z Sponge and Foam Products Ltd., Beaver Plastics Ltd., Clariant Canada Inc. Masterbatches Division, Columbia Foam Inc., ICL Engineering Ltd., Inteplast, Maax Spas BC Inc., Marine Plastics Ltd., Plasti-Fab Ltd., Pliant Packaging of Canada LLC, and Western Concord Manufacturing. Interstyle Ceramic and Glass Ltd. operates a glass product manufacturing business in the Lower Fraser River Area of Interest. There are three corrugated and solid fibre box manufacturers located in the lower mainland, including Crown Packaging, PTPC Corrugated Co., and Smurfit-MBI. The contaminants that are typically associated with these types of activities include: metals (arsenic, cadmium, lead), polymers, phthalates [e.g., bis(2-ethylhexyl)phthalate (BEHP)], solvents, resins, chemical additives, and volatile organic compounds (e.g., carbon tetrachloride).

There are numerous other manufacturing industries that operate within the Lower Fraser River Area of Interest. For example, there are at least four boat-building facilities in the area, including Crescent Custon Yacht Inc., West Bay Sonships Ltd., Zodiac International, and 27222 Developments Ltd. In addition, there are numerous wood products manufacturing operations, such as Bel-Par Industries Ltd. (wood office furniture), Corporate Images Holdings Partnership (household furniture), Laguna Woodcraft Canada Ltd. (wood household furniture), Leggett and Platt Canada Co. (wood products), Stork Craft Manufacturing Inc. (wood products), Terminal Forest Products Ltd. (wood products), Visscher Lumber Inc. (millwork), and W. Kreyenbohm Corp. (wood products). A number of lime and gypsum product manufacturing operations, chemical manufacturers, computer components makers, electrical equipment manufacturers, cleaning compound producers, an asphalt paving mixture and block manufacturing facility, and textile product mills also operate within the Lower Fraser River Area of Interest (Table 3.12). The substances that could be released from these types of manufacturing facilities include: conventional variables (pH, TSS), major ions (calcium, sulphate), metals (e.g., aluminum, barium, boron, cadmium, copper, chromium, iron, lead, manganese nickel, zinc), cyanide, paints, petroleum hydrocarbons (e.g., BTEX, oil and grease, diesel, and PAHs), phenols, and anti-microbial compounds (e.g., triclosan, triclocarban).

No information was located on other manufacturing facilities in the Bowron River, Quesnel River, Chilko, Seton-Portage, Nahatlatch River, Harrison River, or the Kakawa areas of interest. For a detailed listing of the manufacturing facilities identified during this investigation, see Table 3.12.

In summary, a variety of contaminants may have been released into aquatic ecosystems from other manufacturing facilities operating within the Fraser River Basin. In addition, activities conducted at such facilities can result in alterations of the physical characteristics of receiving water systems. The contaminants and other variables of greatest interest with respect to other manufacturing activities in the study area include:

- Conventional variables (temperature, pH, alkalinity, TSS);
- Major ions (calcium, sulphate);
- Nutrients (nitrate, nitrite, ammonia, phosphorus);
- Metals (e.g., aluminum, arsenic, barium, boron, cadmium, copper, chromium, iron, lead, manganese, nickel, zinc);
- Organotins (tributyltin);
- Phenols (phenol, cresol);
- Monoaromatic hydrocarbons (i.e., BTEX);

- Polycyclic aromatic hydrocarbons (i.e., parent PAHs, alkylated PAHs, total PAHs);
- Petroleum hydrocarbons (e.g., oil and grease, diesel-range organics, alkanes);
- Phthalate esters (e.g., BEHP); and,
- Anti-microbial compounds (e.g., triclosan, triclocarban).

3.1.1.10 Contaminated Sites and Contaminant Spills

In British Columbia, a contaminated site is defined as an area of land in which the soil, underlying groundwater, or sediment contains a hazardous material at levels that exceed the provincial environmental quality standards (Macfarlane *et al.* 2004). In 1997, Environment Canada (Fraser Pollution Abatement Office) and the B.C. Ministry of the Environment (Contaminated Sites Remediation and Assessment Section) collaborated on the development of a Contaminated Sites Registry (Site Information System; SITE). The Registry is designed to provide publically-available information on the investigation and clean-up of contaminated and potentially-contaminated sites throughout the province. Based on the data compiled between 1988 and 1995, there were a total of 2866 non-federal contaminated sites registered in the SITE database and an estimated 342 federal contaminated sites (Environment Canada 1997). Of the 2866 non-federal sites listed in the Registry, 2699 were located in the Fraser River Basin. More recent data on the number and location of federal and non-federal contaminated sites in the Fraser River Basin were not located during this investigation. However, information provided informally by the Contaminated Sites Remediation and Assessment Section (V. Manemeyer, B.C. Environment. Personal communication) suggests that the Registry may currently list at least 5,000 contaminated sites that are located within the study area. The Treasury Board of Canada maintains a contaminated sites database, separate from the registry, which provides information on the location, media types of concern, and the identity of contaminants at each of these sites. Table 3.13 provides a summary of the data contained in the Treasury Board of Canada database for contaminated sites within the study area. Figure 3.10 shows the locations of these contaminated sites.

Accidental spills can also result in releases of contaminants to the Fraser River and/or its tributaries. According to records maintained by the Canadian Coast Guard and the B.C. Ministry of the Environment, spills of raw sewage, partly treated sewage, gasoline, oil, diesel, other fuels, and other substances are common within the study area. However, the information needed to specifically characterize the substances or volumes released is only infrequently available. Therefore, it is difficult to identify the contaminants that are released to aquatic ecosystems due to accidental spills. Nevertheless, data were retrieved from the B.C. Ministry of Environment's Provincial Emergency Program through their Dangerous Goods Incident Reports for March to June 2007 (Figure 3.11; Table 3.14). These data were explicitly targeted to determine if a major spill occurred in 2007 during the period that outmigrant smolts were likely present in the Lower Fraser River (i.e., to determine if a major incident occurred that could explain poor returns of sockeye salmon to the river in 2009). None of the spills reported in 2007 (March - June) were of sufficient volume to result in water quality degradation or sufficient to adversely affect the entire year class of outmigrating sockeye salmon smolts.

Based on experience in conducting contaminated site assessments and evaluations of accidental spills, it is likely that the following contaminants have been released into the Fraser River or its tributaries from one or more contaminated sites or accidental contaminant spills:

- Nutrients (nitrate, nitrite, ammonia);
- Metals (e.g., aluminum, arsenic, barium, boron, cadmium, copper, chromium, iron, lead, manganese, mercury, nickel, zinc);
- Cyanide;
- Organotins (tributyltin);
- Phenolic compounds (phenol, cresol);
- Chlorinated phenolics (e.g., pentachlorophenol);
- Monoaromatic hydrocarbons (i.e., BTEX);
- Polycyclic aromatic hydrocarbons (i.e., parent PAHs, alkylated PAHs, total PAHs);
- Creosote;
- Petroleum hydrocarbons (e.g., oil and grease, diesel-range organics, alkanes);
- Polychlorinated biphenyls (PCBs);
- Phthalate esters (e.g., BEHP);
- Legacy organochlorine pesticides (e.g., aldrin, chlordane, DDTs, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane); and,
- Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans.

3.1.1.11 Municipal Wastewater Treatment Facilities

Municipal wastewater treatment plants are located throughout the Fraser River Basin (Figure 3.12; Table 3.15). At least three such facilities are located in the Nechako Area of Interest (i.e., at Fort St. James, Fraser Lake and Vanderhoof), which collectively discharge up to 5,022 m^3/d of secondary treated wastewater to receiving waters. In the Upper Fraser Area of Interest, there are at least ten wastewater treatment plants that collectively discharge up to 56,760 m^3/d of primary or secondary treated wastewater to the Fraser River. These wastewater treatment plant facilities are located in McBride (1 plant), Prince George (4 plants), Williams Lake (1 plant), Lillooet (1 plant), District of Wells (1 plant), Fraser Valley Regional District-North Bend (1 plant) and Lytton (1 plant). Within the North, Lower, and South Thompson River areas of interest, wastewater treatment plants are being operated at Salmon Arm, Chase, Kamloops, Clinton, Merritt, Enderby, and, Ashcroft. Together, these wastewater treatment plants discharge up to 66,070 m^3/d of secondary or tertiary treated wastewater to the Thompson River and/or its tributaries. As would be expected, the highest density of wastewater treatment plants are located in the Lower Fraser River Area of Interest, which has the highest population density in the study area. There are at least 12 wastewater treatment plants operating with in this geographic area, 10 of which collectively discharge up to 1,475,000 m^3/d of secondary treated wastewater to the Fraser River. One facility, the Iona Island wastewater treatment plant, discharges up to 1,530,000 m^3/d of primary treated wastewater directly to the Strait of Georgia via deep-water outfalls. For a listing of the substances that typically occur in municipal wastewater treatment plant effluents see Table 3.16.

Limited site-specific data confirm that municipal wastewater treatment plants in the Fraser River Basin release a wide range of contaminants into the environment. Sylvestre *et al.* (1998) measured the concentrations of a broad suite on chemicals upstream and downstream of the Annacis Island wastewater treatment plant on the main arm of the Fraser River. The results of this study demonstrated that the levels of chromium, copper, iron, zinc, and total PCBs exceeded water quality guidelines downstream of the wastewater treatment plant. In addition, the levels of nonylphenols, PAHs, ammonia, and microbiological variables were elevated downstream of the facility compared to the concentrations measured at the upstream site.

In addition to these traditional chemicals of potential concern, wastewater treatment plants are also know to contain a variety of pharmaceuticals and personal care products. Information was not located in the literature to document either the concentrations of these contaminants of emerging concern in the effluents of wastewater treatment plant located within the Fraser River Basin or the associated loadings to receiving water systems. However, data from other sources provides a basis for identifying the pharmaceuticals and personal care products that are commonly present at elevated levels in wastewater treatment plant effluents (Table 3.17). Based on all of the available information, the contaminants that may be released to aquatic ecosystems in association with municipal wastewater treatment plant effluent discharges include:

- Conventional variables (BOD, COD, TSS, TDS);
- Microbiological variables (e.g., faecal coliforms, enterococci);
- Nutrients (nitrate, nitrite, ammonia, phosphorus);
- Metals (e.g., aluminum, arsenic, barium, boron, cadmium, copper, chromium, iron, lead, manganese, mercury, nickel, zinc);
- Cyanide;
- Phenolic compounds (phenol, cresol);
- Chlorinated phenolics (e.g., pentachlorophenol);
- Monoaromatic hydrocarbons (i.e., BTEX);
- Polycyclic aromatic hydrocarbons (i.e., parent PAHs, alkylated PAHs, total PAHs);
- Other semi-volatile organic compounds (SVOCs).
- Petroleum hydrocarbons (e.g., oil and grease, alkanes);
- Polychlorinated biphenyls;
- Phthalate esters (e.g., BEHP);
- Plastics-manufacturing chemicals (bisphenol A);
- Fire retardants [i.e., polybrominated diphenyl ethers (PBDEs), perfluorooctane sulphonic acid (PFOS), perfluorooctanoic acid (PFOA), diammonium sulphate, diammonium phosphate, ammonium sulphate, ammonium phosphate, ammonium polyphosphate];
- Steroids, hormones, and hormone-mimicking substances (i.e., 17β-estradiol, estrone, 17α-ethinylestradiol, plant sterols, phytoestrogen metabolites; see Table 3.17);
- Pharmaceuticals (antibiotics, antihypertensives, anticonvulsants, antidepressants, anti-acid reflux, anti-inflammatory, antifungal, and analgesic compounds; see Table 3.17);

- Personal care products (fragrances, insect repellants, detergents, antimicrobials, fungicides, surfactants, and stimulants; see Table 3.17);
- Disinfectants (e.g., bromine, chlorine, iodine and disinfection byproducts); and,
- Nanoparticles (Nowack and Bucheli 2007).

3.1.1.12 Municipal and Industrial Landfills

Landfills have been sited in the vicinity of municipal and industrial developments throughout the Fraser River Basin (Figure 3.13). Contaminants that are disposed of in landfills can be released to surface water bodies through direct discharge of leachates or through surface water recharge by contaminated groundwater. Due to the number of landfills that exist and the number of organizations that operate them (Table 3.18), no attempt was made to characterize landfill leachates on a site-specific basis. Instead, general information on the chemical characteristics of landfill leachates was used to identify the contaminants that may have been released to the Fraser River or its tributaries from municipal or industrial landfills, including those that receive sewage sludges, located in the study area, including (Niininen *et al.* 1994; Herrmann 2001; Environmental Health and Safety Online 2010):

- Conventional variables (COD, TSS);
- Nutrients (ammonia);
- Metals (e.g., aluminum, arsenic, barium, boron, cadmium, copper, chromium, iron, lead, manganese, mercury, nickel, zinc);
- Cyanide;
- Volatile organic contaminants (e.g., methane, chlorinated ethanes, chlorinate ethenes)
- Phenolic compounds (phenol, cresol);
- Chlorinated phenolics (e.g., dichlorophenols, trichlorophenols, tetrachlorophenolds, pentachlorophenol);
- Nitrobenzenes (e.g., nitrobenzene, methylnitrobenzene);
- Monoaromatic hydrocarbons (i.e., BTEX);
- Polycyclic aromatic hydrocarbons (i.e., parent PAHs, alkylated PAHs, total PAHs);
- Other semi-volatile organic compounds (SVOCs).

- Petroleum hydrocarbons (e.g., oil and grease, alkanes);
- Polychlorinated biphenyls;
- Phthalate esters (e.g., BEHP);
- Plastics-manufacturing chemicals (e.g., bisphenol A);
- Fire retardants (i.e., PBDEs);
- Steroids, hormones, and hormone-mimicking substances (e.g., 17β-estradiol, estrone, 17α-ethinylestradiol plant sterols, phytoestrogen metabolites; see Table 3.17);
- Pharmaceuticals (antibiotics, antihypertensives, anticonvulsants, antidepressants, anti-acid reflux, anti-inflammatory, antifungal, and analgesic compounds; see Table 3.17);
- Personal care products (fragrances, insect repellants, detergents, antimicrobials, fungicides, surfactants, and stimulants; see Table 3.17); and,
- Disinfectants (e.g., bromine, chlorine, iodine and disinfection byproducts).

3.1.1.13 Salmonid Enhancement Facilities

There are at least 37 salmonid enhancement facilities located in the Fraser River Basin (Figure 3.14; Table 3.19). These facilities include six major hatcheries (including Chilliwack River Hatchery, Chehalis River Hatchery, Inch Creek Hatchery, Spius Creek Hatchery, Upper Pitt River Hatchery, and Shuswap River Hatchery), four spawning channels (including Weaver Creek Spawning Channel, Nadina River Spawning Channel, Horsefly Spawning Channel, and Gates Creek Spawning Channel), and at least 24 public involvement or community development projects. In addition, at least two lake fertilization projects have been conducted within the study area, including Chilko Lake (fertilized in 1988 and 1990-1993) and Adams Lake (fertilized in 1997; Figure 3.15; Shortreed *et al.* 2001).

All of the salmonid enhancement facilities generate wastewater that is discharged into receiving water systems in the study area. These wastewaters are typically characterized by elevated levels of BOD, TSS, nutrients (nitrate, nitrite, ammonia, and phosphorus), and microbiological variables (such as faecal coliforms). However, effluents from such facilities can also contain a variety of contaminants that occur at trace levels in uneaten fish feeds, such as PCBs, organochlorine pesticides (such as DDTs and lindane), and PCDDs/PCDFs (Maule *et al.* 2007; Bustnes *et al.* 2010; Johnson *et al.* 2010). In addition, the presence of antibiotics in fish hatchery effluents has been documented in recent years, with oxytetracycline, ormetoprim, and sulfadimethoxine being the most commonly detected chemicals (Smital 2008). Furthermore, disinfectants used to clean incubation or rearing facilities or to kill pathogens in the effluent have the potential to occur in effluents from these facilities. Such products may contain chlorine (e.g., Chlorox Commercial 409), iodine (e.g., SparkDin-2), bromine (e.g., Bromax), peroxides (e.g., CalperOx), potassium permanganate (e.g., PermaGard), formalin, formaldehyde (e.g., Microlin; Neomolt), quartenary ammonium compounds (e.g., Bionex 50), isopropanol, and/or potassium monopersulfate (e.g., Virkon; Oplinger and Wagner 2009; Rivas *et al.* 1994). Of the substances that are used at salmonid enhancement facilities, the following disinfectants likely represent the highest priority contaminants relative to the potential for effects on sockeye salmon in the Fraser River Basin:

- Bromine;
- Chlorine;
- Iodine;
- Formalin; and,
- Formaldehyde.

3.1.2 Non-Point Sources

Diffuse or non-point source discharges represent major contaminant sources in the Fraser River Basin. Accordingly, the nature of non-point source discharges from municipal developments, agricultural activities, forestry activities, and other sources are described in this section of the report.

3.1.2.1 Runoff from Forest Management Areas

The upland areas within the Fraser River Basin are, to a large extent, actively managed timber lands, supplying wood fibre to various pulp and paper mills, sawmills, and other forest products manufacturing facilities within and outside the basin. The areas that have been recently harvested (post-1990), historically harvested (pre-1990), and recently affected by wildfires (2005-2010) are shown in Figure 3.16 and described in Table 3.20. The areas affected by mountain pine beetle infestation, which can enhance runoff, are shown in Figure 3.17.

In general, concerns regarding forest management activities are focussed on losses of fine sediment due to accelerated erosion associated with road building and maintenance and with clear-cut logging. Such releases of fine sediment can result in elevated levels of TSS in water and/or degradation of the quality of stream-bed substrates (Newcombe and MacDonald 1991; Caux *et al.* 1997). However, forest management activities can also result in the losses of fertilizer and/or pesticides that are applied to enhance the production of timber (i.e., through runoff to receiving waters). Some of the pesticides that are used to manage forest resources in the study area include (Verrin *et al.* 2004):

- Herbicides, such as glyphosate (which accounts for over 90% of forest pesticide herbicide use), triclopyr (which has increased in use between 1991 and 1998, and has been correlated with pre-spawn mortality in late-run sockeye salmon; Johannessen and Ross 2002), picloram, and 2,4,-dichlorophenoxyacetic acid (2,4-D); and,
- Insecticides, such as BT, fenithrothion, carbaryl, and monosodium methanearsonate (MSMA).

In addition, to nutrients, TSS, and pesticides, runoff from forest management areas has the potential to contain a variety of fire-suppression and fire-retardant chemicals. There are a variety of fire-suppression chemicals on the market (e.g., AnsulSilv-Ex, Angus ForExpan S, Fire Quench, 3M Firebreak, and Phos-ChekWD-881; Adams and Simons 1999). These products are all foams, containing surfactants, foaming agents, and wetting agents. They work by increasing the ability of water to penetrate fuels and, thereby, decreasing their potential to ignite. These products also insulate the fuel from heat and reduce contact with the air. The surfactants contained in these products make them toxic to aquatic organisms at concentrations in the 10 to 100 mg/L range (Gaikowski *et al.* 1996; Mizuki *et al.* 2007)

Long-term fire retardants, such as Phos-Chek D75-F, Phos-Chek D75-R, Fire-Trol GTS-R, and FireTrol 931, typically contain mixtures of diammonium sulphate, diammonium phosphate, ammonium sulphate, ammonium phosphate, and/or ammonium polyphosphate as the active fire retardants (Adams and Simons 1999). These products also contain gum thickeners, an iron oxide-based colouring agent, and preservatives, which are mixed with water to ensure uniform dispersal. The active ingredients react with the products of combustion to lower the combustibility of the fuel (Johannnessen and Ross 2002). The toxicity of fire-retardant chemicals is primarily due to the formation of ammonia and are toxic to aquatic organisms at concentrations in the 100 to 1000 mg/L range (Gaikowski *et al.* 1996; McDonald *et al.* 1997). However, the presence of other ingredients, such as sodium ferrocyanide, can render these products more toxic, primarily because photolysis can lead to the formation of cyanide (which is highly toxic to fish; Little and Calfee 2000).

In summary, the contaminants that could be released into aquatic ecosystems in runoff from forest management areas include:

- Conventional variables (TSS);
- Nutrients (nitrate, nitrite, ammonia, phosphorus);
- Herbicides (glyphosate, triclopyr, picloram, and 2,4-D);
- Surfactants (e.g., amphoteric fluorosurfactants, non-ionic fluorosurfactants, anionic hydrocarbon surfactants);
- Fire retardants (diammonium sulphate, diammonium phosphate, ammonium sulphate, ammonium phosphate, and/or ammonium polyphosphate); and,
- Cyanides.

3.1.2.2 Runoff from Agricultural Operations

A diversity of agricultural activities are practised within the Fraser River Basin. In the central and northern portions of the watershed (i.e., Nechako River, Bowron River, Quesnel River, Chilko River, and North Thompson River areas of interest), agricultural activities are primarily focussed on livestock production (i.e., cattle ranching), with extensive grazing occurring on range lands. Intensive livestock production may also occur in certain areas (e.g., feed lots; chicken farms). In addition, hay production represents an important land use in these areas, with multiple crops produced annually on irrigated lands. Water quality concerns associated with ranching and associated feed production include:

- Production of TSS where livestock are permitted access to streams for watering;
- Releases of nutrients (nitrate, nitrite, ammonia, phosphorus) associated with fertilizer use or manure spreading;
- Releases of nutrients and microorganisms from feedlots or when livestock have direct access to streams; and,
- Releases of pesticides used in forage crop and hay production, including herbicides (e.g., 2,4-D, atrazine, glyphosate), insecticides (e.g., chlorpyrifos, carbaryl), and fungicides (chlorothalonil, sulfur; Verrin *et al.* 2004).

In the South Thompson River and Thompson River mainstem areas of interest, agricultural activities are also dominated by cattle ranching. However, production hay, forage crops, and tree fruit are also important commodities in this region of the province. Vegetable crops are also produced throughout the Southern Interior region (Verrin *et al.* 2004). In addition to the water quality concerns identified for the central and northern Fraser River basin, tree fruit production and other agricultural activities results in applications of additional pesticides, such as Verrin *et al.* 2004) :

- Glyphosate, paraquat, and pendimethalin (herbicides used on cherries, pears, peaches, grapes, and/or apples);
- Abamectin, *Bacillus thuringiensis*, carbaryl, diazinon, dormant oil, and phosmet (insecticides used on cherries, pears, peaches, grapes, and/or apples); and,
- Copper, iprodione, metiram, myclobutanil, sulphur, and lime sulphur (fungicides used on cherries, pears, peaches, grapes, and/or apples).

Among the 15 areas of interest considered in this investigation, agricultural activities are the most intensive in the Lower Fraser River Area of Interest (Figure 3.18; Table 3.21). This area is characterized by a proliferation of dairy operations, feed lots, and intensive production of hogs, chickens, and turkeys. In addition, berries, grapes, vegetables, and ginseng represent important crops in this region of the Fraser River Basin. In addition to nutrients and microbiological variables, water quality concerns associated with agricultural operations in the lower mainland are focussed on releases of such pesticides as (Verrin *et al.* 2004):

- 2,4-D, bentazon, diquat, glyphosate, linuron, napropamide, simazine, and trifluralin (herbicides used in berries, grapes, and vegetables);
- Acetmapiprid, azinophos-methyl, chlorpyrifos, cyhalothrin-lambda, cypermethrin, deltamethrin, diazinon, dimethoate, methamidophos, methomyl, and pirimicarb (insecticides used in berries, grapes, and vegetables); and,
- Captan, copper, chlorothalonil, iprodione, mancozeb, metalaxyl, and thiram (fungicides used in berries, grapes, and vegetables).

Proximity to water and/or heavy pesticide application have resulted in crops such as potatoes, cranberries, and ginseng being identified to be of particular concern relative to potential effects on aquatic organisms (Verrin *et al.* 2004). For example, control of wireworm infestations in potatoes often requires heavy applications of organophosphorus insecticides, such as phorate, terbufos, or fonofos. Elevated concentrations of insecticides, such as azinphosmethyl and diazinon, have been detected in irrigation ditches, runoff, and tributaries in the vicinity of cranberry bogs. Ginseng farms, which are frequently sited adjacent to waterways, are also known to utilize substantial quantities of herbicides (such as fluazifop-p-butyl), insecticides (such as diazinon), and fungicides (such as iprodione; Harrison *et al.*1991). Furthermore, use of pyrethroids in various agricultural and other applications represents an emerging concern due to their mobility and high toxicity to aquatic organisms (Kemble *et al.* 2010).

The results of this review, indicate that a wide variety of contaminants can be released to aquatic ecosystems within the Fraser River Basin in runoff from agricultural operations. Based on the quantities of these substances that are used in the province, it is likely that the highest priority contaminants associated with agricultural activities in the study area include (MDH 1999; Verrin *et al.* 2004):

- Conventional variables (BOD, TSS);
- Nutrients (i.e., nitrate, nitrite, ammonia, urea, phosphorus);
- Metals (i.e., arsenic, cadmium, copper, lead, zinc);
- Organochlorine pesticides (i.e., chlordane, DDTs, dieldrin, endosulfan, hexachlorobenzene, lindane, nonachlor);
- In-use herbicides (i.e., atrazine, 2,4-D, ethalfluralin, glyphosate, mineral oil, paraquat, pendimethalin, simazine, triallate, trifluralin);
- In-use insecticides (i.e., azinphosmethyl, *Bacillis thuringiensis*, chlorpyrifos, diazinon, endosulfan, malathion, mineral oil, parathion)
- In-use fungicides (i.e., captan, copper, chlorothalonil, dazomet, mancozeb, metam, metiram, lime sulphur); and,
- Other pesticides (i.e., formaldehyde, formalin).

3.1.2.3 Runoff of Municipal Stormwater

Runoff of stormwater from urban centres (including associated road and railway rights-of-way) can represent an important non-point source of contaminants to receiving water systems. The locations of municipal developments in the Fraser River Basin are shown in Figure 3.19. While the nature of the substances that are released to surface waters is a function of land use activities in the area (Table 3.22), the contaminants that are commonly associated with such runoff include road salts, metals, PAHs, oil and grease, TSS, nutrients, and pesticides. In addition to causing water quality impairments, many of the contaminants associated with such runoff are persistent and tend to accumulate in bottom sediments. Hence, depositional areas of small streams can accumulate metals, PAHs, and other substances to levels that are toxic to benthic invertebrates and/or benthic fish species (MacDonald *et al.* 2000a). Importantly, recent research has demonstrated that the presence of pyrethroid pesticides in sediments can explain much of the toxicity to benthic invertebrates that is observed in wadeable streams in the vicinity of metropolitan areas (Holmes *et al.* 2008; Kemble *et al.* 2010). Therefore, the principal contaminants that are associated with municipal stormwater runoff include:

- Conventional variables (TSS);
- Major ions (chlorides);
- Metals (arsenic, cadmium, copper, chromium, lead, mercury, nickel, zinc);
- Monoaromatic hydrocarbons (i.e., BTEX);
- Polycyclic aromatic hydrocarbons;
- Petroleum hydrocarbons (e.g., oil and grease, diesel-range organics, alkanes);
- Polychlorinated biphenyls;
- Organochlorine pesticides (i.e., chlordane, DDTs, dieldrin, endosulfan, lindane, nonachlor); and,
- In-use pesticides (e.g., bifenthrin).

The information needed to estimate loadings of all of these substances to aquatic ecosystems in the Fraser River Basin is not readily available. However, Gray and Tuominen (1999) reported estimated loadings of selected contaminants from urban runoff to four areas within the basin, including the upper Fraser River, middle Fraser River, lower Fraser River, and the Thompson River during the early 1990's (Table 3.23; from Gray and Tuominen 1999). In addition, total loadings of these contaminants to the basin were estimated. These results confirm that substantial quantities of suspended solids, nutrients, metals, phenols, and total hydrocarbons have been released to the Fraser River and the Thompson River from non-point municipal sources. It is likely that current loadings of these substances to aquatic ecosystems within the study area are substantially higher than those reported over a decade ago by Gray and Tuominen (1999).

3.1.2.4 Runoff from Linear Developments

Linear developments in the Fraser River Basin include road networks, rail networks, electrical transmission lines, and seismic lines used in oil and gas development (Figure 3.20). The road network in the study area consists of public highways and roads that are constructed and maintained by provincial and municipal governments and a substantial number of industrial roads that are used in forest management, mining development, and other industrial activities. The rail network is also well developed within the study area, with the major operators including VIA Rail Canada, Canadian Pacific Railroad, and CN. Releases of contaminants to aquatic ecosystems can occur during the construction, maintenance, or decommissioning of linear developments. Spills of hazardous substances during transport can also result in contamination of receiving water systems. The substances of greatest concern relative to linear developments include:

- Conventional variables (TSS);
- Major ions (e.g., chloride, as a result of road salt applications);
- Nutrients (e.g., nitrates, nitrite, and ammonia, which are associated with blasting);
- Metals (arsenic, cadmium, copper, chromium, lead, mercury, nickel, zinc, which may be released during combustion of fossil fuels);
- Polycyclic aromatic hydrocarbons;
- Petroleum hydrocarbons (e.g., oil and grease, diesel-range organics, alkanes); and,
- In-use herbicides (glyphosate, triclopyr, picloram, and 2,4-D, which may be used to maintain rights-of-way).

3.1.3 Atmospheric Sources

Transport in the atmosphere can represent an important process for distributing contaminants originating within the watershed, elsewhere in North America, and worldwide. Accordingly, potential atmospheric sources of contaminants to the Fraser River Basin are described in the following sections of the report.

3.1.3.1 Natural Sources of Atmospheric Pollutants

Point source discharges and non-point source releases associated with anthropogenic activities represent the primary sources of contaminants in the Fraser River Basin.

Nevertheless, there are a number of natural sources of atmospheric contaminants that can result in contamination of aquatic ecosystems. These sources primarily include forest fires and volcanoes (Figure 3.21; Table 3.24). Information from various sources indicates that wood smoke contains a number of contaminants, including particulates, carbon monoxide, phenolic compounds (e.g., guaiacols, phenols, syringols, catechols), PAHs, benzene, alkyl benzenes, PCDDs/PCDFs, and numerous volatile organic compounds (USEPA 1993; Gingrich and Macfarlane 2002). By comparison, the substances most commonly associated with volcanic smoke and ash include silica, aluminum, potassium, sodium, calcium, magnesium, iron, sulfate, hydrochloric acid, hydrofluoric acid, and sulfuric acid (Smith *et al.* 1983). For the purpose of developing the Inventory of Aquatic Contaminants, substances associated with natural atmospheric sources were not considered.

3.1.3.2 Anthropogenic Sources of Atmospheric Pollutants

There are numerous localized sources of atmospheric pollutants in the Fraser River Basin. For example, emissions from gasoline-fuelled vehicles have been demonstrated to contain various gases (e.g., carbon dioxide, carbon monoxide, nitrogen dioxide, nitric oxide, sulfur dioxide), particulates, metals (e.g., copper, manganese, zinc), methanol, ethanol, benzene, toluene, and PAHs (Westerholm and Egeback 1994). Diesel exhaust contains many of the same substances, but typically at higher concentrations than is the case for gasoline-fuelled vehicle emissions. In addition, diesel exhaust contains ethylene, propylene, formaldehyde, acetaldehyde, benzofuran, coumarin, menadione, and other substances (Westerholm and Egeback 1994; USDL 2010). Aquatic ecosystems in the study area can also be contaminated by such localized atmospheric sources of contaminants as industrial emissions and agricultural emissions (e.g., pesticides, fertilizers).

Long-range transport of atmospheric pollutants also represents a potential source of contaminants to aquatic ecosystems in the Fraser River Basin. For many persistent semi-volatile organic compounds (SVOCs), long-range atmospheric transport represents an important environmental fate process that results in movement of the substance from its point of release to distant locations (MacLeod and Mackay 2004). While the detailed mechanism for long-range atmospheric transport is still uncertain, it has been hypothesized that long-range atmospheric transport occurs due to repeated volatilization and deposition of persistent substances over time, typically resulting in net transport of SVOCs towards higher altitude and higher latitude areas (Gouin *et al.* 2004). As a result, chemicals that are produced or used in Central America, Mexico, the United States, or southern Canada can be transported to terrestrial and aquatic ecosystems in the Canadian North. Because the substances most amenable to long-range atmospheric transport are persistent and hydrophobic, they tend to contaminate aquatic food webs and accumulate in higher trophic level predators (such as seals, whales, and polar bears; Muir *et al.* 2005). The substances of greatest concern relative to long-range atmospheric transport include (Braune *et al.* 1999):

- Metals (mercury);
- Polychlorinated biphenyls;
- Legacy organochlorine pesticides (e.g., DDTs, chlordane, hexachlorobenzene, toxaphene);
- Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (total 2,3,7,8-TCDD toxic equivalents); and,
- Polybrominated diphenyl ethers.

3.2 Aquatic Contaminant Inventory

Land use information was compiled for each of the areas of interest within the study area (Table 3.25; Figures 3.22 to 3.36). The chemicals that may be released to aquatic ecosystems in conjunction with these land uses were also identified (Table 3.26). This information on sources and releases of contaminants was then integrated to identify the substances that may have been released into aquatic ecosystems within each area of interest and the Fraser River Basin, in general (Table 3.27). This list of chemicals of potential concern, which comprises the Inventory of Aquatic Contaminants for the Fraser River Basin (Table 3.28), includes the following classes of contaminants:

- Conventional variables (temperature, pH, alkalinity, BOD, COD, TSS, TDS);
- Microbiological variables (faecal coliforms, enterococci);
- Major ions (e.g., calcium, chlorides, potassium, sodium, sulphates, sulphides);
- Nutrients (i.e., nitrate, nitrite, ammonia, urea, phosphorus);
- Metals (i.e., aluminum, arsenic, barium, boron, cadmium, copper, chromium, cobalt, iron, lead, mercury, manganese, molybdenum, nickel, selenium, silver, strontium, vanadium, zinc);
- Organometallics (i.e., methylmercury, organotins);
- Cyanides;

- Monoaromatic hydrocarbons (i.e., BTEX);
- Polycyclic aromatic hydrocarbons (i.e., individual parent PAHs, alkylated PAHs, total low molecular weight PAHs, total high molecular weight PAHs, total PAHs);
- Petroleum hydrocarbons (oil and grease, diesel range organics, lube oils, alkanes);
- Phenolic compounds (i.e., phenol, cresol);
- Chlorinated phenolic compounds (i.e., chlorophenols, chloroguaiacols, chlorocatechols);
- Polychlorinated biphenyls (total 2,3,7,8-TCDD toxic equivalents, total PCBs as sum of congeners, sum of homologs, or sum of Aroclors);
- Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (total 2,3,7,8-TCDD toxic equivalents, 210 congeners);
- Resin acids (e.g., abietic acid; see Table 3.28);
- Fatty acids (e.g., palmitic acid; see Table 3.28);
- Legacy organochlorine pesticides (i.e., aldrin, chlordane, DDTs, dieldrin, endrin, endosulfan, heptachlor, heptachlor epoxide, HCB, lindane, methoxychlor, nonachlor, toxaphene);
- In-use herbicides (i.e., atrazine, 2,4-D, ethalfluralin, glyphosate, mineral oil, paraquat, pendimethalin, picloram, simazine, triallate, triclopyr, trifluralin);
- In-use insecticides (i.e., azinphosmethyl, *Bacillis thuringiensis*, chlorpyrifos, diazinon, endosulfan, malathion, mineral oil, parathion)
- In-use fungicides (i.e., captan, chlorothalonil, copper, dazomet, mancozeb, metam, metiram, lime sulphur);
- Other pesticides (i.e., formaldehyde, formalin);
- Wood preservatives [i.e., creosote, chromated copper arsenate (CCA), ammoniacal copper zinc arsenate (ACZA), pentachlorophenol];
- Anti-sapstain chemicals [i.e., didecyldimethyl ammonium chloride (DDAC), 3-iodo-2propynyl butyl carbamate (IPBC)];
- Surfactants (i.e., alkylphenol ethoxylates, fluorosurfactants);
- Fire retardants [i.e., PBDEs (209 congeners and 10 homolog groups), PFOS, PFOA, diammonium sulphate, diammonium phosphate, ammonium sulphate, ammonium phosphate, ammonium polyphosphate];

- Plastic-related compounds (i.e., phthalate esters, bisphenol A);
- Steroids, hormones, and hormone-mimicking substances (e.g., 17β-estradiol, estrone, 17α-ethinylestradiol, plant sterols, phytoestrogen metabolites; see Table 3.28);
- Pharmaceuticals (antibiotics, antihypertensives, anticonvulsants, antidepressants, anti-acid reflux, anti-inflammatory, antifungal, and analgesic compounds; see Table 3.28);
- Personal care products (fragrances, insect repellants, detergents, antimicrobials, fungicides, surfactants, and stimulants; see Table 3.28);
- Disinfectants (i.e., bromine, residual chlorine, and iodine), disinfection byproducts (e.g., trihalomethanes and haloacetic acids); and,
- Nanoparticles.

All of these substances were considered to be chemicals of potential concern in the Fraser River Basin. Accordingly, these chemicals of potential concern were evaluated in the preliminary assessment of the potential effects of contaminants on Fraser River sockeye salmon (Chapter 4).

Chapter 4 Preliminary Evaluation of Chemicals of Potential Concern

4.1 Introduction

The Inventory of Aquatic Contaminants (Chapter 3) identifies over 200 chemical substances (termed chemicals of potential concern) that have been released or are likely to have been released into aquatic habitats within the Fraser River Basin. As it is challenging to conduct a detailed evaluation of the effects of each of these chemicals on sockeye salmon, a commonly-utilized screening procedure was applied to identify the substances that occur in abiotic environmental media (i.e., surface water or sediment) at concentrations sufficient to pose potential risks to aquatic organisms, including sockeye salmon, utilizing habitats in the study area. This procedure is consistent with the methods that are typically used to conduct screening-level ecological risk assessments (CCME 1996; USEPA 1997; SAB 2005) and consisted of five general steps, including:

- Pathway Analysis (i.e., which was conducted to identify potentially-complete exposure pathways through which sockeye salmon could be exposed to the chemicals of potential concern);
- Effects Assessment (i.e., which was conducted to identify conservative thresholds for adverse effects on aquatic organisms, which are termed toxicity screening values; TSVs);
- Exposure Assessment (i.e., which was conducted to identify the concentrations of chemicals of potential concern that sockeye salmon and other aquatic organisms could be exposed to, which are termed exposure point concentrations or EPCs);
- Hazard Evaluation [i.e., which was conducted to identify the substances that occur in one or more media types at concentrations sufficient to pose potential risks to aquatic organisms, including sockeye salmon; i.e., by calculating hazard quotients, (HQs), where HQ = EPC/TSV]; and,
- Uncertainty Analysis (i.e., which was conducted to identify the substances for which insufficient information was available to determine if they pose potential risks to aquatic organisms, including sockeye salmon).

The screening-level assessment was designed to provide a consistent basis for identifying all of the chemicals of potential concern that pose potential risks to aquatic organisms, including sockeye salmon utilizing spawning and incubation habitats, rearing habitats, and migration corridors within the Fraser River Basin. Accordingly, conservative assumptions were used in the effects and exposure assessments (i.e., the maximum concentration measured for each habitat type in each Area of Interest was selected as the exposure point concentration for each chemical of potential concern; estimates of no-effect concentrations for aquatic organisms were selected as the toxicity screening values). Chemicals for which all measured concentrations were below the corresponding no-effect concentrations were considered to be unlikely to cause adverse effects on sockeye salmon or other aquatic organisms within the Fraser River Basin and were not considered further in the investigation. Chemicals for which one or more measured concentrations exceeded the selected toxicity screening value were identified as contaminants of concern and subjected to further evaluation (see Chapter 5 for additional information). Chemicals for which insufficient information was available to complete the assessment were identified as uncertain contaminants of concern and were evaluated using qualitative analyses (see Chapter 6 for more information). Each of these steps in the preliminary evaluation of chemicals of potential concern is described in the following sections of this Chapter. In addition, the results of these analyses are presented herein.

4.2 Identification of Potentially-Complete Exposure Pathways

Based on the results of the evaluation conducted in Chapter 3, it is apparent that land and water use activities in the study area and in areas spatially removed from the watershed have resulted or are likely to have resulted in the release of 200 or more chemical substances into aquatic habitats within the Fraser River Basin. Each of these contaminants partition into water, sediment, and/or biological tissues in accordance with their physical-chemical properties and the conditions within the receiving water system. Such partitioning and other environmental fate processes determine which media (i.e., water, sediment, and/or biota) become contaminated and, thereby, represent potentially-complete exposure pathways to sockeye salmon in the study area. For an exposure pathway to be complete, a contaminant must be able to travel from the source to the ecological receptor under consideration and must be taken up by that ecological receptor via one or more exposure routes.

There are a number of pathways through which Fraser River sockeye salmon can be exposed to the substances identified in the Aquatic Contaminants Inventory (Table 3.28). For the substances that partition into water, direct exposure to contaminated water represents the most important exposure pathway for sockeye salmon (i.e., uptake through the gills and/or through the skin). For substances that partition into sediments, direct exposure to contaminants in sediment and/or pore water during incubation and consumption of contaminated prey during rearing represent the most important exposure pathways. As sockeye salmon tend to utilize coarse-grained sediments (i.e., gravels and cobbles) for incubation and limnetic habitats (i.e., open water) for rearing (with the exception of side-channel habitats in the lower Fraser River), exposure to sediments is likely to be of minor importance. For bioaccumulative substances, the ingestion of contaminated prey species represents the most important route of exposure for the majority of aquatic organisms, including sockeye salmon.

4.3 Selection of Toxicity Screening Values

Exposure to contaminated surface water has the potential to adversely affect the survival, growth, or reproduction of sockeye salmon utilizing habitats within the Fraser River Basin. The analysis of effects is intended to provide a basis for determining the nature of toxic effects that are associated with exposure to contaminants and the magnitude of the toxic effects as a function of exposure (Suter *et al.* 2000). In this assessment, exposure of sockeye salmon was evaluated using information on the concentrations of chemicals of potential concern in surface water and in sediments. As such, it was necessary to compile information on the effects on aquatic organisms associated with exposure to these chemicals in these media types.

In this study, the screening-level ecological effects evaluation involved identification and compilation of toxicity screening values for surface water and sediment. The toxicity screening values used in the preliminary effects assessment are intended to provide conservative numerical estimates of the concentrations of chemicals of potential concern in environmental media below which there will be no or negligible adverse effects on the ecological receptor group of concern (i.e., aquatic organisms, including sockeye salmon). Accordingly, the selected toxicity screening values are considered to be sufficiently conservative to support identification of the chemicals of potential concern that are not considered to pose potential risks to sockeye salmon or other aquatic organisms (i.e., when none of the samples have concentrations in excess of the toxicity screening value). Such chemicals of potential concern can be eliminated from further consideration if the existing data provide adequate spatial coverage of the study area.

Because the toxicity screening values generally represent no observed adverse effect levels for long-term (chronic) exposures to a chemical of potential concern, exceedance of a toxicity screening value does not necessarily indicate unacceptable risks to sockeye salmon. Rather, exceedance of a toxicity screening value indicates that a chemical warrants further assessment to determine if exposure is sufficient to pose unacceptable risks. The toxicity screening values selected for each of the media types were adopted from publically-available literature sources and using the procedure described below.

- ***Toxicity Screening Values for Surface Water*** - A tiered approach was used to select toxicity screening values for surface-water chemistry data for the Fraser River Basin. Using this procedure, the lower of the Canadian water quality guidelines (CCME 1999) or the British Columbia approved and working water quality criteria (BCMOE 2010a) was selected as the toxicity screening value for a chemical of potential concern. Both types of benchmarks define the concentrations of these chemicals in water that would not adversely affect any life stage of any aquatic species that are exposed for extended time periods. If such guidelines or criteria were not available for a substance, then the criterion continuous concentration promulgated by USEPA (2009a) or a similar value (i.e., JWQB 1998) was selected as the toxicity screening value. For toxicity screening values that are hardness, pH, or temperature dependent, data on the characteristics of each water sample were used to calculate a sample-specific toxicity screening value for that chemical of potential concern in water.
- ***Toxicity Screening Values for Sediment*** - Exposure to contaminated sediments has the potential to adversely affect sockeye salmon during incubation of eggs and alevins. In addition, some sockeye salmon (e.g., Harrison River fish) can be exposed to sediment-associated contaminants through the consumption of benthic invertebrates during early rearing in areas that are dominated by benthic production (e.g., sloughs in the Lower Fraser River Area of Interest). Numerical sediment quality guidelines provide a basis for assessing the effects on benthic invertebrates and other aquatic organisms associated with exposure to sediment-associated chemicals of potential concern. A hierarchical approach was employed to compile toxicity screening values for use in this assessment. Consensus-based threshold effect concentrations (MacDonald *et al.* 2000a, MacDonald *et al.* 2000b) were chosen as toxicity screening values for some metals, PAHs, sum PCBs, and organochlorine pesticides. Interim sediment quality guidelines promulgated by CCME (1999) were selected for the contaminants for which consensus-based threshold effect concentration values have not been developed. The BCMOE Compendium of Working Water Quality Guidelines for sediments (Nagpal *et al.* 2006) and the peer-reviewed literature (e.g., MacDonald 1994) was used to further identify threshold effect concentration-type values for use in the screening-level assessment.

Listings of the toxicity screening values that were selected for evaluating surface water quality data collected and sediment quality within the study area are provided in Tables 4.1 and 4.2, respectively.

4.4 Evaluation of Exposure to Chemicals of Potential Concern

Exposure is defined as the co-occurrence or contact of a stressor with an ecological receptor, both in time and space (USEPA 1997). In this study, exposure was evaluated for each life stage of sockeye salmon within each area of interest using data on the concentrations of chemicals of potential concern that have been measured in surface water and sediment. These data were obtained from multiple sources and assembled in a GIS-compatible, relational database (see Appendix 3 for additional information). Subsequently, the locations of the sampling sites were mapped on an area of interest-by-area of interest basis. The resultant maps were examined and used to identify the stations that could be grouped to characterize conditions within spawning and incubation areas, juvenile rearing areas, smolt out-migration corridors, and adult up-stream migration corridors. Figures 4.1 to 4.4 illustrate the distribution of stations that were selected to characterize conditions within each of these four habitat types within the study area. Figures 4.5 to 4.19 illustrate the distribution of the selected sampling stations for each area of interest. While all of the stations used to characterize conditions in spawning and rearing habitats are included on the individual area of interest maps, conditions within migration corridors were evaluated using the data for identified stations on the area of interest maps and the data for all downstream stations on the Fraser River and/or Thompson River mainstem, as applicable.

To evaluate exposure of sockeye salmon to chemicals of potential concern in the Fraser River Basin, the available water chemistry data were compiled for each life history stage for each brood year. For example, the data needed to evaluate exposure of the 1991 brood year of sockeye salmon for the Quesnel River Area of Interest were compiled as follows:

- Data collected for spawning and incubation areas between August 1, 1991 and May 31, 1992 were compiled to evaluate exposure of eggs and alevins to chemicals of potential concern during spawning and incubation;
- Data collected for rearing areas between April 1, 1992 and March 31, 1993 were compiled to evaluate exposure of fry to chemicals of potential concern during rearing in nursery lakes;

- Data collected for migration corridors between May 1, 1993 and June 30, 1993 were compiled to evaluate exposure of smolts to chemicals of potential concern during outmigration;
- Data collected for migration corridors between June 1, 1995 and September 30, 1995 were compiled to evaluate exposure of adults to chemicals of potential concern during upstream migration.

This approach to summarizing the available surface-water chemistry data is based on several assumptions. First, it assumes that the general life history pattern is the same for all stocks (i.e., one year of freshwater rearing followed by two years of ocean residence). In addition, it assumes that the timing for each life history stage is the same for all sockeye salmon stocks. While both of these assumptions are not precisely correct, they are sufficiently reasonable to support evaluations that facilitate comparisons of exposure over time and space.

Due to limitations on the availability of sediment chemistry it was not possible to sort the data in a way that would support spatial or temporal trend assessment for most of the areas of interest and most of the life history stages. Therefore, the data were grouped into two categories for each area of interest to determine if the concentrations of chemicals of potential concern exceeded toxicity screening values during the pre-1990 and post-1990 time frames. These two time periods were identified for several reasons. First, examination of the general trends in sockeye salmon abundance show marked declines over the past 20 years (Figure 1.1). Accordingly, the available productivity data (i.e., mean Ricker residuals were plotted for the pre-1990, and post-1990 time periods (Figure 4.20). These results showed that most of the Fraser River sockeye salmon stocks had mean Ricker residuals (i.e., positive values) indicative of increasing productivity prior to 1990. However, marked declines in productivity (as indicated by negative mean Ricker residuals) for most stocks was observed after 1990. Hence examination of water quality conditions for these two periods could provide information relevant for explaining declines in the abundance of sockeye salmon in the Fraser River Basin.

In this study, exposure of sockeye salmon to chemicals of potential concern was quantified by calculating exposure point concentrations. More specifically, exposure point concentrations were estimated for each of the habitat types (e.g., spawning and incubation habitat) contained within each area of interest (e.g., Chilko River Area of Interest) for each time period (e.g., August 1, 1991 and May 31, 1992) by determining the maximum concentration of each chemical of potential concern. This is consistent with the available guidance for estimating exposure point concentrations in screening-level ecological risk assessments (CCME 1996; USEPA 1997; SAB 2005). The methods that were used to acquire, compile, evaluate, and analyse the available exposure data are summarized in Appendix 3 (data acquisition) and Appendix 4 (data methodology and treatment). The results of the exposure assessment are presented in Tables 4.3 to 4.15 for water and in Table 4.16 for sediment.

4.5 Preliminary Hazard Evaluation

The purpose of the preliminary hazard evaluation is to determine whether or not aquatic contaminants occur in the Fraser River Basin at levels sufficient to pose potential threats to aquatic organisms, including sockeye salmon. In addition, this step of the process is intended to identify the substances that may be causing or substantially contributing to effects on sockeye salmon and/or aquatic organisms. These substances are termed contaminants of concern, as opposed to the broader list of chemicals of potential concern that were considered in the preliminary hazard assessment. This information is generated by integrating the results of the exposure assessment with the results of the effects assessment for each media type.

In this evaluation, two lines of evidence were used to evaluate hazards posed to aquatic organisms, including sockeye salmon, associated with exposure to aquatic contaminants, including surface-water chemistry and sediment chemistry. For each area of interest, habitat type, and brood year combination, a hazard quotient was calculated for each chemical of potential concern by dividing the exposure point concentration (i.e., maximum concentration measured) by the selected toxicity screening value. A hazard quotient of < 1.0 indicates that the chemical of potential concern under consideration does not pose a potential hazard to sockeye salmon or other aquatic organisms. In contrast, a hazard quotient > 1.0 indicates that the chemical of potential concern poses a potential threat to exposed aquatic organisms, including sockeye salmon. The substances that occurred in one or more areas of interest during any life history stage at levels in excess of the toxicity screening values were termed contaminants of concern; further evaluation is needed to determine if exposure to the contaminants of concern is likely causing or substantially contributing to adverse effects on the survival, growth, or reproduction of sockeye salmon. Uncertain contaminants of concern were also identified as a result of this analysis (i.e., those chemicals of potential concern for which exposure point concentrations could not be calculated or toxicity screening values could not be established).

Hazard quotients were calculated for all chemicals of potential concern for which useable exposure data and toxicity reference values were available. Tables 4.17 and Table 4.18 summarize the availability of water and sediment chemistry data, respectively, that are usable for evaluating the potential effects on sockeye salmon associated with exposure to chemicals of potential concern in the Fraser River Basin. For most areas of interest, habitat type, and brood year combinations, hazard quotients were calculated for conventional variables (e.g., pH and TSS), major ions, nutrients, and/or total metals. In some cases, data were also available for chlorophenols, phenols, or cyanide (WAD). Hence, hazard quotients were calculated for only a subset of the aquatic contaminants that were identified in the Fraser River and its tributaries. To help address this limitation on the available data and to address the lower reliability of the hazard quotients for certain chemicals of potential concern (e.g., nutrients, total metals) as indicators of potential effects on aquatic organisms (such a sockeye salmon), the hazard quotient data were summarized for the pre-1990 and post-1990 periods to provide a basis for determining if water quality conditions have changed over the past two decades.

4.5.1 Potential Risks to Sockeye Salmon Exposed to Surface Water

Data on water quality conditions in the Fraser River Basin were obtained from the BCMOE EMS database (BCMOE 2010b; See Appendix 3). Data were obtained for 12 of the 15 geographic areas in the watershed (Figure 4.21). In addition, water quality data from Fraser River at Red Pass, a federal/provincial water quality monitoring station at the headwaters of the Fraser River, were summarized to represent reference conditions. Water quality data were not available for the Harrison River, Nahatlatch, or Seton-Portage areas of interest. The available water chemistry data facilitated characterization of the levels of conventional variables, major ions, nutrients, metals, cyanide, phenolic compounds and chlorinated phenolic compounds concentrations in selected riverine and lacustrine waters (Tables 4.3 to Tables 4.15). A summary of available water chemistry data for each of the life history stages (e.g., juvenile rearing) is presented in Table 4.17.

The assessment of the water chemistry data was conducted for key life-history stage exposure periods (i.e., spawning and incubation, rearing, smolt outmigration and upstream adult migration) for two distinct historical time periods: prior to and including 1990 (i.e., pre-1990); and, 1991 up to and including 2010 (i.e., post-1990), where data were available. The maximum hazard quotients for each chemical of potential concern in each area of interest, grouped by life-history stage and by pre-1990 and post-1990 time periods, are presented in Tables 4.19 to 4.31. In addition, the frequency of exceedance of the selected toxicity screening values was determined for each measured chemical of potential concern, for each area of interest, for each life-history stage, and for both the pre-1990 and post-1990 time periods (Tables 4.32 to 4.44). The maximum hazard quotient for the entire period of record (i.e., the maximum hazard quotient of the pre-1990 and the post-1990) was used to identify chemicals of potential concern that have potential to adversely affect sockeye salmon during individual key life-history stage exposure periods (e.g., juvenile rearing; Tables 4.45 to 4.48).

The results of this assessment indicated that 23 chemicals of potential concern have been measured in surface water at concentrations sufficient to pose potential risks to sockeye salmon eggs, alevins, fry, smolts, or adults (Table 4.49), including:

- Conventional variables (pH, TSS, and turbidity);
- Nutrients (nitrate, nitrite, and phosphorus);
- Major ions (chloride, fluoride, and sulphate);
- Metals (aluminum, arsenic, boron, cadmium, chromium, cobalt copper, iron lead, mercury, nickel, selenium, and silver); and,
- Phenols

Although the maximum hazard quotients for cadmium, chromium, and mercury were almost certainly influenced by sample contamination issues, there were numerous results that showed exceedances of the toxicity screening values for these metals that were not contaminated during sample collection, handling or transport. Therefore, all of these substances were identified as contaminants of concern (Table 4.49).

In the Fraser River Basin, both spawning and incubation habitats and adult upstream migration habitats had a higher percentage of measured chemicals of potential concern exceeding toxicity screening values during post-1990 period, compared to the pre-1990 period (Table 4.50). In spawning and incubation habitats, 69% (20 of 29) chemicals of potential concern had at least one or more exceedances of a toxicity screening value in one or more areas of interest post-1990. For the pre-1990, 62% (17 of 27) of measured chemicals of potential concern had one or more measurements exceeding a toxicity screening value (Table 4.50). Similarly, adult upstream migration habitats had exceedances of the toxicity screening values for 66% of measured chemicals of potential concern (23 of 35) in the post-1990 period compared to 60% (18 of 30) for the pre-1990 period. These results suggest that water quality conditions have degraded over the past two decades. However, the results were reversed for the juvenile rearing and smolt outmigration life stages.

Many other substances have the potential to partition into water and may pose potential hazards to Fraser River sockeye salmon stocks, including organometallics, monoaromatic hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), resin and fatty acids, petroleum hydrocarbons, pesticides, wood preservation chemicals, surfactants, pharmaceuticals, personal care products, steroids, hormones and hormone mimickers, disinfectants, fire retardants, plastics-related chemicals, and nanoparticles. However, insufficient data were available to characterize exposures to these contaminants and/or toxicity screening values were not located for these substances. As such, it was not possible to evaluate the hazards posed to sockeye salmon in the Fraser River associated with exposure to these contaminants. Accordingly, these substances were identified as uncertain contaminants of concern and were considered, to the extent possible, in the qualitative evaluation of endocrine disrupting chemicals and contaminants of emerging concern (Chapter 6).

4.5.2 Potential Risks to Sockeye Salmon Exposed to Sediments

Data on sediment quality conditions in the Fraser River Basin were obtained from the BCMOE EMS database (BCMOE 2010b) and from reports generated from the Metro Vancouver Regional District (ENKON Environmental Ltd. 2007; see Appendix 3). Data were obtained for four geographic areas in the watershed (Figure 4.22), including the Lower Fraser River, the Harrison River (specifically Lillooet Lake), the Lower Thompson River (specifically Nicola Lake), and the South Thompson River (specifically Shuswap Lake, and Harris and Bessette creeks) areas of interest. These sediment chemistry data facilitated characterization metal, pesticide, PAH, and PCB concentrations in selected riverine and lacustrine sediments (Table 4.16). The summary of available sediment chemistry data for each of the areas of interest is presented in Table 4.18.

As the availability of sediment chemistry data was limited both temporally and spatially, the data obtained from BCMOE and Metro Vancouver were amalgamated for use in the preliminary hazard evaluation. Furthermore, the assessment of the sediment chemistry data was not conducted for key exposure times (i.e., spawning and incubation, rearing, smolt outmigration and upstream adult migration). Rather, the maximum hazard quotients were calculated for each of the chemicals of potential concern in each area of interest (Table 4.51) for the pre-1990 and post-1990 time periods. In addition, the frequency of exceedance of the selected toxicity screening value was determined for each of the chemicals of potential concern during the pre-1990 and post-1990 time period for each area of interest (Table 4.52).

The results of this assessment indicate that a number of chemicals of potential concern pose potential risks to sockeye salmon and other aquatic organisms, utilizing habitats within the Fraser River Basin. The substances with hazard quotients > 1.0 for one or more areas of interest are (Table 4.53):

- Metals (arsenic, cadmium, chromium, copper, iron, lead, and nickel);
- Phthalates (BEHP); and,
- PAHs [acenaphthalene, benz(a)anthracene, and dibenz(a,h)anthracene].

These substances were identified as contaminants of concern and retained for further evaluation in the detailed assessment of risks to sockeye salmon in the Fraser River Basin (Chapter 5). While insufficient data were available to conduct temporal analyses for most chemicals of potential concern in most areas of interest, it appears that contamination of sediments by metals has increased over the past 20 years in the Lower Fraser River Area of Interest.

Many other substances have the potential to partition into the sediments and pose potential hazards to Fraser River sockeye salmon stocks. For sediments, the other chemicals of potential concern included organometals, cyanides, monoaromatic hydrocarbons, chlorinated and non-chlorinated phenolic compounds, resin and fatty acids, PBDEs, hormone mimicking substances, personal care products, and nanoparticles. However, insufficient data were available to characterize exposures to these contaminants and/or toxicity screening values were not located for these substances. As such, it was not possible to evaluate the hazards posed to sockeye salmon in the Fraser River associated with exposure to these contaminants. Accordingly, these substances were identified as uncertain contaminants of concern and were considered, to the extent possible, in the qualitative evaluation of endocrine disrupting chemicals and contaminants of emerging concern (Chapter 6).

Chapter 5 Evaluation of Contaminants of Concern

5.0 Introduction

A preliminary evaluation of the substances identified in the Inventory of Aquatic Contaminants was conducted to determine if one or more chemicals of potential concern occurred in environmental media within the Fraser River Basin at concentrations sufficient to pose potential hazards to sockeye salmon (See Chapter 4 for more information). The preliminary evaluation was conducted using the existing surface-water chemistry and whole-sediment chemistry data from the study area. These data were evaluated using toxicity screening values from various sources. Because the concentrations of one or more substances exceeded the toxicity screening values, it was concluded that chemicals of potential concern pose potential risks to aquatic organisms in the study area. More specifically, it was concluded the following substances represent contaminants of concern in the Fraser River Basin:

- Conventional variables (pH, TSS, turbidity);
- Major ions (chloride, fluoride, sulphate);
- Nutrients (nitrate, nitrite, phosphorus);
- Metals (aluminum, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, silver);
- Total phenols;
- Polycyclic aromatic hydrocarbons [acenaphthene, benz(a)anthracene, dibenz(a,h)anthracene]; and,
- Plastics-related chemicals [bis(2-ethylhexyl)phthalate].

Accordingly, a more detailed evaluation was conducted to determine if one or more of these contaminants of concern occur at concentrations sufficient to cause or substantially contribute to adverse effects on the survival, growth, or reproduction of sockeye salmon in the Fraser River Basin. This evaluation consisted of four main steps, including:

- Refinement of the list of contaminants of concern;
- Selection of salmonid-specific toxicity thresholds (or toxicity reference values);
- Refinement of the exposure point concentrations; and,
- Calculation of effect-based hazard quotients.

Each of these steps in the contaminant of concern evaluation process are described in the following sections of this chapter. The results of this evaluation are also presented and discussed.

5.1 Refinement of the List of Contaminants of Concern

The preliminary evaluation of the aquatic contaminants (i.e., chemicals of potential concern) was designed to identify all of the substances that could, potentially, pose threats to sockeye salmon or other aquatic organisms utilizing habitats within the Fraser River Basin (i.e., contaminants of concern). While the results of the preliminary evaluation provide a systematic basis for identifying substances that pose negligible threats to sockeye salmon, the conservative nature of the assessment means that the resultant list of contaminants of concern can include substances that are unlikely to have caused or substantially contributed to declines of sockeye salmon in the study area. For example, the selected toxicity screening values represent conservative estimates of toxicity thresholds for ecological receptors, typically equivalent to no observed adverse effect levels. In addition, the exposure point concentrations were established based on the maximum measured concentration of each chemical of potential concern in each habitat type for each area of interest. Furthermore, it was assumed that 100% of the measured concentrations of the chemicals of potential concern were biologically available, which is unlikely for total metals in surface water that carry substantial suspended sediment loads.

To ensure that additional analyses were focussed on the substances that represent potential risk drivers for sockeye salmon, a contaminant of concern refinement process was used to identify the substances that would be included in the detailed evaluation. Refinement of the list of contaminants of concern involved reviewing the maximum hazard quotients calculated in the preliminary assessment and eliminating any substance with a maximum hazard quotient of < 2.0. This approach to contaminant of concern refinement was used because the toxicity screening values used in the preliminary assessment represent no-effect concentrations for the most sensitive life stage of the most sensitive aquatic species for indefinite exposure periods. Based on a review of the toxicological data for many substances, MacDonald (1993) concluded that the ratio of no-effect levels to lowest-effect levels was typically on the order of 2.0. Therefore, it is highly unlikely that contaminants of concern with hazard quotients of < 2.0 would pose potential risks to sockeye salmon (i.e., maximum concentrations would be below the lowest observed adverse effect concentration for a sensitive life stage of a sensitive aquatic species.

For surface water and sediment, the refined lists of contaminants of concern included the following substances:

Surface Water

- Conventional variables (TSS);
- Nutrients (nitrite);
- Major ions (chloride and sulfate);
- Metals (aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, and silver); and,
- Phenols.

Sediment

- Metals (cadmium, iron, and nickel);
- Phthalates (BEHP); and,
- PAHs [dibenz(a,h)anthracene].

As the preliminary evaluation considered data on the levels of chemicals of potential concern in abiotic media only (i.e., water and sediment), contaminants of concern for fish tissue were not explicitly identified. However, metals (such as mercury and selenium), PCBs, PCDDs/PCDFs, organochlorine pesticides, and other substances have the potential to accumulate in the tissues of sockeye salmon. All of these substances were identified as contaminants of concern in fish tissues.

5.2 Selection of Toxicity Thresholds for Sockeye Salmon

The toxicity screening values that were used in the preliminary evaluation of the chemicals of potential concern (Chapter 4) were intended to represent no adverse effect levels for aquatic organisms. That is, the toxicity screening values used in the preliminary evaluation are intended to protect all life stages of all species of aquatic organisms (including aquatic plants, aquatic invertebrates, fish, and amphibians) exposed to chemicals of potential concern for extended periods of time (i.e., whole life cycles). Accordingly, such toxicity screening values provide conservative tools for screening water quality data (i.e., identifying the chemicals of potential concern that are unlikely to be associated with adverse effects on sockeye salmon). In contrast, the evaluation of contaminants of concern is intended to identify the substances that occur at concentrations sufficient to adversely affect the survival, growth, or reproduction of sockeye salmon in the Fraser River Basin. For this reason, it is necessary to establish toxicity thresholds (which are also termed toxicity reference values) for sockeye salmon that can be used to determine if the presence of contaminants in aquatic habitats within the study area could have caused or substantially contributed to declines in sockeye salmon productivity over the past two decades. For the purpose of conducting a detailed analysis of the contaminants of concern, a toxicity threshold is defined as the concentration of a contaminant in water, sediment, or fish tissues above which adverse effects on survival, growth, or reproduction are likely to be observed in sockeye salmon exposed for extended periods of time to environmental media that contain the substance, either alone or in complex mixtures of contaminants.

Toxicity Thresholds for Water - A total of 17 substances were identified as contaminants of concern in water based on the results of the preliminary evaluation and subsequent refinement process (see Section 5.1). For each of these substances, toxicity thresholds for sockeye salmon or other salmonid fishes were estimated using data and information contained in the published literature. More specifically, compilations of the available toxicity data (such as contained within substance-specific water quality guidelines and water quality criteria documents) were reviewed to support the identification of toxicity thresholds for each contaminant of concern in water. The sockeye salmon-specific or salmonid-specific toxicity thresholds were established using the following procedures:

- For substances for which the toxicity screening value used in the preliminary evaluation was based on toxicity data for non-salmonid species (i.e., data on the toxicity of the substance to aquatic plants, invertebrates, non-salmonid fishes, or amphibians), toxicity thresholds for evaluating the potential effects of contaminants of concern on sockeye salmon were established using one of the following procedures:
  1. Identify the lowest median lethal concentration (LC_{50}) obtained in a toxicity test conducted on sockeye salmon or another salmonid species that extended for at least 96 hours. The lowest LC_{50} was then multiplied by a safety factor of 0.1, in accordance with CCME (1999) procedures;
  2. Identify the lowest effective concentration (i.e., EC_{25}-type value) for a non-lethal endpoint obtained in a toxicity test conducted on sockeye salmon or another salmonid species that extended for at least 96 hours. The lowest EC_{25} was then multiplied by a safety factor of 0.5;

3. For hardness-dependent water quality guidelines, substitute the intercept value for sockeye salmon or the most sensitive salmonid species for the intercept value for the non-salmonid species used to derive the toxicity screening value (the slope was not adjusted, however);
4. Calculate the ratio of the final acute value for sockeye salmon or the most sensitive salmonid species to the final acute value for the species that was used to derive the water quality guidelines. Multiply the toxicity screening value by the ratio of final acute values derived in this manner to estimate the toxicity threshold for sockeye salmon; or,
5. Identify the toxicity threshold directly from the maximum acceptable toxicant concentration reported for a sub-lethal endpoint obtained based on the results of an acceptable long-term study on sockeye salmon or another salmonid species.

- For substances for which the selected toxicity screening value was based on toxicity data for salmonid species, toxicity thresholds for sockeye salmon were established using the following procedures:
    1. Calculate the ratio of the final acute value for sockeye salmon to the final acute value for the salmonid species that was used to derive the water quality guideline. Multiply the toxicity screening value by the ratio of final acute values derived in this manner to estimate the toxicity threshold for sockeye salmon.

In some cases, the toxicity screening values used in the preliminary evaluation were adopted directly as the toxicity thresholds for sockeye salmon. In these cases, the toxicity screening value was already based on salmonid toxicity data and/or no sockeye-salmon specific toxicity data were available. The toxicity thresholds that were selected for evaluating surface-water chemistry data from the Fraser River Basin are presented in Table 5.1.

For each surface water sample, a water quality index score was also calculated using the methods described in CCME (1999). The water quality index provides a consistent basis for evaluating the proportion of toxicity screening values exceeded, the frequency of exceedance of the toxicity screening values, and the magnitude of exceedance of the toxicity screening values. Accordingly, the water quality index provides a convenient tool for comparing water quality conditions across geographic areas and across time periods (see Appendix 5 and CCME 1999 on detailed information for calculating the water quality index).

Toxicity Thresholds for Sediment - A total of five substances were identified as contaminants of concern in sediment based on the results of the preliminary evaluation and subsequent refinement process (see Section 5.1). Sockeye salmon-specific, salmonid-specific, or fish-specific sediment quality guidelines were not located in the literature to support the detailed evaluation of sediment chemistry data for the Fraser River Basin. For this reason, effects-based sediment quality guidelines for the protection of benthic invertebrates were obtained from multiple jurisdictions and reviewed to identify toxicity thresholds that could be used to assess sediment quality conditions in the study area. A tiered-approach was used to select toxicity thresholds for use in the evaluation and involved:

- Selecting probable effect concentrations (PECs) or median effect concentrations (MECs) from MacDonald *et al.* (2000a; 2000b) when such values were available;
- Selecting probable effect levels (PELs) from CCME (1999) or MacDonald (1994) when PECs/MECs were not available; and,
- Selecting the lowest effect levels from Nagpal *et al.* (2006) for those substances for which none of the other sediment quality guidelines were available.

Such toxicity thresholds represent the concentrations of contaminants of concern above which adverse effects on the benthic invertebrate community are likely to be observed when the contaminants of concern occur in complex mixtures with other contaminants. The toxicity thresholds that were selected for evaluating sediment chemistry data from the Fraser River Basin are presented in Table 5.2.

Toxicity Thresholds for Fish Tissues - Accumulation of certain contaminants in tissues has the potential to adversely affect the survival, growth, or reproduction of sockeye salmon. In this study, toxicity thresholds for fish tissues were identified from selected reviews of the scientific literature that evaluate adverse effects on fish associated with accumulation of contaminants of concern in their tissues. The toxicity thresholds that were selected for evaluating fish-tissue chemistry data from the Fraser River Basin are as follows:

- Mercury - 0.4 µg/g WW (Dillon *et al.* 2010);
- Selenium - 1.58 µg/g WW (USEPA 2010b); and,

- 2,3,7,8-TCDD toxic equivalents - 3.0 pg/g lipid (Giesy *et al.* 2002; DeBruyn *et al.* 2004).

Toxicity thresholds were unavailable for many other contaminants of concern that have the potential to accumulate in fish tissues.

5.3 Estimation of Exposure of Sockeye Salmon to Contaminants of Concern

Surface-water chemistry, whole-sediment chemistry, and fish-tissue chemistry data provide a basis for evaluating exposure of sockeye salmon to contaminants of concern in the Fraser River Basin. In the preliminary evaluation of the chemicals of potential concern, exposure was estimated for each habitat type/exposure period combination (e.g., spawning and incubation habitats) within each area of interest by determining the maximum concentration of each substance in each media type. This approach was selected to provide a conservative basis for identifying the substances that pose potential risks to sockeye salmon in the Fraser River Basin (i.e., to minimize the potential for eliminating from further consideration substances that could be adversely affecting aquatic organisms in the study area, including sockeye salmon).

The objective of the detailed assessment is to determine if contaminants are causing or substantially contributing to the decline of sockeye salmon in the Fraser River over the past two decades. Accordingly, more realistic assumptions were used to estimate exposure of sockeye salmon to the contaminants of concern that emerged from the preliminary evaluation and those that accumulate in fish tissues (USEPA 1997; 1998). More specifically, exposure point concentrations for surface water were estimated for each habitat type within each area of interest for sockeye salmon by determining the 95th percentile concentration of each substance (Tables 5.3 to 5.6). For sediment and fish tissues, limitations on the available data precluded determination of habitat-specific exposure point concentrations. Therefore, exposure point concentrations were calculated for each area of interest by determining the 95th percentile concentration of each substance, as possible based on data availability (Table 5.7 and Table 5.8). These exposure point concentrations were used to evaluate risks to sockeye salmon associated with exposure to individual contaminants of concern in surface water, sediment, or fish tissues.

Because ecological receptors can be adversely affected by exposure to mixtures of contaminants of concern (i.e., in addition to individual contaminants of concern), water quality index scores were also calculated for each habitat sockeye salmon stock combination. Such water quality index scores were plotted over time for the entire watershed to determine if temporal trends in water quality conditions were evident. The results of this evaluation showed that water quality conditions in spawning and incubation habitats did not exhibit any significant trend (Figure 5.1). However, the ranges of the water quality index scores for the pre-1990 and post-1990 (and particularly post-1992) periods suggest that water quality conditions may have become less variable and poorer over the last 15 - 20 years. No such trends are evident for the rearing areas over the period of record (i.e., 1970 to 2009). For the migration corridors, water quality conditions generally showed a downward trend for the period 1965 to 1990, are consistent between 1990 and 2003, and show improvement thereafter (Figure 5.1). However, these latter results (i.e., for the post-2003 period) should be interpreted cautiously because such changes in water quality conditions coincided with the time that municipalities assumed responsibility for ambient environmental quality monitoring. The results of such monitoring activities are typically not included in the EMS database that was accessed to compile the data used to support this evaluation. Hence, it is uncertain if the observed improvements in water quality conditions after 2003 reflect actual conditions in the migration routes of sockeye salmon.

5.4 Evaluation of the Potential Effects of Contaminants of Concern on Sockeye Salmon

Adverse effects on sockeye salmon utilizing habitats in the Fraser River Basin associated with exposure to contaminants of concern were evaluated by integrating exposure and effects data and information. More specifically, hazard quotients were calculated for each contaminant of concern in surface water for each of the following habitats in each area of interest:

- Spawning and incubation habitats;
- Rearing habitats;
- Smolt outmigration habitats, and,
- Adult upstream-migration habitats.

In this evaluation, hazard quotients (HQs) were calculated by dividing the exposure point concentration (EPC) by the selected toxicity threshold (TT) (i.e., HQ = EPC ÷ TT). For sediments and fish tissues, hazard quotients were calculated for each contaminant of concern by area of interest (rather than by habitat type), due to limitations on the available exposure data. In addition, the measured concentration of each contaminant of concern in each surface water, sediment, or fish-tissue sample was compared to the corresponding toxicity threshold to determine the frequency of exceedance of the selected toxicity thresholds for each area of interest.

5.4.1 Potential Effects on Sockeye Salmon Associated with Exposure to Contaminants of Concern in Surface Water

The results of this assessment indicate that numerous contaminants of concern occur in one or more habitats at concentrations sufficient to adversely affect the survival, growth, or reproduction of Fraser River sockeye salmon (Table 5.9 to 5.12). In spawning and incubation habitats, the substances that pose the highest risks to sockeye salmon include TSS and six metals (aluminum, chromium, copper, iron, mercury, and silver). While risks to sockeye salmon were generally lower in juvenile rearing habitats, three metals (aluminum, chromium, and iron) occurred at concentrations in excess of the selected toxicity thresholds. Water quality conditions in smolt outmigration and adult upstream migration corridors were similar, with the concentrations of TSS, five metals (aluminum, chromium, copper, iron, and mercury), and/or phenols sufficient to adversely affect sockeye salmon. The frequency of exceedance of the salmonid-specific toxicity thresholds in each habitat type in each area of interest is presented in Tables 5.13 to 5.16.

The results of the risk analysis indicate that sockeye salmon utilizing habitats within the Fraser River Basin are exposed to water-borne contaminants of concern at levels sufficient to cause adverse effects. However, these results warrant closer scrutiny before they are used to draw conclusions regarding the role of contaminants in the decline of Fraser River sockeye salmon. Some of the factors that potentially mitigate the effects on sockeye salmon associated with exposure to these contaminants include:

- The toxicity thresholds for TSS and turbidity are normally expressed relative to background conditions. However, habitat-specific background data for TSS and turbidity were not located for any area of interest in the watershed, with the possible exception of the Upper Fraser River Area of Interest (i.e., reference data were compiled for the monitoring station located at Red Pass). Therefore, the toxicity thresholds that applied to the lowest background levels of TSS and turbidity were selected to support the calculation of hazard quotients. Accordingly, effects on sockeye salmon could be over-estimated. In addition, the available data did not support determination of the duration of exposure of sockeye salmon to elevated levels of TSS and turbidity, a factor that has been shown to be important for accurately predicting effects on salmonid fishes (Newcombe and MacDonald 1991). As a result, further investigations are needed to fully evaluate the potential effects of TSS and turbidity on sockeye salmon in the watershed;

- Total phosphorus levels were elevated in incubation, rearing and migration habitats in the study area. However, it is unlikely that exposure to elevated levels of phosphorus would result in direct effects on sockeye salmon. More likely, elevated phosphorus levels would translate into higher primary and, likely secondary productivity (i.e., increased growth of algae and invertebrates), which is generally beneficial for sockeye salmon (provided that oxygen levels remain acceptable and gas supersaturation does not become problematic). In addition, total phosphorus does not always provide a reliable indicator of the amount of phosphorus that is available to plants (i.e., soluble reactive phosphorus and dissolved phosphorus are often better indicators of the biologically-available fraction). Therefore, further investigations are needed to fully evaluate the potential effects of elevated phosphorus levels on sockeye salmon in the watershed.
- Total metal levels were also elevated in spawning and incubation, rearing, and migration habitats throughout much of the study area. However, examination of the underlying data indicate that at least some of the results were likely affected by contamination during sample collection, sample handling, or sample transport. Although procedures were implemented to identify and remove outliers from the data sets used in this evaluation, hazard quotients based on the 95^{th} percentile concentrations may overestimate risks to sockeye salmon associated with exposure to metals, particularly for cadmium, chromium, and mercury. In addition, measurements of total concentrations may not reflect the biologically-available metal fraction, especially when TSS/turbidity levels are elevated in surface waters. Under such conditions, dissolved metal concentrations provide a more reliable basis for evaluating effects associated with exposure to metals. All of the toxicity thresholds for metals are based on the results of toxicity tests in which salmonid fishes were exposed to dissolved metals (i.e., metals were added to exposures as metallic salts; e.g., $CdCl_2$). As a result, further investigations are needed to fully evaluate the potential effects of total metals on sockeye salmon in the watershed;
- Levels of total mercury were elevated throughout the study area. In many cases, the reported levels exceeded the solubility of mercury at 20^{o}C (about

0.05 mg/L; Glew and Hames 1971). As such results are unlikely to be reliable, they were removed from the database. Many of the remaining samples had mercury levels that were about 1000 times the commonly reported detection limits of 0.02 µg/L and 0.05 µg/L. In addition, such elevated results were commonly reported at stations that frequently had mercury levels below the analytical detection limits. Together, these observations suggest that there may be a problem with the underlying data (i.e., the units assigned to the results may have been incorrect; however, it was not possible to confirm this hypothesis because the original data sheets were not available). Hence, caution should be exercised in drawing conclusions from the mercury data.

Two approaches were applied to address the uncertainties associated with the evaluation of the effects of individual contaminants of concern on sockeye salmon in the Fraser River Basin. As a first step, the frequency of exceedance of the selected toxicity thresholds were determined for the pre-1990 and post-1990 period, with the understanding that exposures to contaminants of concern would had to have increased over the past 20 years for contaminants to have caused the recent declines in sockeye salmon abundance. However, comparison of the results for the entire watershed for the two time periods revealed that the frequency of exceedance of the toxicity reference values either remained the same or decreased for all contaminants of concern (Table 5.13 to 5.17). Such patterns of decreasing or constant frequency of toxicity reference value exceedance over time were also generally evident across all of the areas of interest. Some exceptions to this trend include aluminum in spawning habitats in South Thompson River Area of Interest; iron in adult upstream migration habitats in Lower Thompson River and Nechako River areas of interest; and, iron in smolt outmigration habitats in Lower Thompson Area of Interest. This information generally shows a lack of concordance between the exposure and productivity data. Hazard quotients across the whole period of record, summarized for all habitat types in the Fraser River Basin (Table 5.18) suggest that aluminum, cadmium, chromium, copper, iron, mercury, silver and, phenols occur in one or more habitats at concentrations sufficient to adversely affect sockeye salmon.

In the second step of this evaluation, the productivity of Fraser River sockeye salmon, as a function of exposure to contaminants of concern, was evaluated by plotting freshwater productivity, post-juvenile productivity, and/or entire life-cycle productivity against water quality index scores. If the substances explicitly accounted for in the water quality index (i.e., conventional variables, major ions, nutrients, metals, and/or phenols) have caused the declines of sockeye salmon over the past 20 years, then declining productivity should be correlated with exposure to contaminants (Figure 5.2). However, the results of this analysis do not provide convincing evidence that the measured levels of contaminants of concern in surface water have played a major role in the recent declines in sockeye salmon abundance in the Fraser River Basin (Figure 5.3). While surface-water contaminant of concern concentrations in spawning and incubation habitats explained about eight percent of the variability in the freshwater productivity data, the relationship was not statistically significant (Figure 5.3). For fry rearing habitats, smolt outmigration corridors, and adult upstream migration corridors, significant relationships between productivity and water quality index scores were not observed or productivity declined with increasing water quality index scores (i.e., improving water quality conditions; Figure 5.3).

To further evaluate relationships between contaminant of concern exposure and sockeye salmon productivity, the available data were compiled for the pre-1990 and post-1990 period and the relationships between contaminant of concern concentrations and sockeye salmon life-cycle productivity were determined. The results of these analyses show that exposure to contaminants of concern in any of the four habitat types did not explain more than seven percent of the variability in the productivity data for Fraser River sockeye salmon for either the pre-1990 period or the post-1990 period (Figure 5.4). Therefore, it is likely that exposure to the contaminants of concern represented in the water quality index is not the most important factor influencing the abundance of sockeye salmon in the study area. Examination of the available productivity and contaminant exposure data on a conservation unit-specific basis (Figures 5.5 to 5.23) revealed a number of relationships that are consistent with the expected pattern (e.g., Weaver outmigration for both periods, Birkenhead outmigration for both periods, Gates outmigration for post-1990, Portage outmigration for both periods, Raft outmigration for pre-1990, Seymour outmigration for pre-1990, late Shuswap rearing for post-1990, Scotch rearing for pre-1990, Chilko outmigration for both periods, late Stuart outmigration for post-1990, Stellako spawning for pre-1990 and outmigration for post-1990, Nadina outmigration for post-1990, and Bowron outmigration for post-1990). However, most of these relationships are not statistically significant, do not explain much of the variability in the productivity data, and/or have limited range of the exposure variable (water quality index).

In summary, the results of analyses of the available data do not implicate water quality conditions as a major factor influencing trends in sockeye salmon abundance in the Fraser River Basin. However, these results should be kept in perspective considering the limitations on the available data. These data gaps and limitations are listed in Section 7.4 of this document. Furthermore, as shown in Figure 4.20, all of the sockeye salmon stocks that rear for protracted periods (at least one year) in freshwater habitats have exhibited declining productivity over the past 20 years. The Harrison River stock, which spends the least time rearing in freshwater habitats, has exhibited increasing productivity over the same period. Such observations suggest that one or more factors associated with freshwater systems could be contributing to the decline of Fraser River sockeye salmon.

Of the four classes of contaminants of concern that were identified as potentially problematic in the Fraser River Basin, it would be prudent to consider two of them in greater detail. While, the data needed to fully evaluate TSS levels in spawning and incubation habitats were not available, numerous studies have documented the effects of TSS and deposited sediment on the quality of incubation and rearing habitats. Importantly, data on land use activities suggest that the average annual harvest rates of forest resources (as indicated by percent of watershed logged) have increased substantially over the last 20 years in virtually all of the areas of interest within the study area. Such increases in harvest rates would be expected to result in increases in sediment production, especially in the Bowron, Chilko, Nechako, North Thompson, and Quesnel River areas of interest (which have had the highest rates of increase of timber harvest). Therefore, TSS and associated sediment deposition should not be discounted as a potential factor influencing the egg-to-fry survival rates of sockeye salmon.

The available data show that average escapements of sockeye salmon to most of the areas of interest in the Fraser River Basin have decreased substantially over the past 20 years. There is an increasing body of evidence that suggests that the nutrients provided by spawning adult salmon play critical roles in maintaining the productivity of freshwater ecosystems. Therefore, the potential effects of reduced productivity of freshwater habitats, due to decreasing returns of sockeye salmon, should be evaluated more thoroughly.

5.4.2 Potential Effects on Sockeye Salmon Associated with Exposure to Contaminants of Concern in Sediment

The potential effects of sediment-associated contaminants of concern on sockeye salmon in the Fraser River Basin were evaluated using methods similar to those used to evaluate surface water quality. For each area of interest, exposure point concentrations were estimated by calculating the 95th percentile concentration of each of the contaminants of concern that were retained for detailed evaluation (i.e., cadmium, iron, nickel, BEHP, and dibenz(a,h)anthracene; Table 5.7). These exposure point concentrations were used to calculate hazard quotients for each contaminant of concern in each area of interest (i.e., by dividing the exposure point concentration by the selected toxicity reference values for sediment; Table 5.19).

The results of this analysis showed that iron and nickel in the Lower Fraser River Area of Interest and nickel in the South Thompson River Area of Interest occurred in sediments at concentrations sufficient to adversely affect exposed sockeye salmon (Table 5.19). The frequency of exceedence of the selected toxicity thresholds for the two metals indicates that exposure to sediment-associated contaminants has likely increased in the Lower Fraser River Area of Interest over the past 20 years (Figure 5.17).

While the concentrations of certain metals exceeded the selected toxicity thresholds at up to 39% of the stations sampled, it is unlikely that exposure to contaminated sediments represents a significant factor in the decline of sockeye salmon over the past 20 years. Most importantly, interactions between sockeye salmon and contaminated sediments are likely to be minimal under most circumstances. In some cases, sockeye salmon rearing in areas dominated by benthic productivity (e.g., freshwater sloughs) could be exposed to sediment-associated contaminants through consumption of contaminated prey. However, as nickel and iron are only minimally bioaccumulated, this exposure route is likely not significant for these metals. Dietary exposure is likely important for many hydrophobic organic contaminants that accumulate in fish tissues, however.

5.4.3 Potential Effects on Sockeye Salmon Associated with Accumulation of Contaminants of Concern in Fish Tissues

Data from several studies indicate that sockeye salmon accumulate a variety of persistent contaminants in their tissues (DeBruyn *et al.* 2004; Kelly *et al.* 2007; Siska Traditions Society 2009). In this study, risks to sockeye salmon associated with exposure to bioaccumulative contaminants of concern were evaluated by comparing the measured concentrations of bioaccumulative substances in fish tissues to critical body burdens for fish or tissue-specific toxicity thresholds (i.e., toxicity reference values). For each geographic area, exposure point concentrations were estimated for each tissue type (i.e., eggs and muscle) by calculating the 95^{th} percentile concentration of each of the contaminants of concern that were retained for detailed evaluation (i.e., mercury, selenium, PCBs, PCDDs, and PCDFs; Table 5.8). Sockeye salmon exposure to PCBs, PCDDs, and PCDFs was evaluated by calculating 2,3,7,8-TCDD toxic equivalents for each tissue sample. These exposure point concentrations were used to calculate hazard quotients for each contaminant of concern in each geographic area (i.e., by dividing the exposure point concentration by the selected toxicity reference values for fish tissues; Table 5.20).

The results of this analysis indicate that bioaccumulation of contaminants in fish tissues has the potential to adversely affect the productivity of sockeye salmon stocks in the Fraser River Basin. Siska Traditions Society (2009) collected eggs and muscle from Weaver Creek and Adams River sockeye salmon and from Thompson River chinook salmon. These tissue samples were analysed to determine the concentrations of metals and pesticides (Table 5.21 and 5.22). Comparison of the measured concentrations of these contaminants to the selected toxicity reference values indicates that the concentrations of selenium and 2,3,7,8-TCDD toxic equivalents in salmon eggs were sufficient to adversely affect fish reproduction (Table 5.20).

In 2001, Kelly *et al.* (2007) collected early-run Stuart and Weaver Creek sockeye salmon at up to five locations along the approach to and within the Fraser River. Samples of muscle, eggs, testes, and/or liver were obtained at each sampling site for each sockeye salmon population. The concentrations of PCBs, PCDDs, and PCDFs were measured in each tissue sample collected, with the results expressed as 2,3,7,8-TCDD toxic equivalents. The maximum concentration of 2,3,7,8-TCDD in salmon roe from these two stocks was 0.89 pg/g lipid, which is below the toxicity threshold of 3.0 pg/g lipid in eggs (Table 5.23). However Debruyn *et al.* (2004) measured concentrations of PCBs, PCDDs, and PCDFs, in conjunction with contaminant magnification factors, to model the levels of 2,3,7,8-TCDD toxic equivalents in the eggs of sockeye salmon migrating various distances in the Fraser River Basin. The results of this study indicated that the eggs of Adams River, Chilko River, and Stuart River sockeye salmon could have 3.4 to 6.9 pg/g lipid of 2,3,7,8-TCDD toxic equivalent by the time these stocks reached their natal streams (Table 5.23). These levels exceed the toxicity threshold of 3 pg/g for salmon eggs, which is associated with 30% mortality of fish eggs. These latter results suggest that PCBs, PCDDs, and PCDFs could be adversely affecting sockeye salmon reproduction in the stocks that migrate substantial distances to their spawning grounds.

5.5 Summary of the Evaluation of the Potential Effects of Contaminants of Concern on Fraser River Sockeye Salmon

A risk-based approach was used to evaluate the potential effects on sockeye salmon associated with exposure to aquatic contaminants in the Fraser River Basin. This approach involved:

- Refining the list of contaminants of concern;

- Estimating realistic exposure point concentrations;
- Identifying salmonid-specific toxicity thresholds; and,
- Calculating effect-based hazard quotients.

Three types of data were used to evaluate risks to sockeye salmon associated with exposure to the contaminants of concern, including surface-water chemistry, sediment chemistry, and fish-tissue chemistry data. The results of this assessment indicate that exposure to contaminated surface water and sediment or accumulation of contaminants in fish tissues pose potential hazards to sockeye salmon utilizing spawning, rearing, or migration habitats within the Fraser River Basin. More specifically, these results indicate numerous contaminants of concern occur in one or more habitats at concentrations sufficient to adversely affect the survival, growth, or reproduction of Fraser River sockeye salmon. These substances include TSS, six metals (aluminum, chromium, copper, iron, mercury and silver), and phenols (Table 5.18). However, the results of supplemental analysis of the available data indicate that water quality conditions in freshwater habitats, as indicated by the concentrations of the contaminants of concern included in the water quality index, are likely not the primary factor influencing sockeye salmon productivity in the study area. These supplemental results showed that water quality (as indicated by water quality index scores) does not exhibit strong temporal trends, as would be expected if the declines in sockeye salmon abundance over the past 20 years were primarily caused by water quality impairments. In addition, the productivity of sockeye salmon (as indicated by life-cycle Ricker residuals) was not correlated with water quality index scores in a way that would suggest that water quality conditions are playing a significant role in dictating sockeye salmon abundance. However, the observed results of the analysis and the limitations on the available data make it difficult to conclude that water quality is not a factor that has contributed to the declines of sockeye salmon in the study area since about 1990. Decreases in the productivity of sockeye salmon stocks that utilize freshwater habitats for extended period of time implicates freshwater conditions as a factor contributing to the declines of this species in the Fraser River Basin. Further evaluation is needed to elucidate the roles of suspended sediments in spawning habitats, sediment deposition in incubation habitats, and nutrients in rearing habitats on sockeye salmon productivity and abundance.

Exposure to contaminated sediments also has the potential to adversely affect sockeye salmon in the Fraser River basin. Although the available data were limited, the results of the risk assessment showed that iron and/or nickel occurred in sediments at concentrations sufficient to adversely affect exposed sockeye salmon in the Lower Fraser River Area of

Interest and in the South Thompson River Area of Interest. However, it is unlikely that contaminated sediments represents a significant factor in the decline of sockeye salmon over the past 20 years because interactions between sockeye salmon and contaminated sediments are likely to be minimal under most circumstances and the identified contaminants of concern are not highly bioaccumulative. More information is needed to fully evaluate the potential effects of contaminated sediments on Fraser River sockeye salmon, particularly for highly bioaccumulative substances and contaminants of emerging concern.

Accumulation of contaminants in fish tissues represents a potentially important factor influencing the status of sockeye salmon populations in the Fraser River Basin. The results of this evaluation showed that selenium and 2,3,7,8-TCDD toxic equivalents occurred in salmon eggs at concentrations sufficient to adversely affect sockeye salmon reproduction. In addition, 2,3,7,8-TCDD toxic equivalents are predicted to reach levels associated with egg mortality in up-river sockeye salmon stocks. While the magnitude and extent of such effects could not be determined with the available data, bioaccumulation-mediated effects could be important contributing factors to the decline of sockeye salmon in the Fraser River Basin over the past two decades. In particular, the interactive effects of elevated water temperatures, infection by various disease agents, and bioaccumulation of toxic substances warrants further evaluation (See Chapter 6 for further information).

Chapter 6 Evaluation of the Potential Effects of Endocrine Disrupting Chemicals and Contaminants of Emerging Concern on Fraser River Sockeye Salmon

6.0 Introduction

The procedures described in the preceding chapters of this report provide a systematic basis for identifying contaminants of concern in the Fraser River Basin and evaluating their potential effects on sockeye salmon in the Fraser River Basin. However, the data and information needed to conduct the screening-level (Chapter 4) and/or detailed (Chapter 5) assessments were not available for all of the contaminants of concern identified during this investigation. In many cases, data on the concentrations of aquatic contaminants in surface water, sediment, or fish tissues were not readily available. In other cases, toxicity screening values or toxicity reference values were not available for one or more media types. Accordingly, it was not possible to evaluate the risks posed to Fraser River sockeye salmon associated with exposure to many of the substances included in the Inventory of Aquatic Contaminants. The substances that fell into this category were considered to be uncertain contaminants of concern relative to their potential effects on sockeye salmon utilizing habitats within the Fraser River Basin. The contaminants that could not be evaluated or could not be fully evaluated (i.e., uncertain contaminants of concern) are considered to include:

- Microbiological variables (i.e., faecal coliforms, Enterococci);
- Organometals [i.e., methyl mercury (MeHg), organotins];
- Cyanides;
- Monoaromatic hydrocarbons (i.e., BTEX);
- Polycyclic aromatic hydrocarbons (i.e., individual parent PAHs, alkylated PAHs, total low molecular weight PAHs, total high molecular weight PAHs, total PAHs);
- Phenolic compounds (i.e., phenol, cresol);
- Chlorinated phenolic compounds (i.e., chlorophenols, chloroguaiacols, chlorocatechols);
- Polychlorinated biphenyls (total 2,3,7,8-TCDD toxic equivalents, total PCBs as a sum of congeners, sum of homologs, or sum of Aroclors);

- Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (total 2,3,7,8-TCDD toxic equivalents);
- Resin acids (e.g., abietic acid);
- Fatty acids (e.g., palmitic acid);
- Legacy organochlorine pesticides (i.e., aldrin, chlordane, DDTs, dieldrin, endrin, endosulfan, hexachlorobenzene, heptachlor, heptachlor epoxide, lindane, methoxychlor, nonachlor, toxaphene);
- Petroleum hydrocarbons (i.e., oil and grease, diesel range organics, alcanes, lube oil);
- In-use herbicides (i.e., atrazine, 2,4-D, 2,4-D amine, ethalfluralin, glyphosate, mineral oil, paraquat, pendimethalin, picloram, simazine, triallate, triclopyr, trifluralin);
- In-use insecticides (i.e., azinphosmethyl, *Bacillis thuringiensis*, chlorpyrifos, diazinon, endosulfan, malathion, mineral oil, parathion);
- In-use fungicides (i.e., captan, chlorothalonil, dazomet, mancozeb, metam, metiram, lime sulphur);
- Other pesticides (i.e., formaldehyde, formalin);
- Wood preservatives [i.e., creosote, chromated copper arsenate (CCA), ammoniacal copper zinc arsenate (ACZA), pentachlorophenol];
- Anti-sapstain chemicals [i.e., didecyldimethyl ammonium chloride (DDAC), 3-iodo-2propynyl butyl carbamate (IPBC)];
- Surfactants [i.e., alkylphenol ethoxylates (APEOs), fluorosurfactants];
- Fire retardants [i.e., PBDEs (209 congeners and 10 homolog groups), perfluorooctanesulfonic acid (PFOS), perfluorooctanic acid (PFOA), diammonium sulphate, diammonium phosphate, ammonium sulphate, ammonium phosphate, ammonium polyphosphate];
- Plastics and polymer related chemicals (i.e., phthalate esters, bisphenol A);
- Steroids, hormones and hormone-mimicking substances (e.g., estradiol, estrone, 17α-ethinylestradiol, plant sterols, phytoestrogen metabolites);
- Pharmaceuticals (i.e., antibiotics, antihypertensives, anticonvulsants, antidepressants, anti-acid reflux, anti-inflammatory, antifungal, and analgesic compounds);
- Personal care products (i.e., fragrances, insect repellants, detergents, antimicrobials, fungicides, surfactants, and stimulants);

- Disinfectants and disinfectant byproducts (i.e., bromine, chlorine, and iodine); and,
- Nanoparticles.

As it was not possible to conduct a quantitative evaluation of the effects on Fraser River sockeye salmon associated with exposure to uncertain contaminants of concern, an alternate approach was adopted to determine if these substances could be causing or substantially contributing to the decline of Fraser River sockeye salmon. This approach involved conducting qualitative evaluations of the potential effects of endocrine disrupting compounds and contaminants of emerging concern on sockeye salmon. This chapter described the methods that were used in the qualitative evaluations and presents the results of these analyses.

6.1 Potential Effects of Endocrine-Disrupting Chemicals on Sockeye Salmon

There is a substantial body of scientific evidence demonstrating that many of the substances released to the environment due to human activities have the potential to modulate or disrupt the endocrine system of aquatic organisms, wildlife, and humans. The term, endocrine-disrupting chemicals, has been used to describe the chemicals that interfere with the production, release, metabolism, binding, action, or elimination of the natural hormones that are responsible for the maintenance of homeostasis (i.e., metabolic equilibrium), reproduction, development, and/or behaviour (USEPA 2010a). This section provides background information on the endocrine system, identifies potential endocrine disrupting compounds in the Fraser River Basin, evaluates the potential effects of endocrine disrupting compounds in fish, describes potential exposure of sockeye salmon to endocrine disrupting compounds, and assesses potential risks to sockeye associated with exposure to endocrine disrupting compounds in the Fraser River Basin.

6.1.1 Role of the Endocrine System in Fish

The endocrine system is a complex internal chemical signalling system comprised of glands, organs, and tissues that secrete hormones into the bloodstream (MPCA 2008). Hormones are chemical messengers that regulate many bodily processes in fish and other vertebrates, including maintenance of homeostatis (i.e., internal equilibrium), growth, development, metabolic processes, sexual reproduction, and behaviour (USEPA 2010a). Hormones can be characterized into several classes of compounds, including glycoproteins, polypeptides, peptides, steroids, modified amino acids, catecholamines, prostoglandins, and retinoic acid. These substances are transported in the blood at low concentrations and bind to specific sites on cell membranes (i.e., for non-steroidal hormones) or the nucleus of the cells (i.e., for steroidal hormones) of the target tissues and organs. These binding sites, termed receptors, are located throughout the body, are often located far from the gland that produced the hormone. Some of the major endocrine glands in fish include the hypothalamus, pituitary gland, thyroid gland, parathyroid gland, pancreas, adrenal gland, ovary, and testes. Some of the target organs and tissues under endocrine control include mammary glands, bone, muscle, the nervous system, and reproductive organs (Crisp *et al.* 1998). An overview of selected major endocrine glands and their target tissues is provided in Figure 6.1 (Tarrant *et al.* 2005).

6.1.2 Identification of Endocrine-Disrupting Chemicals in the Fraser River Basin

An environmental endocrine disruptor can be described as an exogenous substance or mixture of substances that interferes with the synthesis, secretion, transport, binding, action, or elimination of natural hormones and causes an adverse effect on the maintenance of homeostasis, development, reproduction, or behaviour (Crisp *et al.* 1998). An endocrine disruptor is considered to be any natural substance, synthetic chemical, or chemical mixture that mimics, enhances, or inhibits the action of hormones.

Endocrine-disrupting chemicals are not a discrete class of chemicals. Rather, endocrine disrupting compounds include a wide variety of substances that are released into the environment from natural and anthropogenic sources. While there is no universally-accepted system for identifying or classifying endocrine disrupting compounds, these contaminants can be classified into a number of general categories based on their origin or chemical characteristics, including pharmaceuticals and personal care products, industrial chemicals, pesticides, inorganic and organometallic compounds, and biogenic compounds (MPCA 2008). Each of these general categories of endocrine disrupting compounds are briefly described below. In addition, the contaminants in the Fraser River Basin that are known or suspected to be endocrine disrupting compounds were identified using the priority list developed for the European Commission (BKH Consulting Engineers 2000).

Pharmaceutical and Personal Care Products - This category of endocrine disrupting compounds includes synthetic hormones, over-the-counter medications, prescription drugs, and ingredients found in cosmetics, toiletries, detergents, and cleaning products. Natural steroid hormones (such as estrone, 17ß-estradiol, and estriol) and synthetic hormones [such as the synthetic estrogens (e.g., 17 -ethinylestradiol) and progestins (e.g., norgestrel) found in birth control pills] are likely to occur in wastewaters from sewage treatment plants located throughout the study area. While little research has been conducted to evaluate the endocrine disrupting effects of the pharmaceuticals that are typically found in sewage treatment plant effluents, the antidepressant fluoxetine has been shown to affect reproduction in aquatic organisms (Fong 1998). Among the personal care products commonly found in municipal wastewater treatment plant effluents, phthalates and synthetic musks (e.g., galaxolide) can exhibit endocrine disruption activity (MPCA 2008).

Industrial Chemicals - There are a wide range of industrial chemicals that are known or suspected endocrine disrupting compounds, including PCBs, PBDEs, PCDDs/PCDFs, plasticizers, alkylphenols, naphthols and naphthalenes, siloxanes, and PAHs (MPCA 2008). Many of these substances have been identified as contaminants of concern in the Fraser River Basin, including PCBs, PBDEs, PCDDs/PCDFs, phthalate esters, bisphenol A, APEOs, ethoxylates, and PAHs. Other known or suspected endocrine disrupting compounds originating from industrial sources in the study area include phenols, dichlorophenols, and surfactants (e.g., nonylphenols).

Pesticides - A number of pesticides have been identified as known or suspected endocrine disrupting compounds, including certain organochlorine pesticides, organophosphate pesticides, pyrethroids, herbicides, fungicides, and carbamates (MPCA 2008). Of the organochlorine pesticides of concern in the Fraser River Basin, the following are known or suspected endocrine disrupting compounds: chlordane, DDTs, dieldrin, endosulfan, and hexachlorobenzene. While the use of these substances in Canada has been eliminated or greatly reduced, they are still transported to the Fraser River via long-range atmospheric transport, still present in soils and sediments due to past use in the basin, and may, to a limited extent, still be used in the study area (i.e., stock-piled supplies).

The in-use insecticides that are currently used in substantial quantities in the Fraser River Basin, known or suspected to be endocrine disrupting compounds, include: chlorpyrifos, diazinon, malathion, and parathion. No pyrethroids were identified as uncertain contaminants of concern in the Fraser River Basin; however, it is likely that bifenthrin and/or other pyrethroid pesticides have been released to aquatic ecosystems, particularly in the Lower Fraser River Area of Interest.

In-use herbicides in the Fraser River Basin are known to include atrazine, 2,4-D, ethalfluralin, glyphosate, mineral oil, paraquat, pendimethalin, simazine, triallate, and trifluralin. Of these, three are known or suspected to be endocrine disrupting compounds, including atrazine, 2,4-D, and simazine. Of the seven high use fungicides identified in the Inventory of Aquatic Contaminants, only metam has been identified as an endocrine disrupting compound.

Inorganic and Organometallic Compounds - Many metals and organometallic complexes (i.e., compounds that include a carbon-metal bond) have been identified as suspected endocrine disrupting compounds. Of the metals that were identified in the Inventory of Aquatic Contaminants, none were identified by the European Commission as likely endocrine disrupting compounds. However, MeHg and several organotin complexes (i.e., tributyltin, triphenyltin, tetrabutyltin, tri-n-propyltin) have been explicitly identified as endocrine disrupting compounds in wildlife.

Biogenic Compounds - Several estrogen-like compounds occur naturally in the environment. These chemicals, which are derived from plants, are known as phytoestrogens (such as genistein, naringenin, and coumestrol; Gillesby and Zacharewski 1998). Such phytosterols and phytoestrogen metabolites have been identified as contaminants in the Fraser River Basin because their concentrations in surface waters are likely to be increased by anthropogenic activities (primarily those associated with manufacturing of wood- and fibre-based products).

6.1.3 Sources and Releases of Endocrine-Disrupting Chemicals in the Fraser River Basin

There are numerous sources of endocrine disrupting compounds in the Fraser River Basin. Information compiled to develop the Inventory of Aquatic Contaminants was used to identify the likely sources of endocrine disrupting compounds in the study area. This evaluation was conducted for each of the four groups of endocrine disrupting compounds identified in the previous section of this report, including pharmaceuticals and personal care products s, industrial chemicals, pesticides, inorganic and organometallic compounds, and biogenic compounds.

Pharmaceuticals and Personal Care Products - The primary sources of these products in the study area are municipal wastewater treatment plants. These facilities can release endocrine disrupting compounds into aquatic ecosystems within the watershed by direct discharges to surface water, through disposal of contaminated sludge in landfills (and subsequent leaching of contaminants to surface water), and through placement of biosolids in upland areas (and subsequent contamination of surface water via runoff from application sites). Of these, direct discharges to surface water are likely to result in the highest concentrations of hormones, synthetic hormones, and other endocrine disrupting compounds in surface water. Certain pharmaceuticals and personal care products could also be released from the various facilities that manufacture detergents, fabric softeners, or other personal care products that contain nonylphenols or other surfactants.

Industrial Chemicals - There are many ongoing and historic sources of industrial chemicals in the Fraser River Basin. For chlorinated organic compounds (such as PCDDs/PCDFs, chlorophenols, and other substances), pulp and paper mills using chlorine bleaching were primary sources. However, process changes implemented in the early 1990's reduced or eliminated the use of chlorine bleaching. This resulted in substantial reductions in the production of absorbable organic halides (AOX) during the pulp and paper-making process (Clapp *et al.* 1996). Nevertheless, it is likely that sediments in the vicinity of pulp and paper mill effluent discharges and, to a less extent, ongoing releases from these facilities, continue to be ongoing sources of chlorinated organic compounds in the watershed (Figure 3.1). However, wood preservation facilities (Figure 3.3) and/or contaminated sites (Figure 3.10) may now represent more important sources of chlorinated phenolic compounds and, possibly, PCDDs/PCDFs. Atmospheric transport also represents a potential source of chlorinated organic compounds in the study area. Phenols and dichlorophenols are likely to be released primarily from pulp and paper mills, wood preservation facilities, and municipal wastewater treatment plants in the Fraser River Basin. Chlorinated organic compounds are released to the aquatic environment through resuspension of contaminated sediments, bioaccumulation (and associated food web transfer) of sediment-associated chemicals, direct effluent discharges, and deposition of atmospheric contaminants.

The sources of PAHs in the Fraser River Basin include virtually all of the anthropogenic activities that are conducted in the watershed. Of these, discharges from municipal wastewater treatment plants, runoff from wood preservation facilities using creosote, runoff from urban areas and contaminated sites, and petroleum spills are probably the most important sources of petrogenic PAHs (i.e., oil-derived PAHs; Sekala *et al.* 1995; ENKON Environmental Ltd. 1999; Shaw *et al.* 2009). In contrast, pyrogenic PAHs in the study area are principally derived from forest fires and other combustion sources (e.g., internal combustion engines, incineration of wood wastes, and home wood heating; Johannessen and Ross 2002). *In situ* sediments also represent potential sources of PAHs in areas that have received substantial inputs in the past. As a class, PAHs are typically released to aquatic ecosystems via resuspension of contaminated sediments, direct effluent discharges from various sources, runoff from urban areas and contaminated sites, and accidental spills.

Polychlorinated biphenyls (PCBs) are a group of 209 individual chemicals that were used in various applications before being banned in Canada in 1977 and in the United States in 1979. PCBs were primarily used in transformers, capacitors, and heat transfer systems (60%), as plasticizers (25%), in hydraulic fluids (10%), and other uses (5%; EIP Associated 1997). In the past, the primary sources of PCBs in the Fraser River Basin may have included electric power generation facilities, pulp and paper mills, scrap metal recycling facilities, paper recycling operations, automobile salvage facilities, and various repair facilities. Current sources of these contaminants likely include *in situ* sediments, runoff from contaminated sites, wastewater treatment plant discharges, landfill leachates, and atmospheric deposition.

Polybrominated diphenyl ethers (PBDEs) are a group of 209 individual chemicals (i.e., congeners) that have been used as fire retardants in a variety of consumer products. While PBDEs are not manufactured in Canada, they are imported in such products as computer housings, household appliances, polyurethane foams used in household furniture, mattresses, carpets, and car seats, a variety of electrical and electronic components, paint, textiles, building materials, and plastics (Environment Canada 2004). About 90% of the PBDEs produced worldwide is used in polyurethane foams. According to Environment Canada (2006), PBDEs are released to the environment via municipal or industrial wastewater discharges, landfill leachates, and municipal incineration facilities. Of these, municipal wastewater effluents appear to be one of the more important sources of PCDEs (Johannessen *et al.* 2008). In addition, PBDEs are released in association with in-service use of products containing polyurethane foam. Long-range atmospheric transport contributes to loadings of PBDEs to the Canadian environment in general and the Fraser River Basin in particular (Environment Canada 2006; Noël *et al.* 2009).

Bisphenol A and phthalate esters are industrial chemicals that are used in the plastics manufacturing industry. Bisphenol A is one of the chemicals used to produce polycarbonate plastics, food can linings, electrical sheathings, polyvinyl chloride, and adhesives. The term, phthalates, describes a group of chemicals that are used as plasticizers (i.e., to make plastic soft), as solvents in perfumes, hairsprays, and insect repellants, and in floorings, paints, and adhesives (MPCA 2008). These substances can be released to the environment during the production of consumer products, as these products are used, or as such products age and weather. The principal sources of bisphenol A and phthalate esters are municipal wastewater treatment plant, landfills, contaminated sites, and other facilities that utilize products containing these chemicals.

Alkylphenol ethoxylates (APEOs) are a group of non-ionic surfactants that have numerous agricultural, industrial, and household applications (MPCA 2008). These substances are used in the production of detergents, paints, fragrances, spermicides, and certain pesticide formulations (MPCA 2008). Nonylphenol and octylphenol are breakdown products of APEOs. The principal sources of APEOs in the Fraser River Basin are likely to include municipal wastewater treatment plant effluents, textile plant effluents, and runoff or effluent from industrial sites (Johannessen and Ross 2002). Landfills and contaminated sites are likely to be additional sources of these contaminants.

Pesticides - A wide variety of legacy and in-use pesticides were identified as uncertain contaminants of concern in the Fraser River Basin. Legacy organochlorine pesticides are derived from multiple sources, with long-range atmospheric transport and contaminated soils/sediments likely being the most important. In-use pesticides are released to the environment from wood preservation facilities, agricultural operations, and forest management activities. Land fills and wastewater treatment plants can also represent significant sources of these contaminants.

Inorganic and Organometallic Compounds - Methyl mercury and organotins are the principal inorganic and organometallic contaminants in the Fraser River Basin that have been demonstrated or suspected to act as endocrine disruptors. The principal sources of mercury in the study area include *in situ* sediments contaminated in the past, active and abandoned mines, industrial facilities, municipal wastewater treatment plants, and atmospheric deposition (Rudd 1995). Inorganic mercury can be converted to MeHg in lake, riverine, or wetland sediments. The principal source of organotins to the aquatic environment is through the application and weathering of antifouling paints on ocean-going vessels (Maguire 1996). Therefore, sediments in the vicinity of bulk storage and shipping facilities in the Lower Fraser River represent the main sources of organotins within the study area.

Biogenic Compounds - Phytosterols and phytoestrogens are naturally occurring substances that can act as endocrine disruptors when released into the environment.

Pulp and paper mills, saw mills, and other wood processing facilities are likely to represent the principal anthropogenic sources of these contaminants in the Fraser River Basin.

6.1.4 Pathways for Exposure of Fraser River Sockeye Salmon to Endocrine-Disrupting Chemicals

Sockeye salmon utilizing habitats in the Fraser River Basin can be exposed to endocrine disrupting compounds through several pathways. First, direct contact with surface water is likely to represent an important exposure route for the endocrine disrupting compounds that tend to partition into water. Fish have been shown to accumulate nonylphenols, chlorinated phenols, and 17 -ethinylestradiol through direct exposure to surface water (Asplund *et al.* 1999; Larsson *et al.* 1999; Lye *et al.* 1999). Certain pesticides (e.g., organophosphates) and low molecular weight PAHs have octanol-water partition coefficients (log K_{ow}s) of < 4.0 and, hence, can partition into water. Therefore, surface water represents a relevant exposure route to these chemicals for sockeye salmon.

Many of the endocrine disrupting compounds identified in the study area (see Section 6.1.2) have log K_{ow}s that exceed four and, hence, are considered to be hydrophobic. As a result, endocrine disrupting compounds such as PCBs, PCDDs/PCDFs, PBDEs, high molecular weight PAHs, organochlorine pesticides, phthalate esters, and organometallic compounds tend to partition into particulate matter upon release into aquatic ecosystems. Sockeye salmon can be exposed to these classes of endocrine disrupting compounds during incubation (i.e., if contaminated sediments are present in incubation substrates or contaminated groundwater is discharged through such habitats). In addition, sockeye salmon can be exposed to these substances when particulate matter is released in association with effluent discharges from an upland source (e.g., municipal or industrial wastewater) or when contaminated sediments are resuspended in the water column. Exposure to contaminated suspended sediments is most likely to occur during smolt outmigration and/or upstream migration of adult sockeye salmon (i.e., direct releases of endocrine disrupting compounds to nursery lakes were not identified in this investigation).

Hydrophobic endocrine disrupting compounds also tend to be lipophillic and, hence, tend to accumulate in the tissues of aquatic organisms. There is a substantial body of literature demonstrating that PCBs, PCDDs/PCDFs, PBDEs, organochloride pesticides, and mercury bioaccumulate and/or biomagnify in aquatic food webs. While sockeye salmon could be exposed to such endocrine disrupting compounds during rearing in nursery lakes, it is more likely that such exposures would occur in rearing habitats in the Lower Fraser

River. Hence, this route of exposure is likely to be important for those stocks that spend a considerable period of time rearing in habitats located in the lower Fraser River (e.g., Harrison River stocks).

6.1.5 Potential Effects of Endocrine-Disrupting Chemicals on Fish

Exposure to endocrine disrupting compounds has the potential to cause a variety of adverse effects in fish. Based on a review of the available literature, Crisp *et al.* (1998) identified the following types of effects in vertebrates exposed to endocrine disrupting compounds:

- Abnormal thyroid function;
- Decreased fertility;
- Decreased hatching success;
- Demasculinization and feminization;
- Defeminization and masculinization; and,
- Alteration of immune function.

The following sections of this document provide brief summaries of the types of effects that have been observed in salmonids or other fish species exposed to the endocrine disrupting compounds that are likely to occur in aquatic habitats within the study area.

Pharmaceuticals and Personal Care Products - Hormones, synthetic hormones, nonylphenols, and other surfactants were identified as the principal pharmaceuticals and personal care products that have been released into the Fraser River and/or its tributaries that are known or suspected to be endocrine disruptors. Based on the results of controlled laboratory studies, it is apparent that exposure to these classes of endocrine disrupting compounds can cause a variety of adverse effects on fish, including salmonids.

Natural Hormones - There are a number of natural hormones that are commonly released to surface waters in discharges from municipal wastewater treatment plants. To evaluate the effects of such hormones on fish, McCormick *et al.* (2005) administered four doses (2 µg/g each) of 17ß-estradiol, the predominant sex hormone in women, to Atlantic salmon (*Salmo salar*) parr during the course of the experiment. After 14 days, exposed and control fish were placed in seawater to assess salinity tolerance. The results of this study indicated that parr-smolt transformation and salinity tolerance were significantly compromised in the fish that were administered 17ß-estradiol, as evidenced by increased plasma sodium and calcium levels. Gill sodium-potassium ATPase activity was reduced by about 20% compared to the control treatment, but the difference was not statistically significant.

Synthetic Hormones - Exposure of fish to synthetic hormones, such as 17α-ethinylestradiol (a common component of oral contraceptives), can also cause adverse effects on fish. For example, Scholz and Gutzeit (2000) reported that exposure of newly hatched male Japanese medaka (*Oryzias latipes*) to 100 ng/L of 17α-ethinylestradiol for two months resulted in sex reversal of 100% of the fish (i.e., all male fish developed ovaries). Reduced egg production and gonado-somatic index were observed in female medaka exposed to 10 or 100 ng/L of this substance for 60-d (Scholz and Gutzeit 2000). Similar results were observed in an 85- to 110-d test with this species, with 91% of the fish in the 100 ng/L exposure group identified as female (Metcalfe *et al.* 2001). Ovotestis was observed in males exposed to 1 ng/L or 10 ng/L of this substance. In a life-cycle (305-d) test with fathead minnows (*Pimephales promelas*), Lange *et al.* (2001) observed significant changes in sex ratios of fish exposed to concentrations of 17α-ethinylestradiol as low as 4.0 ng/L. A no observed effect level of 1.0 ng/L was reported based on the results of this study. In three-spined sticklebacks (*Gasterosteus aculeatus*), chronic exposure to 100 ng/L of 17α-ethinylestradiol reduced the survival of males, increased growth in fry, juveniles, and sub-adults, and increased the frequency of risky foraging behaviour (Bell 2004). Insufficient data were obtained to establish toxicity thresholds of synthetic hormones for salmonid fishes; however, a level of 1.0 ng/L might be generally protective of fish against estrogenic effects associated with exposure to 17 -ethinylestradiol.

Alkylphenols and Alkylphenol polyethoxylates - Alkylphenols and alkylphenol polyethoxylates have been shown to have adverse effects on fish in laboratory studies. For example, McCormick *et al.* (2005) injected Atlantic salmon (*Salmo salar*) parr with doses of 4-nonylphenol ranging from 0.5 to 150 μg/g, in each case repeating the treatment on days 4, 8, and 11. Exposed and control fish were transferred to seawater on day 14 of the experiment to assess salinity tolerance. The results of this study indicated that parr-smolt transformation and salinity tolerance were significantly compromised in the fish that were administered the highest dose of 4-nonylphenol, as evidenced by increased plasma sodium and calcium levels. Gill sodium-potassium ATPase activity was reduced by about 30% compared to the control treatment, but the difference was not statistically significant.

In recent years, vitellogenin induction has been used as an indicator of exposure to endocrine disrupting compounds that have estrogenic effects in male fish. Data from various studies have shown that exposure to 17β-estradiol, alkylphenols (such as 4-nonylphenol, 4-tert-butylphenol, 4-tert-octylphenol), and alkylphenol polyethoxylates (such as nonylphenol diethoxylate,) induces vitellogen production in male fish (Jobling and Tyler 2003a; 2003b; Pait and Nelson 2002). Data from laboratory studies indicate that male sheepshead minnows (*Cyprinodon variegatus*) exposed to concentrations of 4-nonylphenol as low as 5.4 µg/L had significant increases in plasma vitellogenin levels (Hemmer *et al.* 2001). The relative potencies of selected estrogenic compounds are presented in Table 6.1 (Jobling and Sumpter 1993). The results of field studies conducted in the U.K. have demonstrated that vitellogenin induction is correlated with an elevated incidence of intersex (i.e., the simultaneous presence of both male and female gonadal characteristics in fish) and reductions in gonad size (i.e., as indicated by reduced gonadosomatic index scores; which is the ratio of gonad weight to body weight), both of which can reduce reproductive success (Jobling *et al.* 1998).

The results of laboratory studies provide a basis for identifying effective concentrations of alkylphenols in water. In Japanese medaka, 90-d exposure of newly hatched males to 50 or 100 µg/L of 4-nonylphenol resulted in increased frequency of intersex (50% and 86% of the fish developed ovotestis; Gray and Metcalfe 1997). In a life-cycle study on this species, a significantly increased incidence of intersex (as indicated by the presence of ovotestis) was observed in the progeny of fish exposed to 4-nonylphenol concentrations as low as 8.2 µg/L (Yokata *et al.* 2001). Decreased fertility was also observed in adults exposed to 17.6 µg/L of 4-nonylphenol. Insufficient toxicity data were located to establish toxicity thresholds for alkylphenols or APEOs that could be applied to assess effects on Fraser River sockeye salmon associated with exposure to this class of contaminant.

Industrial Chemicals - The industrial chemicals in the Fraser River Basin that have been shown or are suspected of having endocrine disruption effects include APEOs, bisphenol A, phthalates, chlorophenols, PAHs, PCBs, PCDDs/PCDFs, and PBDEs (and PBBs). The estrogenic effects of APEOs were discussed in the above section on pharmaceuticals and personal care products.

<u>Bisphenol A</u> - The results of laboratory studies show that exposure to bisphenol A causes estrogenic effects in salmonids and other fish species. In fathead minnows, exposure to 160 µg/L of bisphenol A for $\geq$71 days results in elevated plasma vitellogenin levels in males (Sohoni *et al.* 2001). In the same study, egg production

and gonadosomatic index scores were significantly reduced in fish exposed to 640 µg/L for 164 days. For salmonids, Lindholst *et al.* (2000) reported that short-term exposure (i.e., 6-d) of rainbow trout (*Onchorynchus mykiss*) to bisphenol A concentrations ranging from 10 to 500 µg/L increased plasma vitellogen levels in a dose-dependent manner. However, vitellogenin levels remained significantly elevated at day 12 of the exposure period only in the 500 µg/L treatment. Exposure of rainbow trout to 228 µg/L of bisphenol A for two days induced significant vitellogenic production (Sumpter and Jobling 1995). Insufficient toxicity data were located to establish a toxicity thresholds for bisphenol A that could be applied to assess effects on Fraser River sockeye salmon associated with exposure to this class of contaminant.

<u>Phthalate Esters</u> - Although the available data are limited, it appears that certain phthalate esters are estrogenic in fish (Pait and Nelson 2002). For example, Jobling *et al.* (1995) reported that bis(2-ethylhexyl)phthalate (BEHP), butylbenzyl phthalate (BBP), and di-n-butyl phthalate (DBP) inhibited the binding of 17β-estradiol in rainbow trout livers, with DBP exhibiting the highest affinity for estrogen-receptors. In a related study, Christiansen *et al.* (1998) injected immature rainbow trout with BBP or DBP. Plasma vitellogenic levels increased by a factor of three in the BBP-treatment group, but did not increase in the DBP-treatment group. Together, these data suggest that BEHP and BBP likely cause estrogenic effects, while DBP may have antiestrogenic potential (i.e., through competitive binding at the estrogen-receptor sites). Insufficient toxicity data were located to establish toxicity thresholds for phthalate esters that could be applied to assess effects on Fraser River sockeye salmon associated with exposure to this class of contaminant.

<u>Polycyclic aromatic hydrocarbons</u> - Exposure to PAHs, petroleum, and/or oil have been demonstrated to cause a variety of adverse effects in fish (Tuvikene 1995). These effects include reduced survival, immune suppression, increased incidence of liver lesions, increased liver-somatic index scores, haematological effects, and reproductive impairment (Tuvikene 1995).

In contrast to many other industrial chemicals, PAHs appear to elicit anti-estrogenic effects in many fish species. Although little information was obtained on the effects of PAHs on male fish, such effects have been demonstrated in female fish, as evidenced by reduced production of estrogens and vitellogenin (Pait and Nelson 2002). For example, Anderson *et al.* (1996) reported that rainbow trout injected with 17β-estradiol and β-napthoflavone, a PAH, had depressed vitotellogenin synthesis compared with fish injected with 17β-estradiol alone. These effects may be due to competitive binding of the PAH with the estrogen receptor. In Atlantic croakers (*Micropogonias undulatus*), dietary exposure to benzo(a)pyrene (BAP; 0.4 mg/70g fish/day) for 30-d during seasonal maturation significantly impaired ovarian development compared to the control treatment (Thomas 1988). The associated gonadosomatic index scores for the BAP group were about 66% of those for the control group. Fathead minnows treated with anthracene had lower reproductive output (as measured by mean number of eggs laid) compared to control fish (Tilghman Hall and Oris 1991). Collectively, these results demonstrate the potential for endocrine disruption in fish exposed to PAHs, but are insufficient to support selection of toxicity thresholds for PAHs in water, sediment, or fish tissues that are directly relevant for evaluating endocrine disruption effects on Fraser River sockeye salmon.

<u>Polychlorinated biphenyls (PCBs)</u> - Due to their chemical characteristics, PCBs tend to be highly lipophillic. As such, they tend to accumulate to biological tissues when released into the environment. Accumulation of PCBs in fish tissues can result in reproductive and/or developmental effects. For example, Bengtsson (1980) reported that minnows, *Phoxinus phoxinus*, that accumulated 15 mg/kg WW of Clophen A50 experienced delayed and reduced spawning. In addition to the effects on spawning, reduced egg hatchability was also observed in minnows that accumulated 170 mg/kg WW of PCBs (as Aroclor 1254) in their tissues. Similarly, fathead minnows, *Pimephales promelas*, that accumulated 13.7 mg/kg WW in their tissues were observed to spawn less frequently and produce fewer eggs than the control group (USACE 1988). Orn *et al.* (1998) reported that zebrafish that accumulated 2.7 mg/kg WW of total PCBs in their tissues had impaired reproduction relative to control fish (i.e., ovary weight was decreased by about 80%). In salmonids, increased sensitivity to toxic chemicals and decreased growth were observed in trout (*Salvelinus sp.*) and/or charr (*Salmo sp.*) that accumulated 0.28 to 1.1 mg/kg WW of PCBs in their tissues (Bills *et al.* 1981; Bills and Marking 1977; Fisher *et al.* 1994). Matta *et al.* (1998) reported that rainbow trout accumulating 2.1 mg/kg WW of Aroclor 1260 in their tissues had increased incidence of abnormal gonads compared to control fish.

More recently, Meador *et al.* (2002) conducted a review of the scientific literature to establish a residue effect threshold for salmonid fishes. The results of this investigation indicated that a total of 15 studies met the evaluation criteria established by the authors. The lowest observed effect concentration of PCBs ranged from 0.11 to 250 mg/kg WW in these studies. The tissue concentration that corresponded to the 10^{th} percentile of the lowest observed effect concentrations, 0.14 mg/kg WW (2.4 mg/kg lipid), was selected as the residue effect threshold for salmonid fishes. The median of the lowest observed effect concentrations from these studies was 1.1 mg/kg WW or 12.1 mg/kg lipid. The endpoints that were measured in these studies included growth, sensitivity to toxic chemicals, enzyme activity, thyroid activity, immune system abnormalities, and others.

The results of field studies are also relevant for identifying toxicity thresholds for PCBs in freshwater fish. For example, Adams *et al.* (1989; 1990; 1992) reported that redbreast sunfish (*Lepomis auritus*) exposed to elevated levels of PCBs and mercury in the field had reduced fecundity and lower growth than fish exposed to lower levels of these contaminants. More specifically, the mean length and mean weight of sunfish with 0.4 mg/kg WW of PCBs in their tissues (whole body) were 11% and 29% lower, respectively, than sunfish with 0.3 mg/kg WW in their tissues.

Similarly, field studies conducted in the vicinity of the Bloomington PCB site confirm that accumulation of PCBs in their tissues can adversely affect freshwater fish. More specifically, Henshel *et al.* (2006a) reported that the age structure and growth of creek chub (*Semotilus atromaculatus*) exposed to PCBs in Clear Creek and Conard's Branch of Richland Creek were altered relative to fish from a reference site (Little Indian Creek). Weight at Age IV of male creek chub that accumulated 2.1 to 19.2 mg/kg WW (whole body) was significantly lower than the weight of fish of similar age with 0.01 mg/kg WW of total PCBs in their tissues. Importantly, Age IV and older female creek chub were virtually absent from the population at the PCB-contaminated sites (i.e., whole body tissue concentrations of ≥2.1 mg/kg WW; Henshel *et al.* 2006a). Henshel *et al.* (2006b) reported that the fish from the PCB-contaminated sites also had higher incidences of external (2.3 to 5.8%) and internal (1.4 to 7.3%) abnormalities relative to fish from the control site (0% internal and external abnormalities). Furthermore, Sparks *et al.* (2005) reported adverse reproductive effects, such as ovarian atresia, at whole body tPCB concentrations as low as 0.56 mg/kg WW. Based on these data, it is apparent that ecologically-relevant effects (i.e., at the whole organism level) occur in fish species at whole body PCB concentrations of ≥ 0.4 mg/kg WW or higher (Adams *et al.* 1989; 1990; 1992). None of the samples of tissue from Fraser River sockeye salmon had total PCB concentrations above this toxicity threshold.

<u>Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDDs/PCDFs)</u> - A number of dose-response studies have been conducted on salmonid fish which provide insight into the toxicity of tissue-associated PCDD and PCDF congeners [e.g., 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (T_4CDD) and 2,3,7,8-

tetrachlorodibenzofurans (T_4CDF)]. Mehrle *et al.* (1988) exposed rainbow trout fry to T_4CDD and T_4CDF in water for a period of 28 days, and observed fish through a 28-day depuration period. After 56 days, significant mortality (45%) was observed in trout with maximum tissue residue levels of 0.99 μg $T_4CDD \cdot kg^{-1}$ BW. Twenty-two percent mortality was observed after 56 days in fish that had a maximum tissue residue level of 11.9 μg $T_4CDF \cdot kg^{-1}$ BW (or 1.19 μg $TEQ \cdot kg^{-1}$ BW) in their tissues (Mehrle *et al.* 1988).

The results of egg injection studies appear to confirm the results of investigations in which test organisms were exposed to T_4CDD in the water column. Walker *et al.* (1992) reported that the survival of rainbow trout alevins was greatly reduced (i.e., by > 60%) when eggs were injected with a dose of 0.437 μg $T_4CDD \cdot kg^{-1}$ egg. A median lethal dose (LD_{50}) of 0.421 $\mu g \cdot kg^{-1}$ egg was reported in this study. Similarly, significant mortality during the hatching to swim-up stage was observed when rainbow trout eggs were injected with a dose of 8.0 μg $T_4CDF \cdot kg^{-1}$ egg (or 0.8 μg $TEQ \cdot kg^{-1}$ egg; Walker and Peterson 1991). Median lethal doses (LD_{50}) of other PCDD and PCDF congeners ranged from 0.099 μg $TEQ \cdot kg^{-1}$ egg for 1,2,3,4,7,8-H_6CDF to 0.367 $\mu g \cdot TEQ \cdot kg^{-1}$ egg for 1,2,3,7,8-P_5CDF in this study.

Single dose exposures (via intraperitoneal injection) of T_4CDD have also resulted in adverse biological effects in juvenile rainbow trout. For example, Spitsbergen *et al.* (1988) reported that growth rates were significantly reduced up to 80 days following administration of a single dose of 5 $\mu g \cdot kg^{-1}$ BW of T_4CDD to rainbow trout fingerlings. Extreme mortality (90%) was observed following administration of 25 $\mu g \cdot kg^{-1}$ BW in this study. While mortality generally follows exposure to high doses of T_4CDD, more subtle effects have been observed at lower dosage rates. In juvenile rainbow trout, administration of doses as low as 0.03 $\mu g \cdot kg^{-1}$ BW resulted in the accumulation of erythrocytes in the spleen after 21 or 42 days (van der Weiden *et al.* 1992). Haemorrhages in the skin and fins of these fish were evident at a higher dosage rate (0.3 $\mu g \cdot kg^{-1}$ BW); significant mortality (20%) was only observed at ten times this exposure level (3.06 $\mu g \cdot kg^{-1}$ BW; van der Weiden *et al.* 1992).

The available data indicate that lake trout are one of the most sensitive species of freshwater fish. Walker *et al.* (1992) injected lake trout eggs with doses of T_4CDD of up to 0.103 $\mu g \cdot kg^{-1}$ BW and monitored survival during incubation (i.e., to swim-up). The results of this study indicate that small incremental changes in exposure levels can have very significant effects on survival rates. The LD_{50} of T_4CDD, considering survival from hatching to swim-up, was 0.047 $\mu g \cdot kg^{-1}$ egg for this species. Similarly, Spitsbergen *et al.* (1991) reported that the survival of lake trout eggs, alevins, and fry was significantly reduced when eggs were exposed to T_4CDD contaminated water for a period of 48 hours. Long-term survival was slightly but significantly impaired (i.e., reduced by 2%) at a tissue residue level of 0.04 $\mu g \cdot kg^{-1}$ egg, while 100% mortality occurred at 0.40 $\mu g \cdot kg^{-1}$ egg. In a separate study, Walker *et al.* (1991) reported that the lethal concentration (LC_{50}) of T_4CDD in lake trout eggs, considering survival to 60 days after swim-up, was 0.065 $\mu g \cdot kg^{-1}$ egg. More recently, DeBruyn *et al.* (2004) reported that decreased survival of salmon eggs (30% reduction) is observed at 2,3,7,8-TCDD-toxic equivalent level of 3 ng/kg lipid in roe. This toxicity threshold is likely relevant for assessing the effects on PCDDs/PCDFs on Fraser River sockeye salmon (see Section 5.4.3 for more information).

Polybrominated diphenyl ethers (PBDEs) and Polybrominated biphenyls (PBBs) - Two classes of brominated hydrocarbons are typically included in the group of chemicals that are termed brominated flame retardants, including PBDEs and PBBs. These chemicals are structurally similar to PCBs and have similar behaviours when released into the environment. Both groups of substances are hydrophobic, fat soluble, and resistant to breakdown (De Wit 2002). Hence, PBDEs and PBBs tend to bind to sediment and soil particles, accumulate in biological tissues, and persist for extended periods of time in the environment (De Wit 2002).

Few data were located to evaluate the toxicity of PBDEs or PBBs to salmonid fishes in aqueous exposures. However, the data available on other fish species suggest that these classes of chemicals are toxic in short- or long-term exposures. For example, Mhadhbi *et al.* (2010) reported 96-h median LC_{50}s of 14 to 30 µg/L for larval turbot (*Psetta maxima*) for two PBDE congeners (PBDE-47 and PBDE-99), with lowest observed effect concentrations of 1.6 and 3.2 µg/L established for these substances. Hatching success was reduced at concentrations higher than those that caused larval mortality (Mhadhbi *et al.* 2010). Exposure to these contaminants also resulted in abnormal skeletal formation and increased incidence of pericardial oedemas in larval turbot. The types of effects observed and the concentrations of PCBEs that elicited adverse effects in turbot were consistent with the results of earlier aqueous-exposure studies conducted on zebrafish (*Danio rerio*; Lema *et al.* 2007) and killifish (*Fundulus heteroclitus*; Timme-Laragy *et al.* 2006).

The results of feeding studies demonstrate that dietary exposure to PDBEs can adversely affect fish. For example, Muirhead *et al.* (2006) reported reproductive effects in Japanese medaka that were administered a single dose of PBDE-47, including cessation of egg-laying behaviour and reduction in mature sperm. Similarly, spawning success was reduced by 80% in three-spined sticklebacks (*Gasterosteus aculeatus*) fed high doses of a commercial PBDE mixture (Bromkal 70-5DE) for a 3.5 month period (the tissue concentration was 1630 µg/kg lipid; Holm *et al.* 1993). Importantly, juvenile lake trout (*Salvelinus namaycush*) fed diets containing high (25 ng/g per PBDE congeners) or low (2.5 ng/g per PBDE congeners) levels of 13 PBDE congeners had lower levels of plasma thyroxine than did control fish, indicating that these contaminants may influence thyroid homeostatis in fish (Tomy *et al.* 2004). In rainbow trout, dietary exposure to PBDE-47 for six or more days resulted in a 75% reduction in ethoxyresorufin-O-deethylase (EROD) activity, indicating that EROD activity may be a good indicator of exposure of salmonid fishes to PBDEs (Tjarnlund *et al.* 1998).

In mammals, PBDEs are known to be neurotoxic, thyrotoxic, estrogenic, and possibly carcinogenic. However, the data needed to identify the concentrations of PBDEs in water, diet, or fish tissues that are sufficient to cause developmental dysfunctions, thyroid hormone imbalances, vitellogenin induction, or tumour induction/promotion have not been established. Therefore, it is possible that PBDEs could cause adverse effects in fish at concentrations lower than those associated with larval mortality or spawning success.

No data were located on the toxicity of PBBs to fish. However, the results of studies on mammalian species indicate that these chemicals cause reproductive effects in monkeys and elicit carcinogenic effects in other species (Siddiqi *et al.* 2003). Reduced growth, egg production, and egg hatchability were observed in chickens exposed to PBBs in dietary exposure studies (Darnerud 2003). A tolerable daily intake of 0.15 µg/kg body weight (BW) has been established for PBBs in humans to protect against carcinogenic effects (based on a no observed adverse effect level of 0.15 mg/kg BW; IPCS 1994).

Given the relative dearth of information on PBDEs and PBBs, it is clear that further investigations are needed to establish toxicity thresholds of these substances for sockeye salmon utilizing habitats within the Fraser River and its tributaries.

<u>Legacy Organochlorine and Other Pesticides</u> - A number of organochlorine pesticides have been identified as endocrine disrupting compounds. Some of these chemicals appear to the antiestrogenic (i.e., endosulfan), while others appear to be capable of inducing vitellogenesis in male fish (DDTs and methoxychlor). For example

Chakravorty *et al.* (1992) observed declines in plasma vitellogenin levels in female catfish (*Clarias batrachus*) exposed to endosulfan (nominal concentration of 1.5 µg/L) for 16 days. Similarly, male sheephead minnows exposed to endosulfan at concentrations of 0.28 to 0.79 µg/L for 40-d did not accumulate detectable levels of vitellogenin in their plasma (Hemmer *et* al. 2001).

Hemmer *et al.* (2001) also evaluated vitellogenin induction in male sheepshead minnows exposed to methoxychlor at concentrations of 5.6 and 12.1 µg/L. The results of this experiment indicated that the parent compound was not estrogenic. However, the demethylated metabolites can bind to the estrogen receptor. At both exposure levels, plasma vitellogenin levels increased rapidly, reaching 120 mg vitellogenin/mL of plasma in the high exposure group by day 35.

Reproductive effects have been observed in fish exposed to the carbamate insecticide carbofuran. In female dwarf gourami (*Colisa lalia*), 20-d aqueous exposures to this substance (i.e., at 0.7 µg/L) resulted in the production of fewer mature oocytes and a higher incidence of atresia of mature oocytes (oocycte absorption; Sukumar and Karpagaganapathy 1992).

Exposure to DDTs is also known to cause reproductive effects in fish. Cheek *et al.* (2001) exposed Japanese medaka to nominal concentrations of 2,4'-DDT ranging from 0 to 7.5 µg/L for two or eight weeks after hatching. The results of this study showed that 8-week exposures to this substance induced vitellogenin production in all of the treatment groups. Female-skewed sex ratios were observed at the two highest doses, while an increased incidence of ovotestis was observed in fish exposed to 1.94 µg/L of 2,4'-DDT for eight weeks. Dietary exposure of Atlantic croakers (*Micropogonias undulatus*) to 0.02 or 0.1 µg 2,4'-DDT/g BW/day for three or seven weeks resulted in increased plasma gonadotropin hormone levels and increased ovary size (as indicated by gonadosomatic index scores; Khan and Thomas 1998).

In chinook salmon, short-term exposure to 2,4'-DDT (at 10 mg/L) at fertilization (1-h exposure) and at hatch (2-h exposure) did not adversely affect mortality rate, time to hatch, fish length, or fish weight at one month following first feeding (Milston *et al.* 2003). Similarly, sex ratios, gonadal development, and concentrations of plasma estradiol and 11-ketotestosterone were unaffected by the treatment. However, early life stage exposure to this substance resulted in long-term humoral immune incompetence (i.e., immunosuppression) in chinook salmon, which could increase susceptibility to disease. These authors postulated that such effects could be significant at the population level.

Neither dieldrin nor toxaphene exhibited a high affinity for the estrogen receptor or the testosterone receptor in rainbow trout (Knudsen and Pottinger 1999), suggesting a relatively low potential for eliciting estrogenic or antiestogenic effects.

Inorganic and Organometallic Compounds - Methyl mercury and organotins are the principal inorganic and organometallic contaminants in the Fraser River Basin. Data from numerous sources indicate that long-term exposure to mercury is associated with a wide range of effects in fish, including survival, growth, spawning success, time to spawning, fecundity, gonadosomatic index, hatching success, larval survival, and larval growth (Dillon *et al.* 2010). Fish can be exposed to mercury in water, sediment, and/or their diet, with total exposure (as indicated with fish tissue concentrations) providing the most direct basis for evaluating both exposure and adverse effects.

<u>Methyl mercury (MeHg)</u> - Among the endpoints investigated, reproduction provides the most sensitive indicator of mercury toxicity in fish. For example, Drevnick and Sandheinrish (2003) reported significant reductions in the levels of male and female sex hormones in mercury-exposed fathead minnows (diet concentrations ranged from 0.87 to 3.93 mg/kg), which translated into reduced spawning of these fish. Similar effects on spawning or reproductive success were reported in four other studies with this species, two studies with brook trout (*Salvelinus fontinalis*), and one study with rainbow trout (Dillon *et al.* 2010). When taken together, the results of these studies indicate that adverse effects on fish reproduction likely begin at tissue concentrations in excess of 0.1 mg/kg WW (Dillon *et al.* 2010). An EC_{10}-type level derived from data from multiple studies is on the order of 0.4 mg/kg WW (Dillon *et al.* 2010). It is likely that such a toxicity threshold would provide a relevant basis for evaluating the potential effects associated with accumulation of MeHg in the tissues of Fraser River sockeye salmon (see Section 5.4.3 for more information).

<u>Tributyltin (TBT) and other organotins</u> - Accumulation of TBT and other organotins in tissues can adversely affect the survival, growth, or reproduction of fish, with reproduction being the most sensitive endpoint measured in field or laboratory studies. For example, Meador (1997) reported a median lethal tissue residue concentration of 0.83 mg/kg WW (whole body) for starry flounder (*Platichthys stellus*) in a 22-d laboratory exposure. By comparison, significantly decreased gonad development was

observed in saltwater gobies (*Chasmichthys dolichognethus*) that accumulated 0.91 mg/kg WW of TBT in their tissues (i.e., whole body; Shimizu and Kimura 1987). In Japanese medaka, embryonic development, hatching, and swim-up success were significantly affected in fish fed TBT-amended diets (Nakayama and Oshima 2008). In addition, mating behaviour and non-sexual behaviours were altered in fish exposed to TBT. All of these effects were enhanced when fish were simultaneously exposed to TBT and PCBs in their diet. These data demonstrate the potentially additive effects of TBT and PCBs on fish. The available literature also provide evidence of transgenerational toxicity of TBT. Nirmala *et al.* (1999) reported decreased survival of embryos and larvae of Japanese medaka derived from eggs containing 0.279 µg/kg WW of TBT spawned by females containing 2.39 mg/kg WW. In Japanese flounder (*Paralichthys olivaceus*), dietary exposure to TBT (at 0.1 or 1.0 µg TBT/g diet) for 100 or 300 days exhibited decreased growth compared to control fish (Shimasaki *et al.* 2003). Importantly, the proportion of sex-reversed males was significantly increased, relative to controls, in both treatment groups. After 100-d, the concentrations of TBT in the high and low exposure groups averaged about 0.16 mg/kg WW and 0.02 mg/kg WW, respectively. Although the available data are limited, it appears that reproduction is likely to be adversely affected in fish that accumulate more than 0.02 mg/kg WW of TBT in their tissues. This toxicity threshold is likely to be lower when TBT occurs in fish tissues along with other endocrine disrupting compounds, such as PCBs.

<u>Other Metals</u> - The data available to evaluate the endocrine disruption effects of other metals (i.e., beyond MeHg and TBT) are limited. However, Thomas (1988) reported cadmium enhanced vitellogenesis in Atlantic croaker exposed to 1 mg/L for 30 days. In rainbow trout, exposure to 10 or 25 µg/L of cadmium decreased the concentrations of two thyroid hormones (triiodothyronine and thyroxine, which are important for adapting to changes in environmental conditions; e.g., salinity) in plasma and increased plasma cortisol levels (which is involved in stress response; Ricard *et al.* 1998). Rainbow trout exposed to lead at 10 µg/L for 12 days had lower gonadosomatic index scores and smaller oocytes than control fish, indicating an effect on the pituitary gland (Ruby *et al.* 2000). Thomas (1988) also reported lower gonadosomatic index scores for Atlantic croakers exposed to lead in their diets (1.34 mg/70g fish/day) for 30 days.

Biogenic Compounds - Plant sterols and phytoestrogens are naturally occurring substances that can act as endocrine disruptors when released into the environment. Incomplete information is available to evaluate effects on fish associated with exposure to naturally-occurring phytosterols and/or phytoestrogens. However, MacLatchy *et* *al.* (1997) exposed goldfish to concentrations of β-sitosterol (one of the major plant sterols discharged from pulp and paper mills) ranging from 75 to 1200 μg/L for a period of 12 days. These concentrations were considered to be typical for bleached-kraft mill effluent. The results of this study showed that the concentrations of reproductive steroids (androgens and estrogens) in plasma were reduced in fish of both sexes exposed to this substance. In contrast, Tremblay and Van Der Kraak (1998) reported that vitellogenin production was induced in immature rainbow trout exposed to β-sitosterol for three weeks. In the highest exposure treatments (75 and 100 μg/L) plasma testosterone was undetectable in rainbow trout, indicating that exposure to this substance causes androgen suppression (Tremblay and Van Der Kraak 1998).

6.1.6 Potential Exposure of Sockeye Salmon to Endocrine-Disrupting Chemicals in the Fraser River Basin

The available data do not support a quantitative analysis of exposures of sockeye salmon to endocrine disrupting compounds in the Fraser River Basin. However, the information available in the scientific literature indicates that endocrine disruption in fish is most likely to be observed in association with three types of land use, including (Pait and Nelson 2002):

- Sewage treatment plants;
- Pulp and paper mills; and,
- Areas with high industrial activity/chemical contamination.

Although the available data are insufficient to quantitatively evaluate exposure of sockeye salmon to endocrine disrupting compounds associated with these land use activities, information on the location of such activities provides a basis for inferring exposure of sockeye salmon to endocrine disrupting compounds during four life history stages, including spawning and incubation, rearing, smolt outmigration, and/or adult upstream migration. The following discussion is intended to provide such a qualitative evaluation of exposure to endocrine disrupting compounds.

<u>Exposure to Municipal Wastewater Treatment Plant Effluents</u> - Municipal wastewater treatment plants are located throughout the Fraser River Basin. Theoretically, sockeye salmon could be exposed to wastewater treatment plant effluents during all four of the life history stages considered in the previous evaluations of exposure, including spawning and incubation, rearing, smolt outmigration, and/or adult upstream migration

(See Chapters 4 and 5 for further information). However, actual exposure to the endocrine disrupting compounds contained in wastewater treatment plant effluents can occur only when these key life stages are present in exposure areas during periods of discharge to receiving water streams. As such, it is necessary to determine when sockeye salmon are present in areas that receive discharges from municipal wastewater treatment plants.

For incubating sockeye salmon eggs and alevins, exposure to wastewater treatment plant effluent is likely to be negligible for most conservation units. However, significant exposure to endocrine disrupting compounds associated with municipal wastewater is likely to occur for the Harrison River sockeye salmon spawning downstream of the wastewater treatment plant located at Harrison Hotsprings. In addition, certain stocks of sockeye salmon (e.g., Salmon River) associated with the Shuswap River conservation unit may be exposed to diluted wastewater treatment plant effluent during incubation.

No information was located that indicated that any of the wastewater treatment plants in the Fraser River Basin discharge directly into nursery lakes used for early rearing by sockeye salmon. Accordingly, it is assumed that exposure of sockeye salmon to wastewater treatment plant effluent is negligible for virtually all stocks in the study area. The exception could be the Harrison River stocks that rear in backwater areas and sloughs within the Lower Fraser River for a period of time before migrating to Georgia Strait.

There are numerous wastewater treatment plant located along the migration corridors for sockeye salmon in the Fraser River Basin (Figure 3.12). The magnitude and duration of exposure to endocrine disrupting compounds associated with wastewater treatment plant effluents is a function of the level of treatment used (i.e., primary, secondary, or tertiary treatment), the volume of effluent discharged to receiving waters, the dilution capacity of receiving water systems, distance travelled during downstream or upstream migration, and sockeye salmon residence time in areas with significant effluent discharges. As residence time of outmigrating smolts and upstream migrating adults in various sections of the Fraser River mainstem is unknown for most stocks, it is assumed that the magnitude and duration of exposure to endocrine disrupting compounds in wastewater treatment plant effluents are high for up-river stocks with the longest migration distances (i.e., those returning to the Quesnel, Bowron, and Nechako river watersheds), moderate for stocks with intermediate migration distances (i.e., those returning to the Chilko, Seton-Portage, and Thompson river watersheds), and low for stocks with the shortest migration distances (i.e., those returning to the Pitt River and Cultus Lake watersheds). Exposure of sockeye salmon to urban stormwater runoff, and associated endocrine disrupting compounds, would generally have the same pattern as exposure to municipal wastewater treatment plant effluents.

Exposure to Pulp and Paper Mill Effluents - There are a total of ten pulp and paper mills in the Fraser River Basin, with two located near Prince George, two located near Quesnel, one located near Kamloops, and five located near Vancouver. Exposure of sockeye salmon to the endocrine disrupting compounds associated with discharges from operating pulp and paper mills occurs when key life history stages are present in areas that receive discharges from pulp and paper mills. Therefore, there is a need to estimate exposure to pulp and paper mill effluent during spawning and incubation, rearing, smolt outmigration, and/or adult upstream migration.

As none of the operating pulp and paper mills in the Fraser River Basin discharge to streams that are used for spawning, exposure of sockeye salmon eggs and alevins to pulp and paper mill effluent is likely to be negligible during the incubation period for all conservation units.

None of the operating pulp and paper mills in the Fraser River Basin discharge effluent directly into nursery lakes used for early rearing by sockeye salmon. Accordingly, it is assumed that exposure of sockeye salmon to diluted or undiluted pulp and paper mill effluent is negligible during early rearing for virtually all stocks in the study area. The exception could be the Harrison River stocks that rear in backwater areas and sloughs within the Lower Fraser River for a period of time before migrating to Georgia Strait. These stocks could be exposed to diluted pulp and paper mill effluent if they rear for some period of time in areas that receive effluent discharges from the pulp and paper mills located in the Lower Fraser River Area of Interest.

All ten pulp and paper mills in the Fraser River Basin are located along the migration corridors for sockeye salmon (Figure 3.1). The magnitude and duration of exposure to endocrine disrupting compounds associated with pulp and paper mill effluents is a function of the processes used at each mill, treatment efficiency (i.e., removal efficiency for endocrine disrupting compounds), the volume of effluent discharged to receiving waters, the dilution capacity of the receiving water systems, distance travelled during downstream or upstream migration, and sockeye salmon residence time in areas with significant effluent discharges. As endocrine disrupting compound removal efficiency of the various pulp and paper mills and residence time of outmigrating smolts and upstream migrating adults in various sections of the Fraser River mainstem is unknown for most stocks, it is assumed that the magnitude and duration of exposure to endocrine disrupting compounds in pulp and paper mill effluents are high for up-river stocks with the longest migration distances (i.e., those returning to the Quesnel, Bowron, and Nechako river watersheds), moderate for stocks with intermediate migration distances (i.e., those returning to the Chilko, Seton-Portage, and Thompson river watersheds), and low for stocks with the shortest migration distances (i.e., those returning to the Pitt River and Cultus Lake watersheds).

It is important to note that the pulp and paper mills in the Fraser River Basin are now under federal regulations (i.e., Pulp and Paper Mill Effluent Regulations). These regulations prohibit releases of PCDDs/PCDFs in pulp and paper mill effluents (as of July 1, 1992). In addition, these regulations prohibit releases of acutely toxic effluent from pulp and paper mills. To address the requirements specified under these regulations, many, if not all, of the pulp and paper mills refined their production methods (i.e., switching from chlorine to chlorine dioxide bleaching) and upgraded their effluent treatment systems (i.e., to secondary treatment; Grant and Ross 2002). These changes in the operation of the mills have resulted in substantial improvements in effluent quality, including (McGreer and Belzer 1999):

- The number of days that toxic effluent is discharged was reduced by 99%;
- The results of 96-h toxicity tests with rainbow trout showed, on average, 100% survival in 100% effluent;
- The concentrations of TSS and BOD decreased by 34% and 88%, respectively. The levels of these variables in the effluents of all pulp and paper mills are now within the allowable limits; and,
- Releases of PCDDs and PCDFs have declined by over 99%.

In spite of these improvements, discharges of treated effluent from pulp and paper mills in the Fraser River Basin still represent potential hazards to sockeye salmon. While implementation of secondary treatment has substantially reduced the concentrations of many of the endocrine disrupting compounds that have been measured in pulp and paper mill effluents (i.e., heavy metals, chlorinated organic compounds, and APEOs; Janz *et al.* 2001), it is uncertain if the concentrations of the metabolites of such chemicals (many of which also have endocrine disruption potential) have also been reduced (Johannessen and Ross 2002). In addition, effluents from pulp and paper mills still contain elevated levels of numerous natural plant hormones that have the potential affect the endocrine systems of exposed fish.

Exposure to Endocrine Disrupting Compounds Associated with Industrial and Other Activities - Point and non-point sources of industrial contaminants exist throughout the Fraser River basin. However, manufacturing, shipping, and agricultural activities are concentrated in the Lower Fraser River Area of Interest. In addition, the highest density of contaminated sites occurs in the lower mainland area. Mining- and forestry-related activities are conducted throughout the study area. Exposure to endocrine disrupting compounds associated with industrial and other activities was evaluated in four life stages of sockeye salmon, including spawning and incubation, rearing, smolt outmigration, and/or adult upstream migration.

Exposure to endocrine disrupting compounds associated with industrial and other activities is likely to be negligible for sockeye salmon eggs and alevins in most of the conservation units within the Fraser River Basin. However, certain stocks of sockeye salmon utilizing habitats located in the vicinity of operating metal mines and/or areas treated with fire suppression chemicals may be exposed to heavy metals and/or surfactants during incubation.

No information was located indicating the presence of point source industrial or other discharges into nursery lakes used for early rearing by sockeye salmon within the Fraser River Basin, with the possible exception of the Endako Mine (which discharges indirectly to Fraser Lake). Accordingly, exposure of sockeye salmon to endocrine disrupting compounds originating from industrial or other sources during early rearing is considered to be negligible for virtually all stocks in the study area. The exception could be the Harrison River stocks that rear in backwater areas and sloughs within the Lower Fraser River for a period of time before migrating to Georgia Strait.

There are numerous point source and non-point source discharges of contaminants along the migration corridors for sockeye salmon in the Fraser River Basin (Figures 3.1 through 3.21). The magnitude and duration of exposure to endocrine disrupting compounds associated with such discharges is a function of the characteristics of the discharge, the volume of material discharged to receiving waters, the dilution capacity of the receiving water systems, distance travelled during downstream or upstream migration, and sockeye salmon residence time in areas with significant effluent discharges. As loadings of endocrine disrupting compounds to the watershed from point and non-point source discharges are virtually unknown and the residence time of outmigrating smolts and upstream migrating adults in various sections of the Fraser River mainstem is unknown for most stocks, it was assumed that the magnitude and duration of exposure to endocrine disrupting compounds originating from industrial and other sources are high for up-river stocks with the longest migration distances (i.e., those returning to the Quesnel, Bowron, and Nechako river watersheds), moderate for stocks with intermediate migration distances (i.e., those returning to the Chilko, Seton-Portage, and Thompson river watersheds), and low for stocks with the shortest migration distances (i.e., those returning to the Pitt River and Cultus Lake watersheds).

6.1.7 Potential Risks to Sockeye Salmon Associated with Exposure to Endocrine-Disrupting Chemicals in the Fraser River Basin

There is a substantial body of scientific evidence demonstrating that many of the substances released to the environment due to human activities have the potential to modulate or disrupt the endocrine system in fish. Because limitations on the availability of exposure data precluded implementation of a quantitative analysis, a qualitative approach was used to evaluate the risks posed to sockeye salmon associated with exposure to endocrine disrupting compounds in the Fraser River Basin. This approach relied on a spatial analysis of the types of land uses that are typically associated with releases of endocrine disrupting compounds into aquatic ecosystems. The three types of land uses considered in this evaluation included (Pait and Nelson 2002):

- Sewage treatment plants;
- Pulp and paper mills; and,
- Areas with high industrial activity/chemical contamination.

Based on the results of the qualitative exposure assessment presented in Section 6.1.6, it is apparent that Fraser River sockeye salmon may be exposed to endocrine disrupting compounds originating from multiple sources. For all three types of land use activities, the greatest quantities of endocrine disrupting compounds are likely to be released to the Lower Fraser River Area of Interest. Significant releases of such chemicals also likely occur in the upper Fraser River mainstem, the Thompson River mainstem, and certain other tributaries within the watershed (e.g., Stuart River, Nechako River, Salmon River, Harrison River). As exposure areas and intensities are likely to be similar for all three land uses, it is reasonable to conduct a single evaluation of risks to sockeye salmon associated with exposure to endocrine disrupting compounds originating from all three source types.

Exposure of sockeye salmon to endocrine disrupting compounds originating from multiple sources varies by life history stage. While there is some potential for exposure to endocrine disrupting compounds during incubation and rearing in freshwater systems (e.g., for Harrison River and, possibly, South Thompson River stocks), such exposure is likely to be minimal for most of the sockeye salmon stocks located within the study area. In contrast, the migration corridors in the Fraser River Basin are likely to represent important areas of exposure to endocrine disrupting compounds. Therefore, sockeye salmon utilizing migration corridors are likely exposed to endocrine disrupting compounds derived from multiple sources, with the majority of their exposure occurring during smolt outmigration and upstream migration of adult fish.

The duration of exposure to endocrine disrupting compound-contaminated surface water is likely to be variable for the various stocks of sockeye salmon in the study area. Although stock-specific data were not located, Burgner (1991) reported that sockeye salmon smolts average about 40 km/day during downstream migration. Accordingly, outmigration may take one to three weeks for Fraser River sockeye salmon stocks, depending on the distance travelled. Similarly, the duration of exposure to endocrine disrupting compounds in surface water during upstream migration varies by stock. Chilko River fish travel about 600 km to their spawning grounds in about 18 days, while Stuart Lake fish cover about 1000 km in 24 days (Burgner 1991). Migration times for lower river stock would be shorter. Exposure time could be increased if fish holding at the mouth of the river prior to initiating upstream migration spend a significant amount of time in the Fraser River plume. Overall, this information suggests that stocks utilizing spawning habitats located furthest from the mouth of the river (i.e., those with the longest residence times in migration corridors) are likely to have the highest exposure to endocrine disrupting compounds, while those destined for natal streams nearby the mouth of the Fraser River are likely to have the lowest exposure to these chemicals. The duration and intensity (i.e., relative concentration of endocrine disrupting compounds; L=low, M=moderate, and H=high) of exposure to endocrine disrupting compounds during smolt outmigration and upstream migration of adults is estimated below:

Location of Natal Stream	Duration of Exposure	Exposure Intensity
Upper watershed	18 - 24 days	High for 6 days Low to Moderate for up to 18 days
Middle watershed	12 - 18 days	High for 6 days Low for up to 12 days
Lower watershed	6 - 12 days	High for 6 days Low for up to 6 days

Pait and Nelson (2002) reviewed the literature describing the effects on fish associated with exposure to endocrine disrupting compounds in laboratory (Table 6.2) and field studies (Table 6.3). The indicators considered in that evaluation of the effects of endocrine disrupting compounds on fish included vitellogenin levels, testosterone levels, 17β-estradiol levels, gonadosomatic index scores, gonadal development, and incidence of intersex. The results of studies conducted with individual chemicals indicate that long-term exposure to a variety of endocrine disrupting compounds can have significant effects on such ecologically-relevant endpoints as the incidence of intersex in males and impaired gonadal development in fish. The results of field studies confirm that exposure to municipal wastewater treatment plant effluent or pulp and paper mill effluents can adversely affect reproduction of fish. Such reproductive abnormalities can lead to population level impacts on exposed fish species (Sparks *et al.* 2005).

For Fraser River sockeye salmon, exposure to endocrine disrupting compounds during incubation and rearing is likely to be negligible. Therefore, significant exposure to endocrine disrupting compounds is likely to occur primarily during migration periods. The duration of exposure to endocrine disrupting compounds during smolt outmigration or upstream migration of adults is likely to be on the order of 6 to 24 days for sockeye salmon. For this reason, data from laboratory or field studies, compiled by Pait and Nelson (2002), with exposure durations of ≤ 30 days (i.e., consistent with the duration of exposure for the most highly exposed stocks during migration) were considered to evaluate potential effects on Fraser River sockeye salmon associated with exposure to endocrine disrupting compounds.

The results of the laboratory studies conducted on multiple species of fish, including salmonids, demonstrated that induction of vitellogen production was commonly observed in fish exposed to endocrine disrupting compounds for ≤ 30 days (Pait and Nelson 2002). In some laboratory studies, gonadosomatic indices were altered relative to control fish. In a few cases, impaired gonad development and/or decreased testosterone or 17β-estradiol levels were reported. These latter effects were typically observed in fish exposed to high molecular weight PAHs (i.e., BAP), pesticides (i.e., carbofuran), or plant-derived steroids (β-sitosterol) for 12 to 30 days. The results of *in situ* studies (duration of $\leq$30 days) conducted to evaluate the effects on fish associated with exposure to municipal wastewater treatment plant- or pulp and paper mill-effluent contaminated surface water, confirm that induction of vitellogenin production occurs in exposed fish. In one study, increased incidence of intersex in male fish was also reported (Gray and Metcalfe 1997).

Collectively, the results of laboratory and field studies conducted on numerous fish species indicate that exposure to endocrine disrupting compounds at levels at or above those that are likely to be observed in the Fraser River basin has the potential to adversely affect reproduction. However, when only the results of studies conducted for exposure durations relevant to migrating sockeye salmon are considered, adverse reproductive effects (e.g., intersex in males, impaired gonadal development) have been observed only infrequently. Most of these shorter-term studies report effects on vitellogenin production and/or the production of sex hormones. Such decreases in production of sex hormones could, potentially, influence the incidence of pre-spawning mortality in the most highly exposed stocks of sockeye salmon. However, the likelihood of observing such effects cannot be determined with the information currently available. It is important to note, however, that low frequency incidence of intersex has been documented in Fraser River sockeye salmon (Veldhoen *et al.* 2010).

It is unlikely that reproductive effects associated with endocrine disrupting compound exposure are sufficient to explain the declines in sockeye salmon abundance over the past two decades or the poor returns of sockeye salmon that were observed in 2009. Such endocrine disrupting compound-related effects are likely not the causative factor in such declines of sockeye salmon because:

- Exposure to endocrine disrupting compounds in pulp and paper mill effluents has likely decreased during the past two decades;
- Exposure durations to endocrine disrupting compounds during migration may be insufficient to elicit significant reproductive effects; and,
- There is little evidence for differential response among stocks that possibly receive different exposures to endocrine disrupting compounds (i.e., upriver versus down river stocks).

Nevertheless, it is possible that exposure to endocrine disrupting compounds are causing other types of effects that could be sufficient to adversely affect the survival, growth, or reproduction of sockeye salmon in the Fraser River Basin. There is a growing body of evidence from laboratory and field studies indicating that exposure to endocrine disrupting compounds can compromise the immune system of exposed fish. O'Halloran *et al.* (1998) conducted a review of the literature and concluded that metals, TBT, organochlorine and organophosphate pesticides, PAHs, PCBs, PBBs, and PCDDs/PCDFs elicit significant imunotoxicity in fish. Importantly, such adverse effects on immune response have been demonstrated in Pacific salmon exposed to PAHs, PCBs, and mixtures of contaminants (Arkoosh *et al.* 1991; 1994; Milston *et al.* 2003; Misumi *et al.* 2005). Reduced immunocompetance associated with exposure of fish to these and other substances tends to exacerbate disease states by lowering resistance and allowing the invasion of infectious agents (Zelikoff and Cohen 1996; Jacobson *et al.* 2003).

Reduced immunocompetance represents a serious concern for outmigrating sockeye salmon smolts. To evaluate the significance of exposure to endocrine disrupting compounds on salmon smolts, Varanasi *et al.* (1993) collected chinook salmon from contaminated and uncontaminated estuaries in Washington State and held these fish for 40 days in saltwater. The results of this study showed that chinook salmon with higher exposure to endocrine disrupting compound-type contaminants (as indicated by PAH, PCB, and organochlorine pesticide concentrations in stomach contents, PAH metabolites in fish bile, and hepatic cytochrome P450 activity) had lower survival during the transition to the saltwater environment than did fish in the low exposure treatment groups. More specifically, chinook from the Duwamish Waterway and Puyallup estuary (two contaminated systems) had 56% and 58% survival, respectively, after 40 days in salt water. By comparison, survival rates for fish from the relatively uncontaminated Nisqually estuary (81%), from the Green River Hatchery (86%), and Kalama Creek Hatchery (88%) were significantly higher. In addition, impaired survival during the parr-smolt transformation has been reported for Atlantic salmon exposed to low levels of atrazine (i.e., $\geq$1 µg/L; Fairchild *et al.* 2002). Adverse effects on the parr-smolt transformation and impaired ability of fish to adapt to saline conditions have also been reported for Atlantic salmon exposed to 4-nonylphenol (at 5 µg/L) and estrogen (at 0.1 µg/L; Fairchild *et al*. 1999). Furthermore, juvenile chinook salmon that were exposed to PAHs or PCBs had higher mortality (i.e., about 60%) than control fish (i.e., about 15%) 14 days after exposure to the marine pathogen, *Listenella anguillarum* (the bacterium formerly known as *Vibrio anguillarum*; Arkoosh *et al.* 1998). Finally, Filby *et al.* (2007) demonstrated that effects on the immune system were greater when fish were exposed to mixtures of endocrine disrupting compounds (i.e., compared to exposure to individual chemicals).

Collectively, the results of studies on immunosuppression indicate that exposure to endocrine disrupting compounds has the potential to adversely affect salmon during their transition to the marine environment. If the concentrations of endocrine disrupting compounds were sufficient to elicit these types of effects in the Fraser River, the resultant mortality of smolts during transition to the marine environment could have contributed to long-term declines in sockeye salmon abundance.

Exposure to endocrine disrupting compounds may be an even greater concern for sockeye salmon returning to the Fraser River for several reasons. Sockeye salmon are exposed to persistent endocrine disrupting compounds, such as PCBs, PCDDs, and PCDFs, during outmigration and during their residence in the marine environment (Krummel *et al.* 2003). During upstream migration, adult sockeye salmon utilize lipid and protein stores to support gonadal development (females) and morphological alterations (males). The rigours of upstream migration and associated physiological changes can result in 50 - 90% depletion of somatic energy reserves (Hendry and Berg 1999). As a result, the concentrations of these contaminants in somatic or gonadal tissues can increase dramatically between the time fish enter the mouth of the Fraser River and arrive at their natal streams. DeBruyn *et al.* (2004) estimated that the concentrations of PCBs, PCDDs, and PCDFs in muscle tissue could increase by 4.8 to 10.4 times for various Fraser River sockeye salmon stocks, with the highest magnification rates predicted for the fish that complete the longest migration. Predicted contaminant magnification rates were somewhat lower (i.e., 3.9 to 7.9) for gonads. Such contaminant magnification was predicted to result in concentrations in eggs that exceeded the toxicity threshold for salmonid fishes of 3 ng/kg lipid, which is associated with 30% mortality of eggs (DeBruyn *et al.* 2004). Although little information is available with which to make inferences, it is possible that exposure of adult sockeye salmon to endocrine disrupting compounds in surface water during upstream migration could also compromise immunocompetence. If so, such exposures could make sockeye salmon more susceptible to infection by disease agents, particularly during migration periods characterized by elevated water temperatures. Such effects could translate into increases in en-route mortality and/or pre-spawning mortality.

6.2 Potential Effects of Contaminants of Emerging Concern on Sockeye Salmon

The term “contaminants of emerging concern” is used to describe a broad group of chemicals that were previously unknown or were not previously recognized as being of concern relative to human or environmental health. Because these contaminants are of emerging concern, there are few standard lists of these substances. However, the Commonwealth of Massachusetts has defined contaminants of emerging concern as hazardous materials or mixtures that are characterized as having:

- A perceived threat to human health, public safety, or the environment;
- No published health standards or guidelines;
- Insufficient or limited available toxicological information or toxicity information that is evolving or being re-evaluated; or,
- Significant new source, pathway, or detection limit information.

This definition of contaminants of emerging concern provides a reasonable framework for identifying and evaluating chemicals of potential interest in the Fraser River Basin.

6.2.1 Identification of Contaminants of Emerging Concern in the Fraser River Basin

A compiled list of contaminants of emerging concern in the Fraser River Basin was not located in the scientific literature. For this reason, information compiled by USGS (2010) to support a national reconnaissance of these contaminants in U.S. streams was used to identify chemicals of potential interest in the Fraser River Basin. Based on this information, contaminants of emerging concern in the Fraser River Basin are likely to include (Table 6.4):

1. Veterinary and human antibiotics, including:
    - Tetracyclines (e.g., tetracycline);
    - Fluoroquinolones (e.g., ciprofloxacin);
    - Macrolides (e.g., erythromycin);
    - Sulfonamides (e.g., sulfamethazine); and,
    - Other antibiotics (e.g., lincomycin);
2. Drugs, including:
    - Prescription drugs (e.g., cimetidine, warfarin); and,
    - Non-prescription drugs (e.g., caffeine, codeine);
3. Industrial and household waste products, including:
    - Insecticides (e.g., diazinon, carbaryl, bifenthrin);
    - Plasticizers (e.g., phthalates);

    - Surfactants (i.e., APEOs, such as octylphenols and nonylphenols);
    - Fire retardants [e.g., tri(2-chloroethyl)phosphate];
    - Antioxidants (e.g., 2,6-di-tert-butylphenol);
    - Other chemicals (e.g., phenols, bisphenol A, and triclosan);
4. Sex and storoidal hormones, including:
    - Biogenics (e.g., estriol, estrone, progesterone);
    - Pharmaceuticals (e.g., 17α-ethynylestradiol, mestranol); and,
    - Sterols (e.g., cholesterol, stigmastanol).

In addition to these substances, it is likely that the following chemicals also represent contaminants of emerging concern in the Fraser River Basin:

- Organometallic substances (TBT);
- In-use herbicides (ethalfluralin, pendimethalin);
- In-use fungicides (dazomet, mancozeb, metam, metiram);
- Wood preservatives (CCA, ACZA);
- Anti-sapstain chemicals (DDAC, IPBC);
- Additional fire retardants, including PBDEs and PBBs;
- Fluorosurfactants, including PFOS, PFOA;
- Polychlorinated paraffins; and,
- Nanoparticles.

These latter substances should be identified as contaminants of emerging concern because they are being used or are likely being used in the study area, they have been measured in environmental media at elevated or increasing levels, environmental quality guidelines for water, sediment, and/or fish tissues are not available in Canada, and/or incomplete information is available on their toxicity to fish and other aquatic organisms.

6.2.2 Sources and Releases of Contaminants of Emerging Concern in the Fraser River Basin

There are numerous sources of contaminants of emerging concern in the Fraser River Basin. For the pharmaceuticals and personal care products, natural hormones and nanoparticles, municipal wastewater treatment plants represent the primary sources of these substances to aquatic ecosystems. However, run-off from biosolids application sites, feedlots, and/or manure application sites represents a potential source of these chemicals. Various fire retardants and surfactants can also be released from municipal and industrial wastewater treatment plants. Discharges and runoff from industrial and manufacturing facilities also represent sources of plasticizers, industrial chemicals, fire retardants, and surfactants. Wood preservation facilities represent the primary sources of wood preservatives and anti-sapstain chemicals released to receiving waters. Tributyltin and other organotins are likely to be released to the environment from anti-fouling paints applied to ocean-going vessels. Atmospheric transport and deposition likely represents an important source of certain contaminants of emerging concern, such as PBDEs and PBBs. Chapter 3 provides more information on the sources of these contaminants in the study area.

6.2.3 Potential Effects of Contaminants of Emerging Concern on Fish

Incomplete information is available in the scientific literature to evaluate the nature of effects associated with exposure of fish to contaminants of emerging concern. However, the available data on the endocrine disruption effects of certain groups of these contaminants were discussed in Section 6.1.5 of this document. An evaluation of the toxicity of the other contaminants of emerging concern in the Fraser River Basin was not conducted as part of this investigation.

6.2.4 Potential Exposure of Sockeye Salmon to Contaminants of Emerging Concern in the Fraser River Basin

Few data are available with which to document exposure of sockeye salmon to contaminants of emerging concern within the Fraser River Basin. However, information on the locations of likely sources can be used to infer the levels of exposure of various life stages of sockeye salmon to these contaminants. This information suggests that exposure to contaminants of emerging concern associated with industrial or municipal wastewater treatment plant discharges is likely to be negligible for sockeye salmon eggs and alevins in most of the conservation units within the Fraser River Basin. However, all stocks of sockeye salmon are likely to be exposed to these contaminants for which atmospheric transport represents an important source. Similarly, it is assumed that exposure of sockeye salmon to contaminants of emerging concern originating from municipal or industrial sources is negligible during early rearing for virtually all stocks in the study area. The exception could be the Harrison River stocks that rear in backwater areas and sloughs within the Lower Fraser River for a period of time before migrating to Georgia Strait.

Contaminants of emerging concern are likely to be released to surface waters from numerous point source and non-point source discharges that are primarily located along the migration corridors for sockeye salmon. As was the case for endocrine disrupting compounds, it is assumed that the magnitude and duration of exposure to these contaminants originating from municipal and industrial sources are high for up-river stocks with the longest migration distances (i.e., those returning to the Quesnel, Bowron, and Nechako river watersheds), moderate for stocks with intermediate migration distances (i.e., those returning to the Chilko, Seton-Portage, and Thompson river watersheds), and low for stocks with the shortest migration distances (i.e., those returning to the Pitt, Harrison, and Cultus river watersheds).

6.2.5 Potential Risks to Sockeye Salmon Associated with Exposure to Contaminants of Emerging Concern in the Fraser River Basin

Due to the general paucity of toxicity and exposure data, it is difficult to evaluate the risks to sockeye salmon associated with exposure to contaminants of emerging concern in the Fraser River Basin. Nevertheless, Johannessen and Ross (2002) used the results of a detailed review of the available data and information to classify contaminants into four groups (high risk, moderate risk, low risk, and unknown) based on their potential to adversely affect late-run sockeye salmon in the Fraser River Basin. The contaminants of emerging concern that fell into each of these categories included:

<u>Contaminants Posing High Risk</u> - The following substances were considered to pose the highest risk to late-run sockeye salmon in the Fraser River Basin. Such contaminants are the most likely to be contributing, along with other factors (such as oceanographic conditions, disease, and water temperatures during upstream migration), to the decline of sockeye salmon in the study area:

- Pesticides (metam and chlorothalonil; Rationale: Use of these substances is increasing in the Fraser River Basin and its use is correlated with reductions in sockeye salmon abundance);
- Polybrominated diphenylethers (PBDEs; Rationale: Levels are rapidly increasing in the environment and these substances are known endocrine disruptors);
- Phthalate esters (Rational: Ubiquitous distribution in the environment, known endocrine disruptors, and potentially toxic to fish); and,

- Alkylphenol ethoxylates (APEOs; Rationale: Widely used, found in municipal wastewaters, pulp mill effluents, and urban runoff, known endocrine disruptors, implicated in population level impacts on Atlantic salmon, and treatment breaks them down into more toxic degradation products).

<u>Contaminants Posing Moderate Risk</u> - The following substances were considered to pose moderate risk to late-run sockeye salmon in the Fraser River Basin. Such contaminants are potentially contributing, along with other factors (such as oceanographic conditions, disease, water temperatures during upstream migration, etc.), to the decline of sockeye salmon in the study area:

- Pesticides (triclopyr; Rationale: Increasing use in forestry sector and use is correlated with declines in sockeye salmon abundance);
- Sodium ferrocyanide [Rationale: Increasing use of FireTrol 931 as fire retardant in forest applications, degrades to cyanide (which is toxic to fish), use correlated with declines in sockeye salmon abundance]; and,
- Antisapstain chemicals [DDAC, IPBC, and borax-based chemicals; Rationale: Use appears stable, toxic to fish at low levels (i.e. approximately 1 μg/L), best management practices have reduced spills and runoff, and acutely toxic in sediment at low levels; Szenasy 1999).

<u>Contaminants Posing Low Risk</u> - The following substances were considered to pose low risk to late-run sockeye salmon in the Fraser River Basin. Such contaminants are considered to be the least likely to be contributing, along with other factors (such as oceanographic conditions, disease, water temperature, etc.), to the decline of sockeye salmon in the study area:

- Tributyltin (Rationale: Use restricted to ocean-going vessels and effects have declined in North America);
- Anti-sapstain chemicals (sodium carbonate and 2-(thiocyanomethylthio)benzothiazole; Rationale: Use is declining and best management practices have reduced spills and runoff); and,
- Pesticide degradation products.

Contaminants Posing Unknown Risk - The following substances were considered to pose unknown risk to late-run sockeye salmon in the Fraser River Basin. It is unknown if such contaminants could be contributing, along with other factors (such as oceanographic conditions, disease, water temperature, etc.), to the decline of sockeye salmon in the study area:

- Pharmaceuticals and personal care products (Rationale: Increasing evidence of effects and U.S. data show chemicals are common in receiving waters;
- Polychlorinated paraffins (Rationale: Production is declining, but compounds are persistent in the environment); and,
- Perfluorinated surfactants (PFOA and PFOS; Rationale: Found in wildlife tissues worldwide, ubiquitous in the environment, and toxicity uncertain)

Other contaminants that pose unknown risks ro Fraser River sockeye salmon are likely to include pesticides (such as diazinon, carbaryl, ethalfluoralin, pendimethalin, dazomet, mancozeb, metam, and metiram), wood preservatives (such as CCA and ACZA), and nanoparticles.

Insufficient information was located to support a detailed evaluation of the risks posed to sockeye salmon associated with exposure to contaminants of emerging concern in the Fraser River Basin. Nevertheless, the results of the evaluation of selected contaminants by Johannessen and Ross (2002) suggest that contaminants of emerging concern are a significant environmental concern that needs to be addressed in British Columbia. In recognition of the potential effects of these chemicals on aquatic organisms, wildlife, and human health, many jurisdictions have developed or are in the process of developing strategies for identifying priorities for assessing and managing contaminants of emerging concern. Based on the information presented by Johannessen and Ross (2002), development of such a strategy is warranted for the Fraser River Basin and elsewhere in British Columbia.

6.3 Discussion on the Potential Role of Endocrine Disrupting Chemicals and Contaminants of Emerging Concern in the Decline of Fraser River Sockeye Salmon

The results of the preliminary screening indicated that insufficient information was available to evaluate risks to sockeye salmon associated with exposure to many of the chemicals of potential concern identified in the Inventory of Aquatic Contaminants for the Fraser River Basin (See Chapter 4 for more information). In some cases, the data needed to determine the concentrations of chemicals of potential concern in surface water or sediment (i.e., exposure point concentrations) were unavailable. For other chemicals of potential concern, exposure levels that corresponded to no observed adverse effect concentrations (i.e., toxicity screening values) were not defined in the scientific literature. All of the chemicals of potential concern that fell into these two categories were identified as uncertain contaminants of concern and carried forward into the detailed assessment.

In the detailed assessment, more realistic exposure assumptions were adopted to evaluate the potential effects of contaminants of concern and uncertain contaminants of concern on sockeye salmon utilizing habitats within the Fraser River Basin. In addition, salmonid-specific toxicity thresholds (termed toxicity reference values) replaced the toxicity screening values used in the screening level assessment. In most cases, however, uncertainty regarding the potential effects of uncertain contaminants of concern could not be resolved in the detailed assessment process. Accordingly, most of these contaminants retained their designations as uncertain contaminants of concern (See Chapter 5 for more information).

Many of the uncertain contaminants of concern identified in the preliminary and detailed assessments are classified as known endocrine disrupting compounds, potential endocrine disrupting compounds, and/or contaminants of emerging concern. As insufficient information was located to conduct quantitative evaluations of the potential effects of such uncertain contaminants of concern, a qualitative approach was adopted to assess the risks to sockeye salmon associated with exposure to endocrine disrupting compounds and contaminants of emerging concern in the Fraser River Basin. The results of these qualitative assessments suggest that endocrine disrupting compounds and/or contaminants of emerging concern could be causing or substantially contributing to the declines of sockeye salmon observed over the past two decades.

Direct evidence to demonstrate the effects of endocrine disrupting compounds and contaminants of emerging concern on Fraser River sockeye salmon is not available. Nevertheless, indirect lines-of-evidence can be used together, in an ecoepidemiological approach, to support or weaken the case that a cause and effect relationship accounts for the patterns observed in the environment (Suter *et al.* 2007). In this assessment, such an ecoepidemiological approach was used to evaluate the following hypothesis:

Exposure to endocrine disrupting chemicals and/or contaminants of emerging concern caused or substantially contributed to declines in the abundance of Fraser River sockeye salmon over the past two decades and/or to low returns of Fraser River sockeye salmon in 2009.

A total of five characteristics of causal associations (as identified by Suter *et al.* 2007) were used to consider the available evidence for a cause and effect relationship between exposure of sockeye salmon to endocrine disrupting compounds and/or contaminants of emerging concern and declines in sockeye salmon abundance in the Fraser River, including:

- <u>Co-occurrence</u> - For a cause and effect relationship to exist, an effect must occur where and when its cause occurs and cannot occur in the absence of its cause. For endocrine disrupting compounds and, potentially, certain contaminants of emerging concern, it is hypothesized that increased mortality occurs when sockeye salmon that have been exposed to such contaminants during smolt outmigration transition to the marine environment. All stocks of sockeye salmon are exposed to these contaminants in the lower Fraser River, with the magnitude of exposure likely increasing over the past two decades. The evidence suggests that sockeye salmon exhibit high mortality after leaving the Fraser River. The observed effect is consistent with observations that juvenile chinook salmon exhibit high mortality during transition to saltwater after exposure to endocrine disrupting compounds (such as PCBs and PAHs) in contaminated estuaries (Varanasi *et al.* 1993; Arkoosh *et al.* 1998). As exposure of sockeye salmon to such endocrine disrupting compounds has likely increased over the past two decades and returns of sockeye salmon to the Fraser River have declined over the same time period, it is likely that there is a co-occurrence between the cause and the effect. This co-occurrence between the cause and the effect would be demonstrated if toxicity thresholds of one or more endocrine disrupting compounds were exceeded on an increasingly frequent during the post-1990 period, but not or only infrequently before that time. However, the data needed to determine if critical levels of endocrine disrupting compounds were exceeded starting in the early 1990's are not available.

  The status of the Harrison River stock potentially provides evidence against co-occurrence between the cause (endocrine disrupting compound exposure) and effect (reduced sockeye salmon abundance). Based on the available productivity data, it is apparent that the Harrison River stock has higher productivity than other sockeye salmon stocks in the Fraser River. For the co-occurrence between cause and effect to exist for the Harrison River stock, either its exposure to endocrine disrupting compounds and other contaminants would need to be lower than that for other sockeye salmon stocks or a factor that triggers mortality in sockeye salmon exposed to these contaminants would need to be absent for this stock. Although little is known about exposure of Harrison River sockeye salmon during freshwater residence, it could be postulated that this stock receives increased exposure to endocrine disrupting compounds and/or other contaminants of emerging concern while rearing in freshwater sloughs and backwaters within the Lower Fraser River Area of Interest (i.e., assuming that such areas are more contaminated by endocrine disrupting compounds than the lakes utilized by other sockeye salmon stocks). If this is true, then co-occurrence can only exist if Harrison River fish are not exposed to a supplemental factor (e.g., disease agent) that triggers mortality in other sockeye salmon stocks or their prolonged residence in the estuary provides some protection against acute infection by a disease agent. Alternatively, co-occurrence can exist for Harrison River fish if the freshwater sloughs in which they rear are actually less contaminated than other areas within the lower Fraser River and the fish have low exposure to endocrine disrupting compounds in the lower Fraser River due to their short migration to saltwater.

Data on the productivity of sockeye salmon stocks utilizing spawning and rearing habitats in other river systems may provide evidence against exposure to endocrine disrupting compounds and other contaminants of emerging concern as a causative factor in the decline of sockeye salmon in the Fraser River Basin. For example, Columbia River sockeye salmon generally demonstrated a trend toward increasing abundance during the period 1995 to 2008 (NOAA Fisheries 2009). The Pacific Salmon Commission (Gallaugher and Woods 2010) indicated that such improving productivity occurred despite considerable contamination in the Columbia River Basin. However, sockeye salmon in the Columbia River (i.e., Osoyoos /Skaha Lakes and Lake Wenatchee stock) are not directly exposed to contaminants originating in the Willamette River (i.e., Portland Harbor Superfund Site) and contamination of surface waters within the Hanford Reach is uncertain. Therefore, it is uncertain if the supposition of exposure to considerable contamination is directly relevant to upper Columbia River sockeye salmon stocks.

Peterman et *al.* (2011) also indicated that poor productivity of Smiths Inlet and Rivers Inlet sockeye stocks since the mid-1990's, despite little industrial development in these regions, provides evidence of the absence of co-occurrence between cause (exposure to contaminants) and effect (declines in sockeye salmon abundance). For this postulation to be correct, freshwater survival of sockeye salmon must not have been the limiting factor in the overall productivity of these stocks. The results of an analysis by McKinnell *et al.* (2001) appears to confirm that freshwater abundance of Owikeno Lake stocks (Rivers Inlet) has been relatively consistent between about 1970 and 1998. Therefore, declines in the abundance of these stocks since about 1970 are most likely the result of poor marine survival. The relevance of this comparison may be limited, however, because Fraser River sockeye salmon did not exhibit the consistent declines over the period 1970 to 1990 that were observed for Owikeno Lake fish (as would be expected if factors defining ocean conditions were the same for the two sockeye production areas). Hence, it is not clear that patterns of sockeye decline in the Smiths Inlet and Rivers Inlet sockeye stocks provide evidence for or against co-occurrence of cause and effect for Fraser River sockeye salmon stocks.

Collectively, the available data are not sufficient to demonstrate that co-occurrence between cause and effect do not exist for the general decline of sockeye salmon in the Fraser River over the past 20 years. Reliable exposure data are needed to further resolve this question.

There is no evidence that the low returns of sockeye salmon to the Fraser River in 2009 were the result of elevated exposure of smolts to endocrine disrupting compounds during the spring of 2007. Therefore, evidence of co-occurrence between cause and effect is not available for sockeye salmon returning to the river in 2009. Finally, returns of sockeye salmon to the Fraser River in 2010 were among the highest on record. However, there is not enough data available to suggest that these fish had lower exposure to endocrine disrupting compounds or other contaminants of emerging concern than the fish that returned to the river between 1990 and 2009. While exceptional ocean conditions could have compensated for contaminant-mediated mortality during ocean transition, such high returns generally argue against co-occurrence of cause and effect for contaminant exposures.

- Sufficiency - For a cause and effect relationship to exist, the intensity or frequency of a cause must be adequate to produce the observed magnitude of effect. Insufficient data are available to quantify exposures of Fraser River sockeye salmon to endocrine disrupting compounds or contaminants of emerging concern. However, exposure to certain endocrine disrupting compounds, such as PBDEs and PBBs, has likely increased exponentially over the past two decades (Johannessen and Ross 2002). Such increases in exposure is illustrated by levels of PBDEs in osprey eggs collected near Castlegar, British Columbia in 1991 and 1997 (BCMOE 2007). These data suggest that PBDE levels in freshwater fish (the principal component of osprey diets) have increased by nearly a factor of 30 (i.e., bird egg concentrations increased from 7.8 µg/kg WW in 1991 to 195 µg/kg in 1997; BCMOE 2007). Exposure to other contaminants that cause endocrine disruption (e.g., APEOs) has likely also increased over the past two decades. While evidence of increasing exposure to endocrine disrupting compounds and other contaminants of emerging concern provides some of the information needed to demonstrate sufficiency, actual exposure data and toxicity data are needed to determine if the concentrations of these contaminants in the Fraser River Basin are sufficient to cause the decline of Fraser River sockeye salmon over the past two decades.

  No data are available to demonstrate that endocrine disrupting compound concentrations in the study areas in 2007 were sufficient to cause the low returns of sockeye salmon to the river in 2009. Therefore, it is not possible to evaluate the sufficiency of the exposure to elicit the observed effects.

- Temporality - For a cause and effect relationship to exist, a cause must precede its effect. For endocrine disrupting compounds and contaminants of emerging concern, exposure occurs primarily within migration corridors within the upper Fraser River mainstem, the Thompson River mainstem, and the lower Fraser River. The results of several studies indicate that juvenile chinook salmon are exposed to endocrine disrupting compounds or other chemicals of potential concern during residence in contaminated estuaries. Mortality of these juvenile salmon occurs during transition to the marine environment, frequently in conjunction with infection by one or more disease agents (Varanasi *et al.* 1993). Therefore, the cause (i.e., exposure to endocrine disrupting compounds and contaminants of emerging concern with immunosuppressive effects) precedes the effect (i.e., mortality of salmon following entry into the marine environment). Such effects have not been demonstrated in sockeye salmon, however.

Adult sockeye salmon are exposed to certain contaminants (i.e., PCBs, PCDDs, and PCDFs) primarily during their residence in the marine environment. Additional exposure to these substances occurs during upstream migration. The physiological changes that occur during upstream migration result in the magnification of these contaminants in muscle and gonads. For the salmon that cover the greatest distance while migrating to their natal streams, the concentrations of these contaminants in eggs has the potential to increase to levels associated with toxicity. Therefore, the cause (exposure to contaminants) precedes the effect (increased egg mortality).

- Manipulation - For a cause and effect relationship to exist, changing the cause must change its effect. In the experiments conducted by Varanasi *et al.* (1993), juvenile chinook salmon collected from uncontaminated estuaries had survival rates that were similar to those observed to hatchery fish. Therefore elimination of the cause (i.e., exposure to endocrine disrupting compounds and/or other contaminants) reduced or eliminated the effects. These results provide strong causal evidence that exposure to endocrine disrupting compounds or other contaminants during estuarine residence cause mortality in juvenile chinook salmon during transition to marine conditions. This effect appears to be mediated by disease agents, such as *Listenella anguillarum* (the bacterium formerly known as *Vibrio anguillarum;* Arkoosh *et al.* 1998). While alteration of the cause altered the effect in other salmonids, such effects have not been demonstrated in sockeye salmon. In addition data to show that the cause was absent or reduced in 2008 are unavailable. Hence, the high returns of sockeye salmon to the river in 2010 are difficult to explain from a contaminant exposure perspective, unless ocean conditions were so favourable in 2008 and 2009 that they more than compensated for early life stage mortality.

- Coherance - For a cause and effect relationship to exist, the relationship between a cause and the effect must be consistent with scientific knowledge and theory. There is a substantial and growing body of knowledge demonstrating that exposure to endocrine disrupting compounds results in reduced immunocompetence in fish, including salmonids. In addition, the results of several studies show that such immunosuppression can lead to

> infection by various disease agents and that infections lead to increased mortality during the transition to residence in the marine ecosystem. Therefore, the relationship between cause and effect is consistent with the existing scientific data and information.

Peterman et *al.* (2011) indicated that it is highly unlikely that there were direct kills of sockeye salmon from exposure to toxic chemicals in the Fraser River. These authors also indicated that sublethal effects on sockeye salmon are possible and could be a secondary factor contributing to reduced productivity. Furthermore, the potential influence of persistent bioaccumulative and toxic contaminants (such as PCBs, PCDDs, and PCDFs) on the growth, development, and reproduction of sockeye salmon was identified. Evidence for such effects on sockeye salmon reproduction was provided by DeBruyn *et al.* (2004), who demonstrated that the levels of 2,3,7,8-TCDD toxic equivalents in sockeye salmon eggs can exceed the levels that are associated with increased egg mortality. Therefore, it is reasonable to believe that exposure to endocrine disrupting compounds and/or other contaminants could have caused or, more likely, contributed to declines of sockeye salmon in the Fraser River.

6.4 Summary

Insufficient data were available to evaluate relationships between exposure (i.e., concentrations in surface water, sediment, or fish tissues) and response (i.e., productivity indicators for Fraser River sockeye salmon) for any of the endocrine disrupting compounds and contaminants of emerging concern that were identified in the Fraser River Basin. Therefore, it is not possible to conclude that exposure to these contaminants caused the declines in the abundance of Fraser River sockeye salmon over the past two decades or the low returns of Fraser River sockeye salmon in 2009. In addition, the results of the ecoepidemiological evaluation indicate that it is unlikely that exposure to endocrine disrupting compounds or other contaminants of emerging concern is the sole cause of the observed patterns in sockeye salmon abundance. The lack of co-occurrence between possible exposure to such contaminants and the productivity of Harrison River chinook salmon provides evidence that contaminant-related effects may not be the most important factor controlling sockeye salmon abundance in the Fraser River. Nevertheless, traditional knowledge compiled by the Siska Traditions Society (2009) on physiological indicators reveals that the length, weight, and girth of sockeye salmon have changed over the last couple of decades. In addition, changes in skin condition (blotchy colour, increased scarring, scab formation, reduced slime) and in the colour of internal organs have been observed in recent years. Furthermore, feminization of one male sockeye salmon (i.e., a genetic male with ovaries) collected in 2007 was reported (Siska Traditions Society 2009). Such changes in salmon physiology are not unlike those that could occur in response to endocrine disrupting compounds and/or other contaminants.

Overall, the results of this evaluation also demonstrate that the contaminant exposures cannot be discounted as a potential contributing factor for responses of Fraser River sockeye salmon over the past two decades and/or for the low returns of sockeye salmon to the river in 2009. For all five lines-of-evidence, it was not possible to categorically disprove the hypothesis that exposure to endocrine disrupting compounds or other contaminants of emerging concern have contributed to the decline of Fraser River sockeye salmon. Therefore, it is concluded that exposure to endocrine disrupting compounds and/or other contaminants of emerging concern represents a possible contributing factor in the decline of sockeye salmon abundance in the Fraser River basin. The pathways through which such effects on sockeye salmon abundance could be expressed include:

- Immunosuppression due to exposure to endocrine disrupting compounds (such as PAHs, PCBs, PBDEs, and other endocrine disrupting compounds) during smolt outmigration and associated increased susceptibility to infection by disease agents, leading to higher rates of mortality;
- Reduced ability to adapt to conditions in marine ecosystems due to exposure to endocrine disrupting compounds (such as APEOs and associated metabolites) during smolt outmigration, an effect that is likely enhanced by increased susceptibility to infection by disease agents; and,
- Reduced survival of sockeye salmon eggs due to magnification of persistent, bioaccumulative, and toxic contaminants (such as PCBs, PCDDs, and PCDFs) in gonad tissues during upstream migration. This effect is likely to be most severe for those stocks that travel the longest distances during upstream migration.

In addition, it is possible that exposure of adult sockeye salmon to endocrine disrupting compounds and/or other contaminants of emerging concern in the lower Fraser River during upstream migration could result in some level of immunosuppression. Such effects could lead to increases in en-route and/or pre-spawning mortality, especially for those stocks that migrate upstream at times when water temperatures exceed 18º C (Hinch and Martins 2011). Such sockeye salmon adults would be particularly susceptible to infection by the pathogen, *Parvicapsula sp.* Resolving uncertainties regarding the nature, magnitude, and spatial extent of effects on Fraser River sockeye salmon associated with exposure to endocrine disrupting compounds and other contaminants of emerging concern will necessitate development and implementation of well-designed research and monitoring programs over the next ten years.

Chapter 7 Uncertainty and Data Gap Analysis

7.0 Introduction

There are a number of sources of uncertainty in assessments of risk to sockeye salmon associated with exposure to contaminants in the Fraser River Basin, including uncertainties in the conceptual model (i.e., pathway analysis), uncertainties in the effects assessment, and uncertainties in the exposure assessment. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and direction of such uncertainties. The purpose of this section is to evaluate the uncertainty in a manner that facilitates the attribution of the level of confidence that can be placed in the assessments conducted using the various lines of evidence. Accordingly, the uncertainties associated with the assessment of risks to Fraser River sockeye salmon are described in the following sections. Key data gaps are also identified.

7.1 Uncertainties Associated with the Conceptual Model

The conceptual model (i.e., including the pathways analysis) is intended to define the linkages between stressors, potential exposure, and predicted effects on ecological receptors. As such, the conceptual model provides the scientific basis for selecting assessment and measurement endpoints to support the risk assessment process. Potential uncertainties arise from lack of knowledge regarding ecosystem functions; failure to adequately address spatial and temporal variability in the evaluations of sources, fate, and effects; omission of stressors; and overlooking secondary effects (USEPA 1998). The types of uncertainties that are associated with the conceptual model used to link contaminant sources to effects on Fraser River sockeye salmon include those associated with the identification of chemicals of potential concern, environmental fate and transport of these chemicals, and exposure pathways.

Identification of chemicals of potential concern represents an important source of uncertainty in the conceptual model for the Fraser River Basin. In this study, an Inventory of Aquatic Contaminants was developed using information on the sources and releases of chemicals of potential concern based on the land-uses which comprise the Fraser River Basin. Information on land and water uses in the Fraser River Basin was acquired from many sources and verified using the results of an independent analysis conducted by Nelitz *et al.* (2010). As such, it is likely that the majority of potential sources of chemicals of potential concern were documented and that many of the chemicals that may have been released from these sources were identified. Nevertheless, it is possible that additional sources contributed one or more chemicals of potential concern to aquatic habitats within the study area. In particular, there is substantial uncertainty regarding the types and quantities of herbicides, fungicides, and insecticides that are currently being used within the watershed. In addition, limitations on the available source and monitoring data made it difficult to identify all of the pharmaceuticals and personal care products, endocrine disrupting compounds, and contaminants of emerging concern that could have been released within the study area. Nevertheless, the potential for missing possible risk drivers is likely low due to the breadth of the analysis that was conducted to develop the Inventory of Aquatic Contaminants.

Evaluation of the fate and transport of chemicals of potential concern also represents a source of uncertainty in the conceptual model. While a great deal is known about the environmental fate of many contaminants, such information is generally lacking for certain endocrine disrupting compounds and contaminants of emerging concern. As a result, partitioning and persistence of these contaminants is difficult to predict.

Identification of exposure pathways also represents a potential source of uncertainty in the conceptual model. In this assessment, it was assumed that surface water and sediments (and associated pore water) represent the most important pathways for exposing sockeye salmon to chemicals of potential concern. However, the importance of the sediment-based pathway is uncertain for most stocks. Hence, evaluation of risks to the sockeye salmon associated with exposure to sediments may not be directly relevant for many sockeye salmon stocks.

7.2 Uncertainties Associated with the Effects Assessment

The effects assessment is intended to describe the effects that are caused by stressors, link them to the assessment endpoints, and evaluate how effects change with fluctuations in the levels (i.e., concentrations) of the various stressors. There are several sources of uncertainty in the assessment of effects on aquatic receptors, including measurement errors, extrapolation errors, and data gaps.

In this investigation, the effects on sockeye salmon associated with exposure to chemicals of potential concern were evaluated using several types of information, including toxicity thresholds for surface water, toxicity thresholds for sediment chemistry, and toxicity thresholds for fish tissues. Two types of toxicity thresholds were established from the scientific literature for each chemical of potential concern in each exposure medium (i.e., surface water and sediments), including toxicity screening values and toxicity reference values. The toxicity screening values were intended to identify the concentrations of chemicals of potential concern below which adverse effects on aquatic organisms were unlikely to be observed (i.e., toxicity screening values represented no observed adverse effect concentrations). By comparison, toxicity reference values were intended to identify the concentrations of chemicals of potential concern below which adverse effects on sockeye salmon were unlikely to be observed (i.e., toxicity reference values represented salmonid-specific lowest observed adverse effect concentrations). As such, the benchmarks are not subject to measurement errors.

There are several sources of extrapolation errors in the effects assessment. The selected toxicity screening values are intended to represent no observed adverse effect concentrations. However, as the toxicity screening value is a conservative value, the actual effects thresholds for sockeye salmon could be higher. This limitation was mitigated by applying the toxicity screening values in a screening-level assessment only. By comparison, the toxicity reference values were intended to identify lowest observed adverse effect concentrations for sockeye salmon, or other salmonid species. Actual toxicity thresholds for sockeye salmon could be higher or lower than the selected toxicity reference values. As it was not possible to evaluate the reliability of the selected toxicity reference values, the level of uncertainty associated with the assessments of risks to sockeye salmon associated with exposure to surface-water or sediment, and associated with the accumulation of contaminants in fish tissues, cannot be determined.

Uncertainty in the effects assessments for aquatic receptors is also increased by gaps in the available data. Specific data gaps in the effects assessment are presented in Section 7.4. Such data gaps in the effects assessment (i.e., absence of toxicity screening values or toxicity reference values) generally results in under-estimating risks to sockeye salmon utilizing spawning, rearing, and migration habitats within the Fraser River Basin. That is, the effects of many chemicals of potential concern on the survival, growth, and reproduction of sockeye salmon could not be evaluated.

7.3 Uncertainties in the Exposure Assessment

The exposure assessment is intended to describe the actual or potential co-occurrence of stressors and receptors. As such, the exposure assessment identifies the exposure pathways and the intensity and extent of contact with stressors for each receptor or group of receptors at risk. There are a number of potential sources of uncertainty in the exposure assessment, including measurement errors, extrapolation errors, and data gaps.

In this assessment, exposure of sockeye salmon to chemicals of potential concern was evaluated using the results of chemical analyses of environmental media (i.e., surface water, sediment, and fish tissues). Analytical errors and descriptive errors represent potential sources of uncertainty for surface-water, sediment, and fish-tissue chemistry data. Three approaches were used to address concerns relative to these sources of uncertainty. First, analytical errors were evaluated using information on the accuracy, precision, and detection limits that were generated to support each of the studies represented in the project database (i.e., based on any metadata that were provided with the analytical results). The results of this analysis indicated that most of the data used in this assessment were likely to be reliable. Second, all data entry, data translation, and data manipulations were audited to assure their accuracy. Data auditing involved a check of approximately 10% of the data against the primary data sources. In addition, statistical analyses of resultant data were conducted to evaluate data distributions, generate summary statistics, and evaluate variability in the observations. As such, measurement errors in the surface-water, sediment, and fish-tissue chemistry data are considered to be of minor importance and are generally unlikely to substantially influence the results of the assessment (with mercury in water being a notable exception).

Extrapolation errors have the potential to influence the results of the assessment. These types of errors were minimized by using most of the data for evaluating exposure of ecological receptors to chemicals of potential concern in their original form. However, application of the total metals data in this way likely resulted in overestimation of the effects of metals on sockeye salmon, as particulate metal complexes are not highly bio-available. In addition, no exposure data were available for many chemicals of potential concern. For these substances (i.e., in-use pesticides), exposure was estimated based on product use patterns or trends in exposure intensity over time. In addition, available surface-water data were extrapolated spatially (i.e., to adjacent or hydrologically-connected waterbodies) to estimate exposure to sockeye salmon where data were not available. As a result, risks to ecological receptors may have been underestimated or overestimated for the chemicals of potential concern and areas of interest for which such extrapolations were made.

Data gaps also represent a source of uncertainty in the assessments of exposure for aquatic receptors. There were numerous data gaps that have the potential to influence the results of this assessment. These data gaps are explicitly identified in Section 7.4. Collectively, these limitations on the availability of exposure data almost certainly result in underestimates of the effects of contaminants on Fraser River sockeye salmon.

7.4 Key Data Gaps

The preliminary and detailed assessments of the potential effects of contaminants on Fraser River sockeye salmon (Chapters 4 and 5, respectively) were constrained by limitations on the availability of effects and exposure data. These data gaps are explicitly identified herein to provide a basis for identifying monitoring and research priorities that, if implemented, would reduce uncertainties in the assessment. This section presents the results of the data gap analysis, identifying the key data gaps that should be addressed to ensure that the necessary and sufficient data to conduct a thorough assessment of the role of contaminants in the decline of Fraser River sockeye salmon are available in the future. Information shortfalls that significantly affected our ability to conduct a comprehensive assessment of the effects on sockeye salmon associated with exposure to aquatic contaminants included gaps in the data on the composition of effluents, gaps in the spatial coverage of data, temporal coverage of data, availability of contaminant data, availability of environmental benchmarks, availability of information for assessing the interactive effects of multiple contaminants, and, finally, in the accessibility of environmental data.

7.4.1 Identification of Chemicals of Potential Concern

- Little information was located on the characteristics of wastewater discharges to the Fraser River. While limited information was available for many industrial sectors, no data were located for wood preservation, seafood processing, and most mining facilities.

7.4.2 Spatial Coverage of Environmental Data

- No water chemistry data were available for any life history period (e.g., spawning) for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch River, and Seton-Portage areas of interest.
- No sediment chemistry data were available for the following areas of interest within the Fraser River Basin: Upper Fraser River, Pitt River, Cultus Lake, Kakawa Lake, Nahatlatch River, Seton-Portage, North Thompson River,

Chilko River, Quesnel River, Nechako River, and Bowron River areas of interest, and the reference area (i.e., Fraser River at Red Pass).

- Data on the concentrations of chemicals of potential concern in surface water or sediments were not available for the majority of the stream reaches that are used for spawning and incubation by sockeye salmon in the study area (e.g., Upper Pitt River, Chilliwack River, Stuart Lake, tributaries to the Takla/Trembleur Lake system, Upper Adams River). Accordingly, exposure to chemicals of potential concern during spawning and incubation were estimated using data available for other locations (typically downstream or hydrologically-connected sites) in each area of interest. This extrapolation of the available data to upstream sites substantially increased uncertainty in the results of the exposure assessment for the spawning and incubation period.
- Data on the concentrations of chemicals of potential concern in surface water or sediments were not available for most of the nursery lakes or stream reaches that are used for freshwater rearing by sockeye salmon in the study area (e.g., Chilliwack Lake, Kakawa Lake, the Stuart/Takla/Trembleur Lake System, Adams Lake, Lilliooet Lake). Accordingly, exposure to chemicals of potential concern during freshwater rearing was generally estimated using data available for other locations (typically downstream or hydrologically-connected sites) in each AoI. This extrapolation of the available data to unsampled lacustrine sites substantially increased uncertainty in the results of the exposure assessment for the freshwater rearing period.
- Fish-tissue chemistry data were located for a limited number of sockeye salmon stocks (i.e., Early Stuart, Weaver, and Adams stocks) and a limited number of contaminants. No data were located on the levels of persistent bioaccumulative contaminants in the tissues of outmigrating smolts from the Fraser River. This limitation makes it difficult to evaluate exposure of sockeye salmon to persistent bioaccumulative contaminants. As a result, risks to sockeye salmon utilizing spawning and rearing habitats within numerous areas of interest could not be evaluated for bioaccumulative contaminants.
- Data were primarily collected for the purposes of environmental impact assessments, water quality objectives monitoring, trend analysis, compliance monitoring, and background characterization. As such, water quality sampling stations were only infrequently co-located with sockeye-use areas. As impacts to freshwater habitats can be localized, the available data may not accurately reflect the exposure scenarios for Fraser River sockeye salmon.

7.4.3 *Temporal Coverage of Environmental Data*

- Data on the concentrations of chemicals of potential concern in surface water and, to a lesser extent, sediments were available for many of the areas used as migration corridors by sockeye salmon. However the temporal coverage of environmental data in these areas was often limited and was not consistent across the study area. These limitations rendered uncertain the comparisons of exposure for the various sockeye salmon conservation units during smolt outmigration and adult upstream migration.
- While the requisite data may be available, information on the timing and specific habitat use by each sockeye salmon stock during downstream migration were not located. This limitation necessitated adoption of the assumption that outmigration timing and habitat use within the lower Fraser River was similar for all stocks, with the exception of the Harrison River stock. This assumption could result in erroneous conclusions regarding the role of contaminants in the decline of sockeye salmon if the various stocks have differential exposure to contaminants.

7.4.4 *Availability of Data on the Contaminant and Ancillary Variables*

- The assessment of exposure of sockeye salmon to contaminants of potential concern relies on the comparison of observed contaminant concentrations in environmental media (e.g., surface water and sediments) to environmental benchmarks. As many contaminants are influenced by the chemistry of the media, ancillary information on water quality and/or sediment quality is often needed to accurately characterize exposure. That is, data on ancillary variables (i.e., water hardness, temperature, and pH) are often required to calculate sample-specific benchmarks (i.e., toxicity screening values and/or toxicity reference values). The variables that fall into this category include ammonia, fluoride, aluminum, copper, lead, manganese, and nickel. Therefore, spatial and temporal coverage of ammonia, fluoride and some metals was limited to those stations and samples only for which the ancillary parameters were also measured.
- Calculation of the water quality index (Saffran *et al.* 2001) requires at least four independent measurements of at least four water quality variables for each period of time. As data on water quality variables were not consistent spatially or temporally for all stocks, the variables and samples used in the index calculations had the potential to be inconsistent within and between stocks from year-to-year.

- The majority of the available data on the levels of metals in surface water were generated using methods that measure extractable or total metal concentrations. However, the toxicity screening values and toxicity reference values selected for use in this investigation are based on the results of toxicity tests in which dissolved metal concentrations were measured. As extractable and total metals data may overestimate the biologically-available fraction under certain circumstances (i.e., high TSS load), evaluations based on such measurements likely overestimate risks to sockeye salmon. Therefore, limitations on the available data for dissolved metals represents an important data gap.
- No data were located on the levels of in-use herbicides, insecticides, fungicides, or other pesticides in water, sediment, or fish tissues for any location within the Fraser River Basin. Therefore, exposure of sockeye salmon to these contaminants can be only inferred from pesticide sales data.
- No surface-water chemistry or sediment chemistry data were located for many of the contaminants that are typically associated with pulp and paper mill wastewaters (e.g., resin acids, fatty acids, PAHs, plant sterols, degradation products of parent compounds). For phenols and chlorophenols, surface-water chemistry data were located for only a limited number of locations and for only a limited number of sampling dates. Similarly, only limited data were located to evaluate the concentrations of PCDD/PCDFs in sediments. In this assessment, it was assumed that sockeye salmon exposure to contaminants arising from pulp and paper mills has decreased over the past 15 to 20 years. However, this assumption may not be true for certain classes of contaminants such as plant sterols, or the degradation products of parent compounds that act as endocrine disruptors.
- No surface-water chemistry or sediment chemistry data were available for any of the contaminants that are typically associated with wood preservation facilities, with the exception of PCP. This represents a significant data gap because the most recent data available indicate that creosote, CCA, and DDAC are the top three pesticides used in British Columbia, based on sales data. Absence of data on the levels of these contaminants in the environment could result in significant underestimates of risks to sockeye salmon exposed to these substances.
- No data were located on the concentrations of surfactants (such as APEOs) or fire retardants (such as PBDEs, PBBs, or PFOS/PFOA) in surface water. Few data were located on the concentrations of these substances in sediments (PBDEs only) and fish tissues. As these classes of contaminants are widely

used, are persistent and bioaccumulative, are ubiquitously distributed, are increasingly being released into the environment (based on data for wildlife and humans), and may elicit endocrine disruptive effects, risks to sockeye salmon were likely underestimated due to the lack of data on concentrations of these contaminants in the environment.

- Data on the levels of hormones, pharmaceuticals, personal care products, disinfectants, disinfectant by-products and nanoparticles are generally lacking for the study area. As exposure of sockeye salmon to these contaminants could elicit a variety of adverse effects, the absence of data on these contaminants results in substantial uncertainties in the results of the current assessment of effects of contaminant exposure on Fraser River sockeye salmon.

7.4.5 Availability of Environmental Benchmarks

- Toxicity data for many of the aquatic contaminants identified in this investigation (e.g., PBDEs, PBBs, APEOs, pharmaceuticals, personal care products) are lacking or limited in the scientific literature. This general limitation makes it difficult to estimate hazards posed by such contaminants to fish and, hence, increases uncertainty in the current assessment.
- Numerical water quality guidelines and/or salmonid-specific toxicity thresholds were not located for many chemicals of potential concern identified in the Fraser River Basin. This limitation increased uncertainty in the evaluation of effects on sockeye salmon associated with exposure to surface water in the study area.
- Numerical sediment quality guidelines and/or salmonid-specific toxicity thresholds were not located for many chemicals of potential concern identified in the Fraser River Basin. This limitation increased uncertainty in the evaluation of effects on sockeye salmon associated with exposure to sediments in the study area.
- Numerical tissue-residue guidelines and/or salmonid-specific toxicity thresholds for fish tissues were not located for certain chemicals of potential concern (e.g., PBDEs) identified in the Fraser River Basin. This limitation increased uncertainty in the evaluation of effects on sockeye salmon associated with accumulation of bioaccumulative contaminants in their tissues.

7.4.6 *Information on Interactive Effects of Multiple Contaminants*

- Data on the interactive effects of contaminants (such as endocrine disruptors), disease agents, and water temperature on sockeye salmon are not available for the Fraser River Basin or elsewhere. As contaminants are likely to be contributing to, rather than causing, adverse effects of Fraser River sockeye salmon, the absence of data on such interactive effects during smolt transition to the marine environment and during upstream migration of adults, seriously limits evaluations of the cumulative effects of multiple stressors.

7.4.7 *Direct Evaluations of Effects on Sockeye Salmon*

- Data on the effects of exposure to contaminated surface water, exposure to contaminated sediments, or accumulation of contaminants in fish tissues on the survival, growth, or reproduction of sockeye salmon were generally unavailable in the literature. While limited monitoring of salmon morphology and/or physiology has been conducted (e.g., Siska Traditions Society 2009), direct measurement of contaminant-related effects on sockeye salmon are generally lacking. This represents a major data gap.

7.4.8 *Data Accessibility*

- It is likely that at least some of the information needed to fill the data gaps identified herein have been generated for the Fraser River basin. However, many agencies and regulated interests maintain their own databases that are not readily available to the public or do not have a systematic means of storing and retrieving such data. As such, it is difficult or impossible to assemble all of the information needed to conduct a comprehensive assessment of the risks posed to sockeye salmon associated with exposure to contaminants in the Fraser River Basin.

Chapter 8 Summary and Conclusions

8.0 Introduction

The productivity of sockeye salmon utilizing habitats within the Fraser River Basin has declined markedly over the past 20 years (Figure 1.1). Concerns over the productivity of Fraser River sockeye salmon intensified in 2007 and 2008, when low returns severely curtailed the fisheries on this species (McKinnell *et al.* 2011). The return of only 1.5 million adult sockeye salmon in 2009 - the lowest number since 1947, about 10% of the pre-season forecast of 10.5 million fish (Peterman *et al.* 2010) - reinforced these concerns and prompted the Governor General in Council to establish a Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (i.e., Cohen Commission). In accordance with its terms of reference, the Cohen Commission is:

- Considering the policies and practices of Fisheries and Oceans Canada with respect to the sockeye salmon fishery in the Fraser River;
- Evaluating the causes for the decline of Fraser River sockeye salmon;
- Investigating the current state of Fraser River sockeye salmon and the long-term projections for those stocks; and,
- Developing recommendations for improving the future sustainability of the sockeye salmon fishery in the Fraser River.

To assist it in fulfilling this mandate, the Cohen Commission have engaged a team of scientists to evaluate the potential causes of the decline of Fraser River sockeye salmon. This study was conducted to develop an Inventory of Aquatic Contaminants for the Fraser River Basin and to evaluate the potential effects of those contaminants on Fraser River sockeye salmon (See Appendix 1 for information on the Statement of Work for this project). To achieve these objectives, a work plan was developed that consisted of four distinct tasks, including:

- Preparation of an Inventory of Aquatic Contaminants in the Fraser River in relation to the distribution of sockeye salmon conservation units;
- Comparison of data on water quality conditions in the Fraser River to toxicity data for sockeye salmon;

- Development of an overall assessment of the suite of contaminants (e.g., metals, pesticides) and natural substances (e.g., TSS) that are encountered by juvenile and adult sockeye salmon; and,
- Evaluation of the extent to which reductions in Fraser River sockeye salmon abundance are associated with contaminant conditions in the Fraser River.

8.1 Study Approach

A step-wise approach was developed to evaluate the potential effects on Fraser River sockeye salmon associated with exposure to contaminants. Implementation of the approach necessitated completion of the following steps:

- Identification of the areas and times that sockeye salmon could be exposed to aquatic contaminants in the Fraser River Basin (this information was used to define the geographic and temporal scope of the study);
- Identification of the chemical substances and natural variables that have been released into the Fraser River or its tributaries due to human activities (this list of substances was termed the Inventory of Aquatic Contaminants, which are also referred to as chemicals of potential concern);
- Determination of whether any of the chemicals of potential concern have occurred in surface water, sediment, or fish tissues at levels sufficient to pose potential threats to aquatic organisms (this assessment was termed the preliminary evaluation of chemicals of potential concern and resulted in identification of contaminants of concern that required further evaluation);
- Determination of whether the concentrations of any of the contaminants of concern in surface water, sediment, or fish tissues in the Fraser River or its tributaries were sufficient to adversely affect the survival, growth, or reproduction of sockeye salmon (this assessment was termed the evaluation of contaminants of concern);
- Evaluation of the potential effects of endocrine disrupting chemicals and other contaminants of emerging concern on sockeye salmon;
- Identification of uncertainties in the assessment and key data gaps; and,
- Development of conclusions and recommendations relative to the effects of contaminants on Fraser River sockeye salmon.

8.2 Temporal and Spatial Scope of Study

Adverse effects on ecological receptors can occur when stressors and receptors are present in the same place and at the same time. As such, determination of exposure of sockeye salmon to contaminants in the Fraser River Basin requires an understanding of the life history of this species. Based on a review of the literature on life history characteristics, four key time periods when sockeye salmon could be exposed to contaminants in freshwater habitats were identified, including:

- Spawning and incubation of sockeye salmon eggs and alevins in stream and lakeshore habitats (August 1 to May 31);
- Early rearing of sockeye salmon fry in nursery lakes (April 1 to March 31);
- Downstream migration of sockeye salmon smolts through riverine and estuarine (i.e., Fraser River and tributaries) habitats (May 1 to June 30); and,
- Upstream migration of sockeye salmon adults through estuarine and riverine (i.e., Fraser River and tributaries) habitats (June 1 to September 30).

Sockeye salmon utilize spawning and rearing habitats throughout much of the Fraser River Basin. In addition, juvenile and adult sockeye salmon utilize migration corridors within the basin. Sockeye salmon can be exposed to aquatic contaminants in spawning habitats, rearing habitats, and/or migration corridors. Therefore, it is necessary to identify key exposure areas within the Fraser River Basin that are relevant to the various sockeye salmon conservation units. These exposure areas, which are referred to as areas of interest, are shown in Figure 2.3.

8.3 Aquatic Contaminant Inventory

Land use information was compiled for each of the areas of interest within the study area (Table 3.25; Figures 3.22 to 3.36). In addition, the chemicals that may be released to aquatic ecosystems in conjunction with these land uses were identified (Table 3.26). This information on sources and releases of contaminants was then integrated to identify the substances that may have been released into aquatic ecosystems within each area of interest and the Fraser River Basin as a whole (i.e., Table 3.27). All of the substances included in the Inventory of Aquatic Contaminants (Table 3.28) were considered to be chemicals of potential concern in the Fraser River Basin.

8.4 Preliminary Evaluation of Chemicals of Potential Concern

The Inventory of Aquatic Contaminants identifies over 200 chemical substances (termed chemicals of potential concern) that have been released or are likely to have been released into aquatic habitats within the Fraser River Basin. As it is challenging to conduct a detailed evaluation of the effects of each of these chemicals on sockeye salmon, a commonly-utilized screening procedure was applied to identify the substances that occur in abiotic environmental media (i.e., surface water or sediment) at concentrations sufficient to pose potential risks to sockeye salmon utilizing habitats in the study area. This procedure consisted of five general steps, including:

- Pathway Analysis (which was conducted to identify potentially-complete exposure pathways through which sockeye salmon could be exposed to the chemicals of potential concern);
- Effects Assessment (which was conducted to identify conservative thresholds for adverse effects on aquatic organisms, which are termed toxicity screening values; TSVs);
- Exposure Assessment (which was conducted to identify the concentrations of chemicals of potential concern that sockeye salmon could be exposed to, which are termed exposure point concentrations or EPCs);
- Hazard Evaluation [which was conducted to identify the substances that occur in one or more media types at concentrations sufficient to pose potential risks to sockeye salmon; i.e., by calculating hazard quotients, (HQs), where HQ = EPC/TSV]; and,
- Uncertainty Analysis (which was conducted to identify the substances for which insufficient information was available to determine if they pose potential risks to sockeye salmon).

The screening-level assessment was designed to provide a consistent basis for identifying all of the chemicals of potential concern that pose potential risks to sockeye salmon utilizing spawning and incubation habitats, rearing habitats, and migration corridors within the Fraser River Basin. Accordingly, conservative assumptions were used in the effects and exposure assessments (i.e., the maximum concentration measured for each habitat type in each area of interest was selected as the exposure point concentration for each chemical of potential concern; estimates of no-effect concentrations for aquatic organisms were selected as the toxicity screening values). Chemicals for which all measured concentrations were below the corresponding no-effect concentrations were considered to be unlikely to cause adverse effects on sockeye salmon within the Fraser River Basin and were not considered further in the investigation. Chemicals for which one or more measured concentrations exceeded the selected toxicity screening value were identified as contaminants of concern and subjected to further evaluation. Chemicals for which insufficient information was available to complete the assessment were identified as uncertain contaminants of concern and were evaluated using qualitative analyses.

The results of the preliminary assessment indicate that a number of chemicals of potential concern pose potential risks to sockeye salmon utilizing habitats within the Fraser River Basin. The water-borne and sediment-associated substances with hazard quotients > 1.0 for one or more areas of interest included:

Water Contaminants of Concern

- Conventional Variables (TSS, turbidity, pH)
- Nutrients (nitrate, nitrite, phosphorus);
- Major Ions (chloride, fluoride, sulphate)
- Metals (aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, silver); and,
- Phenols.

Sediment Contaminants of Concern

- Metals (cadmium, chromium, copper, iron, nickel);
- Phthalates (BEHP); and,
- PAHs [acenaphthalene, benz(a)anthracene, and dibenz(a,h)anthracene].

These substances were retained for further evaluation in the detailed assessment of risks to sockeye salmon in the Fraser River Basin. Many other substances have the potential to adversely affect Fraser River sockeye salmon, including organometals, cyanides, monoaromatic hydrocarbons, chlorinated and non-chlorinated phenolic compounds, resin and fatty acids, PBDEs, hormone mimicking substances, personal care products, and nanoparticles. However, insufficient data were available to characterize exposures to these contaminants and/or toxicity screening values were not located for these substances. As such, it was not possible to evaluate the hazards posed to sockeye salmon in the Fraser River associated with exposure to these contaminants. Accordingly, these substances were identified as uncertain contaminants of concern.

8.5 Evaluation of the Potential Effects of Contaminants of Concern on Fraser River Sockeye Salmon

A risk-based approach was used to evaluate the potential effects on sockeye salmon associated with exposure to contaminants of concern in the Fraser River Basin. This approach involved:

- Refining the list of contaminants of concern;
- Estimating more realistic exposure point concentrations;
- Identifying salmonid-specific toxicity thresholds; and,
- Calculating effect-based hazard quotients.

Three types of data were used to evaluate risks to sockeye salmon associated with exposure to contaminants of concern, including surface-water chemistry, sediment chemistry, and fish-tissue chemistry data. The results of this assessment indicate that exposure to contaminated surface water and sediment, or accumulation of contaminants in fish tissues, pose potential hazards to sockeye salmon utilizing spawning, rearing, or migration habitats within the Fraser River Basin.

Comparison of surface-water chemistry data to the selected toxicity threshold indicate that exposure to surface water can adversely affect the survival, growth, or reproduction of Fraser River sockeye salmon. More specifically, concentrations of TSS, six metals (aluminum, chromium, copper, iron, mercury and silver), and phenols are sufficient to adversely affect sockeye salmon. However, the results of supplemental analysis of these data indicate that water quality conditions in freshwater habitats may not be the primary factor influencing sockeye salmon productivity in the study area. These supplemental results showed that water quality (as indicated by water quality index scores) does not exhibit strong temporal trends, as would be expected if the declines in sockeye salmon abundance over the past 20 years were primarily caused by water quality impairments. In addition, the productivity of sockeye salmon (as indicated by life-cycle Ricker residuals) was not correlated with water quality index scores in a way that would suggest that water quality conditions (as indicated by levels of conventional variables, major ions, nutrients, metals, or phenols) are playing a significant role in dictating sockeye salmon abundance. However, the results of the analysis and the limitations on the available data make it difficult to conclude that water quality is not a factor that has contributed to the declines of sockeye salmon in the study area since about 1990. Further evaluation is needed to elucidate the roles of suspended sediments in spawning habitats, sediment deposition in incubation habitats, and nutrients in rearing habitats on sockeye salmon productivity and abundance.

Exposure to contaminated sediments also has the potential to adversely affect sockeye salmon in the Fraser River basin. Although the available data were limited, the results of the risk assessment showed that iron and/or nickel occurred in sediments at concentrations sufficient to adversely affect exposed sockeye salmon in the Lower Fraser River and the South Thompson River areas of interest. However, it is unlikely that contaminated sediments represents a significant factor in the decline of sockeye salmon over the past 20 years because interactions between sockeye salmon and contaminated sediments are likely to be minimal under most circumstances and the identified contaminants of concern are not highly bioaccumulative. More information is needed to fully evaluate the potential effects of contaminated sediments on Fraser River sockeye salmon, however.

Accumulation of contaminants in fish tissues represents a potentially important factor influencing the status of sockeye salmon populations in the Fraser River Basin. The results of this evaluation showed that selenium occurred in salmon eggs at concentrations sufficient to adversely affect sockeye salmon reproduction. In addition, magnification of tissue 2,3,7,8-TCDD toxic equivalent levels during upstream migration could result in concentrations in roe sufficient to cause mortality of sockeye salmon eggs, particularly for upriver stocks. Furthermore, traditional knowledge compiled by the Siska Traditions Society (2009) suggests that sockeye salmon morphology and/or physiology has changed in recent years, potentially in response to contaminant exposures. While the magnitude and extent of such effects could not be determined with the available data, bioaccumulation-mediated effects could be important contributing factors to the decline of sockeye salmon in the Fraser River Basin over the past two decades. Of particular concern is the potential for interactive effects of elevated water temperatures, infection by various disease agents, and bioaccumulation of toxic substances.

8.6 Evaluation of Effects of Endocrine Disrupting Chemicals and Contaminants of Emerging Concern

Insufficient data were available to evaluate relationships between exposure (i.e., concentrations in surface water, sediment, or fish tissues) and response (i.e., productivity indicators for Fraser River sockeye salmon) for any of the endocrine disruption chemicals and contaminants of emerging concern that were identified in the Fraser River Basin. Therefore, it is not possible to determine if exposure to these contaminants caused the declines in the abundance of Fraser River sockeye salmon over the past two decades or the low returns of Fraser River sockeye salmon in 2009. In addition, the results of the ecoepidemiological evaluation indicate that it is unlikely that exposure to endocrine disrupting compounds or other contaminants of emerging concern is the sole cause of the observed patterns in sockeye salmon abundance. The lack of co-occurrence between possible exposure to such contaminants and the productivity of Harrison River chinook salmon provides evidence that contaminant-related effects may not be the most important factor controlling sockeye salmon abundance in the Fraser River. However, the results of this evaluation also demonstrate that the contaminant exposures cannot be ruled out as a potential contributing factor for responses of Fraser River sockeye salmon over the past two decades and/or for the low returns of sockeye salmon to the river in 2009. For all five lines-of-evidence, it was not possible to categorically disprove the hypothesis that exposure to endocrine disrupting compounds or other contaminants have contributed to the decline of Fraser River sockeye salmon. Therefore, it is concluded that exposure to endocrine disrupting compounds and/or other contaminants of emerging concern represents a possible contributing factor in the decline of sockeye salmon abundance in the Fraser River Basin.

8.7 Uncertainty and Data Gap Analysis

There are a number of sources of uncertainty in assessments of risk to the sockeye salmon associated with exposure to contaminants in the Fraser River Basin, including uncertainties in the conceptual model, uncertainties in the exposure assessment, and uncertainties in the effects assessment. As each of these sources of uncertainty can influence the estimations of risk, it is important to describe and, when possible, quantify the magnitude and direction of such uncertainties. The results of this assessment indicate that uncertainty associated with the conceptual model is generally low. However, both the effects assessment and exposure assessment have moderate to high levels of uncertainty, which limit the confidence that can be placed in the results of the assessment of risks to sockeye salmon associated with exposure to contaminants in the Fraser River Basin. The key data gaps that were identified are listed in Section 7.4 of this report.

8.8 Conclusions

This study was conducted to determine if exposure to aquatic contaminants has caused or substantially contributed to declines in the abundance of sockeye salmon over the past two decades and/or the low returns of sockeye salmon to the Fraser River in 2009. While limitations on the available data make it difficult to answer this question conclusively, the results of this study suggest that the exposure to contaminants in surface water, sediments, or fish tissues is not the primary factor influencing the productivity or abundance of Fraser River sockeye salmon. However, it is a strong possibility that exposure to the contaminants of concern and/or uncertain contaminants of concern (i.e., endocrine disrupting compounds and contaminants of emerging concern) has contributed to the decline of sockeye salmon abundance in the Fraser River Basin over the past 20 years. The pathways through which such effects on sockeye salmon could be expressed include:

- Decreased egg to fry survival due to exposure to suspended and deposited sediment during incubation;
- Decreased fry to smolt survival due to reduced productivity of nursery lakes in response to lower returns of adult sockeye salmon (i.e., depressed nutrient delivery from the marine environment);
- Decreased smolt survival due to exposure to toxic chemicals (such as metals and phenols) during downstream migration;
- Immunosuppression due to exposure to endocrine disrupting compounds (such as PAHs, PCBs, PBDEs) during smolt outmigration and associated increased susceptibility to infection by disease agents;
- Reduced ability to adapt to conditions in marine ecosystems due to exposure to endocrine disrupting compounds (such as APEOs and associated metabolites) during smolt outmigration, an effect that is likely enhanced by increased susceptibility to infection by disease agents;
- Reduced survival of sockeye salmon eggs due to magnification of persistent, bioaccumulative, and toxic contaminants (such as PCBs, PCDDs, and PCDFs) in gonad tissues during upstream migration. This effect is likely to be most severe for those stocks that travel the longest distances during upstream migration; and/or,
- Increased en-route and/or pre-spawning mortality associated with the interactive effects of compromised immunocompetance (resulting from exposure to endocrine disrupting compounds), elevated water temperatures, and infection by disease agents during upstream migration.

8.9 Recommendations

This evaluation of the effects of contaminants on Fraser River sockeye salmon was constrained by a number of key data gaps. As insufficient data were available to fully assess the role of contaminant exposures in the declines of sockeye salmon over the past two decades or the low returns of sockeye salmon to the Fraser River in 2009, several recommendations are offered to enhance the probability that the requisite data and information are available in the future. These recommendations include:

- Effluent monitoring programs for all industrial sectors should be reviewed and evaluated to determine if they provide the necessary and sufficient data to characterize effluents and evaluate effects on aquatic ecosystems. The results of such monitoring programs should be compiled in a single database that is publically accessible.
- Routine monitoring programs should be developed and implemented to provide the data needed to characterize exposure of sockeye salmon to aquatic contaminants in the incubation habitats, rearing habitats, and migratory habitats that are used by sockeye salmon conservation units;
- Such monitoring programs should evaluate water quality, sediment quality, and fish-tissue quality on temporal and spatial scales that are relevant for assessing effects on sockeye salmon and other key indicators of environmental quality conditions;
- Such monitoring programs should address the aquatic contaminants identified in this investigation. To help focus such monitoring programs, the contaminants of concern in each area of interest have been identified (Table 8.1). Near-term priorities should include TSS and streambed substrate quality monitoring in incubation habitats, nutrient monitoring in rearing habitats, dissolved metal monitoring in all habitats, and selenium, PCB, and PCDD/PCDF monitoring in all habitats, and selenium, PCB, and PCDD/PCDF monitoring in fish tissues. It is likely that well-designed surveys will be required to identify the appropriate scale of monitoring for endocrine disrupting compounds and contaminants of emerging concern;
- Ambient monitoring programs should also include direct measures of effects on sockeye salmon, such as morphology, physiology, en-route mortality, pre-spawn mortality, and egg viability;

- Coordination among government agencies and regulated interests should be improved to ensure the requisite data are being collected and are compiled into a single database or multiple databases that are compatible;
- Focussed research programs should be designed and implemented to fill specific data gaps relative to the toxicity of endocrine disrupting compounds and contaminants of emerging concern. As jurisdictions around the world have an interest in better understanding the effects of these contaminants on aquatic organisms, international collaboration on such research programs is strongly recommended;
- Studies should be conducted to evaluate the interactive effects of contaminants (such as endocrine disrupting compounds), disease agents, and/or water temperatures on sockeye salmon during outmigration of smolts and upstream migration of adults. Such studies should be conducted under a regional cumulative effects assessment program that is explicitly designed to evaluate the impacts of multiple disturbance activities within the river basin. While traditional approaches to effects assessment (such as laboratory toxicity tests and field studies) will continue to be important, it is likely that more sensitive tests will be needed to detect sub-lethal effects on sockeye salmon associated with exposure to endocrine disrupting compounds and/or contaminants of emerging concern. In this application, toxicogenomic approaches may be relevant for evaluating toxicant effects on gene expression (See Appendix 3 for more information); and,
- A screening survey should be conducted upstream and downstream of fish processing plants to evaluate the presence of sockeye salmon disease organisms during and following peak salmon (sockeye and other species) processing periods to determine if exposure to diseases from these sources is a factor in the long-term decline of Fraser River sockeye salmon.

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Tables

Table 2.1. Overview of 36 conservation units (CUs) for Fraser River sockeye salmon (Pestal and Cass 2009).

Management Group	CU label	CU type	# of Lakes	# of Sites	Escapement* Obs	Escapement* Avg(all)	Escapement* Latest	Freshwater Adaptive Zone	CU Rationale	Stock**
Early Stuart (EStu)	*Stuart-EStu	lake	1	2	13	59	2007	Middle Fraser	lake	Early Stuart
	Takla/Trembleur-EStu	lake	2	42	70	82,462	2007	Middle Fraser	lake complex	Early Stuart
Early Summer (ES)	Anderson-ES	lake	1	2	59	11,094	2007	Middle Fraser	lake	Gates
	Bowron-ES	lake	1	2-3	70	9,231	2007	Upper Fraser	lake	Bowron
	*Chilko-ES	lake	1	1	19	38,104	1989	Middle Fraser	lake	Chilko
	*Chilliwack-ES	lake	1	2	36	3,787	2007	Lower Fraser	lake	Early Summer Miscellaneous
	Francois-ES	lake	1	3-4	67	12,905	2007	Middle Fraser	lake	Nadina
	*Fraser-ES	lake	1	2	43	583	2005	Middle Fraser	lake	Early Summer Miscellaneous
	*Indian/Kruger-ES	lake	3	1	3	29	1986	Upper Fraser	lake	
	Kamloops-ES	lake	2	9	70	15,246	2007	North Thompson	lake	Raft, Fennel, ES Miscellaneous
	*Nadina-ES	lake	1	1	2	2,516	2001	Middle Fraser	lake	Nadina
	*Nahatlatch-ES	lake	1	2	33	4,540	2007	Fraser Canyon	lake	Early Summer Miscellaneous
	Pitt-ES	lake	1	2	69	28,648	2007	Lower Fraser	lake	Pitt
	Shuswap Complex-ES	lake	8	21-27	66	47,614	2007	South Thompson	lake complex	Scotch, Seymour, ES Misc.
	*Taseko-ES	lake	1	1-2	43	3,286	2007	Middle Fraser	lake	Early Summer Miscellaneous
Summer (S)	Chilko-S	lake	1	3	70	332,114	2007	Middle Fraser	lake	Chilko
	*Francois-S	lake	1	3	9	273	2002	Middle Fraser	lake	Stellako
	Fraser-S	lake	1	1	70	96,733	2007	Middle Fraser	lake	Stellako
	*Mckinley-S	lake	1	1	19	4,432	2007	Middle Fraser	lake	Quesnel
	Quesnel-S	lake	4	51-66	67	293,220	2007	Middle Fraser	lake	Quesnel
	Stuart-S	lake	1	5	64	79,565	2007	Middle Fraser	lake	Late Stuart
	Takla/Trembleur-S	lake	2	4-5	67	48,254	2007	Middle Fraser	lake complex	Late Stuart
Late (L)	Cultus-L	lake	1	1	70	13,805	2007	Lower Fraser	lake	Cultus
	Harrison (D/S)-L	lake	1	6-8	68	3,276	2007	Lower Fraser	lake	Misc. non-Shuswap
	Harrison (U/S)-L	lake	1	4	70	37,636	2007	Lower Fraser	lake	Weaver
	*Kamloops-L	lake	1	1	48	11,853	2006	South Thompson	lake	Misc. Shuswap
	*Kawkawa-L	lake	1	1-2	8	503	1991	Fraser Canyon	lake	

Table 2.1. Overview of 36 conservation units (CUs) for Fraser River sockeye salmon (Pestal and Cass 2009).

Management Group	CU label	CU type	# of Lakes	# of Sites	Escapement* Obs	Escapement* Avg(all)	Escapement* Latest	Freshwater Adaptive Zone	CU Rationale	Stock**
Late (continued)	Lillooet-L	lake	1	8	70	90,409	2007	Lillooet	lake	Birkenhead
	Seton-L	lake	1	1	60	6,073	2007	Middle Fraser	lake	Portage
	Shuswap Complex-L	lake	1	44-58	70	645,208	2007	South Thompson	lake complex	Late Shuswap, Misc. Shuswap
River	*Fraser Canyon	river	-	6	10	3,662	1991	Fraser Canyon	ecotypic	
	*Lower Fraser	river	-	5	70	21,689	2007	Lower Fraser	genetics	Harrison
	*Middle Fraser	river	-	8-10	36	1,185	2007	Middle Fraser	timing + gen. ecotypic, gen. similar to NFR, diff. timing	Stellako, Quesnel
	*Thompson	river	-	2	4	4,255	1991	N&S Thompson		
	*Upper Fraser	river	-	1	1	2	1984	Upper Fraser	ecotypic, status uncertain	
	*Widgeon	river	-	1	65	694	2007	Lower Fraser	genetics	Misc. non-Shuswap
		Total Sites: 271-275								

* Refer to Section 2.2.1 of Pestal and Cass (2009) for comments on these CUs and corresponding escapement data.
** Stocks currently used for forecasts and spawner-recruit models (e.g. DFO 2009). Refer to Section 2.2.2 of Pestal and Cass (2009) for comments.

Table 2.2. Sampling sites for Early Stuart and Early Summer conservation units (CUs; Pestal and Cass 2009).

CU label	Sites	Stock**
*Stuart-EStu	Nahounli Creek, Sowchea Creek	Early Stuart
Takla/Trembleur-ESstu	15 Mile Creek, 25 Mile Creek, Ankwill Creek, Bates Creek, Bivouac Creek, Blackwater Creek, Blanchette Creek, Casimir Creek, Consolidate Creek, Crow Creek, Driftwood River, Dust Creek, Fleming Creek, Forfar Creek, Forsythe Creek, French Creek, Frypan Creek, Gluske Creek, Hooker Creek, Hudson Bay Creek, Kastberg Creek, Kazchek Creek, Kotsine River, Leo Creek, Lion Creek, Maclaing Creek, Mcdougall Creek, Middle River-Rossette Bar, Narrows Creek, O'Ne-Ell Creek, Paula Creek, Point Creek, Porter Creek, Sakeniche River, Sandpoint Creek, Shale Creek, Sidney Creek, Sinta Creek, Takla Lake- Unnamed Creek (North of Blanchette), Tildesley Creek, Tliti Creek, Van Decar Creek	
Anderson-ES	Gates Channel, Gates Creek	Gates
Bowron-ES	Antler Creek, Bowron River, Huckey Creek	Bowron
*Chilko-ES	Chilko Lake-South End	Chilko
*Chilliwack-ES	Chilliwack Lake, Chilliwack River-Upper	Early Summer Miscellaneous
Francois-ES	Nadina River, Nithi River, Tagetochlain Creek	Nadina
*Fraser-ES	Endako River, Ormond Creek	Early Summer Miscellaneous
*Indian/Kruger-ES	Indianpoint Creek	
Kamloops-ES	Barriere River, Clearwater River, Fennell Creek/Saskum Creek, Finn Creek, Harper Creek, Lemieux Creek, Mann Creek, North Thompson River, Raft River	Raft, Fennel, ES Miscellaneous
*Nadina-ES	Glacier Creek	Nadina

Table 2.2. Sampling sites for Early Stuart and Early Summer conservation units (CUs; Pestal and Cass 2009).

CU label	Sites	Stock**
*Nahatlatch-ES	Nahatlatch Lake, Nahatlatch River	Early Summer Miscellaneous
Pitt-ES	Pitt Lake, Pitt River-Upper	Pitt
Shuswap Complex-ES	Adams River, Adams River-Channel, Adams River-Upper, Anstey River, Burton Creek, Bush Creek, Cayenne Creek, Celista Creek, Crazy Creek, Eagle River, Hiuihill Creek, Hunakwa Creek, Loftus Creek, Mcnomee Creek, Momich River, Monich River-Upper, Nikwikwaia Creek, Onyx Creek, Perry River, Ross Creek, Salmon River, Scotch Creek, Seymour River, Shuswap River-Middle, Sinmax Creek, Yard Creek, Crazy Creek	Scotch, Seymour, ES Miscellaneous
*Taseko-ES	Taseko Lake	Early Summer Miscellaneous

EStu = Early Stuart; ES = Early Summer; S = Summer;   L = Late.
* Refer to Section 2.2.1 of Pestal and Cass (2009) for comments on these CUs and corresponding escapement data.
** Stocks currently used for forecasts and spawner-recruit models (e.g. DFO 2009). Refer to Section 2.2.2 of Pestal and Cass (2009) for comments.

Table 2.3. Sampling sites for summer and late conservation units (CUs; Pestal and Cass 2009).

CU Label	Sites	Stock**
Chilko-S	Chilko Channels, Chilko Lake-North End, Chilko River	Chilko
*Francois-S	Francois Lake, Sweetnam Creek, Uncha Creek	Stellako
Fraser-S	Stellako River	Stellako
*Mckinley-S	Mckinely Creek-Upper	Quesnel
Quesnel-S	Abbott Creek, Amos Creek, Bill Miner Creek, Blue Lead Cr. - Lake shore, Blue Lead Creek, Bouldery Cr. - Lake shore, Bouldery Creek, Buckingham Creek, Cameron Creek, Deception Point, Devoe Cr. - Lake shore, Elysia - Shore 1 km west, Franks Creek, Goose Greek, Goose Point, Grain Cr. - Lake Shore, Grain Creek, Hazeltine Creek, Horsefly Channel, Horsefly River, Horsefly River-Upper, Isaiah Creek, Junction Creek, Junction Shore, Killdog Creek, Little Horsefly River, Long Cr. - Lake Shore, Long Creek, Lynx Cr. - Lake Shore, Lynx Creek, Marten Creek, Mckinley Creek, Mitchell River, Moffat Creek, Niagara Creek, North Arm - Unnamed Cove, Penfold Creek, Quesnel Lake, Roaring R. - Lake Shore, Roaring River, Service Creek, Spusks Creek, Sue Creek, Summit Creek, Taku Creek, Tasse Creek, Trickle Creek, Wasko Cr. - Lake Shore, Wasko Creek-Lower, Watt Creek, Whiffle Creek	Quesnel
Stuart-S	Kuzkwa River, Pinchi Creek, Sowchea Creek, Stuart Lake, Tachie River	Late Stuart
Takla/Trembleur-S	Dust Creek, Kazchek Creek, Middle River-Rossette Bar, Sakeniche River, Takla Lake	Late Stuart
Cultus-L	Cultus Lake	Cultus
Harrison (D/S)-L	Big Silver Creek, Cogburn Creek, Douglas Creek, Sloquet Creek, Tipella Creek, Trout Lake Creek	Miscellaneous non-Shuswap
Harrison (U/S)-L	East Creek, Steelhead Creek, Weaver Channel, Weaver Creek	Weaver
*Kamloops-L	South Thompson River	Miscellaneous non-Shuswap

Table 2.3. Sampling sites for summer and late conservation units (CUs; Pestal and Cass 2009).

CU Label	Sites	Stock**
*Kawkawa-L	Sucker Creek	
Lillooet-L	Birkenhead River, Green River, John Sandy Creek, Lillooet River-Upper, Miller Creek, Poole Creek, Ryan River, Sampson Creek	Birkenhead
Seton-L	Portage Creek	Portage
Shuswap Complex-L	Adams L. east side shore, Adams L. north end shore, Adams L. south end shore, Adams Lake, Adams River, Adams River-Shore, Adams River-Channel, Adams River-Upper, Anstey River, Besette Creek, Bush Creek, Bush Creek - Lake shore, Canoe Creek, Cayenne Creek, Celista Creek, Carzy Creek, Cruikshank Point West, Devoe Creek, Eagle River, Four Mile Creak - Shore, Hiuihill Creek, Hlina Creek - Shore, Hunakwa Creek, Knight Creek - Shore, Lee Creek - Shore, Little River, Mara Lake, Mcnomee Creek, Momich River, Momich River - Lake Shore, Nikwikwaia Creek, Noisy Creek, Onyx Creek, Onyx Creek - Shore, Pass Creek - Lake Shore, Perry River, Queest Creek - Shore, Reinecker Creek - Shore, Rienecker Creek, Ross Creek, Ross Creek - Shore, Salmon River, Scotch Creek, Scotch Creek - Shore, Seymour River, Shuswap L. main arm north shore, Shuswap L. main arm south shore, Shuswap L., Salmon Arm north shore, Shuswap L. Salmon Arm south shore, Shuswap Lake, Shuswap River-Lower, Shuswap River-Middle, Sinmax Creek, Tappen Creek, Tsuius Creek, Vanishing Creek - Shore, Wap Creek, Yard Creek.	Late Shuswap, Miscellaneous Shuswap

EStu = Early Stuart; ES = Early Summer; S = Summer; L = Late; U/S = Upstream; D/S = downstream.
* Refer to Section 2.2.1 of Pestal and Cass (2009) for comments on these CUs and corresponding escapement data.
** Stocks currently used for forecasts and spawner-recruit models (e.g. DFO 2009). Refer to Section 2.2.2 of Pestal and Cass (2009) for comments.

Table 2.4. Sampling sites for river-type conservation units (CUs; Pestal and Cass 2009).

CU label	Sites	Stock**
*Fraser Canyon	American Creek, Coquihalla River, Emory Creek, Silverhope Creek, Spuzzum Creek, Yale Creek	
*Lower Fraser	Chehalis River, Chilliwack/Vedder River, Harrison River, Maria Slough, Wahleach Creek	Harrison
*Middle Fraser	Bridge River, Cariboo River, Cayoosh Creek, Chum Creek, Lyon Creek, Nechako River, Seton And Cayoosh Creeks, West Road River, Yalakom River, Quesnel River	Stellako, Quesnel
*Thompson	Deadman River, Thompson River	
*Upper Fraser	Swift Creek	
*Widgeon	Widgeon Creek	Miscellaneous non-Shuswap

* Refer to Section 2.2.1 of Pestal and Cass (2009) for comments on these CUs and corresponding escapement data.
** Stocks currently used for forecasts and spawner-recruit models (e.g. DFO 2009). Refer to Section 2.2.2 of Pestal and Cass (2009) for comments.

Table 3.1. Listing of pulp and paper mills in the Fraser River Basin.

Area of Interest/ Company Name	Facility Name	Principal Products	Production (ADT[1]/Day)	Maximum Discharge Volume (m^3/d)	Variable Listed in Effluent Permit
Lower Fraser River					
Buckeye Canada	Delta Division	Paper	522	N/A	N/A
Norampac Burnaby - Cascades Canada Inc.	Burnaby Division (Previously Crown Paper)	Paperboard, linerboard, gypsumboard	N/A	12500	TSS, BOD5, pH, Temperature, DO, Conductivity, Fecal coliform bacteria
Kruger Products L.P.	Kruger Products (Previously Scott Paper)	Kraft pulp and recycled fibre	276	23,000	pH, Conductivity, Temperature, DO, Toxicity, TSS, BOD_5
Kruger Products L.P.	Carey Island Paper Mill	Paper	N/A	112 tonnes per year	Total Arsenic, Total Cadmium, Total Cobalt, Total Lead, Total Mercury, Total Molybdenum, Total Nickel, Total Selenium, Total Zinc, Total Chromium, Total Kjeldahl Nitrogen, Organic Matter, Moisture Content, pH, Fecal Coliforms
Kruger Products L.P.	Herrling Island Paper Mill	Paper	N/A	112 tonnes per year	Total Arsenic, Total Cadmium, Total Cobalt, Total Lead, Total Mercury, Total Molybdenum, Total Nickel, Total Selenium, Total Zinc, Total Chromium, Total Kjeldahl Nitrogen, Organic Matter, Moisture Content, pH, Fecal Coliforms
Lower Thompson River					
Domtar Inc.	Kamloops Cellulose Fibres (previously Weyerhaeuser)	Cellulose fibres: Papergrade bleached and semi-bleached softwood kraft (short and long fibre) pulp and specialty pulp grades	1250	273000	TSS, Conductivity, BOD, DO, pH, Colour, Temperature, Total phosphorus, Dissolved phosphorus, AOX

Table 3.1. Listing of pulp and paper mills in the Fraser River Basin.

Area of Interest/ Company Name	Facility Name	Principal Products	Production (ADT[1]/Day)	Maximum Discharge Volume (m^3/d)	Variable Listed in Effluent Permit
Quesnel River AoI					
West Fraser Mills Ltd.	Cariboo Pulp and Paper Company	Northern Bleached Softwood Kraft Pulp	950	118200	BOD, TSS, VSS, pH, AOX, Dioxin/Furan, Toxicity, 2,3,7,8-TCDD, 2,3,7,8-TCDF, Temperature, DO, Conductivity, Resin acids, Ammonia as N, Nitrite as N, Organic Nitrogen, Total phosphorus, Total P, Coliform (total and faecal)
West Fraser Mills Ltd.	Quesnel River Pulp	Chemi-Thermo-Mechanical Pulp (CTMP), and a Bleached Chemical Thermal Mechanical Pulp (BCTMP)	818 (as of 1993)	34000	TSS, Volatile suspended solids, Temperature, BOD, pH, DO, Orthophosphate, Kjeldahl nitrogen, Colour, Ammonia
Upper Fraser River AoI					
CANFOR Pulp Limited Parnership	Northwood Pulp Mill	Kraft Pulp	N/A	41	Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS)
CANFOR Pulp Limited Parnership	Prince George Pulp and Paper Mills	Bleach Kraft Pulp and Sack Kraft Paper	1530	240000	TSS, Volatile suspended solids, BOD, DO, Resin acids, AOX, Temperature, pH, Colour

[1]ADT = Air dried tonne.
For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.2. Chemicals of potential concern in pulp mill effluents (Suntio *et al.* 1988).

Acidic compounds
Formic acid
Acetic acid
Chloroacetic acid
Dichloroacetic acid
Trichloroacetic acid
Dichloropropenoic acid
Trichloropropenoic acid
Trichlorobutenoic acid
Tetrachlorobutenoic acid
Anteisoheptadecanoic acid
Arachidic acid
Behenic acid
Linoleic acid
Linolenic acid
Liquoceric acid
Oleic acid
Palmitic acid
Pinolenic acid
Stearic acid
Dichlorostearic acid
9,10-Epoxystearic acid
3-Hydroxypropanoic acid
Glyceric acid
3,4-Dihydroxybutanoic acid
Threonic acid
Erythronic acid
3-Deoxythreopentonic acid
3-Deoxyerythropentonic acid
Arabinoic acid
alpha-Glucoisosaccharic acid
beta-Glucoisosaccharic acid
Oxalic acid
Malonic acid
Chloromalonic acid
Succinic acid
Tartaric acid
Hydroxysuccinic acid
Fumaric acid
Chlorofumaric acid
Maleic acid
Chloromaleic acid
Dichloromaleic acid
3-Chloromuconic acid
Benzoic acid
Chloro-3,4-dihydroxybenzoic acid
Dichloro-3,4-dihydroxybenzoic acid (3 isomers)
Trichloro-3,4-dihydroxybenzoic acid
Dichloro-4-hydroxybenzoic acid
Chlorovanillic acid
Dichlorovanillic acid
Trichlorovanillic acid
Dichlorosyringic acid
Chloromethoxyprotocatechuic acid
Chloro-2-thiophenic acid
Dichloro-2-thiophenic acid
Abietic acid
Dehydroabietic acid
6,8,11,13-Dehydrodehydroabietic acid
Chlorodehydorabietic acid
12-Chlorodehydroabietic acid
16-Chlorodehydroabietic acid
Dichlorodehydroabietic acid
12,14-Dichlorodehydroabietic acid
Dihydroabietic acid
Isopimaric acid
Neoabietic acid
Pimaric acid
Palustric acid
Trichloro-2-oxo-3-pentenoic acid isomer 1
Trichloro-2-oxo-3-pentenoic acid isomer 2
5,5,5-Trichloro-2-oxo-3-pentenoic acid
3,4,5,5-Tetrachloro-2-oxo-3-pentenoic acid
Tetrachloro-2-oxo-3-pentenoic isomer 1
Tetrachloro-2-oxo-3-pentenoic isomer 2
3,4,5,5,5-Pentachloro-2-oxo-3-pentenoic acid
2-Furancarboxylic acid
2-Thiophenecarboxylic acid
Benzenedicarboxylic acid
Chlorothiophendicarboxylic acid

Phenolic compounds
2-Chlorophenol
3-Chlorophenol
4-Chlorophenol
2,3-Dichlorophenol
2,4-Dichlorophenol
2,5-Dichlorophenol
2,6-Dichlorophenol
2,3,6-Trichlorophenol
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,3,4,5-Tetrachlorophenol

Table 3.2. Chemicals of potential concern in pulp mill effluents (Suntio *et al.* 1988).

Phenolic compounds (continued)	*Neutral compounds*
2,3,4,6-Tetrachlorophenol	Arabinose (anhydro sugar)
2,3,5,6-Tetrachlorophenol	Xylose (anhydro sugar)
Pentachlorophenol	Glucose (anhydro sugar)
Dichlorocatechol (2 isomers)	Mannose (anhydro sugar)
3,4-Dichlorocatachol	Methanol
Trichlorocatechol (3 isomers)	Chloro-1-(2-hydroxy)-isopropyl-4-methyl benzene
3,4,5-Trichlorocatechol	Dichloro-1-(2-hydroxy)-isopropyl-4-methyl benzene (5 isomers)
3,4,6-Trichlorocatechol	1,3-Dichloro-2-propanol
Tetrachlorocatechol	1,1,3-Trichloro-2-propanol
3,4,5,6-Tetrachlorocatechol	Glyoxal
Guaiacol	Acetaldehyde
Chloroguaiacol	Chloroacetaldehyde
Dichloroguaiacol	Dichloroacetaldehyde
4,5-Dichloroguaiacol	Trichloroacetaldehyde
3,4,6-Trichloroguaiacol	2-Chloropropenal
3,4,5-Trichloroguaiacol	Chlorobutenal
4,5,6-Trichloroguaiacol	Dichlorobutenal
Tetrachloroguaiacol	Chlorobenzaldehyde
3,4,5,6-Tetrachloroguaiacol	Dichlorobenzaldehyde
6-Chlorovanillin	Furfurol
5,6-Dichlorovanillin	Chloroacetone
Dichlorovanillin	Dichloracetone
Trichlorovanillin	1,1-Dichloroacetone
3,5-Dichloro-4-hydroxybenzaldehyde	1,3-Dichloroacetone
Chloroprotocatechualdehyde	Trichloroacetone
Dichloroprotocatechualdehyde	1,1,1-Trichloroacetone
Chlorosyringealdehyde	1,1,3-Trichloroacetone
Dichlorosyringealdehyde	Tetrachloroacetone
Chloro-1,2,3-trihydroxybenzene	1,1,1,3-Tetrachloroacetone
Dichloro-1,2,3-trihydroxybenzene	1,1,3,3-Tetrachloroacetone
Trichloro-1,2,3-trihydroxybenzene	Pentachloroacetone
Chloro-1,2,4-trihydroxybenzene	Hexachloroacetone
Dichloro-1,2,4-trihydroxybenzene	2-Butenone
Trichloro-1,2,4-trihydroxybenzene	Trichlorocyclopropanone
3,4,5-Trichlorosyringol	Trichlorocyclobutenone
Dichloroacetosyringone	Dichlorocyclopentene-1,2-dione
Dichloro-1,2-dihydroxy-3-methoxybenzene	Trichlorocyclopentene-1,2-dione (2 isomers)
Chloro-3,4-dihydroxypropiophenone	Tetrachlorocyclopentene-1,2-dione
Dichloro-3,4-dihydroxypropiophenone (2 isomers)	Dichloro-1,2-benzoquinone
	Tetrachloro-1,2-benzoquinone
Chloropropioguaiacone (chloropropiovanillone)	3-Chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone
Dichloroconiferyl alcohol	Dichloroacetic acid methyl ester
Trichlorodehydroconiferyl alcohol	Chloroacetic acid ethyl ester
3,4,5-Trichloro-2,6-dimethoxyphenol	Dichloroacetic acid ethyl ester
3,5-Dichloro-2,6-dimethoxyphenol	Trichloroacetic acid ethyl ester
	Dichloromethane

Table 3.2. Chemicals of potential concern in pulp mill effluents (Suntio *et al.* 1988).

Neutral compounds (continued)	
Chloroform	Chlorocalamenene
Carbon tetrachloride	Bromocalamenene
Bromodichloromethane	Chlorodimethylpropyldihydronaphthalene
Dibromochloromethane	Dichlorodimethylpropyldihydronaphthalene
1,2-Dichloroethane	Dichlorodimethylpropylnapthalene
1,1,1-Trichloroethane	Terpenes
1,1,2,2-Tetrachloroethane	Chlorotrimethoxybenzene
Trichloroethene	Trichlorotrimethoxybenzene
Tetrachloroethene	1,1-Dichlorodimethylsulfone
Tetrachloropropene (3 isomers)	1,1,3-Trichlorodimethylsulfone
Pentachloropropene	Trichlorothiophene
Dichloropropadiene	Tetrachlorothiophene
Trichloropropadiene	Dichloro-2-formylthiophene
Tetrachloropropadiene	Trichloro-2-formylthiophene
Trichlorobutatriene (2 isomers)	2-Acetyldichlorothiophene (2 isomers)
Tetrachlorobutatriene	2-Acetyltrichlorothiophene
Pentachlorobutadiene (2 isomers)	Dichloro-2-propionylthiophene (2 isomers)
Methyl chlorobutene (5 isomers)	
Tetrachlorocyclopentadien	
Hexachlorohexatriene (5 isomers)	
Heptachlorohexatriene (2 isomers)	
Toluene	
Benzene	
Chlorobenzene	
1,2-Dichlorobenzene	
1,3-Dichlorobenzene	
1,4-Dichlorobenzene	
1,2,3-Trichlorobenzene	
1,2,4-Trichlorobenzene	
1,3,5-Trichlorobenzene	
1,2,3,4-Tetrachlorobenzene	
1,2,3,5-Tetrachlorobenzene	
1,2,4,5-Tetrachlorobenzene	
Pentachlorobenzene	
Hexachlorobenzene	
Ethyl benzene	
o-Cymene	
p-Cymene	
Chloro-p-cymene	
Chloro-p-cymene (1)	
Chloro-p-cymene (2)	
Dichloro-p-cymene	
Dichloro-p-cymene (1)	
Dichloro-p-cymene (2)	
Trichloro-p-cymene	
Calamenene	

Table 3.3. Listing of sawmills, plywood mills, and other wood product facilities in the Fraser River Basin.

Area of Interest/Company Name	Facility Name	Principal Products	Production (Tonnes/Year)	Effluent Permit	Maximum Discharge Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River						
Andersen Pacific Forest Products Ltd.	Andersen Pacific Forest Products Ltd.	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	Panel And Fibre Division	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	Uneeda Wood Products	N/A	N/A	N/A	N/A	N/A
Cascadia	New Westminster Division	N/A	N/A	N/A	N/A	N/A
CIPA Lumber Co. Ltd.	Annasis Island Veneer Plant	Lumber	N/A	PE-0182	28	pH, TSS, BOD5, Oil & grease, Temperature, Toxicity
Coastland Wood Industries Ltd.	Annacis Division	N/A	N/A	N/A	N/A	N/A
Delta Cedar Products	Delta Cedar	N/A	N/A	N/A	N/A	N/A
Haida Forest Products Ltd.	Haida Forest Products - Burnaby	N/A	N/A	N/A	N/A	N/A
International Forest Products Ltd.	Acorn Forest Products	N/A	N/A	N/A	N/A	N/A
International Forest Products Ltd.	Fraser Remanufacturing Division	White wood, lumber	N/A	PE-413/PE-412	61	Temperature, Oil & Grease, Flow
International Forest Products Ltd.	Mackenzie Seizai Division	N/A	N/A	N/A	N/A	N/A
International Forest Products Ltd.	Queensboro	N/A	N/A	N/A	N/A	N/A
International Forest Products Ltd.	Western Whitewood Division	N/A	N/A	N/A	N/A	N/A
International Forest Products Ltd.	Albion Cedar Division	N/A	N/A	N/A	N/A	N/A
International Forest Products Ltd.	Hammond Cedar Division	Lumber	N/A	PE-2756	2550	Temperature, Oil & grease, Toxicity, pH
Mackenzie Sawmill Limited	Mackenzie	N/A	N/A	N/A	N/A	N/A
Mill and Timber Products Ltd.	Mill And Timber Products Ltd.	N/A	N/A	N/A	N/A	N/A
Mill and Timber Products Ltd.	Panabode Remanufacturing Ltd.	N/A	N/A	N/A	N/A	N/A
Richmond Plywood Corp. Ltd.	Richmond Plywood	N/A	N/A	N/A	N/A	N/A
Slocan Forest Products	Uneeda Wood Products	N/A	N/A	N/A	N/A	N/A
Stave Lake Cedar Mills (1992) Inc.	Stave Lake Cedar Mill	N/A	N/A	N/A	N/A	N/A
Terminal Forest Products Ltd.	Terminal Forest Products Sawmill & Planer	N/A	N/A	N/A	N/A	N/A

Table 3.3. Listing of sawmills, plywood mills, and other wood product facilities in the Fraser River Basin.

Area of Interest/Company Name	Facility Name	Principal Products	Production (Tonnes/Year)	Effluent Permit	Maximum Discharge Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River (continued)						
Terminal Forest Products Ltd.	Mitchel Island Forest Products	N/A	N/A	N/A	N/A	N/A
Western Forest Products Inc.	Vancouver Silvertree Division	N/A	N/A	N/A	N/A	N/A
Weyerhaeuser Company Ltd.	K3 Specialties Division	N/A	N/A	N/A	N/A	N/A
Weyerhaeuser Company Ltd.	Northwest Hardwoods	N/A	N/A	N/A	N/A	N/A
Weyerhaeuser Company Ltd.	New Westminster Division	Cedar and Cyprus Lumber		PE-01664	320	Temperature, Oil & Grease, Flow, TSS, Total metals
Lower Thompson River						
Ainsworth Lumber Co. Ltd	Savona Plywood Division	N/A	N/A	N/A	N/A	N/A
Mill and Timber Products Ltd.	Aspen Planers Ltd.	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Nicola Valley Division	N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.	Chasm Sawmills	N/A	N/A	N/A	N/A	N/A
Weyerhaeuser Company Ltd.	Kamloops Sawmill	N/A	N/A	N/A	N/A	N/A
Nechako River						
Apollo Forest Products Ltd.	Sawmill/Planer Mill Operations	N/A	N/A	N/A	N/A	N/A
Babine Forest Products Ltd.	Babine Sawmill	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	Clear Lake	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	Fort St. James	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	Isle Pierre	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	Plateau Division	N/A	N/A	N/A	N/A	N/A
Cheslatta Forest Products Ltd.	Ootsa Lake Mill	N/A	N/A	N/A	N/A	N/A
Decker Lake Forest Products	N/A	N/A	N/A	N/A	N/A	N/A
Lakeland Mills Ltd.	Sawmill/Planer Mill Operations	N/A	N/A	N/A	N/A	N/A
Nechako Lumber Company Ltd	Nechako Lumber - Vanderhoof	N/A	N/A	N/A	N/A	N/A

Table 3.3. Listing of sawmills, plywood mills, and other wood product facilities in the Fraser River Basin.

Area of Interest/Company Name	Facility Name	Principal Products	Production (Tonnes/Year)	Effluent Permit	Maximum Discharge Volume (m^3/d)	Variables Listed in Effluent Permit
Nechako River (continued)						
Pope & Talbot Ltd.	Fort St. James Sawmill	N/A	N/A	N/A	N/A	N/A
Slocan Group	Plateau Division	N/A	N/A	N/A	N/A	N/A
Stuart Lake Lumber Company Ltd.	Stuart Lake	N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.	Fraser Lake Sawmills	N/A	N/A	N/A	N/A	N/A
West Hill Lumber (1988 Ltd.)						
North Thompson River						
Ainsworth Lumber Co. Ltd	Ainsworth Osb Division	N/A	N/A	N/A	N/A	N/A
Ainsworth Lumber Co. Ltd.	100 Mile House Osb Plant	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd	Vavenby	N/A	N/A	N/A	N/A	N/A
International Forest Products Ltd.	Adams Lake Lumber Division	N/A	N/A	N/A	N/A	N/A
Kamloops Forest Products Ltd	Kamloops Forest Products - Kamloops	N/A	N/A	N/A	N/A	N/A
Slocan Forest Products Ltd.	Vavenby Division	N/A	N/A	N/A	N/A	N/A
Slocan Group	Vavenby Division	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Louis Creek Division	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Heffley Creek Division	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Heffley Creek Division	N/A	N/A	N/A	N/A	N/A
Weldwood of Canada Ltd.	100 Mile House Sawmill	N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.	100 Mile Lumber - A Division Of West Fraser Mills Ltd.	N/A	N/A	N/A	N/A	N/A
Weyerhaeuser Company Ltd.	Vavenby Sawmill	N/A	N/A	N/A	N/A	N/A
Quesnel River						
Canadian Forest Products Ltd.	Quesnel Division	N/A	N/A	N/A	N/A	N/A
Quesnel Waste Disposal Ltd.	N/A	N/A	N/A	N/A	N/A	N/A
Slocan Group	Quesnel Division	N/A	N/A	N/A	N/A	N/A
Weldwood of Canada Ltd.	Quesnel Lumber	N/A	N/A	N/A	N/A	N/A

Table 3.3. Listing of sawmills, plywood mills, and other wood product facilities in the Fraser River Basin.

Area of Interest/Company Name	Facility Name	Principal Products	Production (Tonnes/Year)	Effluent Permit	Maximum Discharge Volume (m^3/d)	Variables Listed in Effluent Permit
Quesnel River (continued)						
West Fraser Mills Ltd.	West Fraser Mills - Quesnel Sawmill	N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.	Northstar Lumber, A Division Of West Fraser Mills Ltd.	N/A	N/A	N/A	N/A	N/A
Seton-Portage						
Ainsworth Lumber Co. Ltd	Lillooet Veneer Division	N/A	N/A	N/A	N/A	N/A
South Thompson River						
Eagle River Industries Inc.	Malakwa Division	N/A	N/A	N/A	N/A	N/A
Federated Co-operatives Ltd.	Sawmill	N/A	N/A	N/A	N/A	N/A
Federated Co-operatives Ltd.	Plywood Plant	N/A	N/A	N/A	N/A	N/A
Louisiana-Pacific Canada Ltd	Malakwa Division	N/A	N/A	N/A	N/A	N/A
North Enderby Timber Ltd.	North Enderby Timber Ltd - Enderby	N/A	N/A	N/A	N/A	N/A
Riverside Forest Products Ltd.	Lumby Division	N/A	N/A	N/A	N/A	N/A
Thompson River Veneer Products LP	TRVP	N/A	N/A	N/A	N/A	N/A
Upper Fraser River						
C & C Wood Products Ltd.	C & C Wood Products Ltd.	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd	Rustad	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd	North Central Plywood	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	Upper Fraser	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	Pg Sawmill	N/A	N/A	N/A	N/A	N/A
Canadian Forest Products Ltd.	North Central Plywood	N/A	N/A	N/A	N/A	N/A
Carrier Lumber Ltd.	Tabor Sawmill	N/A	N/A	N/A	N/A	N/A
Dunkley Lumber Ltd.	Dunkley Lumber - Prince	N/A	N/A	N/A	N/A	N/A

Table 3.3. Listing of sawmills, plywood mills, and other wood product facilities in the Fraser River Basin.

Area of Interest/Company Name	Facility Name	Principal Products	Production (Tonnes/Year)	Effluent Permit	Maximum Discharge Volume (m^3/d)	Variables Listed in Effluent Permit
Upper Fraser River (continued)						
Hauer Bros. Lumber Ltd.	Sawmill	N/A	N/A	N/A	N/A	N/A
Jackpine Engineered Wood Products Inc.	Jackpine Engineered Wood Products	N/A	N/A	N/A	N/A	N/A
Jackpine Forest Products Ltd.	Jackpine Forest Products	N/A	N/A	N/A	N/A	N/A
Lignum Ltd		N/A	N/A	N/A	N/A	N/A
Lytton Lumber Ltd	Lytton Lumber	N/A	N/A	N/A	N/A	N/A
McBride Forest Industries Ltd.	Mcbride	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Lakeview - Williams Lake	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Quest Wood Division	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Quest Wood Division	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Williams Lake (Creekside)	N/A	N/A	N/A	N/A	N/A
TOLKO Industries Ltd.	Soda Creek	N/A	N/A	N/A	N/A	N/A
Weldwood of Canada Ltd.	Quesnel Plywood	N/A	N/A	N/A	N/A	N/A
Weldwood of Canada Ltd.	Williams Lake Plywood	N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.	Westpine Mdf	N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.		N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.	West Fraser Mills - Williams Lake	N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.	Quesnel Plywood, A Division Of West Fraser Mills Ltd.	N/A	N/A	N/A	N/A	N/A
West Fraser Mills Ltd.	Williams Lake Plywood, A Division Of West Fraser Mills Ltd.	N/A	N/A	N/A	N/A	N/A

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.4. Listing of wood preservation facilities in the Fraser River Basin.

Area of Interest/Facility Name	Principal Products	Effluent Permit	Maximum Discharge Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River				
Western Cleanwood Preservers Ltd.	Wooden fences and posts, treated hemlock lumber, western-red cedar shingles and shakes,flame-proofing preparation	N/A	N/A	N/A
Stella-Jones Inc. (New Westminster Plant	Poles, piling, and timbers for industrial and railway market sectors	N/A	N/A	N/A
Western Pacific Wood Preservers Ltd.	Pressure treated lumber and plywood, wood utility poles (Douglas fir transmission and distribution poles), wood railroad ties (creosote, CuNap, and Penta crossties), Dricon fire retardant treated wood, Agricultural products such as fence and vineyard posts, landscape ties	N/A	N/A	N/A
Envirofor Preservers (BC) Ltd.	Preserved lumber for outdoor applications (fencing, landscaping and roofing)	N/A	N/A	N/A
Terminal Forest Products Ltd.	Western red-cedar products	N/A	N/A	N/A
Lower Thompson River				
Riverside Forest Products Ltd.	Lumber, plywood, veneer and wood chips	N/A	N/A	N/A
Tolko Industries Ltd.	Treated railroad ties, switch ties, piling, bridge timbers, as well as supply crossing planks and custom treatment	N/A	N/A	N/A
Nechako River				
Decker Lake Forest Products Ltd.	Treated poles	N/A	N/A	N/A
South Thompson River		N/A	N/A	N/A
Monte Lake Forest Products Inc.	Treated wood and lumber products	N/A	N/A	N/A
Paxton Forest Products Inc.	Treated posts and rails	N/A	N/A	N/A
Kamwood Products Ltd.	Treated wood and lumber products			
Upper Fraser River		N/A	N/A	N/A
Canadian Forest Products Ltd.	Pressure treated lumber	N/A	N/A	N/A
Northwood Inc.	Pressure treated lumber	N/A	N/A	N/A
Northwest Wood Preservers	Chemically treated wood products	N/A	N/A	N/A
Stella-Jones Inc. (Prince George Plant)	Poles and crossties for industrial and railway market sectors			

For sources of the above information see Appendix 5. NA = not available

Table 3.5. Listing of cement and concrete facilities in the Fraser River Basin.

Area of Interest/Facility Name	Principal Products	Production (m^3/yr)	Effluent Permit	Maximum Discharge Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River					
Lafarge Concrete	Portland Cement: Type 10 CSA, Type I ASTM, Type II AASHTO and Type 60	N/A	PE-2439	33	Oil & grease, TSS, pH
Lafarge Canada Inc.	Ready-mix concrete	N/A	PE-00042	6100	Mineral oil & grease, TSS, pH
Lehigh Northwest Cement Ltd. (Delta Cement Plant)	Bulk and bagged cement and concrete products & aggregates	N/A	N/A	N/A	N/A
Tilbury Cement Limited (Delta Cement Plant)	Portland Cement	N/A	PE-4513	18200	Oil & grease, Temperature
ARMTEC Holdings Ltd. (Previously called Con-Force Structures Ltd.)	Precast prestressed concrete construction for buildings, cladding, bridges, food processing, architectural, marine, parkade, schools	N/A	PE-02976	120	pH, Nonfilterable Residue, $BOD_{5,}$ Toxicity
RE-CON Building Products Inc (Abbotsford Plant)	FireFree (light-weight fibner cement product)	N/A	N/A	N/A	N/A
Rempel Bros. Concrere Ltd. (Delta Plant 8)	Ready-mix concrete products & concrete-related building materials	N/A	PE-12181	35	pH
Rempel Bros. Concrete Ltd. (Richmond Plant 9)	Ready-mix concrete products & concrete-related building materials	N/A	PE-1983	N/A	N/A
Lafarge Canada Inc. (Vancouver Cement Plant)	Ready-mix cement	N/A	PE-03432	87	pH, TSS, Mineral oil & grease
Yard-At-A-Time Concrete (1988) Ltd.	Ready-mix cement	N/A	PE-04923	3	pH
Lafarge Canada Inc.	Pre-Cast Concrete	N/A	PE-6835	35	pH, TSS, Mineral oil & grease
Lafarge Canada Inc. (Previously Valley Rite-Mix Ltd.) - Concrete Batch Plant	Ready-Mix Concrete	N/A	PE-7999	128	pH, TSS

Table 3.5. Listing of cement and concrete facilities in the Fraser River Basin.

Area of Interest/Facility Name	Principal Products	Production (m^3/yr)	Effluent Permit	Maximum Discharge Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River (continued)					
Rempel Bros. Concrete Ltd (Chilliwack)		N/A	PE-1982 & PE-04849	225 & 46	N/A
Ocean Construction Supplies Ltd. (Mitchell Island Plant)	Ready-mix concrete	N/A	PE-02273	46	pH
Coquitlam Concrete (1993) Ltd.	ready-mix concrete and precast concrete products	N/A	N/A	N/A	N/A
Valley Rite-Mix Ltd (Truck Washing Facility)	N/A	N/A	PE-5516	17	N/A
South Thompson River					
Lafarge Canada Inc. (Kamloops Cement Plant)	Portland Cement	N/A	N/A	N/A	N/A

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.6. Listing of seafood processing facilities located in the Fraser River Basin.

Area of Interest/Facility Name	Target Species	Effluent Permit	Max Effluent Volume (m^3/d)	Variables listed in Effluent Permit
Lower Fraser River				
Aero Trading Co. Ltd	Groundfish (not specified), Herring, Salmon	PE-07866	N/A	N/A
Arctic Pearl Ice & Cold Storage	Groundfish (not specified)	N/A	N/A	N/A
Arctic Seafoods Products		N/A	N/A	N/A
Azuma Foods (Canada) Co. Ltd.	Groundfish (not specified), Salmon	N/A	N/A	N/A
Bella Coola Fisheries Ltd.	Groundfish (not specified), Herring roe, Salmon	PE-5400	1400	BOD, TSS, Oil & grease, Residual chlorine, Temperature
Billingsgate Fish Limited	Groundfish (not specified), Salmon	N/A	N/A	N/A
Blundell Seafoods Ltd.	Groundfish (not specified), Salmon	N/A	N/A	N/A
Breakers Fish Company Ltd.	Cod, Dogfish, Flounder, Hake, Halibut, Pollock, Rockfish, Sablefish, Skate, Sole, Whiting	N/A	N/A	N/A
British Columbia Packers Ltd.	Salmon, Herring	PE-01830	11800	BOD, TSS, Oil & grease, Residual chlorine, Temperature
C.B. Island Fisheries Ltd.	Groundfish (not specified), Tuna, Salmon	N/A	N/A	N/A
Coastwise Processors Inc.	Salmon	N/A	N/A	N/A
Delta Pacific Seafoods Ltd.	Groundfish (not specified), Herring, Salmon	SC-100113-FSA	N/A	N/A
English Bay Seafoods (Intl) Ltd.	Cod, Halibut, Salmon	N/A	N/A	N/A
Fraser Seafood	Cod, Halibut, Rockfish, Tuna	N/A	N/A	N/A
Grand Hale Marine Products Co. L	Hake, Herring, Sardine, Salmon	N/A	N/A	N/A
Kanata Holdings Ltd. dba Orca	Groundfish (not specified), Salmon	N/A	N/A	N/A
Kawaki (Canada) Ltd.	Groundfish (not specified), Herring, Salmon	N/A	N/A	N/A
Leader Cold Storage Ltd.	Groundfish (not specified), Herring, Salmon	N/A	N/A	N/A
Lions Gate Fisheries Ltd.	Cod, Hake, Halibut, Pollock, Rockfish, Sole, Herring Roe, Arctic char, Sardine, Tuna, Salmon	PE-3139	800	BOD, TSS, Oil & grease, Residual chlorine
Majestic Seafood Products (2002)	Groundfish (not specified), Rockfish	N/A	N/A	N/A
Maple Seafood Inc.	Fin fish	N/A	N/A	N/A
New West Net Co. Ltd.	Salmon, Cod	PE-8167	22.7	BOD, pH, TSS

Table 3.6. Listing of seafood processing facilities located in the Fraser River Basin.

Area of Interest/Facility Name	Target Species	Effluent Permit	Max Effluent Volume (m^3/d)	Variables listed in Effluent Permit
Lower Fraser River (continued)				
North Delta Processing Ltd.	Hake, Halibut, Sablefish, Herring, Sardine, Tuna, Salmon	N/A	N/A	N/A
North -West Seafood Ltd.		N/A	N/A	N/A
Ocean Fisheries Ltd.	Groundfish (not specified), Cod, Dogfish, Flounder, Hake, Halibut, Pollock, Rockfish, Sablefish, Skate, Sole, Whiting, Herring, Salmon	PE-01975	7240	Temperature, Residual chlorine, 24 hour effluent volume
Oceanfood Industries Ltd.	Salmon	N/A	N/A	N/A
P & S Frozen Foods	Salmon	N/A	N/A	N/A
Pacific Point Seafoods Ltd.	Hake, Herring, Salmon	N/A	N/A	N/A
Ridley Ice & Cold Storage Ltd.		N/A	N/A	N/A
S.M. Products (B.C.) Ltd.	Groundfish (not specified), Halibut, Sablefish, Tuna, Salmon	PE-8430	29	BOD, TSS, oil and grease, toxicity
Sea World Trading Ltd.	Groundfish	N/A	N/A	N/A
Seagate Fisheries Ltd.	Groundfish (not specified), Herring	N/A	N/A	N/A
Seven Seas Fish Co. (2005) Ltd.	Groundfish (not specified), Tuna, Salmon	SC-100128-FSA	N/A	N/A
Shearer Seafood Products Ltd.	Salmon, Herring	PE-7785	4.6	pH, BOD5, TSS, residual chlorine
Soo Singapore Jerky Ltd.	Salmon	N/A	N/A	N/A
Tomiyama Enterprises Ltd.	Groundfish (not specified), Salmon	N/A	N/A	N/A
Tradition Seafood Specialties	Salmon	N/A	N/A	N/A
Upper Fraser River				
Siska Traditions Society	Salmon	N/A	N/A	N/A

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.7. Listing of major mining operations in the Fraser River Basin (facilities undergoing environmental assessment are also listed).

Area of Interest/ Company Name	Facility Name	Facility Category	Commodities Produced	Production Status	Maximum Discharge Volume (m^3/d)	Variables listed in Effluent Permit
Metal Mines						
Chilko River						
Taseko Mines Ltd.	Prosperity	Metal	Gold, Copper	Permitting or Environmental Assessment	N/A	N/A
Cultus Lake						
Sumas Shale Ltd.; Clayburn Industrial Group, and cement manfactuirer (partners)	Sumas Mountain	Industrial Mineral	Shale, Clay	Operating	N/A	N/A
Richmix Clays Ltd	Richmix Fireclay	Industrial Mineral	Shale, Clay	Not Operating	N/A	N/A
Harrison River						
Great Pacific Pumice Inc.	Mount Meager	Industrial Mineral	Pumice, Pozzolan		N/A	N/A
Lower Thompson River						
Criagmont Mines Joint Venture	Craigmont	Industrial/ Metal	Magnetite, Copper, Iron, Silver, Gold	Operating	N/A	N/A
Teck Resources	Highland Valley Copper	Metal	Copper, Molybdenum	Operating	1612	Total Copper, Molybdenum, Manganese, Iron, pH, Nitrates, Total N, Ammonia, Total Phosphorous, Dissolved Phosphorous, DO, Sulphate, Nitrates/Nitrites

Table 3.7. Listing of major mining operations in the Fraser River Basin (facilities undergoing environmental assessment are also listed).

Area of Interest/ Company Name	Facility Name	Facility Category	Commodities Produced	Production Status	Maximum Discharge Volume (m^3/d)	Variables listed in Effluent Permit
Lower Thompson River (continued)						
New Gold Inc.	New Afton	Metal	Copper, Gold, Ore	Permitting of Environmental Assessment	84,000	Flow, TSS, pH, Total Alkalinity, Specific Conductance, Sulphate, Total Phosphorous, Total Nitrogen, Ammonia, Nitrate/Nitrite, Hardness, Aluminum, Antimony, Arsenic, Cadmium, Calcium, Copper, Iron, Lead, Magnesium, Manganese, Molybdenum, Potassium, Selenium, Sodium, Zinc.
CP Rail	Walhachin Quarry	Industrial Mineral	Railroad Ballast	Operating	N/A	N/A
Graymont Western Canada Inc.	Pavillion Lime Plant	Industrial Mineral	Limestone, Aggregate	Operating	N/A	N/A
	Ranchlands	Industrial Mineral	Zeolite	N/A	N/A	N/A
IG Maching and Fibre Ltd. (IKO Industries Ltd.)	Ashcroft	Industrial Mineral	Aggregate	Operating	N/A	N/A
Nechako River						
	Dahl Lake	Industrial Mineral	Limestone, Aggregate	N/A	N/A	N/A
Imperial Metals Corporation	Huckleberry	Metal	Copper, Molybdenum, Silver, Gold	Operating	48,600	Copper Dissolved, Iron Dissolved, Zinc Dissolved, TSS, pH, NO_2
Thompson Creek Mining/Sojitz Corporation	Endako	Metal	Molybdenum, Copper, Zinc, Tungsten, Bismuth	Operating	189,000	pH, TSS, Conductivity, S04-Dissolved, Copper Dissolved, Iron Dissolved, Molybdenum Dissolved, Lead Dissolved, Total Cyanide.

Table 3.7. Listing of major mining operations in the Fraser River Basin (facilities undergoing environmental assessment are also listed).

Area of Interest/ Company Name	Facility Name	Facility Category	Commodities Produced	Production Status	Maximum Discharge Volume (m^3/d)	Variables listed in Effluent Permit
North Thompson River						
	Absorbent Products Ltd.	Mineral	Non-Metal Mines	N/A	N/A	N/A
Quesnel River						
Noble Metal Group Inc.	Keithley Creek	Metal	Gold	Not Operating	N/A	N/A
Imperial Metals	Mount Polley	Metal	Copper, Gold, Silver	Operating	2000	Nitrate, Orthophosphorus, Sulphate, Total Copper, Total Iron, Selenium
Barkerville Goldmines Ltd. (Previously 0847423 B.C. Ltd)	QR Mine & Mill	Metal	Gold Ore Mill and Cyanidation Plant	N/A	1800	Cyanide, pH, Dissolved sulphate, Ammonia nitrogen, Dissolve antimony, Dissolved arsenic, Dissolved Chromium, Dissolved cobalt, Dissolved copper, Dissolved iron, Dissolved manganese, Dissolved molybdenum, Dissolved nickel, Dissolved selenium, Dissolved silver, Dissolved zinc.
South Thompson River						
Lafarge Canada Inc	Falkland	Industrial Mineral	Gypsum, Anhydrite	Operating	N/A	N/A
Lafarge Canada Inc	Harper Ranch	Industrial Mineral	Limestone	Operating	N/A	N/A
Lafarge Canada Inc	Buse Lake	Industrial Mineral	Volcanic Ash, Silica, Kaolinite	Operating	N/A	N/A
Upper Fraser River						
CG Mining Ltd.	Wingdam Mine	Metal	Gold	N/A	11000	TSS, Total arsenic, Total Copper, Dissolved Iron, Total Manganese, Total Zinc, DO

Table 3.7. Listing of major mining operations in the Fraser River Basin (facilities undergoing environmental assessment are also listed).

Area of Interest/ Company Name	Facility Name	Facility Category	Commodities Produced	Production Status	Maximum Discharge Volume (m^3/d)	Variables listed in Effluent Permit
Upper Fraser River (continued)						
Taseko Mines Ltd.	Gribraltar	Metal	Copper, Molybdenum, Silver, Gold	Operating	190L/s	Gas pressure, TSS, Sulphate, Nitrate + nitrite, Ammonia, Ortho-phosphorus, D&T aluminum, D&T antimony, D&T arsenic, D&T barium, D&T Boron, D&T iron, D&T manganese, D&T cadmium, Total chromium, D&T calcium, D&T chromium, D&T cobalt, D&T copper, Total lead, Total mercury, D&T molybdenum, D&T nickel, D&T potassium, D&T selenium, D&T selenium, D&T strontium, Total zinc, Toxicity, Temperature, pH(field), Specific Conductivity (field), Hardness, Acidity, Alkalinity, DOC
Barkerville Goldmines Ltd.	Island Mountain and Mosquito Creek	Metal	Gold	N/A	N/A	N/A
N/A	East Anderson	Industrial Mineral	Granite, Dimension Stone, Building Stone	N/A	N/A	N/A
Lightweight Advanced Volcanic Aggregates	Nazko	Industrial Mineral	Aggregate, Pumice	Operating	N/A	N/A
N/A	Dome Creek	Industrial Mineral	Slate, Flagstone, Dimension Stone, Building Stone	N/A	N/A	N/A
N/A	Giscome	Industrial Mineral	Limestone	N/A	N/A	N/A

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.8. Major pipelines transporting oil or gas in the Fraser River Basin.

Name	Type	Areas of Interest Potentially Affected
Duke Energy Corp.	Gas Pipeline	Harrison River AoI, Kakawa Lake AoI, Lower Fraser River AoI, Lower Thompson River AoI, North Thompson River AoI, Nechako River AoI, Upper Fraser River AoI
Duke Energy Corp.	Gas Pipeline	Lower Fraser River AoI
Kinder Morgan Inc.	Gas Pipeline	Lower River, Pitt River AoI
Kinder Morgan Inc.	Gas Pipeline	Lower Thompson River AoI
Kinder Morgan Inc.	Gas Pipeline	Lower Thompson River AoI, South Thompson River AoI
Kinder Morgan Inc.	Gas Pipeline	South Thompson River AoI
Pacific Northern Gas Ltd.	Gas Pipeline	Nechako River AoI
Pacific Northern Gas Ltd.	Gas Pipeline	Nechako River AoI, Upper Fraser River AoI
Kinder Morgan Inc.	Oil Pipeline	Harrison River AoI, Lower Fraser River AoI, Lower Thompson River AoI, North Thompson River AoI, Pitt River AoI, South Thompson River AoI, Upper Fraser River AoI,
Kinder Morgan Inc.	Oil Pipeline	North Thompson River AoI, South Thompson River AoI, Upper Fraser River AoI
Pembina Pipeline Corp.	Oil Pipeline	Harrison River AoI, Kakawa Lake AoI, Lower Fraser River AoI, Lower Thompson River AoI, North Thompson River AoI, Nechako River AoI, Pitt River AoI, South Thompson River AoI, Upper Fraser River AoI, Quesnel River AoI

For sources of the above information see Appendix 5.

Table 3.9. Locations of gas plants, oil refineries, transmission facilities and delivery points in the Fraser River Basin.

Area of Interest/Company Name	Facility Name	Description	Type
Kakawa Lake			
Spectra Energy Transmission	Cs No.8B, Hope/Othello	Services to Oil & Gas Extraction	Transmission Facilities
Lower Fraser River			
Spectra Energy Transmission	Cs No. 9, Rosedale	Services to Oil & Gas Extraction	Transmission Facilities
Lower Thompson River			
Spectra Energy Transmission	Cs No. 6B, Lone Butte	Services to Oil & Gas Extraction	Transmission Facilities
Spectra Energy Transmission	Cs No. 7, Savona	Services to Oil & Gas Extraction	Transmission Facilities
Spectra Energy Transmission	Cs No. 8A, Kingsvale	Services to Oil & Gas Extraction	Transmission Facilities
Quesnel River			
Canadian Natural Resources Limited	Helmet C-35-K	Conventional Oil & Gas Extraction	Delivery Points
Upper Fraser River			
Canadian Natural Resources Limited	Hunter D-21-B/94-H-7	Conventional Oil & Gas Extraction	Transmission Facilities
Spectra Energy Transmission	Cs No. 4B, Hixon	Services to Oil & Gas Extraction	Transmission Facilities
Spectra Energy Transmission	Cs No. 5, Australian	Services to Oil & Gas Extraction	Transmission Facilities
Spectra Energy Transmission	Cs No. 6A, 150 Mi. House	Services to Oil & Gas Extraction	Transmission Facilities
Suncor Energy	Wolverine C-52 A/98-P-3	Conventional Oil & Gas Extraction	Transmission Facilities

For sources of the above information see Appendix 5.

Table 3.10. Locations of oil and gas well heads in the Fraser River Basin.

Area of Interst / Name	Well Status	Fluid Type	Operations Type
Chilko River			
AMOCO Redstone C- 075-A/093-B-04	Abandoned	Undefined	Undefined
BRC HTR Et al Redstone B- 091-D/092-O-14	Cancelled	Undefined	Undefined
BRC HTR Et al Redstone B- 066-D/092-O-14	Cancelled	Undefined	Undefined
BRC HTR Et al Redstone B- 082-C/092-O-14	Abandoned	Undefined	Undefined
BRC HTR Et al Chilcotin B- 022-K/093-C-09	Abandoned	Undefined	Undefined
BRC HTR Redstone D- 094-G/092-O-12	Abandoned	Undefined	Undefined
Lower Fraser River			
Royal City No.1 D- 080-H/092-G-03	Abandoned	Undefined	Undefined
Gulf Ridge No. 1 C- 085-G/092-G-03	Abandoned	Undefined	Undefined
Amarillo Siloani No. 1 C- 013-H/092-G-02	Abandoned	Undefined	Undefined
Fraser Valley Chilliwack D- 077-E/092-H-04	Abandoned	Undefined	Undefined
Suncor Pure Abbotsford B- 056-C/092-G-01	Abandoned	Undefined	Undefined
Nechako River			
Vieco Texacal Punchaw C- 038-J/093-G-06	Abandoned	Undefined	Undefined
Upper Fraser River			
Amarillo Kersley No. 1 C- 086-L/093-B-09	Abandoned	Undefined	Undefined
Amarillo Kersley No. 2 C- 084-D/093-B-16	Abandoned	Undefined	Undefined
Honolulu Nazko A- 004-L/093-B-11	Abandoned	Undefined	Undefined
BRC HTR Et al Nazko D- 096-E/093-B-11	Abandoned	Undefined	Undefined
BRC HTR ESSO Nazko B- 016-J/093-B-11	Abandoned	Undefined	Undefined
NGT Kersley D- 002-E/093-B-16	Abandoned	Undefined	Undefined
BRC HTR Nazko B- 048-C/093-B-11	Cancelled	Undefined	Undefined

For sources of the above information see Appendix 5.

Table 3.11. Listing of bulk storage and shipping facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Products Stored/Shipped
Cultus Lake		
Versacold Canada Corp. - Baker Facility	Refrigerated Warehousing, Storage, Shipping	Refrigerated and frozen-food products
Lower Fraser River		
Apps Cargo Terminals Inc.	Storage, Shipping, Warehousing	General (Not Specified)
Bridgeport Logistics Inc.	Storage, Shipping, Warehousing	General (Not Specified)
CTC Logistics (Canada) Inc.	Warehousing, Distribution	General (Not Specified)
Exel Global Logistics Canada Inc.	Manufacturing, Warehousing, Storage, Shipping	Automotive, chemical, consumer, energy, industrial, life sciences, retail, technology
Fraser Surrey Docks LP	Shipping (rail, water, road), Short-term Storage	General Cargo, Steel (steel plate, coil, pipe and wire rod), Forest Products (Lumber, Panel Products, Logs and Woodpulp)
Fraser Wharves Ltd.	Automobile Processing, Shipping	Vehicles
GL Distribution Ltd.	Warehousing, Storage, Distribution and Shipping	General (Not Specified)
Hutchison Cargo Terminal Inc.	Containers, Cargo, Freight, Storage	General (Not Specified)
Interactive Freight and Warehousing Ltd.	Warehousing, Distribution and Shipping	General (Not Specified)
Kinder Morgan - Burnaby Terminal	Distribution, temporary storage	Crude oil and refined products
Locher Evers International	Warehousing, Ocean Import and Export Freight, Shipping, Storage	General (Not Specified)
Seaville Transport Logistics Ltd.	Warehousing, Distribution, Shipping	General (Not Specified), imported goods
Terasen Pipelines (Trans Mountain) Inc.	Fuel Storage	Fuel
Van Waters & Rogers Ltd.	Warehousing, Storage	Chemicals (wholesale)
Vancouver Trucking Terminal	Storage,Warehousing, Distribution, Shipping	Automobile, heavy equipment loading/unloading, Specialized equipment/material distribution for construction industry
Versacold Canada Corp. - Cliveden Facility	Refrigerated Warehousing, Storage, Shipping	Refrigerated and frozen-food products
Versacold Canada Corp. - Corpak Facility	Refrigerated Warehousing, Storage, Shipping	Refrigerated and frozen-food products
Versacold Canada Corp. - Delta Facility	Refrigerated Warehousing, Storage, Shipping	Refrigerated and frozen-food products
Versacold Canada Corp. - Matsqui Facility	Refrigerated Warehousing, Storage, Shipping	Refrigerated and frozen-food products
Versacold Canada Corp. - Surrey Facility	Refrigerated Warehousing, Storage, Shipping	Refrigerated and frozen-food products

Table 3.11. Listing of bulk storage and shipping facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Products Stored/Shipped
Lower Fraser River (continued)		
Versacold Canada Corp. - Valley Facility	Refrigerated Warehousing, Storage, Shipping	Refrigerated and frozen-food products
West Point Terminal Inc.	Air Cargo (Warehouse, Storage, Distribution)	General (Not Specified), perishable and non-perishable cargo
Pitt River		
Canada West Warehousing Ltd.	Freight, Warehousing, Storage and Container services	General (Not Specified)

For sources of the above information see Appendix 5.

Table 3.12. **Listing of other manufacturing facilities in the Fraser River Basin.**

Area of Interest/Facility Name	Facility Type	Principal Products	Effluent Permit	Maximum Effluent Volume (m^3/d)	Variables Listed in Effluent Permit
Cultus Lake					
Armstrong Cheese Company Ltd.	Dairy Product Mfg.	Dairy Product (except Frozen & Fluid) Mfg.	N/A	N/A	N/A
Saputo Foods Ltd.	Dairy Product Mfg.	Dairy Product (except Frozen & Fluid) Mfg.	N/A	N/A	N/A
Sure-Gro Inc.	Pesticide, Fertilizer & Other Agr. Chem. Mfg.	Mixed Fertilizer Mfg.	N/A	N/A	N/A
Lower Fraser River					
Ahoy Industrial Corp Ltd	Steel Product Mfg. from Purchased Steel	Cold-Rolled Steel Shape Mfg.	N/A	N/A	N/A
Ampacet Canada Company	Plastic Product Mfg.	All Other Plastic Product Mfg.	N/A	N/A	N/A
Apex-Micro Manufacturing Corp.	Computer & Peripheral Equipment Mfg.	Computer & Peripheral Equipment Mfg.	N/A	N/A	N/A
Avcorp Industries Inc.	Aerospace Product & Parts Mfg.	Aerospace Product & Parts Mfg.	N/A	N/A	N/A
A-Z Sponge & Foam Products Ltd.	Plastic Product Mfg.	Urethane & Miscellaneous Foam Product Mfg.	N/A	N/A	N/A
Beaver Plastics Ltd.	Plastic Product Mfg.	Polystyrene Foam Product Mfg.	N/A	N/A	N/A
Belkorp Industries	Pulp, Paper & Paperboard Mills	Mechanical Pulp Mills	N/A	N/A	N/A
Bel-Par Industries Ltd.	Office Furniture (including Fixtures) Mfg.	Wood Office Furniture Mfg.	N/A	N/A	N/A
BPB Canada Inc.	Other Miscellaneous Mfg.	All Other Miscellaneous Mfg.	N/A	N/A	N/A
Bulldog Bag Ltd.	Other Miscellaneous Mfg.	All Other Miscellaneous Mfg.	N/A	N/A	N/A
Canada Bread	Bakeries & Tortilla Mfg.	Commercial Bakeries & Frozen Product Mfg.	N/A	N/A	N/A
Canada Metal (Pacific) Ltd.	Other Fabricated Metal Product Mfg.	All Other Misc. Fabricated Metal Product Mfg.	N/A	N/A	N/A

Table 3.12. Listing of other manufacturing facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Principal Products	Effluent Permit	Maximum Effluent Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River (continued)					
Canadian Autoparts Toyota Inc.	Alumina & Aluminum Production & Processing	Alum. Rolling, Drawing, Extruding & Alloying	N/A	N/A	N/A
Certainteed Gypsum Canada	Lime & Gypsum Product Mfg.	Gypsum Product Mfg.	N/A	N/A	N/A
CGC Inc.	Lime & Gypsum Product Mfg.	Gypsum Product Mfg.	N/A	N/A	N/A
Chemical Lime Company Of Canada Inc.	Lime & Gypsum Product Mfg.	Lime Mfg.	N/A	N/A	N/A
Clariant (Canada) Inc. Masterbatches Division	Plastic Product Mfg.	All Other Plastic Product Mfg.	N/A	N/A	N/A
Coca-Cola Bottling Company	Beverage Mfg.	Soft Drink & Ice Mfg.	N/A	N/A	N/A
Columbia Foam Inc.	Plastic Product Mfg.	Urethane & Miscellaneous Foam Product Mfg.	N/A	N/A	N/A
Corporate Images Holdings Partnership	Household & Inst. Furniture & Cabinet Mfg.	All Other Household Furniture Mfg.	N/A	N/A	N/A
Creation Technologies	Other Electrical Equipment & Component Mfg.	All Other Electrical Equip. & Component Mfg.	N/A	N/A	N/A
Creation Technologies	Other Electrical Equipment & Component Mfg.	All Other Electrical Equip. & Component Mfg.	N/A	N/A	N/A
Crescent Custom Yachts Inc.	Other Miscellaneous Mfg.	All Other Miscellaneous Mfg.	N/A	N/A	N/A
Crown Packaging	Converted Paper Product Mfg.	Corrugated & Solid Fibre Box Mfg.	N/A	N/A	N/A
Dairyland Fluid Division Ltd. (Annacis Plant)	Dairy Product Mfg.	Fluid Milk Mfg.	N/A	N/A	N/A
Dairyland Fluid Division Ltd. (Burnaby Plant)	Dairy Product Mfg.	Fluid Milk Mfg.	N/A	N/A	N/A
EBCO Metal Finishing LP	Coating, Engraving & Heat Treating Activities	Coating, Engraving & Heat Treating Activities	N/A	N/A	N/A

Table 3.12. Listing of other manufacturing facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Principal Products	Effluent Permit	Maximum Effluent Volume ($m^{3/}d$)	Variables Listed in Effluent Permit
Lower Fraser River (continued)					
Enigma Interconnect Inc.	Semiconductor & Electronic Component Mfg.	Semiconductor & Electronic Component Mfg.	N/A	N/A	N/A
Flexstar Packaging Inc.	Printing & Related Support Activities	Other Printing	N/A	N/A	N/A
Gemini Packaging Ltd.	Soap, Cleaning Compound & Toilet Prep. Mfg.	Soap & Cleaning Compound Mfg.	N/A	N/A	N/A
Georgia-Pacific Canada Inc.	Lime & Gypsum Product Mfg.	Gypsum Product Mfg.	N/A	N/A	N/A
Gourmet Baker Inc. (Burnaby Location)	Bakeries & Tortilla Mfg.	Commercial Bakeries & Frozen Product Mfg.	N/A	N/A	N/A
Gourmet Baker Inc. (Laurel Location)	Bakeries & Tortilla Mfg.	Commercial Bakeries & Frozen Product Mfg.	N/A	N/A	N/A
Graphic Packaging Canada Corp.	Printing & Related Support Activities	Other Printing	N/A	N/A	N/A
Herzog Rope Ltd.	Other Textile Product Mills	All Other Textile Product Mills	N/A	N/A	N/A
Highland Foundry Ltd.	Foundries	Steel Foundries	N/A	N/A	N/A
ICL Engineering Ltd.	Plastic Product Mfg.	Plastic Pipe & Pipe Fitting Mfg.	N/A	N/A	N/A
Inteplast Bags & Films Corp.	Plastic Product Mfg.	Plastics Bag Manufacturing	N/A	N/A	N/A
Interstyle Ceramic And Glass Ltd.	Glass & Glass Product Mfg.	Glass Product Mfg. from Purchased Glass	N/A	N/A	N/A
Interstyle Ceramic And Glass Ltd.	Glass & Glass Product Mfg.	Glass Product Mfg. from Purchased Glass	N/A	N/A	N/A
IPAC Chemicals	Basic Chemical Mfg.	All Other Basic Inorganic Chemical Mfg.	N/A	N/A	N/A
J.D. Sweid Ltd.	Meat Product Mfg.	Poultry Processing	N/A	N/A	N/A

Table 3.12. Listing of other manufacturing facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Principal Products	Effluent Permit	Maximum Effluent Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River (continued)					
Jack Cewe Ltd.	Petroleum & Coal Products Mfg.	Asphalt Paving Mixture & Block Mfg.	N/A	N/A	N/A
Labatt Breweries Of British Columbia	Beverage Mfg.	Breweries	N/A	N/A	N/A
Laguna Woodcraft Canada Ltd.	Household & Inst. Furniture & Cabinet Mfg.	Other Wood Household Furniture Mfg.	N/A	N/A	N/A
Layfield Vision Packaging	Printing & Related Support Activities	Other Printing	N/A	N/A	N/A
Leggett & Platt Canada Co.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg.	N/A	N/A	N/A
Maax Spas BC Inc.	Plastic Product Mfg.	Plastic Plumbing Fixture Mfg.	N/A	N/A	N/A
Marine Plastics Ltd.	Plastic Product Mfg.	Motor Vehicle Plastic Parts Mfg.	N/A	N/A	N/A
Masterfeeds Inc.	Animal Food Mfg.	Other Animal Food Mfg.	N/A	N/A	N/A
Metalex Products Ltd.	Other Miscellaneous Mfg.	All Other Miscellaneous Mfg.	N/A	N/A	N/A
Molectro Plating Inc.	Coating, Engraving & Heat Treating Activities	Coating, Engraving & Heat Treating Activities	N/A	N/A	N/A
Pepsicola Botting Group	Beverage Mfg.	Soft Drink & Ice Mfg.	N/A	N/A	N/A
Plasti-Fab Ltd.	Plastic Product Mfg.	Polystyrene Foam Product Mfg.	N/A	N/A	N/A
Pliant Packaging Of Canada LLC	Plastic Product Mfg.	Plastics Bag Manufacturing	N/A	N/A	N/A
PTPC Corrugated Co.	Converted Paper Product Mfg.	Corrugated & Solid Fibre Box Mfg.	N/A	N/A	N/A
Rogers Foods Ltd	Grain & Oilseed Milling	Flour Milling	N/A	N/A	N/A
Samson Rope Technologies	Other Textile Product Mills	All Other Textile Product Mills	N/A	N/A	N/A
Saputo Foods Ltd.	Dairy Product Mfg.	Fluid Milk Mfg.	N/A	N/A	N/A

Table 3.12. **Listing of other manufacturing facilities in the Fraser River Basin.**

Area of Interest/Facility Name	Facility Type	Principal Products	Effluent Permit	Maximum Effluent Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River (continued)					
Sensient Flavors Canada Inc.	Other Food Mfg.	Flavouring Syrup & Concentrate Mfg.	N/A	N/A	N/A
Silver City Galvanizing	Coating, Engraving & Heat Treating Activities	Coating, Engraving & Heat Treating Activities	N/A	N/A	N/A
Smurfit-MBI (Previously Macmillan Bathurst Inc.)	Converted Paper Product Mfg.	Corrugated & Solid Fibre Box Mfg.	PE-00108	23	Temperature
Sonoco Flexible Packaging Canada Corp.	Printing & Related Support Activities	Other Printing	N/A	N/A	N/A
Soyaworld Inc.	Dairy Product Mfg.	Fluid Milk Mfg.	N/A	N/A	N/A
Stork Craft Manufacturing Inc.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg.	N/A	N/A	N/A
Terminal Forest Products Ltd.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg.	N/A	N/A	N/A
The Pepsi Bottling Group (Canada) Co.	Beverage Mfg.	Soft Drink & Ice Mfg.	N/A	N/A	N/A
Transcontinental Printing	Printing & Related Support Activities	Manifold Business Forms Printing	N/A	N/A	N/A
Unifeed Ltd.	Animal Food Mfg.	Other Animal Food Mfg.	N/A	N/A	N/A
Vae Nortrak Ltd.	Machine Shops, Turned Product & Related Mfg.	Machine Shops	N/A	N/A	N/A
Visscher Lumber Inc.	Other Wood Product Mfg.	Other Millwork	N/A	N/A	N/A
Viterra Inc.	Animal Food Mfg.	Other Animal Food Mfg.	N/A	N/A	N/A
W. Kreykenbohm Corp.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg.	N/A	N/A	N/A
West Bay Sonships Ltd	Ship & Boat Building	Boat Building	N/A	N/A	N/A
Western Concord Mfg.	Plastic Product Mfg.	Plastics Bag Manufacturing	N/A	N/A	N/A
Weston Bakeries Ltd.	Bakeries & Tortilla Mfg.	Commercial Bakeries & Frozen Product Mfg.	N/A	N/A	N/A
Zer-O-Loc Enterprises Ltd.	Ventilation, Heating, AC & Refrig. Equip. Mfg	Heating & Commercial Refrigeration Equip. Mfg	N/A	N/A	N/A

Table 3.12. Listing of other manufacturing facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Principal Products	Effluent Permit	Maximum Effluent Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River (continued)					
Zodiac International	Ship & Boat Building	Boat Building	N/A	N/A	N/A
A.B.C. Recycling Ltd	Metal Recycling		PE-04246	2.3	Aluminum dissolved, Barium dissolved, Cadmium dissolved, Chromium (V & III) dissolved, Copper dissolved, Iron dissolved, Lead dissolved, Nickel dissolved, Zinc dissolved, Oil & grease, pH.
Titan Steel & Wire Co. Ltd	Metal Finishing Plant	Steel Manufacturing	PE-00161	4650	Temperature, Zinc dissolved, Toxicity, Hardness, Boron dissolved, Cadmium dissolved, Chromium dissolved, Copper dissolved, Lead dissolved, Manganese dissolved, Phosphate total, Alkalinity.
Western Steel Ltd	Steel mill	Steel Manufacturing	PE-02087	24000	TSS, Oil & grease, pH, Cadmium dissolved, Copper dissolved, Zinc dissolved, Lead dissolved
CPL Paperboard Ltd. (Previously Somerville Belkin Industries Ltd.)	Paperboard	Paperboard Manufacturing	PE-4963	88.67	Temperature
B.C. Frozen Foods Ltd.	Food Processing Facility	Fruit, vegetables and fish processing	PE-13701	325	BOD5, Oil & grease, pH, Total residual chlorine, Temperature
27222 Developments Ltd.	Boat Building Operation	Boat Building	PE-15641	5.5	BOD5, TSS, Fecal Coliform

Table 3.12. Listing of other manufacturing facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Principal Products	Effluent Permit	Maximum Effluent Volume (m^3/d)	Variables Listed in Effluent Permit
Lower Fraser River (continued)					
Happy Days Dairies Ltd.	Goat Farm and Milk Processing Plant	Dairy Product (except Frozen & Fluid) Mfg.	PE-16564	1.89	
Nechako River					
I.G. Machine And Fibers	Other Non-Metallic Mineral Product Mfg.	All Other Non-Metallic Mineral Product Mfg. (Finger-jointed Stud)	N/A	N/A	N/A
Pitt River					
Kamloops Forest Products Ltd.	Veneer, Plywood & Engineered Wood Product Mfg	Hardwood Veneer & Plywood Mills	N/A	N/A	N/A
Advance Chemicals Ltd.	Other Chemical Product Mfg.	All Other Misc. Chemical Product Mfg.	N/A	N/A	N/A
E-One Moli Eenergy (Canada) Ltd.	Other Electrical Equipment & Component Mfg.	Battery Mfg.	N/A	N/A	N/A
Esco Ltd.	Foundries	Steel Foundries	N/A	N/A	N/A
Quebecor World Inc.	Printing & Related Support Activities	Manifold Business Forms Printing	N/A	N/A	N/A
Recochem Inc.	Other Miscellaneous Mfg.	All Other Miscellaneous Mfg.	N/A	N/A	N/A
South Thompson					
Wesgar Industries Ltd.	Steel Product Mfg. from Purchased Steel	Cold-Rolled Steel Shape Mfg.	N/A	N/A	N/A
Dinoflex Manufacturing Ltd.	Rubber Product Mfg.	Other Rubber Product Mfg.	N/A	N/A	N/A
Doepker Industries Ltd.	Motor Vehicle Body & Trailer Mfg.	Truck Trailer Mfg.	N/A	N/A	N/A

Table 3.12. Listing of other manufacturing facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Principal Products	Effluent Permit	Maximum Effluent Volume (m^3/d)	Variables Listed in Effluent Permit
Upper Fraser River					
Pollard Banknote Ltd.	Printing & Related Support Activities	Other Printing	N/A	N/A	N/A
Pacific Bioenergy Corp.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg. (Wood Pellets)	N/A	N/A	N/A
Pacific Bioenergy Corp.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg. (Wood Pellets)	N/A	N/A	N/A
Pinnacle Pellet Inc.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg. (Wood Pellets)	N/A	N/A	N/A
Pinnacle Pellet Meadowbank Inc.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg. (Wood Pellets)	N/A	N/A	N/A
Pinnacle Pellet Williams Lake Inc.	Other Wood Product Mfg.	All Other Misc. Wood Product Mfg. (Wood Pellets)	N/A	N/A	N/A

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.13. Overview of the distribution of contaminated sites within the Fraser River Basin.

Area of Interest	Environmental Matrix (Number of sites with documented contamination of each media type)							Total Number of Sites
	Air	**Groundwater**	**Sediment**	**Soil**	**Surface Soil**	**Surface Water**	**Undefined**	
Bowron River	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chilko River	N/A	1	N/A	22	2	4	27	**56**
Cultus Lake	N/A	16	7	29	4	8	12	**76**
Harrison River	N/A	19	N/A	69	7	1	36	**132**
Kakawa Lake	N/A	N/A	N/A	1	N/A	N/A	2	**3**
Lower Fraser River	N/A	70	25	101	39	28	136	**399**
Lower Thompson River	N/A	10	N/A	52	8	N/A	41	**111**
Nahatlatch River	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nechako River	1	18	6	84	29	N/A	81	**219**
North Thompson River	N/A	N/A	N/A	27	15	N/A	32	**74**
Pitt River	N/A	9	N/A	11	1	1	10	**32**
Quesnel River	N/A	N/A	N/A	2	N/A	N/A	24	**26**
Seton-Portage	N/A	8	5	27	3	1	20	**64**
South Thompson River	N/A	9	6	22	5	1	76	**119**
Upper Fraser River	N/A	33	2	131	52	17	104	**339**
Fraser River Basin	**1**	**124**	**42**	**326**	**100**	**31**	**420**	**1044**

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.14. Listing of spills reported during March - June 2007, in the Fraser River Basin.

Area of Interest/Location	Spill Type	Amount (L)	Incident Number	Description	Incident Date
Lower Fraser River					
1 km west of Alex Fraser Bridge	Thick dark bubbly substance	N/A	DGIR 603642	N/A	03/27/07
1 mile east of the Fort Langley Airport	Slick	N/A	DGIR 700077	N/A	04/11/07
Galanders Road, Chilliwack	N/A	N/A	DGIR 603520	Rainbow sheen on a creek on a private property	03/17/07
Allen Road, Rosedale	Diesel and other chemicals	N/A	DGIR 700091	Property owners dumped waste and burned the waste	04/13/07
River Road, Richmond	Sewage	N/A	DGIR 700100	Marina is dumping sewage into the Fraser River	04/13/07
Annacis Island Wastewater Treatment Plant	Suspended Solids	12400 Kg	DGIR 603459	Load exceedance for the 24 hr period	03/12/07
Barnston Island	Fuel (suspect)	N/A	DGIR 603558	Floatplane started to sink at the tail.	03/20/07
Braid Street Gate House	Raw Sewage	N/A	DGIR 603525	Increased load from rainfall on the sewer interceptor is overflowing the Braid St Gate House	03/17/07
Braid Street Gate House	Raw Sewage	N/A	DGIR 603599	Too much flow in sewage system so they had to open the gate	03/23/07
Close to Marpole Railway, Vancouver	Fuel (suspect)	N/A	DGIR 700534	N/A	07/25/07
Cougar Creek - 7100 block of 120 street in North Delta	Sediment laden water	N/A	DGIR 603496	Coming from a construction site on the Surrey side	03/13/07
Ditch on Leeder Street Coquitlam	Unknown blue material	N/A	DGIR 700097	N/A	04/13/07
Fraser River - Steveston - Third Avenue Pier	Gas/Diesel	N/A	DGIR 603349	Skiff had a spill	N/A
Fraser River Acorn Mills (Alexander Rd, Delta)	Oil	227.3	R2007-0364	N/A	2007
Fraser River, Deas to Crown Forest, Delta	Oil	N/A	DGIR 700396	Rainbow sheen	05/11/07
Fraser Surrey Docks, Surrey	Neutralized Acid	N/A	DGIR 700482	Sewers and toilets backed up at Titan Steel	05/20/07

Table 3.14. Listing of spills reported during March - June 2007, in the Fraser River Basin.

Area of Interest/Location	Spill Type	Amount (L)	Incident Number	Description	Incident Date
Lower Fraser River (continued)					
Inside Steveston Channel	Diesel	N/A	DGIR 700600	Diesel spill	05/29/07
Just West of the Queensborough bridge	Oil	409.15	R2007-0411	N/A	2007
Lulu Island Wastewater Treatment Plant	Primary and Secondary Effluent	N/A	DGIR 700821	One tank overflowed as it was taken out of service	06/19/07
Middle Arm Fraser	Oil	1600	R2007-0711	Believed to originate from Mitchell Island from a fuel transport vehicle, but sighted at the middle arm swing bridge. Caused by work being done on the bridge crossing the North Arm where a piece of steel was left in such a position that it punctured the fuel tank of a locomotive crossing the bridge	2007
Near the local maple ridge airport	Diluted Sewage	N/A	DGIR 603429	Pump house overflowed	N/A
No 4. Rd and River Rd, Richmond	Oil	N/A	DGIR 700186	Black stuff coming out of drains	04/22/07
North end of No. 4 Rd near River Drive, Richmond	Oil (suspect)	Est. 20-40 L/Hr	DGIR 700155	Coming from a pipe that is connected to a pump that comes from the drainage system	04/19/07
Northwest Langley Wastewater Treatment Plant	Partially treated sewage	N/A	DGIR 603441	Controlled release due to the high rainfall	03/11/07
Outfall diversion structure at foot of Brand St, New Westminster	Sewage	30 ft^3/second	DGIR 603524	Overflow due to rainfall	03/17/07
River Rd south foot of Alex Fraser Bridge	Thick black sludge	N/A	DGIR 603517	Material smelling like sewage	03/16/07
Several Marinas - Skyline Marina at River Rd, Richmond	Sewage	N/A	DGIR 603571	Float homes and house boats	03/22/07
Sewage Plant on Braid St. by Burnet Skytrain	Diluted Sewage	N/A	DGIR 603580	Too much flow in sewage system so they had to open the gate	03/22/07
Skyline Marina, Moray Channel	Oil	100	R2007-0705	N/A	2007
Small Stream off River Rd. between Bella Coola Fisheries and a Muslim Hall, Delta	Dark coloured substance	N/A	DGIR 603570	N/A	03/21/07

Table 3.14. Listing of spills reported during March - June 2007, in the Fraser River Basin.

Area of Interest/Location	Spill Type	Amount (L)	Incident Number	Description	Incident Date
Lower Fraser River (continued)					
Steveston Area, Richmond	Diesel (suspect)	N/A	DGIR 603562	Slick from Steveston Harbout fo the S16 buoy.	03/21/07
Steveston Harbour, Richmond	Bilge material mixed with diesel	N/A	DGIR 700693	Assumed pollution from fishboats	06/08/07
Steveston, End of No. 1 Rd., Richmond	Diesel	1/4 Mile Long	DGIR 700036	Old Oil	04/05/07
Stoney Creek, Coquitlam, Between North Rd and Clark Rd.	Milky White Substance	N/A	DGIR 700355	N/A	05/08/07
Underneath the # 3 Bridge to the Airport, Richmond	Oil	N/A	DGIR 700657	N/A	06/04/07
Upstream from Mission Bridge, Mission	Suspect Sewage	N/A	DGIR 700399	Sewage floating	05/12/07
Upstream of Annacis Island Swing Bridge	Oil	2	R2007-0076	N/A	2007
Vito Shipyard, Alex Fraser Bridge	Fuel Slick	N/A	DGIR 700024	N/A	04/04/07
Wallace Street, Vancouver	Chlorinated Water	N/A	DGIR 700804	N/A	06/18/07
Morkill Drainage	Jet 'A'	5x45 gallon drums	DGIR 603340	Bonnet broke while slining in fuel	03/02/07
Northwood Pulp Mill Rd, Prince George	Treated Pulp Mill Effluent	N/A	DGIR 700669	Effluent lagoon overflowing into the Fraser River	06/06/07
Tributary to Coquihalla river, spawning channel off of Kakawa Creek	Diesel (suspect)	N/A	DGIR 603338	Suspected trailer park	03/01/07
Nechako River					
Mile 127.8 Fraser Subdivision, Prince George	Lumber	N/A	DGIR 700897	Lumber fell into river as train was derailed	06/27/07
Yellow Head Bridge, Prince George	Sewage	N/A	DGIR 700001	Blocked sewer main, sewage spilled on bridge and into the Fraser River	03/31/07

Table 3.14. Listing of spills reported during March - June 2007, in the Fraser River Basin.

Area of Interest/Location	Spill Type	Amount (L)	Incident Number	Description	Incident Date
North Thompson River					
North Thompson River in Barriere at Highway 5, 5 km North of Barriere	Diesel and Oil	N/A	DGIR 700080	Motor vehicle accident between a vehicle and an Edmonton tractor trailer unit	04/12/07
Pitt River					
Maple Ridge	Fuel	5 tans, 2 floating	DGIR 700680	Found the tanks on property	06/06/07
McKinney Creek, Berry Avenue, Maple Ridge	White Milky Substance	N/A	DGIR 700061	N/A	04/09/07
Nicolas Street of Ottawa, Port Coquitlam	Chlorinated Water	100 Gallons	DGIR 700837	Faulty pipe	06/21/07
Old Chilliwack river/slough behind Melville Street	N/A	N/A	DGIR 603518	Bubbling in the Old Chilliwack River (Slough) and odour of fertilizer	N/A
Under the CP Rail Bridge at the mouth of the Stave River	Sheen	N/A	DGIR 700286	Sheen on the river	05/01/07
South Thompson River					
South Thompson River in Valleyview, Kamloops	Soapy Detergent	N/A	DGIR 700113	Flowing from a drainage pipe under the highway	04/15/07

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.15. Listing of municipal wastewater treatment plants in the Fraser River Basin.

Area of Interest/Facility Name	Treatment Type	Permitted Effluent Volume (m^3/d)	Variables Listed in Effluent Permit	Effluent Permit
Harrison River				
Resort Municipality of Whistler	Primary/Secondary/Tertiary	N/A	N/A	N/A
Village of Harrison Hot Springs	Secondary	2400	BOD, TSS, Ammonia, Fecal coliform	N/A
Kakawa Lake				
District of Hope	Primary	8820	TSS, BOD5, Fecal coliforms	PE-04125
Lower Fraser River				
Joint Abbotsford Mission Environmental System (JAMES)	Secondary	122500	BOD, TSS, Ammonia, Fecal coliform, Orth-Phosphate	N/A
Annacis Island	Secondary	1050000	Chlorine residual, TSS, CBOD, Fecal coliform, Ammonia nitrogen, Fish Bioassy	ME-00387
Lulu Island WWTP	Secondary	233000	Chlorine residual, TSS, CBOD, Fecal coliform, Ammonia nitrogen, Fish Bioassy	ME-00233
Chilliwack Pollution Control Centre	Secondary	45000	TSS, Ammonia, Fecal coliform	N/A
Wes Del Marina	Secondary	22	N/A	N/A
District of Kent	Secondary	3600	TSS, Total Kjeldahl Nitrogen, Arsenic, Cadmium, Cobalt, Chromium, Copper, Mercury, Molybdenum, Nickel, Lead, Selenium, Zinc, PCBs, BOD5, Fecal Coliform, Toxicity, Ammonia N	PE-00137
Iona Island Wastewater Treatment Plant	Primary	1530000	N/A	N/A
Regional District of Fraser-Cheam	N/A	6800	N/A	N/A
District of Mission	Secondary	9546	N/A	N/A
Morris Valley	Secondary	N/A	N/A	N/A
Northwest Langley WWTP	Secondary	42000	CBOD5, TSS, Chlorine residual, Ammonia as N, Fecal coliform	ME-04339
Lantic Real Property Limited Partnership	Secondary	300	pH, TSS, Total Copper, Total Cobalt, Ammonia nitrogen, Total phosphate phosphorus, Phenols, Benzene, Toluene, Toxicity	PE-00041

Table 3.15. Listing of municipal wastewater treatment plants in the Fraser River Basin.

Area of Interest/Facility Name	Treatment Type	Permitted Effluent Volume (m^3/d)	Variables Listed in Effluent Permit	Effluent Permit
Lower Thompson River				
Ashcroft Sewage Treatment Plant	Secondary	2273	N/A	N/A
Clinton Sewage Treatment	N/A	727	N/A	N/A
City of Merritt	Tertiary	3014	N/A	N/A
Nechako River				
Regional District of Bulkley-Nechako	Secondary	182	N/A	N/A
Village of Burns Lake	Tertiary	4550	BOD5, TSS, Chlorine, E-Coli, Total Phosphorus, Ammonia, pH, Specific Conductance, Temperature	PE-0403
Village of Fort St. James	N/A	3200	N/A	N/A
Village of Vanderhoof Sewage Treatment Facilit	Secondary	1640	N/A	N/A
North Thompson River				
City of Kamloops Wastewater Treatment Centre	Tertiary	55000	N/A	N/A
Quesnel River				
Cariboo Pulp and Paper Mill (Processes Municipal Effluent)	Secondary	6300	BOD5, TSS, VSS, AOX, 2,3,7,8-TCDD, 2,3,7,8-TCDF, Temperature, pH, Conductivity, Resin Acids, Ammonia as N, Nitrite as N, Organic Nitrogen as N, Total Phosphorus, Coliform (total and faecal), Colour	PE-1152
South Thompson River				
City of Enderby	Secondary	N/A	pH, Temperature, DO, Chlorine	N/A
Salmon Arm Water Pollution Control Centre	Tertiary	6700	N/A	N/A
Village of Chase	N/A	1370	N/A	N/A
Upper Fraser River				
Blackburn Wastewater Treatment Plant	Primary/Secondary	1375	BOD, TSS	PE-3868
Lansdowne Road Wastewater Treatment Centre	Secondary	45000	N/A	N/A

Table 3.15. Listing of municipal wastewater treatment plants in the Fraser River Basin.

Area of Interest/Facility Name	Treatment Type	Permitted Effluent Volume (m^3/d)	Variables Listed in Effluent Permit	Effluent Permit
Upper Fraser River (continued)				
District of Lillooet	N/A	1260	N/A	N/A
Lytton Wastewater Treatment Plant	Secondary	365	N/A	N/A
Village of McBride	Primary	750	N/A	N/A
City of Prince George - BCR Industrial Park	Primary	1400	N/A	N/A
Danson Wastewater Treatment Plant	Secondary	1000	N/A	N/A
City of Williams Lake		6820	N/A	N/A
District of Wells	Tertiary	50	BOD5, TSS, Nitrate as N, Nitrite as N, Ammonia as N, pH, Conductivity	PE-4337
Fraser Valley Regional District (North Bend)	N/A	N/A	N/A	N/A

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.16. List of chemicals frequently detected in municipal wastewater (MacDonald *et al.* 2007).

Conventional Variables
- Alkalinity
- BOD (5 day carbonaceous)
- BOD (5 day total)
- Chemical oxygen demand
- Conductivity
- Cyanide (SAD) + thiocyanate
- Cyanide SAD
- Cyanide WAD
- Hardness, dissolved (as $CaCO_3$)
- Hardness, total (as $CaCO_3$)
- Oil & grease (mineral)
- Oil & grease (total)
- pH
- Total organic carbon
- Total suspended solids

Microbiological Variables
- Fecal coliform

Nutrients
- Nitrogen, ammonia
- Nitrogen, nitrate
- Nitrogen, nitrite
- Nitrogen, total kjeldahl
- Phosphate
- Phosphorus, total
- Phosphorus, dissolved

Major Ions
- Chloride, total
- Sodium, total
- Sodium, dissolved
- Sulphate, total
- Sulphate, dissolved
- Sulphide, total

Total Metals
- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Bismuth
- Boron
- Cadmium
- Calcium

Total Metals (continued)
- Chromium
- Chromium III
- Chromium VI
- Cobalt
- Copper
- Iron
- Lead
- Lithium
- Magnesium
- Manganese
- Mercury
- Molybdenum
- Nickel
- Potassium
- Selenium
- Silver
- Strontium
- Tellurium
- Thallium
- Tin
- Titanium
- Uranium
- Vanadium
- Zinc

Dissolved Metals
- Aluminum, dissolved
- Antimony, dissolved
- Arsenic,dissolved
- Barium,dissolved
- Beryllium,dissolved
- Bismuth, dissolved
- Boron,dissolved
- Cadmium, dissolved
- Calcium, dissolved
- Chromium VI, dissolved
- Chromium, dissolved
- Cobalt, dissolved
- Copper, dissolved
- Fluoride dissolved
- Iron, dissolved
- Lead, dissolved
- Lithium, dissolved
- Magnesium, dissolved
- Manganese, dissolved
- Mercury, dissolved

Table 3.16. List of chemicals frequently detected in municipal wastewater (MacDonald *et al.* 2007).

Metals Dissolved (continued)
Molybdenum, dissolved
Nickel, dissolved
Potassium, dissolved
Selenium, dissolved
Silver, dissolved
Strontium, dissolved
Thallium, dissolved
Tin, dissolved
Titanium, dissolved
Uranium, dissolved
Vanadium, dissolved
Zinc, dissolved

Aldehydes
Acrolein

Chlorinated Phenolics
2-Chlorophenol
2,4-Dichlorophenol
4-Chloro-3-methylphenol
2,4,6-Trichlorophenol
Pentachlorophenol

Non-Chlorinated Phenolics
2,4-Dimethylphenol
2,6-Dinitrophenol
2,4-Dinitrophenol
2-Methyl-4,6-dinitrophenol
2-Nitrophenol
4-Nitrophenol
Phenol
Total phenols

Organochlorine Pesticides
2,4-DDE
4,4-DDE
Dieldrin
Endosulfan sulphate
HCH, beta-
HCH, gamma- (lindane)

Polycyclic Aromatic Hydrocarbons (PAHs)
Acenaphthene
Acenaphthylene
Anthracene
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
2-Chloronaphthalene
Chrysene
Dibenzo(a,h)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-c,d)pyrene
2-Methylnaphthalene
Naphthalene
Phenanthrene
Pyrene
LMW PAHs
HMW PAHs
Total PAHs

Semivolatile Organic Compounds
Phthalates
Bis(2-ethylhexyl)phthalate
Butylbenzyl phthalate
Dibutyl phthalate
Diethyl phthalate
Dimethyl phthalate
Di-n-butyl phthalate
Di-n-octyl phthalate

Miscellaneous
Acetone
Benzidine
Chloroform
3,3-Dichlorobenzidine
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
Isophorone
Nitrobenzene
1,3-Dichlorobenzene
N-nitrosodimethylamine
N-nitrosodi-n-propylamine
N-nitrosodiphenylamine
Trans-1,3-dichloropropene

Table 3.16. List of chemicals frequently detected in municipal wastewater (MacDonald *et al.* 2007).

Volatile Organic Compounds (VOCs)

Monocyclic Aromatic Hydrocarbons
- 1,1,2,2-Tetrachloroethane
- 1,4-Dichlorobenzene
- Benzene
- Ethylbenzene
- Styrene
- Toluene
- m,p-Xylene
- o-Xylene
- Xylenes, total

Aliphatic
- Acrylonitrile
- Methyl tertiary butyl ether

Chlorinated Aliphatic
- Cis-1,3-dichloropropene
- Chloroethane
- Dichloromethane
- Tetrachloroethene

Trihalomethanes
- Tribromomethane
- Trichloromethane

Ketones
- Dimethyl ketone
- Methyl ethyl ketone
- Methyl isobutyl ketone

Terpenes
- Terpineol, alpha-

BOD = biological oxygen demand; SAD = strong acid dissociable; WAD = weak acid dissociable; DDE = dichlorodiphenyldichloroethylene; HCH = hexachlorocyclohexane; LMW = low molecular weight; HMW = high molecular weight.

Table 3.17. List of contaminants of emerging concern that are commonly present at elevated levels in wastewater treatment plant effluents.

Chemical Category/Analyte	Application of Chemical Substance
Pharmaceuticals	***Personal Care Products***
Atenolol	Antihypertension
Azithromycin	Antibiotic
Carbamazepine	Anticonvulsant
Cimetidine	Anti acid reflux
Ciprofloxacin	Antibiotic
Diphenhydramine	Decongestant
Doxycycline	Antibiotic
4-Epitetracycline	Antibiotic
Erythrmycin	Antibiotic
Fluoxetine	Antidepressant
Ibuprofen	Analgesic
Miconazole	Antifungal
Ofloxacin	Antibiotic
Oxytetracycline	Antibiotic
Naproxen	Non-sterol anti inflammatory
Sertraline	Antidepressant
Tetracycline	Antibiotic
Steroids and Hormones	
Androstenedione	Hormone
Beta Stigmastanol	Hormone
Campesterol	Hormone
Cholestanol	Hormone
Cholesterol	Hormone
Coprostanol	Hormone
17a-ethinylestradiol	Hormone
Epicoprostanol	Hormone
Estriol	Hormone
Stigmasterol	Hormone
Testosterone	Hormone
Personal Care Products	
Benzophenone	UV light protrection
Caffeine	Stimulant
Celestolide	Fragrance
Galaxolide (HHCB)	Fragrance
n-Nonylphenol	Surfactant
Pentachloronitrobenzene	Fungicide
Toluamide	Insect repellant
Tonalida	Fragrance
Triclocarban	Antimicrobial
Triclosan	Antimicrobial

Table 3.17. List of contaminants of emerging concern that are commonly present at elevated levels in wastewater treatment plant effluents.

Chemical Category/Analyte	Application of Chemical Substance
Endocrine Disrupting Compounds	
Alkyl phenols	Detergents
Atrazine	Herbicide
Bisphenol A	Plastics production
Phthalates	Plasticizers
Polybrominated diphenyl ethers	Fire retardant
Vinclozolin	Fungicide

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Chilko River			
Small Municipal: Landfill with serving population < 5,000	Cariboo Regional District	Chilanko Forks	2
	Cariboo Regional District	Nemaiah Valley	2.3
	Cariboo Regional District	Tatla Lake	1.9
	Cariboo Regional District	Punzi Lake	1.1
	Unknown	Chilko River AoI Lake Municipal Landfill	1
Medium Municipal: Landfill with serving population of 5,000 to 50,000	Cariboo Regional District	Alexis Creek	23
Logging: Remote sites receiving predominantly wood debris	Sigurdson Brothers Logging Company Limited	Hanceville-Near	0.1
First Nations: Receives municipal type waste from First Nations community	Anahim Indian Band	Anahim's Flat Indian Reserve #1	1.2
	Alexis Creek Indian Band	Redstone Flat Indian Reserve #1	0.5
First Nations: Receives municipal type waste from First Nations community	Nemaiah Valley Indian Band	Chilko River AoI Lake Indian Reserve #1A, Nemaiah Valley	0.5
	Nemaiah Valley Indian Band	Lohbiee Indian Reserve #3	0.5
Cultus Lake			
Medium Municipal: Landfill with serving population of 5,000 to 50,000	District of Chilliwack	Chilliwack	80
Camps/Recreation/Personal: Small, usually remote sites receiving residential type wastes	Cultus Lake Parks Board	Cultus Lake	1.3
Harrison River			
Small Municipal: Landfill with serving population < 5,000	Squamish-Lillooet Regional District	Pemberton, 10 Km South Of	5.3
First Nations: Receives municipal type waste from First Nations community	Skookumchuk Indian Band	Skookumchuk	0.2
	Pemberton Indian Band	Mount Currie, Pemberton Indian Reserve #6	0.3

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Lower Fraser River			
DLC/Contractors: Demolition, land clearing and construction wastes	RNG Recycling; 7437 Holdings	9376 River Road, Delta	0
Medium Municipal: Landfill with serving population of 5,000 to 50,000	The Corporation of the District of Matsqui	Abbotsford	12
	The Corporation of the District of Matsqui	Abbotsford And Matsqui	150
DLC/Contractors: Demolition, land clearing and construction wastes	Unknown	Athopa Landfill Site	0
Municipal - Primary: Landfill with serving population > 50,000	Greater Vancouver Regional District	Braid Street, Coquitlam, south of Hwy 1	408
Large Municipal: Landfill with serving population > 50,000	City of Burnaby	Burnaby	1
	The Corporation of the District of Burnaby	Burnaby, Stride Vaenue and Marine Way	110
Pulp Mills: Pulp mill wastes	Crown Packaging Limited	Burnaby-Wiggins Street	484
Medium Municipal: Landfill with serving population of 5,000 to 50,000	District of Chilliwack	Chilliwack-Matheson Road	96
Sawmills/ Wood Manufacture: Sawmills, wood manufacture and wood treatment wastes	Stella-Jones Incorporated	Coquitlam	264
Miscellanious Industry: Variety of industries (metal, chemical, agriculture etc.)	Crane Canada Incorporated	Coquitlam - North Road	27
Sawmills/ Wood Manufacture: Sawmills, wood manufacture and wood treatment wastes	Unknown	Delta Shake and Shingle Landfill	0
DLC/Contractors: Demolition, land clearing and construction wastes	Brown, Robert	Delta, 8950, 8970 & 9108 River Road	52
	Buckingham Development Corporation	Delta, 9184 River Road	57
	A D P Holdings Limited	Delta, 9236 River Road	15
	Meadowland Peat Limited	Delta, 9265 & 9283 River Road	120
	7437 Holdings Limited	Delta, 9356 & 9376 River Road	81
Municipal - Primary: Landfill with serving population > 50,000	City of Vancouver	Delta, Burns Bog	1230
Miscellanious Industry: Variety of industries (metal, chemical, agriculture etc.)	Vito Steel Boat And Barge Construction Limited	Delta-River Road	40

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Lower Fraser River (continued)			
DLC/Contractors: Demolition, land clearing and construction wastes	White, C. And I.	Delta-River Road	4
	Alpha Manufacturing Incorporated	Delta-River Road	80
	Unknown	Demolition Waste Landfill	0
Miscellanious Industry: Variety of industries (metal, chemical, agriculture etc.)	Unknown	ESCO Foundry Sands	0
Government Industrial Waste: Government landfills which receive non-municipal type wastes	Greater Vancouver Regional District	GVRD Coquitlam Landfill Sludge Use	0
Municipal - Primary: Landfill with serving population > 50,000	City of Vancouver	Kerr Road and 64th Ave., City of Vancouver	300
First Nations: Receives municipal type waste from First Nations community	Omahill Indian Band	Laidlaw	0.1
Miscellanious Industry: Variety of industries (metal, chemical, agriculture etc.)	Unknown	M.R. Lidskey Landfill	0
Municipal - Primary: Landfill with serving population > 50,000	Corporation of the District of Maple Ridge	Maple Ridge, Cottonwood Drive, Landfill	1
Medium Municipal: Landfill with serving population of 5,000 to 50,000	The Corporation of the District of Matsqui	Matsqui	45
Large Municipal: Landfill with serving population > 50,000	Greater Vancouver Regional District	Matsqui Transfer Station	1
Medium Municipal: Landfill with serving population of 5,000 to 50,000	The Corporation of the District of Matsqui	Matsqui-Valley Road	14
Miscellanious Industry: Variety of industries (metal, chemical, agriculture etc.)	Unknown	Oaklands Site 21 Landfill	0
Government Industrial Waste: Government landfills which receive non-municipal type wastes	Fraser River Harbour Commission	Richmond Landfill (Frhc Site)	0
DLC/Contractors: Demolition, land clearing and construction wastes	Ecowaste Industries Limited	Richmond, 15111 Williams Road	350

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Lower Fraser River (continued)			
Government Industrial Waste : Government landfills which receive non-municipal type wastes	Vancouver Sewerage and Drainage District	Richmond, Iona Island	610
Miscellanious Industry: Variety of industries (metal, chemical, agriculture etc.)	Western Steel Limited	Richmond-Mitchell Road	0
	Lafarge Canada Incorporated	Richmond-No. 9 Road	1400
First Nations: Receives municipal type waste from First Nations community	Seabird Island Indian Band	Seabird Island, Kent	1.3
Municipal - Primary: Landfill with serving population > 50,000	The Corporation of the District of Surrey	Surrey, Port Mann Bridge	500
Large Municipal: Landfill with serving population > 50,000	Ven Dev Enterprises Limited	Terra Nova, Coquitlam, south of Hwy 1	270
Small Municipal: Landfill with serving population < 5,000	Savona Waterworks District	Savona	1
	Thompson-Nicola Regional District	Spences Bridge	0.6
	Thompson-Nicola Regional District	Ashcroft	1
	Thompson-Nicola Regional District	70 Mile House	0.7
	Thompson-Nicola Regional District	Clinton	25
	Thompson-Nicola Regional District	Mammit Lk, South Of Logan Lk	1
	Cariboo Regional District	Watch Lake	0.8
	Thompson-Nicola Regional District	Loon Lake	1
	Cariboo Regional District	Watch Lake	0.5
Sawmills/ Wood Manufacture: Sawmills, wood manufacture and wood treatment wastes	Tolko Industries Limited	Merritt	0.5
	Georgia Pacific Bldg. Material Sales Limited	Cache Creek	3223
Pulp Mills: Pulp mill wastes	Weyerhaeuser Canada Limited	Kamloops Pulp Mill	2180
Mining: Discharge to land permits associated with mining companies	Afton Operating Corporation	Kamloops	2

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Lower Thompson River (continued)			
Medium Municipal: Landfill with serving population of 5,000 to 50,000	Thompson-Nicola Regional District	Logan Lake Off Highway 97C	12
	Thompson-Nicola Regional District	Lower Nicola/Merritt Area	28
	City of Merritt	Merritt	25
Large Municipal: Landfill with serving population > 50,000	City of Kamloops	Kamloops	166
	Wastech Services Limited	Cache Creek	1370
First Nations: Receives municipal type waste from First Nations community	Upper Nicola Indian Band	Nicola Lake, Nicola Lake Indian Reserve #1	0.7
	Upper Nicola Indian Band	Douglas Lake, Douglas Lake Indian Reserve #3	0.7
	Shackan Indian Band	Shackan Indian Reserve #11	0.3
	Shackan Indian Band	Shackan Indian Reserve #11	0.3
	Skeetchestn Indian Band	Deadman's Creek Indian Reserve, north of Savona	0.3
	Bonaparte Indian Band	Bonaparte Indian Reserve #2	0.4
	Bonaparte Indian Band	Bonaparte Indian Reserve #3/3A	0.4
	Lower Nicola Indian Band	Nicola Mameet Indian Reserve #1	0.6
	Coldwater Indian Band	Coldwater Indian Reserve #1	0.5
Nechako River			
Small Municipal: Landfill with serving population < 5,000	Regional District of Bulkley-Nechako	Tatalrose	0.2
	Fraser-Fort George Regional District	West Lake Landfill	3.3
	Regional District of Bulkley-Nechako	Cluculz L. Transfer Stn	0.8
	Regional District of Bulkley-Nechako	South Bank	1
	Regional District of Bulkley-Nechako	Palling	0.4
	Regional District of Bulkley-Nechako	Francois Lake	1
	Fraser-Fort George Regional District	Mud R. Landfill	1.3
	Regional District of Fraser Fort George	In The Bednesti, Berman & Norman Lake Areas	1
	Regional District of Bulkley-Nechako	Endako	0.6

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Nechako River (continued)			
Small Municipal: Landfill with serving population < 5,000 (cont.)	Regional District of Bulkley-Nechako	Ootsa Lake	0.4
	Regional District of Bulkley-Nechako	Fort Fraser Lf	1.3
	Regional District of Bulkley-Nechako	Fraser Lake Lf	5
	Regional District of Bulkley-Nechako	Grassy Plains	0.2
	Fraser-Fort George Regional District	Berman L. Landfill	1
Medium Municipal: Landfill with serving population of 5,000 to 50,000	Regional District of Bulkley-Nechako	Burns Lake	16
	Regional District of Bulkley-Nechako	Vanderhoof Landfill	15
Government Industrial Waste: Government landfills which receive non-municipal type wastes	Unknown	CFS Baldy Hughes Landfill	0
First Nations: Receives municipal type waste from First Nations community	Fraser Lake Indian Band	Nautley Indian Reserve #1, east end of Fraser Lake	0.4
	Fraser Lake Indian Band	Seaspunkut Indian Reserve #1	0.4
Small Municipal: Landfill with serving population < 5,000	Fraser-Fort George Regional District	Chief L. Landfill	5.4
Medium Municipal: Landfill with serving population of 5,000 to 50,000	Regional District of Bulkley-Nechako	Fort St. James Lf	8.5
Large Municipal: Landfill with serving population > 50,000	City of Prince George	Hart Landfill	157
North Thompson River			
Small Municipal: Landfill with serving population < 5,000	Thompson-Nicola Regional District	Little Fort	0.4
	Cariboo Regional District	Forest Grove	2
	Thompson-Nicola Regional District	Barriere	11
	Thompson-Nicola Regional District	Blue River	0.7
	Thompson-Nicola Regional District	Birch Island	0.3
	Thompson-Nicola Regional District	Avola	0.4
	Thompson-Nicola Regional District	Mclure	1
	Cariboo Regional District	Lone Butte	2.2
	Cariboo Regional District	Eagle Creek	4

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
North Thompson River (continued)			
Small Municipal: Landfill with serving population < 5,000 (cont.)	Cariboo Regional District	Sheridan Lake	4
	Thompson-Nicola Regional District	Paul Lake	0.9
	Cariboo Regional District	Mahood Lake	2
Sawmills/ Wood Manufacture: Sawmills, wood manufacture and wood treatment wastes	Tolko Industries Limited	Heffley Creek	0.5
	Tolko Industries Limited	Heffley Creek	0.5
	Slocan Forest Products Limited	Vavenby	0.8
Medium Municipal: Landfill with serving population of 5,000 to 50,000	Thompson-Nicola Regional District	Clearwater	15
	Thompson-Nicola Regional District	Heffley Creek	24
	Cariboo Regional District	100 Mile House, Exeter	40
Government Industrial Waste: Government landfills which receive non-municipal type wastes	Unknown	Former CFS Kamloops Landfill: Site A	0
	Unknown	Former CFS Kamloops Landfill: Site B	0
First Nations: Receives municipal type waste from First Nations community	Kamloops Indian Band	Kamloops Indian Reserve	18
	North Thompson Indian Band	North Thompson Indian Reserve #1, Darfield	0.4
Pitt River			
Miscellanious Industry: Variety of industries (metal, chemical, agriculture etc.)	Kennametal Incorporated	Port Coquitlam, 1651 Kingsway Avenue	2
Quesnel River			
Small Municipal: Landfill with serving population < 5,000	Cariboo Regional District	Likely	5.5
	Cariboo Regional District	Big Lake	2
Pulp Mills: Pulp mill wastes	Cariboo Pulp and Paper Company Limited	South And East Of Quesnel River At Fraser River	1677
	Cariboo Pulp and Paper Company Limited	Quesnel-Barkerville Highway	1677
Mining: Discharge to land permits associated with mining companies	Kinross Gold Corporation	Quesnel - 58 Km Southeast Of	2

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Quesnel River (continued)			
Medium Municipal: Landfill with serving population of 5,000 to 50,000	Cariboo Regional District	Horsefly	9.2
Large Municipal: Landfill with serving population > 50,000	City of Quesnel	Carson Pit Rd.	126
Seton-Portage			
Small Municipal: Landfill with serving population < 5,000	Squamish-Lillooet Regional District	Devine	4
First Nations: Receives municipal type waste from First Nations community	Seton Lake Indian Band	Seton Lake, Slosh Indian Reserve #1	0.7
	Anderson Lake Indian Band	Nequatque Indian Reserve #1,	0.3
South Thompson River			
Small Municipal: Landfill with serving population < 5,000	Sicamous Waterworks District	Sicamous	26
	Columbia Shuswap Regional District	Glenemma	1
	Columbia Shuswap Regional District	Scotch Creek	1
	Columbia Shuswap Regional District	Falkland	3
	Thompson-Nicola Regional District	Westwold	2.6
	Thompson-Nicola Regional District	Monte Lake	0.2
	Thompson-Nicola Regional District	Brennan Creek	1
	Columbia Shuswap Regional District	Seymour Arm	4
	Columbia Shuswap Regional District	Tappen	25
	Columbia Shuswap Regional District	Malakwa	2
	Thompson-Nicola Regional District	Pritchard	1.2
	Thompson-Nicola Regional District	Agate Bay	1
Miscellanious Industry: Variety of industries (metal, chemical, agriculture etc.)	Lafarge Canada Incorporated	Kamloops	1
	Federated Co-Operatives Limited	Canoe	0.7
Medium Municipal: Landfill with serving population of 5,000 to 50,000	Thompson-Nicola Regional District	Chase	22
	City of Kamloops	Barnhartvale	66
	District of Salmon Arm	Salmon Arm	34

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
South Thompson River (continued)			
First Nations: Receives municipal type waste from First Nations community	Spallumcheen Indian Band	Enderby Indian Reserve #2, south of Enderby	0.6
	Neskainlith Indian Band	Neskainlith Indian Reserve #2, south of Chase	0.4
	Adams Lake Indian Band	Sahhaltkum Indian Reserve #1, west of Chase	0.7
DLC/Contractors: Demolition, land clearing and construction wastes	Valleyview Enterprises Limited	Kamloops	32
Upper Fraser River			
Small Municipal: Landfill with serving population < 5,000	Lillooet Village of	Lillooet	3
	Squamish-Lillooet Regional District	Lillooet	6
	Squamish-Lillooet Regional District	Goldbridge	0.6
First Nations: Receives municipal type waste from First Nations community	Bridge River Indian Band	Bridge River Indian Reserve #1, north of Lillooet	0.3
Small Municipal: Landfill with serving population < 5,000	Fraser-Fort George Regional District	2Km E Of Hwy 97 Hixon Bridge	1.4
	Fraser-Fort George Regional District	Stoner Landfill, Stone Cr. Frst Rd.	0.7
	Cariboo Regional District	150 Mile House	7.2
	Cariboo Regional District	Chimney Lake	2
	Cariboo Regional District	Alexandria	0.5
	Cariboo Regional District	Williams Lake	3.2
	Thompson-Nicola Regional District	Lytton	1.2
	Cariboo Regional District	Mcleese Lake	7.6
	Cariboo Regional District	Puntchesakut Lake	4.5
	Cariboo Regional District	Frost Creek	1.5
	Cariboo Regional District	Cottonwood House	1
	Cariboo Regional District	Frost Creek	2
	Cariboo Regional District	Riske Creek	1
	Regional District of Fraser-Cheam	North Bend	2.4
	Cariboo Regional District	Baker Creek	4.7

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Upper Fraser River (continued)			
Sawmills/ Wood Manufacture: Sawmills, wood manufacture and wood treatment wastes	J.S. Jones Holdings Limited	Boston Bar	1.2
	Lignum Ltd. And Riverside Forest Products Ltd.	Williams Lake	4.9
	Weldwood of Canada Limited	Williams Lake, Glendale	1.7
Medium Municipal: Landfill with serving population of 5,000 to 50,000	Fraser-Fort George Regional District	Cummings Rd. Landfill	8.4
	City of Williams Lake	Mackenzie Ave.	200
	Cariboo Regional District	Wildwood	8.4
	Cariboo Regional District	Lac La Hache	12
	The Corporation of the Town of Hope	Hope	9
Government Industrial Waste: Government landfills which receive non-municipal type wastes	Government of British Columbia, Highways	Quesnel	0
First Nations: Receives municipal type waste from First Nations community	Lytton Indian Band	Nesikep Indian Reserve #6, north of Lytton	1.5
	Lytton Indian Band	Papyum Indian Reserve #27, Lytton	1.5
	Fountain Indian Band	Fountain Indian Reserve #1A, north-east of Lillooet	0.8
	Pavilion Indian Band	Pavilion Indian Reserve #1	0.3
	Pavilion Indian Band	Marble Canyon Indian Reserve #3, Pavilion Lake	0.3
	Soda Creek Indian Band	Soda Creek Indian Reserve #1	0.2
	Williams Lake Indian Band	Williams Lake Indian Reserve #1	0.4
	Alexandria Indian Band	Alexandria Indian Reserve #1, north of Marguerite	0.1
	Alexandria Indian Band	Alexandria Indian Reserve #3, north of Marguerite	0.1
	Canoe Creek Indian Band	Dog Creek Indian Reserve #1	0.5
	Canoe Creek Indian Band	Canoe Creek Indian Reserve #1	0.5

Table 3.18. Location of municipal and industrial landfills within the Fraser River Basin.

Area of Interest/Type: Description	Owner / Operator	General Location	Capacity tonnes/day
Upper Fraser River (continued)			
Small Municipal: Landfill with serving population	Fraser-Fort George Regional District	Willow R. Landfill	0.9
< 5,000	Regional District of Fraser Fort George	In Electoral Area F" (Aleza Lake) "	1
	Fraser-Fort George Regional District	Dome Cr. Landfill	0.2
	Village of Valemount	Valemount Landfill	4.3
	Cariboo Regional District	Wells	0.6
	Fraser-Fort George Regional District	Shelley Landfill	2.2
	Fraser-Fort George Regional District	Sinclair Mills Landfill	0.2
	Fraser-Fort George Regional District	Mcbride Landfill, Legrand Rd.	3.9
	Fraser-Fort George Regional District	Aleza Lake Landfill	0.7
	Cariboo Regional District	Wells	4
	Cariboo Regional District	Nazko - Marmot Lake	4.7
Pulp Mills: Pulp mill wastes	Northwood Pulp And Timber Limited	Prince George	2928
	Canadian Pacific Forest Products Limited	Prince George	2624

Table 3.19. Listing of salmonid enhancement facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Species Targetted	Organization
Cultus Lake			
Chilliwack River Hatchery	Hatchery	Chinook, Coho, Chum, and Steelhead	DFO Operations
Fraser Valley Trout Hatchery	Hatchery	Native and Domestic Rainbow Trout, Anadromous and Coastal Cutthroat Trout, and Steelhead Trout	Freshwater Fisheries Society of BC
Centre Creek Streamkeeper Program	Hatchery	N/A	Public Involvement Programs (Volunteer)
Harrison River			
Chehalis River Hatchery	Hatchery	Coho, Chinook, Chum, Steelhead and Cutthroat Trout	DFO Operations
Weaver Creek Spawning Channel	Spawning Channel	Sockeye, Chum and Pink	DFO Operations
Fee Creek Spawning and Rearing Channel	Hatchery	Coho	Public Involvement Programs (Volunteer)
Lower Fraser River			
Inch Creek Hatchery	Hatchery	Coho, Chinook, Chum, and Steelhead Trout	DFO Operations
Bell-Irving Kanaka Creek Hatchery	Hatchery	Chum, Coho, Pink, Steelhead and Cutthroat Trout	Public Involvement Programs (Volunteer)
Beecher Creek Streamkeepers	Hatchery	Coho, Cutthroat and Rainbow Trout	Public Involvement Programs (Volunteer)
Al Grist Memorial Hatchery	Hatchery	Coho, Chinook, and Pink	Public Involvement Programs (Volunteer)
Chilliwack River Action Commitee (Trap Site)	Hatchery	Steelhead Trout, Coho, Chinook, Chum, and Pink	Public Involvement Programs (Volunteer)
Stave Valley Salmonid Enhancement Society	Hatchery	Coho and Chum	Public Involvement Programs (Volunteer)
Nicomen Slough Spawning Channel	Hatchery	Coho and Chum	Public Involvement Programs (Volunteer)
Musqueam Creek Project	Hatchery	Coho, Chum, and Cutthroat Trout	Public Involvement Programs (Volunteer)
Steveston High School Hatchery (on-site)	Hatchery	Coho and Chinook	Public Involvement Programs (Volunteer)
Cougar Creek Salmonid Enhancement Group	Hatchery	Coho	Public Involvement Programs (Volunteer)
Hoy Creek Hatchery	Hatchery	Coho	Public Involvement Programs (Volunteer)
River Springs Salmon Enhancement and Streamkeepers	Hatchery	Coho, Chum, and Chinook	Public Involvement Programs (Volunteer)
Lower Thompson River			
Spius Creek Hatchery	Hatchery	Chinook, Coho and Steelhead Trout	DFO Operations
Loon Creek Hatchery	Hatchery	Rainbow Trout and Kokanee	Community Development Program Hatcheries
Deadman River Hatchery	Hatchery	Chinook and Coho	Community Development Program Hatcheries

Table 3.19. Listing of salmonid enhancement facilities in the Fraser River Basin.

Area of Interest/Facility Name	Facility Type	Species Targetted	Organization
Nechako River			
Nadina River Spawning Channel	Spawning Channel	Sockeye	DFO Operations
Spruce City Wildlife Fish Hatchery	Hatchery	Chinook	Public Involvement Programs (Volunteer)
North Thompson River			
Clearwater Trout Hatchery	Hatchery	Rainbow Trout and Kokanee Salmon	Freshwater Fisheries Society of BC
Dunn Lake Hatchery	Hatchery	Coho and Chinook	Community Development Program Hatcheries
Pitt River			
Upper Pitt River Hatchery	Hatchery	Chinook, Sockeye	DFO Operations
ALLCO Hatchery	Hatchery	Coho, Steelhead, Cutthroat, Pink and Chinook	Public Involvement Programs (Volunteer)
Hyde Creek Hatchery	Hatchery	Coho and Chum	Public Involvement Programs (Volunteer)
Quesnel River			
Horsefly Spawning Channel	Spawning Channel	Sockeye	DFO Operations
Seton-Portage			
Gates Creek Spawning Channel	Spawning Channel	Pink	DFO Operations
Seton Creek Spawning Channels	Spawning Channel	Pink	DFO Operations
South Thompson River			
Shuswap River Hatchery	Hatchery	Chinook	DFO Operations
Kingfisher Community Hatchery	Hatchery	Coho, Spring, Sockeye, and Kokanee	Public Involvement Programs (Volunteer)
Adams River	Fishway	Sockeye	DFO Operations
Upper Fraser River			
Penny Hatchery	Hatchery	Chinook	Community Development Program Hatcheries
Anderson Lake Fish Hatchery	Hatchery	Sockeye and Kokanee	Public Involvement Programs (Volunteer)
Hells Gate Fishways	Fishway	Sockeye, Coho, Pink, Chinook, Steelhead Trout	DFO Operations

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.20. Summary of forest management activities in the Fraser River Basin.

Area of Interest/Principal Harvested Species	Percent of Land Area Harvested From 1960 to 1990 (inclusive)	Area (Ha) Harvested From 1960 to 1990 (inclusive)	Percent of Land Area Harvested Since 1990	Area (Ha) Harvested Since 1990	Percent of Land Area Affected by Wild Fires (1990-2010)	Area (Ha) Affected by Wildfires (1990-2010)	Total Area of AoI (Ha)
Bowron River							
Black Cottonwood, Engelmann Spruce, Interior Douglas-fir, Lodgepole Pine, Spruce Hybrid, Subalpine Fir, Western Hemlock, Western Red Cedar, White Spruce	19.72%	71,400	29.18%	106,000	0.37%	1,330	362,000
Chilko River							
Douglas-fir, Interior Douglas-fir, Limber Pine, Lodgepole Pine, Spruce Hybrid	4.99%	97,800	7.20%	142,000	7.35%	144,000	1,960,000
Cultus Lake							
Amabilis Fir, Bigleaf Maple, Coastal Douglas-fir, Douglas-fir, Engelmann Spruce, Fir (Balsam), Hemlock, Mountain Hemlock, Paper Birch, Red Alder, Shore Pine, Western Hemlock, Western Red Cedar	9.84%	9,820	9.59%	9,570	0.03%	30.5	99,800
Harrison River							
Amabilis Fir, Aspen, Cottonwood or Poplar, Bigleaf Maple, Bitter Cherry, Black Cottonwood, Coastal Douglas-fir, Douglas-fir, Engelmann Spruce, Fir (Balsam), Hemlock, Interior Douglas-fir, Lodgepole Pine, Mountain Hemlock, Paper Birch, Red Alder, Shore Pine, Subalpine Fir, Western Hemlock, Western Red Cedar, Yellow Cedar	7.24%	61,000	6.63%	55,900	0.59%	4,970	843,000

Table 3.20. Summary of forest management activities in the Fraser River Basin.

Area of Interest/Principal Harvested Species	Percent of Land Area Harvested From 1960 to 1990 (inclusive)	Area (Ha) Harvested From 1960 to 1990 (inclusive)	Percent of Land Area Harvested Since 1990	Area (Ha) Harvested Since 1990	Percent of Land Area Affected by Wild Fires (1990-2010)	Area (Ha) Affected by Wildfires (1990-2010)	Total Area of AoI (Ha)
Kakawa Lake							
Amabilis Fir, Coastal Douglas-fir, Douglas-fir, Douglas-fir, Engelmann Spruce, Hemlock, Mountain Hemlock, Poplar, Red Alder, Spruce Hybrid, Subalpine Fir, Western Hemlock, Western Red Cedar	10.24%	7,640	7.95%	5,930	0.03%	19.5	74,600
Lower Fraser River							
Amabilis Fir, Bigleaf Maple, Black Cottonwood, Cedar, Coastal Douglas-fir, Douglas-fir, Douglas-fir, Grand Fir, Hemlock, Hybrid Poplars, Mountain Hemlock, Paper Birch, Poplar, Red Alder, Western Hemlock, Western Red Cedar, Yellow Cedar	6.45%	24,300	5.25%	19,800	0.03%	114	377,000
Lower Thompson River							
Amabilis Fir, Black Spruce, Cedar, Coastal Douglas-fir, Douglas-fir, Engelmann Spruce, Engelmann x Sitka Spruce, Engelmann x White Spruce, Interior Douglas-fir, Larch, Lodgepole Pine, Norway Spruce, Ponderosa Pine, Shore Pine, Spruce, Spruce Hybrid, Subalpine Fir, Trembling Aspen, Western Hemlock, Western Red Cedar, White Spruce	7.23%	128,000	6.03%	107,000	1.96%	34,700	1,770,000
Nahatlatch River							
Amabilis Fir, Black Cottonwood, Coastal Douglas-fir, Douglas-fir, Engelmann Spruce, Mountain Hemlock, Spruce Hybrid, Western Hemlock, Western Red Cedar	1.84%	2,230	1.89%	2,290	1.74%	2,100	121,000

Table 3.20. Summary of forest management activities in the Fraser River Basin.

Area of Interest/Principal Harvested Species	Percent of Land Area Harvested From 1960 to 1990 (inclusive)	Area (Ha) Harvested From 1960 to 1990 (inclusive)	Percent of Land Area Harvested Since 1990	Area (Ha) Harvested Since 1990	Percent of Land Area Affected by Wild Fires (1990-2010)	Area (Ha) Affected by Wildfires (1990-2010)	Total Area of AoI (Ha)
Nechako River							
Amabilis Fir, Aspen, Cottonwood or Poplar, Balsam Fir, Black Spruce, Coastal Douglas-fir, Douglas-fir, Engelmann Spruce, Engelmann x White Spruce, Interior Douglas-fir, Jack Pine, Lodgepole Pine, Norway Spruce, Paper Birch, Pine, Red Pine, Shore Pine, Spruce, Spruce Hybrid, Subalpine Fir, Tamarack, Trembling Aspen, White Spruce, Whitebark Pine	6.13%	290,000	9.02%	426,000	2.08%	98,500	4,730,000
North Thompson River							
Amabilis Fir, Balsam Fir, Birch, Black Spruce, Cedar, Douglas-fir, Engelmann Spruce, Engelmann x Sitka Spruce, Engelmann x White Spruce, Fir (Balsam), Interior Douglas-fir, Larch, Lodgepole Pine, Mountain Hemlock, Paper Birch, Ponderosa Pine, Poplar, Red Alder, Sitka Spruce, Spruce, Spruce Hybrid, Subalpine Fir, Trembling Aspen, Western Red Cedar, Western White Pine, White Spruce	4.93%	102,000	8.72%	181,000	2.72%	56,400	2,070,000
Pitt River							
Amabilis Fir, Coastal Douglas-fir, Hemlock, Mountain Hemlock, Red Alder, Western Hemlock, Western Red Cedar, Yellow Cedar	3.63%	6,090	4.82%	8,110	0.11%	177	168,000

Table 3.20. Summary of forest management activities in the Fraser River Basin.

Area of Interest/Principal Harvested Species	Percent of Land Area Harvested From 1960 to 1990 (inclusive)	Area (Ha) Harvested From 1960 to 1990 (inclusive)	Percent of Land Area Harvested Since 1990	Area (Ha) Harvested Since 1990	Percent of Land Area Affected by Wild Fires (1990-2010)	Area (Ha) Affected by Wildfires (1990-2010)	Total Area of AoI (Ha)
Quesnel River							
Alder, Amabilis Fir, Balsam Fir, Black Cottonwood, Black Spruce, Douglas-fir, Engelmann Spruce, Engelmann x White Spruce, Interior Douglas-fir, Lodgepole Pine, Paper Birch, Poplar, Spruce, Spruce Hybrid, Subalpine Fir, Trembling Aspen, Western Hemlock, Western Red Cedar, White Spruce	9.17%	110,000	10.87%	131,000	0.24%	2,840	1,200,000
Seton-Portage							
Amabilis Fir, Balsam Fir, Coastal Douglas-fir, Douglas-fir, Engelmann Spruce, Interior Douglas-fir, Lodgepole Pine, Spruce, Spruce Hybrid, Subalpine Fir, Western Hemlock, Western Red Cedar	4.07%	7,730	4.07%	7,730	3.29%	6,250	190,000
South Thompson River							
Amabilis Fir, Aspen, Cottonwood or Poplar, Balsam Fir, Bitter Cherry, Black Cottonwood, Black Spruce, Cedar, Douglas-fir, Engelmann Spruce, Engelmann x White Spruce, Hemlock, Interior Douglas-fir, Larch, Lodgepole Pine, Mountain Hemlock, Norway Spruce, Paper Birch, Ponderosa Pine, Shore Pine, Spruce, Spruce Hybrid, Subalpine Fir, Trembling Aspen, Western Larch, Western Red Cedar, Western White Pine, White Spruce, Willow	77.14%	135,000	10.08%	176,000	26.51%	46,400	175,000

Table 3.20. Summary of forest management activities in the Fraser River Basin.

Area of Interest/Principal Harvested Species	Percent of Land Area Harvested From 1960 to 1990 (inclusive)	Area (Ha) Harvested From 1960 to 1990 (inclusive)	Percent of Land Area Harvested Since 1990	Area (Ha) Harvested Since 1990	Percent of Land Area Affected by Wild Fires (1990-2010)	Area (Ha) Affected by Wildfires (1990-2010)	Total Area of AoI (Ha)
Upper Fraser River							
Alder, Amabilis Fir, Balsam Fir, Black Cottonwood, Black Spruce, Coastal Douglas-fir, Douglas-fir, Engelmann Spruce, Engelmann x White Spruce, Fir (Balsam), Interior Douglas-fir, Lodgepole Pine, Mountain Hemlock, Paper Birch, Ponderosa Pine, Red Alder, Shore Pine, Spruce, Spruce Hybrid, Subalpine Fir, Trembling Aspen, Western Hemlock, Western Red Cedar, Whitebark Pine	8.48%	631,000	3.63%	787,000	3.53%	263,000	7,440,000
Fraser River Basin	7.78%	1,680,000	5.79%	2,160,000	3.06%	661,000	21,600,000

For sources of the above information see Appendix 5.

Table 3.21. Summary of agricultural activities in the Fraser River Basin.

Area of Interest /Principal Agricultural Activities	Total AoI Area (Ha)	Area Affected (Ha)	Percent of Land Area Affected
Bowron River			
Herbs, Forage	362000	773	0.21%
Chilko River			
Ranching, Potatoes, Hay, Forage	1960000	74300	3.79%
Cultus Lake			
Animal Specialty Farms, Raspberries	99800	16600	16.63%
Harrison River			
Hazelnuts	843000	5580	0.66%
Lower Fraser River			
Greenhouse Productions; Livestock Combination Farms, Asparagus, Beans, Blueberries, Cabbage, Carrots, Bok Choy, Corn, Cranberries, Floriculture, Grapes and Wine, Greenhouse vegetables (tomatoes, cucumbers, lettuce, peppers), Hazelnuts, Herbs, Holly, Lettuce, Mushrooms, Nursery Crops, Onions, Peas, Potatoes, Pumpkin, Raspberries, Strawberries, Turfgrass Sod, Chickens, Dairy-Milk, Eggs, Game Birds, Hogs, Llamas, Ostrich, Sheep, Turkeys	377000	52100	13.82%
Lower Thompson River			
Eggs, Fallow Deer, Ranching, Sheep	1770000	249000	14.07%
Nahatlatch			
Forage	121000	39.3	0.03%
Nechako River			
Forage, Grains, Ranching	4730000	128000	2.71%
North Thompson River			
Eggs, Fallow Deer, Ranching, Sheep	2070000	44800	2.16%

Table 3.21. Summary of agricultural activities in the Fraser River Basin.

Area of Interest /Principal Agricultural Activities	Total AoI Area (Ha)	Area Affected (Ha)	Percent of Land Area Affected
Pitt River			
Blueberries, Cranberries	168000	7780	4.63%
Quesnel River			
Ranching	1200000	21100	1.76%
Seton-Portage			
Ranching, Apples	190000	931	0.49%
South Thompson			
Livestock Combination Farms, Apples, Asparagus, Beans, Carrots, Cherries, Corn, Grain, Grapes and Wine, Nursery Crops, Onions, Pears, Plums, Potatoes, Pumpkin, Raspberries, Stawberries, Turfgrass Sod, Dairy-Milk, Eggs, Fallow Deer, Hogs, Llamas, Ostrich, Ranching, Sheep	1750000	93900	5.37%
Upper Fraser			
Ginseng, Ranching	21700000	238000	1.10%

For sources of the above information see Appendix 5.

Table 3.22. Listing of municipal developments in the Fraser River Basin.

Area of Interest/Municipality	Population (2009)	Primary Industries
Harrison River		
Harrison Hot Springs	1594	Tourism & Recreation
Pemberton	2416	Agriculture, Forestry, Tourism & Recreation
Kakawa Lake		
Hope	6269	Forestry, Oil & Gas Development, Agriculture, Hydro Development
Lower Fraser River		
Abbotsford	135866	Agriculture, Transportation, Manufacturing, Retail
Burnaby	222802	Forestry, Fishing, Mining and Minerals
Chilliwack	76106	Agriculture, Manufacturing, Tourism
Coquitlam	123213	Agriculture, Forestry
Mission	37167	Forestry, Hydroelectricity, Agriculture
New Westminster	65016	
Port Coquitlam	56446	Agriculture
Richmond	193255	Services, retailing, tourism, technology industries, light manufacturing, airport services and aviation, agriculture, fishing and government
Vancouver	628621	Manufacturing, Forest products, Mining, Software development, Biotechnology, Film industry
Lower Thompson River		
Ashcroft	1740	Tourism, Agriculture, Mining, Forestry-related activities
Cache Creek	1083	Tourism, Agriculture, Forestry, Tourism, Mining and Waste management
Clinton	597	Forestry, Ranching and Tourism
Merritt	7450	Ranching, Farming, Forestry, Transportation and Tourism
Kamloops	87017	Resource processing (Pulpmill, Plywood & Veener, Cement, Copper Mine), Ranching
Nahatlatch River		
N/A	N/A	N/A
Nechako River		
Burns Lake	2114	Forestry and Forestry products
Fraser Lake	1122	Mining and Forestry
Prince George	74547	Pulp mills, Sawmills, Oil refinery, Forestry, Mining, Transportation

Table 3.22. Listing of municipal developments in the Fraser River Basin.

Area of Interest/Municipality	Population (2009)	Primary Industries
North Thompson River		
One Hundred Mile House	1941	Forestry and Ranching
Pitt River		
N/A	N/A	N/A
Quesnel River		
Quesnel	9710	Forestry & wood products manufacturing, Pulp and Paper, Sawmills & Plywood mills, Mining
Seton-Portage		
N/A	N/A	N/A
South Thompson River		
Chase	2478	Forestry
Enderby	2906	Agriculture (dairy, livestock, feed crops, small fruits & vegetables, exotic animals) and forestry (logging, saw milling, planing, silviculture, small value-added processing)
Lumby	1804	Agriculture and Forestry
Salmon Arm	17220	Forestry, Agriculture, Tourism Commerce, and Manufacturing
Upper Fraser River		
Lytton	226	Forestry and Tourism
Mcbride	674	Forestry and forestry products (sawmill), Tourism
Valemount	1044	Forestry, Ranching and Tourism
Williams Lake	11090	Forestry and forestry products (lumber and value-added manufacturing), Mining (copper, molybdenum, gold), Agriculture, Tourism

For sources of the above information see Appendix 5.
N/A = Data Not Available

Table 3.23. Estimated annual contaminant loading (in tonnes) from urban runoff in the Fraser River (Gray and Tuominen 1999).

Contaminant	Fraser Basin	Lower Fraser	Thompson	Middle Fraser	Upper Fraser
Suspended solids	62782	54584	1689	913	5596
Ammonia	75.3	65.5	2	1.1	6.7
Nitrate/nitrite	351.6	305.7	9.5	5.1	31.3
Total nitrogen	878.9	764.2	23.7	12.8	78.3
Total phosphorus	175.8	152.8	4.7	2.6	15.7
Lead	75.3	65.5	2	1.1	6.7
Copper	17.6	15.3	0.5	0.3	1.6
Zinc	75.3	65.5	2	1.1	6.7
Chromium	5	4.4	0.14	0.07	0.45
Cadmium	4	3.5	0.1	0.06	0.36
Nickel	12.6	10.9	0.3	0.18	1.1
Arsenic	6.5	5.7	0.2	0.1	0.6
Phenols	6.5	5.7	0.2	0.1	0.6
Total hydrocarbons	2009	1747	54.1	29.2	179.1
Polycyclic aromatic hydrocarbons	0.5	0.44	0.01	0.01	0.004

Table 3.24. Listing of potentially active and inactive volcanoes in the Fraser River Basin.

Area of Interest/Volcano Name	Volcanic Feature	Status	Age of Last Eruption[1]
Chilko River			
Chilcotin Creek Cone	Cinder cone	Inactive	Pliocene
Downton Cone 01	Cinder cone	Inactive	Pleistocene
Downton Cone 02	Cinder cone	Inactive	Pleistocene
Downton Cone 03	Cinder cone	Inactive	Pleistocene
Downton Cone 04	Cinder cone	Inactive	Pleistocene
Downton Cone 05	Cinder cone	Inactive	Pleistocene
Downton Cone 06	Cinder cone	Inactive	Pleistocene
Downton Cone 07	Cinder cone	Inactive	Pleistocene
Downton Cone 08	Cinder cone	Inactive	Pleistocene
Downton Cone 09	Cinder cone	Inactive	Pleistocene
Downton Cone 10	Cinder cone	Inactive	Pleistocene
Downton South-B	Cinder cone	Inactive	Pleistocene
Downton South-C	Cinder cone	Inactive	Pleistocene
Downton South-D	Cinder cone	Inactive	Pleistocene
Downton South-E	Cinder cone	Inactive	Pleistocene
Itcha Cone 01	Cinder cone	Inactive	Pleistocene
Itcha Cone 02	Cinder cone	Inactive	Pleistocene
Itcha Cone 03	Cinder cone	Inactive	Pleistocene
Itcha Cone 04	Cinder cone	Inactive	Pleistocene
Itcha Cone 05	Cinder cone	Inactive	Pleistocene
Itcha Cone 06	Cinder cone	Inactive	Pleistocene
Satah Mountain-East	Cinder cone	Inactive	Pleistocene
Satah Mountain-North	Cinder cone	Inactive	Pleistocene
White Creek Cone	Cinder cone	Inactive	Pleistocene
Harrison River			
Bridge River Vent	Crater	Inactive	Pliocene
Capricorn Mt.	Eroded volcanic outcrop	Inactive	Pleistocene
Mosaic Assemblage	Eroded volcanic outcrop	Inactive	Pleistocene
Mount Job	Eroded volcanic outcrop	Inactive	Pleistocene
Mount Meager	Dome	Potentially Active	2350 years ago
Plinth Mountain	Eroded volcano	Potentially Active	2350 years ago
Salal Glacier	Subglacial mound (SUGM)	Inactive	Pleistocene
The Devastator	Eroded volcano	Inactive	Pleistocene
Lower Thompson River			
Nicola (Chester)	Eroded volcanic outcrop	Inactive	Pleistocene
Quilchena Creek	Eroded volcanic outcrop	Inactive	Pleistocene
North Thompson River			
Buck Hill Cone	Cinder cone	Inactive	Pleistocene
Dragon Cone	Cinder cone	Inactive	Holocene
Fiftytwo Ridge	Subglacial volcano	Inactive	Pleistocene
Flatiron	Eroded volcanic outcrop	Inactive	Pleistocene
Flourmill Cone	Cinder cone	Inactive	Holocene

Table 3.24. Listing of potentially active and inactive volcanoes in the Fraser River Basin.

Area of Interest/Volcano Name	Volcanic Feature	Status	Age of Last Eruption[1]
North Thompson River (cont.)			
Gage Hill	Tuya	Inactive	Pleistocene
Hyalo Ridge	Tuya	Inactive	Pleistocene
Ida Ridge	Eroded cinder cone	Inactive	Pleistocene
Jack's Jump	Subglacial volcano	Inactive	Pleistocene
Kostal Cone	Polygenetic cinder cone	Potentially Active	Approx. 1550 A.D.
McLeod Hill	Tuya	Inactive	Pleistocene
Mosquito Mound	Tuya	Inactive	Pleistocene
Pillow Creek	Subglacial volcano	Inactive	Pleistocene
Pointed Stick Cone	Eroded cinder cone	Inactive	Holocene
Pyramid Mountain	Subglacial volcano	Inactive	Pleistocene
Ray Mountain	Subglacial mound (SUGM)	Inactive	Pleistocene
Spanish Bonk	Neck	Inactive	Pleistocene
Spanish Lake Centre	Polygenetic cinder cone	Inactive	Holocene
Spanish Mump	Subglacial mound (SUGM)	Inactive	Pleistocene
White Horse Bluff	Subaqueous volcano	Inactive	Pleistocene
Pitt River			
Glacier Pikes	Dome	Inactive	Pleistocene
Quesnel River			
Boss Mountain	Eroded cinder cone	Inactive	Pleistocene
Jacques Lake	Eroded cinder cone	Inactive	Pleistocene
Quesnel Lake	Eroded cinder cone	Inactive	Pleistocene
Upper Fraser River			
Alixton Creek	Eroded volcanic outcrop	Inactive	Pleistocene
Alkali Lake	Eroded volcanic outcrop	Inactive	Pleistocene
Browns Lake	Eroded volcanic outcrop	Inactive	Pleistocene
Canoe Creek	Eroded volcanic outcrop	Inactive	Pleistocene
Crows Bar	Eroded volcanic outcrop	Inactive	Pleistocene
Dog Creek	Eroded volcanic outcrop	Inactive	Pleistocene
Itcha Cone 07	Cinder cone	Inactive	Pleistocene
Itcha Cone 08	Cinder cone	Inactive	Pleistocene
Leon Creek	Eroded volcanic outcrop	Inactive	Pleistocene
Nichols Valley Flows	Eroded volcanic outcrop	Inactive	Pleistocene
Prentice Gulch	Eroded volcanic outcrop	Inactive	Pleistocene
Sham Hill	Neck	Inactive	Pleistocene
Thaddeus Lake	Eroded volcanic outcrop	Inactive	Pleistocene
Tuber Hill	Stratovolcano	Inactive	Pleistocene
Tuber Hill - East	Eroded volcanic outcrop	Inactive	Holocene
Nazko Cone	Polygenetic cinder cone	Potentially Active	Holocene

[1] Pliocene Age (5,332,000 to 1,806,000 years ago), Pleistocene (1,806,000 to 11,700 years ago), Holocene (11,700 years ago to present day).

For sources of the above information see Appendix 5.

Table 3.25. Summary of land use activities by Area of Interest in the Fraser River Basin.

Area of Interest	*Point Sources*														*Non-Point Sources*				*Atmospheric Sources*	
	Pulp and Paper Mills	Sawmills, Plywood Mills, & Particle Board Mills	Wood Preservation Facilities	Cement Plants	Seafood Processing Facilities	Operating & Abandoned Mines	Oil and Gas Developments	Bulk Storage and Shipping Facilities	Other Manufacturing Facilities	Contaminated Sites & Contaminant Spills	Municipal Wastewater Treatement Facilities	Municipal & Industrial Landfills	Salmonid Enhancement Facilities	Lake Fertilization Projects	Runoff from Forest Management Areas	Runoff from Agricultural Operations	Runoff from Municipal Stormwater	Runoff from Linear Developments[2]	Natural Sources[3]	Anthropogenic Sources
Lower Fraser River	√√√	√√√	√√√	√√√	√√√	√	√	√√√	√√√	√√√	√√√	√√√	√√√		√	√√√	√√√	√√	√	√
Upper Fraser River	√√	√√√	√√√		√	√√√	√√√		√√√	√√√	√√√	√√√	√√		√√√	√√	√	√√	√√√	√√
Pitt River								√	√√√	√√√		√	√√		√√	√√	√	√√	√	√
Harrison River						√				√√√	√√	√√	√√		√√	√	√	√√	√√√	√
Cultus Lake						√√		√	√√	√√√		√√	√√		√√	√√	√	√√	√	√
Kakawa Lake							√			√√	√				√√		√	√√	√	√
Nahatlatch River															√√	√			√	√
Seton-Portage		√								√√√		√√	√√		√√√	√√	√	√	√	√
Lower Thompson River	√	√√√	√√			√√√	√√		√√	√√√	√√	√√√	√√		√√	√√√	√√	√√	√√	√
North Thompson River		√√√				√			√	√√√	√	√√√	√√		√√	√√√	√	√√	√√√	√
South Thompson River		√√√	√√	√		√√			√√√	√√√	√√	√√√	√√	√	√√	√√√	√√	√√	√	√
Chilko River										√√√		√√√		√	√√√	√√√	√		√√√	√
Quesnel River	√√	√√√				√√	√			√√√	√	√√√	√		√√	√	√	√√	√√	√
Nechako River		√√√	√			√√√			√	√√√	√√	√√√	√√		√√√	√√	√	√√	√	√
Bowron River															√√	√√		√	√	√

√ = At least one facility or activity occurs within the watershed
√√ = Two or three facilities or activity common within the watershed
√√√ = More than three facilities or activities prevalent within the watershed

[1] One checkmark in this category indicates one type of agricultural industry (i.e., ranching), two checkmarks indicate two types of agricultural industries (e.g., ranching, and apples), three checkmarks indicate three or more agricultural industries.

[2] One checkmark in this category indicates one type of linear development (major road or railway), two check marks indicate both major roads and railways are present.

[3] For the purpose of developing the Inventory of Aquatic Contaminants, substances associated with natural atmospheric sources were not considered.

Table 3.26. Summary of the classes of contaminants that are typically released in association with various land uses.

Analyte Group	*Point Sources*														*Non-Point Sources*				*Atmospheric Sources*	
	Pulp and Paper Mills	Sawmills, Plywood Mills, & Particle Board Mills	Wood Preservation Facilities	Cement Plants	Seafood Processing Facilities	Operating & Abandoned Mines	Oil and Gas Developments	Bulk Storage and Shipping Facilities	Other Manufacturing Facilities	Contaminated Sites & Contaminant Spills	Municipal Wastewater Treatement Facilities	Municipal & Industrial Landfills	Salmonid Enhancement Facilities	Lake Fertilization Projects	Runoff from Forest Management Areas	Runoff from Agricultural Operations	Runoff from Municipal Stormwater	Runoff from Linear Developments	Natural Sources[1]	Anthropogenic Sources
Conventional Variables	√	√		√	√	√			√		√	√		√	√	√	√	√	√	
Microbiological Variables						√					√									
Major Ions	√	√				√			√								√	√	√	
Nutrients	√	√		√	√	√			√	√	√	√		√	√			√		
Metals	√	√		√		√	√	√	√	√	√	√					√	√	√	√
Organometallics								√	√	√		√								√
Cyanides						√				√	√	√								
Mono Aromatic Hydrocarbons (MAHs)	√					√	√	√	√	√	√	√					√		√	√
Polycyclic Aromatic Hydrocarbons (PAHs)	√					√	√	√	√	√	√	√					√	√	√	√
Phenolic Compounds		√							√	√	√	√								
Chlorinated Phenolic Compounds	√									√	√	√								
Polychlorinated Biphenyls (PCBs)										√	√	√					√			√
Polychlorinated Dibenzo-*p*- Dioxins (PCDDs)	√									√									√	√
Polychlorinated Dibenzofurans (PCDFs)	√									√									√	√
Resin Acids	√	√																		
Fatty Acids	√	√																		
Petroleum Hydrocarbons		√		√	√	√	√	√	√	√	√	√					√	√		
Pesticides										√		√	√		√	√	√	√		√

Table 3.26. Summary of the classes of contaminants that are typically released in association with various land uses.

Analyte Group	***Point Sources***														***Non-Point Sources***				***Atmospheric Sources***	
	Pulp and Paper Mills	Sawmills, Plywood Mills, & Particle Board Mills	Wood Preservation Facilities	Cement Plants	Seafood Processing Facilities	Operating & Abandoned Mines	Oil and Gas Developments	Bulk Storage and Shipping Facilities	Other Manufacturing Facilities	Contaminated Sites & Contaminant Spills	Municipal Wastewater Treatement Facilities	Municipal & Industrial Landfills	Salmonid Enhancement Facilities	Lake Fertilization Projects	Runoff from Forest Management Areas	Runoff from Agricultural Operations	Runoff from Municipal Stormwater	Runoff from Linear Developments	Natural Sources[1]	Anthropogenic Sources
Wood Preservation Chemicals			√							√										
Surfactants	√														√					
Pharmaceuticals											√	√								
Personal Care Products									√		√	√								
Steroids, Hormones, and Hormone Mimickers	√	√									√	√								
Disinfectants					√						√	√	√							
Fire Retardants											√	√			√					√
Plastics-Related Chemicals								√	√	√	√	√								
Nanoparticles											√									

[1] For the purpose of developing the Inventory of Aquatic Contaminants, substances associated with natural atmospheric sources were not considered.

Table 3.27. Listing of classes of chemicals of potential concern that have likely been released into aquatic habitats within Areas of Interest in the Fraser River Basin.

Class of Chemical of Potential Concern	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Conventional Variables	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Microbiological Variables	√	√		√	√				√		√		√	√		√
Major Ions	√	√	√	√	√	√			√	√	√		√	√		√
Nutrients	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Metals	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Organometallics	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Cyanides	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Mono Aromatic Hydrocarbons (MAHs)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Polycyclic Aromatic Hydrocarbons (PAHs	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Phenolic Compounds	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Chlorinated Phenolic Compounds	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Polychlorinated Biphenyls (PCBs)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Polychlorinated Dibenzo-*p*- Dioxins (PCDDs)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Polychlorinated Dibenzofurans (PCDFs)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Resin Acids	√	√							√	√	√		√	√		√
Fatty Acids	√	√							√	√	√		√	√		√
Petroleum Hydrocarbons	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Pesticides	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Wood Preservation Chemicals	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Surfactants	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Table 3.27. Listing of classes of chemicals of potential concern that have likely been released into aquatic habitats within Areas of Interest in the Fraser River Basin.

Class of Chemical of Potential Concern	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Pharmaceuticals	√	√		√	√			√	√	√	√	√	√	√		√
Personal Care Products	√	√	√	√	√			√	√	√	√	√	√	√		√
Steroids, Hormones, and Hormone Mimickers	√	√		√	√			√	√	√	√	√	√	√		√
Disinfectants	√	√	√	√	√			√	√	√	√	√	√	√		√
Fire Retardants	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Plastics-Related Chemicals	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Nanoparticles	√	√		√					√		√			√		√

Table 3.28. Inventory of aquatic contaminants in the Fraser River Basin.

Chemical Class/Chemical Sub-Class	Chemical Name/Analyte
Conventional Variables	Alkalinity
	Biological Oxygen Demand (BOD)
	Chemical Oxygen Demand (COD)
	Conductivity
	Hardness
	pH
	Temperature
	Total Suspended Sediment
	Total Dissolved Solids
Microbiological Variables	Faecal Coliforms
	Enterococci
Major Ions	
Anions	Chlorides
	Sulphates
	Sulphides
Cations	Calcium
	Potassium
	Sodium
Nutrients	Nitrate
	Nitrite
	Ammonia
	Urea
	Phosphorus
Metals	Aluminum
	Arsenic
	Barium
	Boron
	Cadmium
	Chromium (III & VI)
	Cobalt
	Copper
	Iron
	Lead
	Mercury
	Manganese
	Molybdenum
	Nickel
	Selenium
	Strontium
	Silver
	Vanadium
	Zinc

Table 3.28. Inventory of aquatic contaminants in the Fraser River Basin.

Chemical Class/Chemical Sub-Class	Chemical Name/Analyte
Organometallics	
Organotins	Monobutyltin
	Dibutyltin
	Tributyltin
	Tetrabutyltin
Organomercury	Methylmercury
Cyanides	Cyanide (SAD)
	Cyanide (WAD)
Mono Aromatic Hydrocarbons (MAHs)	
	Benzene
	Toluene
	Ethylbenzene
	Xylene
Polycyclic Aromatic Hydrocarbons	
Parent PAHs	Includes Low-Molecular and High-Molecular Weight PAHs
Low-Molecular Weight PAHs	Acenapthene
	Acenaphthylene
	Anthracene
	Fluorene
	Naphthalene
	Phenanthrene
	2,6-dimethylnaphthalene
	1-methylnaphthalene
	2-methylnaphthalene
	1-methylphenanthrene
	2,3,5-trimethylnaphthalene
High-Molecular Weight PAHs	Chrysene
	Fluoranthene
	Pyrene
	Benzo(k)fluoranthene
	Benzo(b)fluoranthene
	Benzo(a)pyrene
	Benzo(a)anthracene
	Benzo(e)pyrene
	Benzo(g,h,i)perylene
	Dibenz(a,h)anthracene
	Indeno(1,2,3-c,d)pyrene
	Perylene
Alkylated PAHs	C1-benzo(a)anthracenes/chrysenes
	C2-benzo(a)anthracenes/chrysenes

Table 3.28. Inventory of aquatic contaminants in the Fraser River Basin.

Chemical Class/Chemical Sub-Class	Chemical Name/Analyte
Polycyclic Aromatic Hydrocarbons (continued)	
Alkylated PAHs (continued)	C3-benzo(a)anthracenes/chrysenes
	C4-benzo(a)anthracenes/chrysenes
	C1-fluoranthenes/pyrenes
	C1-fluorenes
	C2-fluorenes
	C3-fluorenes
	C1-naphthalenes
	C2-naphthalenes
	C3-naphthalenes
	C4-naphthalenes
	C1-phenanthrenes/anthracenes
	C2-phenanthrenes/anthracenes
	C3-phenanthrenes/anthracenes
	C4-phenanthrenes/anthracenes
Total PAHs	
Phenolic Compounds	
Phenols	Phenol
Creosols	Cresol
Chlorinated Phenolic Compounds	
Chlorophenols	Dichlorophenols
	Trichlorophenols
	Tetrachlorophenols
	Pentachlorophenol
Chloroguaiacols	Trichloroguaiacols
	Tetrachloroguaiacols
Chlorocatechols	Trichlorocatechols
	Tetrachlorocatechols
Polychlorinated Biphenyls (PCBs)	
PCB Congeners	209 Congeners
PCB Homologs	10 Homolog Groups
PCB Aroclors	7+ Aroclor Mixtures
Dioxin-like PCBs	2,3,7,8-TCDD Toxic Equivalents
Polychlorinated Dibenzo-*p*- Dioxins (PCDDs)	
PCDD Congeners	75 Congeners
	2,3,7,8-TCDD Toxic Equivalents
Polychlorinated Dibenzofurans (PCDFs)	
PCDF Congners	135 Congeners
	2,3,7,8-TCDD Toxic Equivalents

Table 3.28. Inventory of aquatic contaminants in the Fraser River Basin.

Chemical Class/Chemical Sub-Class	Chemical Name/Analyte
Resin Acids	Abietic Acid
	Neoabietic Acid
	Dehydroabietic Acid
	Palustric Acid
	Levopimaric Acid
	Pimaric Acid
	Isopimaric Acid
Fatty Acids	Palmitic Acid
	Stearic Acid
	Lignoceric Acid
	Oleic Acid
	Linoleic Acid
	Linolenic Acid
Petroleum Hydrocarbons	
Oil and Grease	
Diesel Range Organics	
Alkanes	
Petroleum Hydrocarbons (continued)	
Lube Oils	
Pesticides	
In-Use Herbicides	Atrazine
	2,4-Dichlorophenoxyacetic acid (2,4-D)
	2,4-D Amine
	Ethalfluralin
	Glyphosate
	Mineral Oil (Paraffin base)
	Paraquat
	Pendimethalin
	Picloram
	Simazine
	Triallate
	Triclopyr
	Trifluralin
In-Use Insecticides	Azinphosmethyl
	Bacillus thuringiensis
	Chlorpyrifos
	Diazinon
	Endosulfan
	Malathion
	Mineral Oil
	Parathion

Table 3.28. Inventory of aquatic contaminants in the Fraser River Basin.

Chemical Class/Chemical Sub-Class	Chemical Name/Analyte
Pesticides (continued)	
Legacy Organochlorine Pesticides	Aldrin
	Chlordane
	DDTs
	Dieldrin
	Endrin
	Endosulfan
	Heptachlor
	Heptachlor Epoxide
	Hexachlorobenzene
	Lindane
	Methoxychlor
	Nonachlor
	Toxaphene
In-Use Fungicides	Captan
	Chlorothalonil
	Dazomet
	Mancozeb
	Metam
	Metiram
	Lime Sulphur
Other Pesticides	Formaldehyde
	Formalin
Wood Preservation Chemicals	
Wood Preservatives	Creosote
	Chromated Copper Arsenate (CCA)
	Ammoniacal Copper Zinc Arsenate (ACZA)
	Pentachlorophenol (PCP)
Anti-Sapstains	Didecyldimethyl ammonium chloride (DDAC)
	3-iodo-2-propynyl butyl carbamate (IPBC)
Surfactants	
Alkylphenol Ethoxylates (APEOs)	Nonylphenol Ethoxylates
	Octylphenol Ethoxylates
Fluorosurfactants	Amphoteric Fluorosurfactants
	Non-Ionic flurosurfactants
	Anionic flurosurfactants
Pharmaceuticals	
Antibiotics	Azithromycin
	Ciprofloxacin
	Doxycycline
	4-Epitetracycline
	Erythromycin

Table 3.28. Inventory of aquatic contaminants in the Fraser River Basin.

Chemical Class/Chemical Sub-Class	Chemical Name/Analyte
Pharmaceuticals (continued)	
Antibiotics (continued)	Oflocacin
	Oxytetracycline
	Tetracycline
Antihypertensives	Atenolol
Anticonvulsants	Carbamazepine
Antidepressants	Fluoxetine
	Sertaline
Anti-acid reflux compounds	Cimetidine
Anti-inflamatory compounds	Naproxen
Antifungal compounds	Miconazole
Analgesic compounds	Ibuprofen
Personal Care Products	
Fragrances	Celestolide
	Galaxolide
	Tonalide
Insect Repellants	Toluamide
Detergents	Alkylphenols
Antimicrobial compounds	Triclocarban
	Triclosan
Fungicides	Pentachloronitrobenzene
Surfactants	n-Nonylphenol
Stimulants	Caffeine
Steroids, Hormones, and Hormone Mimickers	
Hormones	Androstenedione
	Beta-Stigmastanol
	Campesterol
	Cholestanol
	Cholesterol
	Coprostanol
	17α-Ethinylestradiol
	Epicporostanol
	Estradiol
	Estrone
	Estriol
	Stigmasterol
	Testosterone
Natural Plant Hormones	Phytosterols
	Phytoestrogen Metabolites

Table 3.28. Inventory of aquatic contaminants in the Fraser River Basin.

Chemical Class/Chemical Sub-Class	Chemical Name/Analyte
Disinfectants	
Disinfectants	Bromine
	Residual Chlorine
	Iodine
Disinfection byproducts	Trihalomethanes
	Haloacetic Acids
	Bromate
	Chlorite
Fire Retardants	
Polybrominated diphenylethers (PBDEs)	209 Congeners
	10 Homolog Groups
Fluorosurfactants	Perfluorooctane Sulfonic Acid (PFOS)
	Perfluorooctanoic acid (PFOA)
Other Fire Retardants	Diammonium Sulphate
	Diammonium Phosphate
	Ammonium Sulphate
	Ammonium Phosphate
	Ammonium Polyphosphate
Plastics-Related Chemicals	
Phthalate Esters	Diethyl Phthalate
	Dimethyl Phthalate
	Di-n-butyl Phthalate
	Bis(2)ethylhexyl Phthalate (BEHP)
Other Plastic-related Chemicals	Bisphenol A
Nanoparticles	Carbon Fullerenes
	Carbon Nanotubes
	Carbon Black
	Metallic Nanoparticles (Copper or Silver)
	Metal Oxide Nanoparticles
	Quantum Dots
	Other Nanoparticles

Priority: H if Sales 1,000 to 10,000 kg and included on four or more lists; Sales >10,000 kg and included on two or three lists; if Sales >100,000 kg and included on one or more lists.
M if Sales 1,000 to 10,000 kg and included on two or three lists; Sales > 10,000 kg and included on at least one list.
L if Sales < 1,000 kg; if Sales 1,000 to 10,000 kg and included on only one list.

Table 4.1. Selected toxicity screening values for assessing surface water quality conditions in the Fraser River Basin.

Chemical of Potential Concern	Selected Toxicity Screening Value	Units	Reference
Conventionals			
pH	6.5 - 9	NA	CCME (1999)
Turbidity	2	NTU	BCMOE (2010a)
Residue: Non-filterable (TSS)	25	mg/L	BCMOE (2010a)
Nutrients			
Nitrogen Ammonia, dissolved	Temperature and pH dependant equation[1]	mg ammonia-nitrogen/L	USEPA (2009b)
Nitrate (NO_3, dissolved)	2.94	mg nitrate-nitrogen/L	CCME (1999)
Nitrogen - Nitrite, dissolved (NO_2)	0.06	mg nitrite-nitrogen/L	CCME (1999)
Phosphorus, total (lakes)	5 - 15	µg/L	BCMOE (2010a)
Phosphorus, total (streams)[2]	5	µg/L	JWQB (1998)
Major Ions			
Chloride, dissolved	230	mg/L	USEPA (2009a)
Fluoride, dissolved	0.2 (Hardness <50mg/L); 0.3 (Hardness ≥50mg/L)	mg/L	BCMOE (2010a)
Sulphate, dissolved	100	mg/L	BCMOE (2010a)
Metals			
Aluminum, total	0.1 (pH≥6.5); 0.005 (pH<6.5)	mg/L	CCME (1999)
Arsenic, total	5	µg/L	BCMOE (2010a)
Boron, total	1.2	mg/L	BCMOE (2010a)
Cadmium, total	0.017	µg/L	CCME (1999)
Chromium, total[3]	1	µg/L	CCME (1999)
Cobalt, total	4	µg/L	BCMOE (2010a)
Copper, total	2 (Hardness ≤ 120mg/L); 3 (120mg/L < Hardness ≤ 180mg/L); 4 (Hardness > 180mg/L).	µg/L	CCME (1999)
Iron, total	300	µg/L	CCME (1999)
Lead, total	1 (Hardness ≤ 60mg/L); 2 (60mg/L < Hardness ≤ 120mg/L); 4 (120mg/L < Hardness ≤ 180mg/L); 7 (Hardness > 180mg/L).	µg/L	CCME (1999)
Manganese, total	(0.0044 * Hardness) + 0.605	mg/L	BCMOE (2010a)

Table 4.1. Selected toxicity screening values for assessing surface water quality conditions in the Fraser River Basin.

Chemical of Potential Concern	Selected Toxicity Screening Value	Units	Reference
Metals (continued)			
Mercury, total[4]	0.02	µg/L	BCMOE (2010a)
Molybdenum, total	73	µg/L	CCME (1999)
Nickel, total	25 (Hardness ≤ 60mg/L); 65 (60mg/L < Hardness ≤ 120mg/L); 110 (120mg/L < Hardness ≤ 180mg/L); 150 (Hardness > 180mg/L).	µg/L	CCME (1999)
Selenium, total	1	µg/L	CCME (1999)
Silver, total	0.1	µg/L	CCME (1999)
Polychlorinated Biphenyls (PCBs)			
PCBs, total	0.1	ng/L	BCMOE (2010a)
Polycyclic Aromatic Hydrocarbons (PAHs)			
Acenaphthene	5.8	µg/L	CCME (1999)
Anthracene	0.012	µg/L	CCME (1999)
Benz(a)anthracene	0.018	µg/L	CCME (1999)
Fluoranthene	0.04	µg/L	CCME (1999)
Fluorene	3	µg/L	CCME (1999)
Naphthalene	1	µg/L	BCMOE (2010a)
Phenanthrene	0.3	µg/L	BCMOE (2010a)
Pyrene	0.025	µg/L	CCME (1999)
Chlorophenols			
Monochlorophenols	7	µg/L	CCME (1999)
Dichlorophenols	0.2	µg/L	CCME (1999)
Trichlorophenols	18	µg/L	CCME (1999)
Tetrachlorophenols	1	µg/L	CCME (1999)
Pentachlorophenol	0.5	µg/L	CCME (1999)
Pesticides			
DDT	0.001	µg/L	USEPA (2009a)
Dieldrin	0.056	µg/L	USEPA (2009a)
Endosulfan sulphate	0.003	µg/L	CCME (1999)
Endrin	0.036	µg/L	USEPA (2009a)
Lindane	0.01	µg/L	CCME (1999)

Table 4.1. Selected toxicity screening values for assessing surface water quality conditions in the Fraser River Basin.

Chemical of Potential Concern	Selected Toxicity Screening Value	Units	Reference
Others			
Benzene	370	µg/L	CCME (1999)
Cyanide (weak acid dissociable)	5	µg/L	BCMOE (2010a)
Phenols[5]	4	µg/L	CCME (1999)
Toluene	2	µg/L	CCME (1999)

NA = not applicable; TSS = total suspended solids.

[1] Ammonia TSV = Criteria Continuous Concentration (CCC) when freshwater mussels present (i.e., most conservative CCC). The AL is calculated with the following formula:

TSV = $0.744*\left(\frac{0.0676}{1+10^{7.688-pH}}+\frac{2.912}{1+10^{pH-7.688}}\right)*\left(0.3443*10^{0.028*(25-MAX)}\right)$; Where MAX = MAX of 7.0 and temperature.

[2] Water quality guideline was adopted for use in riverine systems.

[3] The water quality guideline for chromium VI in CCME (1999) was adopted as the TSV for chromium (total).

[4] The TSV for mercury (total) assumes that methyl-mercury is 0.05% of the, total mercury.

[5] The water quality guideline for mono- and dihydric phenols was adopted.

Table 4.2. Selected toxicity screening values (TSV) for assessing sediment quality conditions in the Fraser River Basin.

Chemical of Potential Concern	Selected TSV	Units (dry-weight)	TSV Type	Reference
Metals				
Arsenic	9.79	mg/kg	TEC	MacDonald *et al.* (2000a)
Cadmium	0.99	mg/kg	TEC	MacDonald *et al.* (2000a)
Chromium	43.4	mg/kg	TEC	MacDonald *et al.* (2000a)
Copper	31.6	mg/kg	TEC	MacDonald *et al.* (2000a)
Lead	35.8	mg/kg	TEC	MacDonald *et al.* (2000a)
Mercury	0.18	mg/kg	TEC	MacDonald *et al.* (2000a)
Nickel	22.7	mg/kg	TEC	MacDonald *et al.* (2000a)
Zinc	121	mg/kg	TEC	MacDonald *et al.* (2000a)
Iron	21,200	mg/kg	LEL	Nagpal *et al.* (2006)
Selenium	2	mg/kg	--	Nagpal *et al.* (2006)
Silver	0.5	mg/kg	--	Nagpal *et al.* (2006)
Organochlorine Pesticides				
Chlordane	3.24	mg/kg	TEC	MacDonald *et al.* (2000a)
Dieldrin	1.90	mg/kg	TEC	MacDonald *et al.* (2000a)
Endosulfan a	2.9	mg/kg	SQAL	USEPA (1997)
Endosulfan b	14	mg/kg	SQAL	USEPA (1997)
Endrin	2.22	mg/kg	TEC	MacDonald *et al.* (2000a)
Heptachlor epoxide	2.47	mg/kg	TEC	MacDonald *et al.* (2000a)
Lindane	2.37	mg/kg	TEC	MacDonald *et al.* (2000a)
Methoxychlor	19	mg/kg	SQAL	USEPA (1997)
Sum DDD	4.88	mg/kg	TEC	MacDonald *et al.* (2000a)
Sum DDE	3.16	mg/kg	TEC	MacDonald *et al.* (2000a)
Sum DDT	4.16	mg/kg	TEC	MacDonald *et al.* (2000a)
Total DDTs	5.28	mg/kg	TEC	MacDonald *et al.* (2000a)
Pesticides				
Aldrin	2.0	mg/kg	LEL	Nagpal *et al.* (2006)
Toxaphene	0.1	mg/kg	ISQG	CCME (1999)
Polycyclic Aromatic Hydrocarbons (PAHs)				
Acenapthalyene	5.87	mg/kg	ISQG	CCME (1999)
Acenapthene	6.71	mg/kg	ISQG	CCME (1999)
Anthracene	57.2	mg/kg	TEC	MacDonald *et al.* (2000a)
Benz(a)anthracene	108	mg/kg	TEC	MacDonald *et al.* (2000a)
Benzo(a)pyrene	150	mg/kg	TEC	MacDonald *et al.* (2000a)
Chrysene	166	mg/kg	TEC	MacDonald *et al.* (2000a)
Dibenz(a,h)anthracene	33	mg/kg	TEC	MacDonald *et al.* (2000a)
Fluoranthene	423	mg/kg	TEC	MacDonald *et al.* (2000a)
Fluorene	77.4	mg/kg	TEC	MacDonald *et al.* (2000a)
Napthalene	176	mg/kg	TEC	MacDonald *et al.* (2000a)

Table 4.2. Selected toxicity screening values (TSV) for assessing sediment quality conditions in the Fraser River Basin.

Chemical of Potential Concern	Selected TSV	Units (dry-weight)	TSV Type	Reference
Polycyclic Aromatic Hydrocarbons (continued)				
Phenanthrene	204	mg/kg	TEC	MacDonald *et al.* (2000a)
Pyrene	195	mg/kg	TEC	MacDonald *et al.* (2000a)
Total PAHs	1610	mg/kg	TEC	MacDonald *et al.* (2000a)
Polychlorinated Biphenyls (PCBs)				
Total PCBs	0.04	mg/kg	TEC	MacDonald *et al.* (2000b)
Plastics-Related Chemicals				
Diethyl phthalate	630	mg/kg	SQAL	USEPA (1997)
Bis (2-ethylhexyl) phthalate	182	mg/kg	TEL	MacDonald (1994)

TEC - Threshold Effects Concentration; LEL - Low-effects Level; SQAL - Sediment Quality Advisory Level; ISQG - Interim Sediment Quality Guideline; TEL - Threshold Effects Level

Table 4.3. Summary of the available surface-water chemistry data for the Lower Fraser River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	226	226	0%	51.6	5.60	51.3	27.5	69.7	43.8	45.9	48.8	51.0	55.0	59.0	60.6
Dissolved Oxygen (mg/L)	141	141	0%	9.92	1.47	9.83	6.00	22.0	8.00	8.40	9.50	10.0	10.3	11.0	11.4
pH (pH units)	332	332	0%	7.89	0.559	7.86	1.90	9.70	7.20	7.48	7.80	7.96	8.00	8.10	8.53
Residue Non-filterable (TSS; mg/L)	88	85	3%	71.2	60.3	49.7	5.00	303	10.4	12.7	28.0	53.0	98.8	143	203
Temperature (C)	282	282	0%	15.8	2.73	15.6	9.00	30.0	11.5	12.0	14.0	16.0	18.0	19.0	19.5
Turbidity (NTU)	234	233	0%	33.7	34.2	22.6	0.0500	390	4.90	8.58	16.0	26.6	41.0	67.9	82.4
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	63	62	2%	46	22	40.1	1	107	20.2	23.8	31	39	54	74.4	94.2
Nitrogen - Nitrite, dissolved (NO_2)	83	50	40%	4.86	5.53	3.7	1	40	1.1	2	2.5	4	5	6.8	9.9
Nitrogen Ammonia, dissolved	35	17	51%	17	40.8	6.5	2.5	240	2.5	2.5	2.5	2.5	15.5	32	46.1
Phosphorus, total (stream)	197	192	3%	100	84.1	66.8	0.25	453	15	23	42.8	68	142	220	257
Major Ions (mg/L)															
Chloride, dissolved	239	219	8%	0.893	0.528	0.768	0.250	3.40	0.250	0.400	0.535	0.800	1.06	1.62	1.90
Fluoride, total	45	45	0%	0.0398	0.0147	0.0374	0.0100	0.100	0.0220	0.0300	0.0300	0.0400	0.0400	0.0560	0.0600
Sulfate, dissolved	134	134	0%	7.26	1.69	7.06	3.60	14.0	4.67	5.36	6.10	7.05	8.48	9.40	10.0
Metals (µg/L)															
Aluminum, total	170	169	1%	2120	2000	1290	0.7	18100	89	329	855	1690	2860	4250	5250
Arsenic, total	136	135	1%	0.774	0.387	NA	0.005	2.09	0.3	0.4	0.5	0.7	0.913	1.35	1.6
Boron, total	53	52	2%	12.4	21.3	4.84	0.05	99	1.1	1.68	2.8	3.7	5.2	41.4	52.2
Cadmium, total	156	155	1%	0.262	0.259	NA	0.0005	1.4	0.0225	0.025	0.099	0.2	0.4	0.6	0.825
Chromium, total	179	177	1%	4.48	4.94	NA	0.0025	44	0.6	0.995	1.79	3.11	5.45	8.58	11.4
Cobalt, total	165	153	7%	1.61	1.28	NA	0.001	9.16	0.3	0.413	0.795	1.25	2.1	3.26	3.97
Copper, total	180	179	1%	7.49	16.1	NA	0.5	159	1.48	1.9	2.6	4.07	6.4	9.51	15.9
Iron, total	223	222	0%	2630	2310	1740	0.2	16400	356	568	1140	1860	3490	5770	7100
Lead, total	180	166	8%	1.6	1.29	NA	0.1	8	0.2	0.4	0.695	1.2	2.1	3.3	3.82
Manganese, total	180	179	1%	69.3	52.3	53.8	5	347	14.1	21.2	34.6	53.2	90.6	143	174
Mercury, total	52	52	0%	19.3	6.97	18	6	40	7.1	10	20	20	20	20	34.5

Table 4.3. Summary of the available surface-water chemistry data for the Lower Fraser River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Molybdenum, total	190	161	15%	1.73	3.95	NA	0.0025	30	0.3	0.4	0.5	0.6	0.7	5	5
Nickel, total	149	149	0%	5.34	4.47	NA	0.5	33	1	1.6	2.5	3.9	6.8	11.1	14.2
Selenium, total	130	102	22%	0.109	0.0666	NA	0.025	0.4	0.05	0.05	0.06	0.1	0.12	0.2	0.2
Silver, total	114	73	36%	0.0621	0.0887	NA	0.0005	0.7	0.00365	0.006	0.012	0.05	0.1	0.1	0.1
Chlorophenols (µg/L)															
Dichlorophenols	11	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Monochlorophenols	11	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Pentachlorophenol	10	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Tetrachlorophenols	11	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Trichlorophenols	11	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	113	113	0%	51.5	8.07	51.0	27.5	115	44.1	46.0	48.7	50.5	54.2	57.7	58.6
Dissolved Oxygen (mg/L)	48	48	0%	11.6	2.51	11.4	9.60	22.0	9.87	10.0	10.3	11.0	11.5	12.6	17.6
pH (pH units)	125	125	0%	7.84	0.283	7.83	6.20	8.10	7.22	7.60	7.80	7.90	8.00	8.04	8.10
Residue Non-filterable (TSS; mg/L)	42	41	2%	167	136	121	5.00	665	29.0	50.4	72.5	134	207	302	454
Temperature (C)	121	121	0%	12.0	2.53	11.7	5.00	18.0	7.50	8.00	10.5	12.0	14.0	15.0	15.0
Turbidity (NTU)	120	120	0%	50.6	31.7	39.6	0.100	147	14.0	19.3	29.0	39.7	66.4	88.8	123
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	34	34	0%	87.7	28.3	83.6	40	166	53.6	56.9	71	85	101	117	145
Nitrogen - Nitrite, dissolved (NO_2)	36	24	33%	4.72	4.94	3.69	1	31	1.75	2	2.5	4.5	5	6	9.25
Nitrogen Ammonia, dissolved	3	1	67%	4	2.6	3.52	2.5	7	2.5	2.5	2.5	2.5	4.75	6.1	6.55
Phosphorus, total (stream)	91	88	3%	193	128	137	0.25	774	35	60	108	171	248	320	427
Major Ions (mg/L)															
Chloride, dissolved	121	112	7%	0.923	0.479	0.807	0.250	2.40	0.250	0.460	0.600	0.800	1.10	1.70	1.90
Fluoride, total	23	23	0%	0.0391	0.0131	0.0374	0.0300	0.0700	0.0300	0.0300	0.0300	0.0300	0.0400	0.0600	0.0690
Sulfate, dissolved	69	69	0%	5.89	0.853	5.82	3.60	7.60	4.44	4.96	5.30	5.90	6.40	6.90	7.10

Table 4.3. Summary of the available surface-water chemistry data for the Lower Fraser River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L)															
Aluminum, total	75	75	0%	3370	1910	2640	0.7	9170	1140	1380	1870	2860	4450	6080	7090
Arsenic, total	60	59	2%	1.15	0.637	0.938	0.005	3.8	0.4	0.49	0.723	1.1	1.4	1.74	1.92
Boron, total	20	19	5%	2.89	1.07	2.31	0.05	4.1	0.478	1.31	2.8	3.15	3.6	3.72	3.91
Cadmium, total	76	75	1%	0.418	0.371	0.246	0.0005	1.6	0.0333	0.0495	0.112	0.3	0.525	0.95	1.13
Chromium, total	76	75	1%	5.91	3.3	4.6	0.0025	15.1	1.98	2.3	3.48	5.37	8.19	11.1	11.7
Cobalt, total	71	70	1%	2.54	1.43	2	0.001	6.9	0.8	1	1.56	2.2	3.35	4.8	5.2
Copper, total	80	80	0%	10.9	15.8	7.44	2.5	95.5	3	3.15	4.5	7	9.74	16	22.1
Iron, total	88	88	0%	5070	3790	3850	0.5	28000	1640	1920	2780	4230	6120	9130	9720
Lead, total	80	79	1%	2.54	1.67	2.07	0.496	8	0.676	0.892	1.4	2.05	3.13	5.12	6
Manganese, total	80	80	0%	121	66.1	105	35.2	360	42.9	53	72.9	100	159	220	227
Mercury, total	21	21	0%	22.8	19.8	18	5	80	6	8	20	20	20	20	80
Molybdenum, total	75	70	7%	0.784	1.02	0.564	0.0025	5	0.359	0.4	0.5	0.516	0.6	0.8	2.2
Nickel, total	69	69	0%	8.56	4.69	7.41	2.7	21.4	3.15	3.66	5	7.2	11.1	15.5	18.2
Selenium, total	56	47	16%	0.142	0.112	0.113	0.025	0.6	0.0438	0.05	0.0875	0.1	0.2	0.2	0.4
Silver, total	51	31	39%	0.0945	0.303	0.0427	0.0005	2.2	0.0115	0.015	0.0285	0.05	0.05	0.1	0.1
Chlorophenols (µg/L)															
Dichlorophenols	3	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Monochlorophenols	3	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Pentachlorophenol	3	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Tetrachlorophenols	3	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Trichlorophenols	3	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.
No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.4. Summary of the available surface-water chemistry data for the Upper Fraser River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	208	208	0%	62.7	6.87	62.4	47.4	105	54.4	56.4	58.6	61.0	65.5	70.9	76.4
Dissolved Oxygen (mg/L)	106	106	0%	10.0	1.03	9.97	7.90	13.3	8.40	8.80	9.43	9.90	10.3	11.0	12.0
pH (pH units)	254	254	0%	7.91	0.298	7.91	5.90	8.59	7.27	7.60	7.90	8.00	8.08	8.10	8.15
Residue Non-filterable (TSS; mg/L)	106	105	1%	79.4	85.6	55.7	2.00	661	15.8	21.5	37.0	57.0	86.0	153	221
Temperature (C)	210	210	0%	13.7	4.77	12.3	0.500	24.7	7.00	9.00	11.0	13.0	16.0	21.0	22.3
Turbidity (NTU)	219	218	0%	35.2	38.4	23.8	0.0500	355	5.18	8.24	16.0	26.0	40.0	62.8	86.7
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	70	70	0%	43.2	22.3	38.9	12	120	21	23	30	36.5	50.8	69	88.7
Nitrogen - Nitrite, dissolved (NO_2)	78	42	46%	3.62	1.63	3.25	1	9	1	2	2.5	2.5	5	5	6
Nitrogen Ammonia, dissolved	35	12	66%	4.5	3.29	3.7	2.5	13	2.5	2.5	2.5	2.5	5.5	9.6	11.6
Phosphorus, total (stream)	133	128	4%	88.6	122	52.9	1	1140	9.8	22	35	56	98	163	214
Major Ions (mg/L)															
Chloride, dissolved	241	215	11%	3.60	38.3	0.888	0.0500	595	0.250	0.250	0.600	0.880	1.30	2.20	3.00
Fluoride, total	40	38	5%	0.0315	0.0146	0.0278	0.00500	0.0700	0.00975	0.0200	0.0200	0.0300	0.0325	0.0510	0.0600
Sulfate, dissolved	128	128	0%	7.74	1.89	7.50	2.00	14.5	5.10	5.54	6.50	7.65	8.80	10.0	11.0
Metals (µg/L)															
Aluminum, total	174	174	0%	1810	1530	1340	12	11400	359	540	900	1450	2200	3290	4560
Arsenic, total	129	129	0%	0.784	0.7	NA	0.2	6.7	0.3	0.34	0.45	0.6	0.9	1.2	1.6
Boron, total	47	45	4%	1.9	0.861	1.54	0.05	4.4	0.33	0.86	1.4	2	2.5	2.74	2.87
Cadmium, total	151	151	0%	0.263	0.321	NA	0.013	2.7	0.018	0.02	0.045	0.2	0.3	0.5	0.85
Chromium, total	166	166	0%	3.83	3.21	NA	0.2	19.1	0.812	1.1	1.73	2.99	4.7	7.3	9.93
Cobalt, total	148	146	1%	1.58	1.49	NA	0.05	10.4	0.325	0.5	0.79	1.18	1.8	2.93	4.27
Copper, total	168	168	0%	5.99	9.98	NA	1	118	1.5	1.8	2.58	3.7	6	10.5	16
Iron, total	209	209	0%	3290	4360	2220	9.8	44000	670	945	1440	2300	3420	5740	8250
Lead, total	168	160	5%	1.82	1.87	NA	0.1	16.2	0.235	0.358	0.8	1.3	2.13	3.5	5.21
Manganese, total	167	167	0%	73.2	70.5	56.4	12.4	530	21.2	25.2	36.2	52.7	81.5	132	175

Table 4.4. Summary of the available surface-water chemistry data for the Upper Fraser River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Mercury, total	40	40	0%	19.1	17.2	8.15	0.05	91	0.0595	0.087	10	20	20	31	50.5
Molybdenum, total	177	152	14%	1.6	3.2	NA	0.05	20	0.259	0.3	0.4	0.5	0.617	5	5
Nickel, total	148	144	3%	5.13	4.75	NA	0.3	26.6	1.34	1.8	2.51	3.71	5.6	9.69	15.1
Selenium, total	124	88	29%	0.11	0.0973	NA	0.025	0.6	0.025	0.025	0.05	0.095	0.1	0.2	0.3
Silver, total	102	69	32%	0.0537	0.0837	NA	0.0005	0.8	0.005	0.006	0.012	0.05	0.061	0.1	0.1
Chlorophenols (µg/L)															
Dichlorophenols	27	0	100%	0.025	7.980E-10	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Monochlorophenols	27	0	100%	0.025	7.98E-10	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Pentachlorophenol	27	0	100%	0.025	7.98E-10	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Tetrachlorophenols	27	0	100%	0.025	7.98E-10	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Trichlorophenols	27	0	100%	0.025	7.98E-10	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Other (µg/L)															
Cyanide WAD	1	0	100%	0.25	NA	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Phenols	29	14	52%	2.48	2.25	1.84	1	10	1	1	1	1	3	5.2	6.6
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	116	116	0%	60.6	4.50	60.5	51.5	87.9	55.1	56.1	58.2	60.3	62.4	64.2	65.3
Dissolved Oxygen (mg/L)	61	61	0%	10.5	1.03	10.4	8.40	13.3	9.20	9.30	9.70	10.2	11.0	12.0	12.0
pH (pH units)	138	138	0%	7.87	0.322	7.86	6.60	8.30	7.09	7.37	7.89	8.00	8.01	8.10	8.10
Residue Non-filterable (TSS; mg/L)	55	55	0%	151	125	119	35.0	661	58.5	63.8	73.5	101	171	314	391
Temperature (C)	118	118	0%	11.2	6.17	8.80	0.500	24.7	0.925	4.00	8.00	11.0	13.0	22.5	22.9
Turbidity (NTU)	119	119	0%	55.5	44.6	42.1	0.0600	249	19.8	21.8	28.0	40.0	66.7	93.3	161
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	39	39	0%	98.8	48.9	88.5	32	254	46.5	52.6	58.5	90	122	151	172
Nitrogen - Nitrite, dissolved (NO_2)	43	24	44%	3.64	1.37	3.35	1	6	2.05	2.5	2.5	4	5	5	5
Nitrogen Ammonia, dissolved	18	10	44%	6.28	4.18	5.05	2.5	16	2.5	2.5	2.5	6	8.75	11.6	13.5

Table 4.4. Summary of the available surface-water chemistry data for the Upper Fraser River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Major Ions (mg/L)															
Phosphorus, total (stream)	69	69	0%	180	179	134	21	1140	51.2	69	86	123	182	406	476
Chloride, dissolved	131	117	11%	1.02	1.25	0.779	0.0500	11.0	0.250	0.250	0.550	0.800	1.20	1.50	1.85
Fluoride, total	22	22	0%	0.0373	0.0212	0.0324	0.0100	0.100	0.0200	0.0200	0.0200	0.0300	0.0500	0.0600	0.0695
Sulfate, dissolved	68	67	1%	5.90	1.25	5.77	2.50	8.70	4.24	4.64	5.08	5.85	6.70	7.50	8.17
Metals (µg/L)															
Aluminum, total	93	93	0%	3140	2190	2480	12	12700	1140	1290	1750	2330	4070	6350	7620
Arsenic, total	70	70	0%	1.24	0.929	1.04	0.3	6.7	0.445	0.6	0.755	1	1.3	2.47	2.8
Boron, total	24	22	8%	1.85	0.746	1.44	0.05	3	0.193	1.03	1.58	2	2.3	2.57	2.86
Cadmium, total	83	83	0%	0.409	0.389	0.243	0.025	1.9	0.036	0.0454	0.099	0.3	0.6	0.98	1.1
Chromium, total	90	90	0%	6.99	5.2	5.57	0.2	30	2.29	2.84	3.63	5.16	8.93	13.4	17.1
Cobalt, total	77	76	1%	2.71	1.94	2.16	0.05	9.7	0.98	1.14	1.4	2.05	3	5.57	6.36
Copper, total	91	91	0%	10.2	12.4	7.51	2	108	3.22	3.5	4.5	6.32	11.7	20.1	24.1
Iron, total	112	112	0%	5420	5200	4040	9.8	44000	1790	2010	2690	3820	6170	10800	13500
Lead, total	91	90	1%	2.81	1.93	2.27	0.35	9.3	0.827	1.04	1.5	2.2	3.55	6	6.45
Manganese, total	91	91	0%	131	93.8	109	34.4	530	52.2	59.4	71	94	150	266	317
Mercury, total	27	27	0%	25.3	24.4	9.6	0.05	91	0.053	0.078	10	20	30	58	84
Molybdenum, total	93	74	20%	1.41	2.57	0.646	0.05	20	0.162	0.266	0.4	0.514	0.7	5	5
Nickel, total	78	77	1%	8.58	5.59	7.24	2.1	28.5	3.59	4.1	4.54	6.35	11	15.8	20.3
Selenium, total	68	56	18%	0.126	0.101	0.0993	0.025	0.6	0.05	0.05	0.06	0.1	0.2	0.2	0.3
Silver, total	54	38	30%	0.0529	0.0312	0.0435	0.011	0.1	0.013	0.0169	0.0253	0.05	0.0908	0.1	0.1
Chlorophenols (µg/L)															
Dichlorophenols	9	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Monochlorophenols	9	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Pentachlorophenol	9	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Tetrachlorophenols	9	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Trichlorophenols	9	0	100%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Other (µg/L)															
Phenols	15	6	60%	2.4	2.77	1.66	1	10	1	1	1	1	2	6	8.6

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Table 4.4. Summary of the available surface-water chemistry data for the Upper Fraser River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.5. Summary of the available surface-water chemistry data for the Pitt River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Dissolved Oxygen (mg/L)	10	10	0%	9.17	0.723	9.14	8.00	10.2	8.14	8.27	8.83	9.15	9.55	10.2	10.2
pH (pH units)	30	30	0%	7.53	0.381	7.52	6.80	8.40	6.95	7.09	7.23	7.55	7.80	7.91	8.06
Residue Non-filterable (TSS; mg/L)	20	20	0%	36.1	36.3	20.8	2.00	154	2.95	3.00	9.50	27.5	45.5	74.4	81.8
Temperature (C)	10	10	0%	15.2	1.60	15.1	13.0	17.0	13.1	13.3	13.9	15.2	16.9	17.0	17.0
Turbidity (NTU)	20	20	0%	13.4	11.7	7.74	0.600	38.0	0.980	1.18	3.78	11.5	19.3	30.6	36.1
Nutrients (µg/L)															
Nitrogen - Nitrite, dissolved (NO_2)	30	2	93%	2.7	0.772	2.63	2.5	6	2.5	2.5	2.5	2.5	2.5	2.5	3.87
Nitrogen Ammonia, dissolved	9	6	33%	6.06	2.91	5.3	2.5	10	2.5	2.5	2.5	7	8	9.2	9.6
Metals (µg/L)															
Aluminum, total	10	8	20%	601	578	336	50	1820	50	50	150	440	853	1260	1540
Iron, total	10	10	0%	791	792	451	80	2530	93.5	107	155	610	1080	1670	2100
Molybdenum, total	10	0	100%	5	< 0.001	5	5	5	5	5	5	5	5	5	5
Chlorophenols (µg/L)															
Pentachlorophenol	4	0	100%	0.05	NA	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Tetrachlorophenols	4	0	100%	0.05	NA	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Trichlorophenols	4	0	100%	0.05	NA	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Juvenile Rearing															
Conventionals															
Dissolved Oxygen (mg/L)	10	10	0%	10.1	0.736	10.1	8.80	11.0	8.85	8.89	9.88	10.3	10.5	10.8	10.9
pH (pH units)	20	20	0%	7.40	0.489	7.38	6.60	8.50	6.70	6.88	7.10	7.40	7.50	8.13	8.41
Residue Non-filterable (TSS; mg/L)	11	8	27%	4.73	3.29	3.92	2.00	13.0	2.00	2.00	2.00	4.00	6.00	7.00	10.0
Temperature (C)	11	11	0%	15.0	2.63	14.7	8.00	18.2	11.3	14.5	14.7	14.9	16.5	17.1	17.7
Turbidity (NTU)	16	16	0%	1.69	1.38	1.36	0.500	6.20	0.650	0.745	0.913	1.20	1.90	2.65	3.80

Table 4.5. Summary of the available surface-water chemistry data for the Pitt River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Nutrients (µg/L)															
Nitrogen - Nitrite, dissolved (NO_2)	15	1	93%	2.67	0.645	2.62	2.5	5	2.5	2.5	2.5	2.5	2.5	2.5	3.25
Nitrogen Ammonia, dissolved	5	2	60%	4.5	2.94	3.85	2.5	9	2.5	2.5	2.5	2.5	6	7.8	8.4
Smolt Outmigration															
Conventionals															
Dissolved Oxygen (mg/L)	2	2	0%	9.80	0.566	9.79	9.40	10.2	9.44	9.48	9.60	9.80	10.0	10.1	10.2
pH (pH units)	2	2	0%	7.50	0.566	7.49	7.10	7.90	7.14	7.18	7.30	7.50	7.70	7.82	7.86
Residue Non-filterable (TSS; mg/L)	2	2	0%	20.0	25.5	8.72	2.00	38.0	3.80	5.60	11.0	20.0	29.0	34.4	36.2
Temperature (C)	2	2	0%	13.5	0.707	13.5	13.0	14.0	13.1	13.1	13.3	13.5	13.8	13.9	14.0
Turbidity (NTU)	2	2	0%	11.8	15.8	3.71	0.600	23.0	1.72	2.84	6.20	11.8	17.4	20.8	21.9
Nutrients (µg/L)															
Nitrogen - Nitrite, dissolved (NO_2)	2	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	2	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Metals (µg/L)															
Aluminum, total	2	1	50%	625	813	245	50	1200	108	165	338	625	913	1090	1140
Iron, total	2	2	0%	825	1050	354	80	1570	155	229	453	825	1200	1420	1500
Molybdenum, total	2	0	100%	5	NA	5	5	5	5	5	5	5	5	5	5

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.6. Summary of the available surface-water chemistry data for the Cultus Lake Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	32	32	0%	146	7.18	146	124	157	136	136	143	147	152	154	155
Dissolved Oxygen (mg/L)	39	39	0%	8.53	1.07	8.46	6.00	10.5	6.38	7.28	7.95	8.50	9.20	10.0	10.0
pH (pH units)	61	61	0%	8.08	0.161	8.07	7.50	8.40	7.80	7.90	8.00	8.10	8.20	8.20	8.30
Residue Non-filterable (TSS; mg/L)	36	19	47%	5.11	8.61	3.25	2.00	51.0	2.00	2.00	2.00	2.00	5.00	7.50	13.3
Temperature (C)	42	42	0%	15.0	2.38	14.8	11.0	20.7	11.0	11.4	13.2	15.0	16.0	17.5	19.2
Turbidity (NTU)	55	55	0%	8.40	24.0	4.53	1.18	180	1.71	2.09	2.91	4.50	5.80	8.58	15.8
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	55	55	0%	2730	629	2640	618	4210	1840	2290	2390	2580	3030	3590	3740
Nitrogen - Nitrite, dissolved (NO_2)	60	60	0%	30.4	29.2	26.1	12	237	15	16	18.8	25	34	40.2	47.4
Nitrogen Ammonia, dissolved	1	1	0%	20	NA	20	20	20	20	20	20	20	20	20	20
Phosphorus, total (stream)	44	44	0%	54.3	31.9	46.5	6	190	21.3	24	32	49.2	66	76.3	112
Major Ions (mg/L)															
Chloride, dissolved	42	42	0%	14.5	1.89	14.4	9.60	18.0	11.5	12.0	14.0	15.0	16.0	16.9	17.0
Sulfate, dissolved	39	39	0%	20.2	2.60	20.1	16.0	30.0	17.9	18.0	18.5	20.0	21.4	23.0	23.7
Metals (µg/L)															
Aluminum, total	13	13	0%	89.3	69	66.7	23.8	250	24.5	25.5	30.1	80	122	158	196
Arsenic, total	20	20	0%	1.1	0.126	1.09	0.86	1.28	0.908	0.946	1.01	1.11	1.21	1.26	1.27
Boron, total	25	24	4%	48.2	11.9	47	25	86	38.8	40.1	41.8	46.6	49.7	60.6	71.4
Cadmium, total	20	20	0%	0.00565	0.00223	0.00527	0.003	0.011	0.003	0.003	0.004	0.005	0.00725	0.0081	0.0091
Chromium, total	23	23	0%	2.18	4.92	0.878	0.276	24	0.292	0.307	0.39	0.541	1.88	3.77	4.9
Cobalt, total	25	20	20%	0.562	0.525	0.369	0.107	1.5	0.119	0.128	0.162	0.304	0.729	1.5	1.5
Copper, total	8	8	0%	0.794	0.247	0.763	0.53	1.2	0.534	0.537	0.66	0.735	0.868	1.15	1.18
Iron, total	25	25	0%	811	349	743	392	1660	396	423	539	742	968	1270	1320
Lead, total	8	8	0%	0.201	0.151	0.151	0.043	0.454	0.0528	0.0626	0.0748	0.178	0.257	0.413	0.433
Manganese, total	8	8	0%	67.1	20.9	64.1	40.3	96.4	40.9	41.4	49.4	68.9	83.4	89.5	92.9
Molybdenum, total	25	20	20%	0.96	0.532	0.863	0.615	2	0.664	0.666	0.677	0.705	0.742	2	2
Nickel, total	8	8	0%	16.9	6.1	15.9	10.2	25.9	10.7	11.1	11.7	15	22.7	23.7	24.8

Table 4.6. Summary of the available surface-water chemistry data for the Cultus Lake Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Selenium, total	20	19	5%	0.171	0.0465	0.159	0.025	0.24	0.0963	0.136	0.168	0.18	0.19	0.221	0.231
Silver, total	20	12	40%	0.00125	0.00079	0.00103	0.0005	0.003	0.0005	0.0005	0.0005	0.001	0.002	0.00205	0.00253
Juvenile Rearing															
Conventionals															
Hardness (mg/L)	11	11	0%	73.8	2.02	73.8	69.5	76.9	70.5	71.5	72.9	74.6	74.9	75.1	76.0
Dissolved Oxygen (mg/L)	61	61	0%	9.48	2.42	9.03	2.20	13.3	4.20	5.20	8.80	10.1	10.7	12.1	12.4
pH (pH units)	40	40	0%	8.03	0.179	8.02	7.36	8.30	7.70	7.80	7.90	8.10	8.10	8.20	8.20
Residue Non-filterable (TSS; mg/L)	30	28	7%	2.27	3.77	1.50	0.500	21.0	0.725	1.00	1.00	1.05	2.00	2.00	5.30
Temperature (C)	64	64	0%	14.3	5.61	13.0	3.10	24.0	4.95	6.00	9.78	16.0	18.9	20.9	21.9
Turbidity (NTU)	42	42	0%	1.08	2.44	0.629	0.200	16.0	0.281	0.300	0.400	0.550	0.800	1.28	1.59
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	12	3	75%	20.8	20.7	15.1	10	70	10	10	10	10	17.5	49	59
Nitrogen - Nitrite, dissolved (NO_2)	26	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	20	16	20%	6.9	3.56	6.04	2.5	17	2.5	2.5	5	6.5	8.25	10.1	11.3
Phosphorus, total (lake)	69	66	4%	6.26	4.19	5.37	1	25	3	3	4	6	7	9.2	12.2
Major Ions (mg/L)															
Chloride, dissolved	25	25	0%	1.23	0.536	1.16	0.700	3.50	0.820	0.900	1.00	1.10	1.20	1.66	1.78
Sulfate, dissolved	25	25	0%	21.8	1.40	21.7	17.0	24.6	19.7	20.7	21.6	21.8	22.3	22.9	23.6
Metals (µg/L)															
Copper, total	17	8	53%	1.62	2.58	0.939	0.5	11	0.5	0.5	0.5	0.5	1	2.8	5.4
Iron, total	14	8	43%	164	274	97.4	50	1100	50	50	50	100	100	200	515
Lead, total	6	1	83%	0.583	0.204	0.561	0.5	1	0.5	0.5	0.5	0.5	0.5	0.75	0.875
Manganese, total	3	0	100%	6.67	2.89	6.3	5	10	5	5	5	5	7.5	9	9.5
Nickel, total	5	1	80%	6	2.24	5.74	5	10	5	5	5	5	5	8	9
Other (µg/L)															
Phenols	14	2	86%	1.36	0.929	1.19	1	4	1	1	1	1	1	2.4	3.35

Table 4.6. Summary of the available surface-water chemistry data for the Cultus Lake Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Spawning & Incubation															
Conventionals															
Hardness (mg/L)	9	9	0%	73.8	2.20	73.7	69.5	76.9	70.3	71.1	72.7	74.6	74.8	75.5	76.2
Dissolved Oxygen (mg/L)	29	29	0%	9.27	2.99	8.60	2.20	13.3	3.66	4.70	8.60	10.0	11.4	12.4	12.5
pH (pH units)	30	30	0%	8.02	0.200	8.02	7.36	8.30	7.70	7.79	7.90	8.10	8.18	8.20	8.20
Residue Non-filterable (TSS; mg/L)	24	23	4%	2.52	4.19	1.61	0.500	21.0	1.00	1.00	1.00	1.50	2.00	2.00	7.10
Temperature (C)	32	32	0%	12.8	5.79	11.3	3.10	23.5	4.80	5.01	8.88	11.4	18.2	20.2	20.6
Turbidity (NTU)	33	33	0%	1.18	2.75	0.641	0.220	16.0	0.292	0.300	0.400	0.500	0.800	1.06	2.64
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	7	1	86%	18.6	22.7	13.2	10	70	10	10	10	10	10	34	52
Nitrogen - Nitrite, dissolved (NO_2)	20	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	14	11	21%	7.04	4.03	6.03	2.5	17	2.5	2.5	5	6	9.5	10.7	13.1
Phosphorus, total (lake)	47	46	2%	7.19	4.62	6.26	1	25	4	4	5	6	7	10	17.2
Major Ions (mg/L)															
Chloride, dissolved	19	19	0%	1.18	0.580	1.11	0.700	3.50	0.790	0.880	1.00	1.10	1.15	1.22	1.52
Sulfate, dissolved	18	18	0%	22.2	0.935	22.1	20.6	24.6	21.1	21.4	21.7	21.8	22.6	23.2	23.8
Metals (µg/L)															
Copper, total	13	7	46%	1.85	2.92	1.02	0.5	11	0.5	0.5	0.5	1	1	3.6	6.8
Iron, total	12	7	42%	179	295	103	50	1100	50	50	50	100	125	200	605
Lead, total	6	1	83%	0.583	0.204	0.561	0.5	1	0.5	0.5	0.5	0.5	0.5	0.75	0.875
Manganese, total	1	0	100%	10	NA	10	10	10	10	10	10	10	10	10	10
Nickel, total	3	1	67%	6.67	2.89	6.3	5	10	5	5	5	5	7.5	9	9.5
Other (µg/L)															
Phenols	12	2	83%	1.42	0.996	1.23	1	4	1	1	1	1	1	2.8	3.45

Table 4.6. Summary of the available surface-water chemistry data for the Cultus Lake Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	17	17	0%	141	10.8	141	109	153	125	133	137	141	149	152	152
Dissolved Oxygen (mg/L)	17	17	0%	8.61	0.666	8.59	7.60	10.0	7.60	7.72	8.30	8.70	8.80	9.36	9.92
pH (pH units)	21	21	0%	8.08	0.117	8.08	7.70	8.21	7.90	8.00	8.10	8.10	8.10	8.20	8.20
Residue Non-filterable (TSS; mg/L)	12	10	17%	15.7	18.8	9.03	2.00	58.0	2.00	2.20	4.75	9.00	13.3	47.9	54.2
Temperature (C)	17	17	0%	14.1	1.72	14.0	12.0	17.0	12.0	12.0	13.0	14.0	16.0	16.4	17.0
Turbidity (NTU)	21	21	0%	11.3	8.87	8.87	2.92	33.5	4.50	4.67	5.80	7.20	11.9	25.3	27.0
Nutrients (mg/L)															
Nitrate (NO_3), dissolved	21	21	0%	2770	586	2720	1730	3950	1880	2020	2480	2770	2960	3670	3710
Nitrogen - Nitrite, dissolved (NO_2)	21	21	0%	36.5	47.3	27.4	15	237	16	17	18	25	34	44	60
Phosphorus, total (stream)	10	10	0%	93.3	83.6	66.4	6	316	25.8	45.6	60	74	92	138	227
Major Ions (mg/L)															
Chloride, dissolved	21	21	0%	13.9	2.10	13.8	9.60	16.9	10.0	11.0	12.6	14.0	15.6	16.0	16.7
Sulfate, dissolved	19	19	0%	17.9	2.79	17.7	14.0	24.0	14.0	14.7	15.8	18.0	19.2	22.0	22.2
Metals (µg/L)															
Aluminum, total	5	5	0%	177	105	160	121	363	121	121	122	131	148	277	320
Arsenic, total	6	6	0%	1.19	0.104	1.18	1.05	1.32	1.06	1.08	1.11	1.18	1.26	1.3	1.31
Boron, total	6	6	0%	42.8	3.58	42.6	36.3	45.8	37.7	39.1	41.9	43.7	45.3	45.6	45.7
Cadmium, total	6	6	0%	0.00883	0.00194	0.00867	0.007	0.012	0.007	0.007	0.00725	0.0085	0.00975	0.011	0.0115
Chromium, total	6	6	0%	3.97	4.05	3.02	1.71	12.2	1.79	1.88	2.11	2.52	2.81	7.52	9.86
Cobalt, total	6	6	0%	1.25	1.03	1.04	0.689	3.34	0.699	0.709	0.769	0.9	0.936	2.14	2.74
Copper, total	5	5	0%	1.07	0.575	0.979	0.7	2.08	0.706	0.712	0.73	0.88	0.96	1.63	1.86
Iron, total	6	6	0%	1550	547	1490	1240	2650	1250	1250	1270	1340	1450	2060	2360
Lead, total	5	5	0%	0.172	0.0272	0.17	0.138	0.211	0.142	0.146	0.159	0.168	0.182	0.199	0.205
Manganese, total	5	5	0%	119	27.7	117	86.5	154	88.5	90.5	96.4	126	134	146	150
Molybdenum, total	6	6	0%	0.643	0.0257	0.643	0.608	0.666	0.61	0.612	0.623	0.654	0.663	0.665	0.665
Nickel, total	5	5	0%	34.9	22.7	31	22.7	75.4	23.1	23.4	24.5	25.9	26.2	55.7	65.6

Table 4.6. Summary of the available surface-water chemistry data for the Cultus Lake Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geo-Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Selenium, total	6	6	0%	0.185	0.0122	0.185	0.17	0.2	0.173	0.175	0.18	0.18	0.195	0.2	0.2
Silver, total	6	6	0%	0.002	0.00155	0.00165	0.001	0.005	0.001	0.001	0.001	0.0015	0.002	0.0035	0.00425

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.7. Summary of the available surface-water chemistry data for the Kakawa Lake Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	11	11	0%	32.6	10.3	31.1	18.7	47.6	19.3	19.9	24.6	31.0	41.3	44.6	46.1
Dissolved Oxygen (mg/L)	10	10	0%	10.6	0.851	10.5	9.40	11.9	9.58	9.76	9.88	10.5	11.1	11.8	11.9
pH (pH units)	11	11	0%	7.83	0.195	7.83	7.50	8.10	7.55	7.60	7.70	7.90	7.95	8.05	8.08
Residue Non-filterable (TSS; mg/L)	8	7	13%	4.94	5.13	2.85	0.500	14.0	0.675	0.850	1.75	2.00	8.00	11.9	13.0
Temperature (C)	10	10	0%	13.7	4.39	13.1	8.50	20.3	8.50	8.50	9.40	15.0	16.5	19.0	19.6
Turbidity (NTU)	2	2	0%	2.05	1.77	1.62	0.800	3.30	0.925	1.05	1.43	2.05	2.68	3.05	3.18
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	7	7	0%	61.4	24.1	57.3	30	100	33	36	45	60	75	88	94
Nitrogen - Nitrite, dissolved (NO_2)	10	1	90%	4.05	4.9	3.05	2.5	18	2.5	2.5	2.5	2.5	2.5	4.05	11
Nitrogen Ammonia, dissolved	7	3	57%	3.86	1.73	3.54	2.5	6	2.5	2.5	2.5	2.5	5.5	6	6
Phosphorus, total (stream)	8	6	25%	6.38	5.39	4.59	1.5	16	1.5	1.5	2.63	4.5	8.5	13.9	15
Major Ions (mg/L)															
Chloride, dissolved	11	8	27%	0.541	0.234	0.491	0.250	1.00	0.250	0.250	0.375	0.500	0.700	0.700	0.850
Sulfate, dissolved	7	5	29%	7.01	3.51	6.05	2.50	10.6	2.50	2.50	4.45	6.80	10.2	10.5	10.6
Metals (µg/L)															
Arsenic, total	1	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Copper, total	7	2	71%	0.929	0.932	0.713	0.5	3	0.5	0.5	0.5	0.5	0.75	1.8	2.4
Iron, total	6	5	17%	258	206	183	50	500	62.5	75	100	200	450	500	500
Lead, total	6	1	83%	0.75	0.612	0.63	0.5	2	0.5	0.5	0.5	0.5	0.5	1.25	1.63
Manganese, total	7	1	86%	10.7	4.5	10	5	20	6.5	8	10	10	10	14	17
Molybdenum, total	1	1	0%	0.6	NA	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Nickel, total	7	0	100%	5	NA	5	5	5	5	5	5	5	5	5	5
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	6	6	0%	22.9	4.75	22.5	18.7	31.0	19.0	19.3	19.9	20.8	25.0	28.6	29.8
Dissolved Oxygen (mg/L)	6	6	0%	11.7	1.62	11.6	9.40	14.4	9.83	10.3	11.2	11.6	11.9	13.2	13.8
pH (pH units)	6	6	0%	7.83	0.184	7.82	7.50	8.05	7.58	7.65	7.80	7.85	7.90	7.98	8.01

Table 4.7. Summary of the available surface-water chemistry data for the Kakawa Lake Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Conventionals (continued)															
Residue Non-filterable (TSS; mg/L)	4	4	0%	7.50	4.93	6.09	2.00	14.0	2.75	3.50	5.75	7.00	8.75	11.9	13.0
Temperature (C)	6	6	0%	8.28	3.97	7.51	4.00	15.0	4.13	4.25	5.50	8.50	9.03	12.1	13.6
Turbidity (NTU)	2	2	0%	14.4	19.2	4.73	0.800	28.0	2.16	3.52	7.60	14.4	21.2	25.3	26.6
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	4	4	0%	77.5	17.1	76.1	60	100	61.5	63	67.5	75	85	94	97
Nitrogen - Nitrite, dissolved (NO_2)	6	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	4	3	25%	4.88	1.65	4.61	2.5	6	2.88	3.25	4.38	5.5	6	6	6
Phosphorus, total (stream)	4	4	0%	16	15.7	11.5	5	39	5.3	5.6	6.5	10	19.5	31.2	35.1
Major Ions (mg/L)															
Chloride, dissolved	6	4	33%	0.450	0.173	0.420	0.250	0.700	0.250	0.250	0.313	0.500	0.500	0.600	0.650
Sulfate, dissolved	5	1	80%	3.28	1.74	3.02	2.50	6.40	2.50	2.50	2.50	2.50	2.50	4.84	5.62
Metals (µg/L)															
Copper, total	4	2	50%	1.5	1.22	1.11	0.5	3	0.5	0.5	0.5	1.25	2.25	2.7	2.85
Iron, total	3	3	0%	300	200	247	100	500	120	140	200	300	400	460	480
Lead, total	3	1	67%	1	0.866	0.794	0.5	2	0.5	0.5	0.5	0.5	1.25	1.7	1.85
Manganese, total	4	2	50%	22.5	18.9	17.8	10	50	10	10	10	15	27.5	41	45.5
Nickel, total	4	1	75%	6.25	2.5	5.95	5	10	5	5	5	5	6.25	8.5	9.25

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.8. Summary of the available surface-water chemistry data for the Lower Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	95	95	0%	64.6	45.7	53.2	30	203	31.1	32.1	33.6	37.4	88.3	132	170
Dissolved Oxygen (mg/L)	69	69	0%	9.79	1.59	9.67	4.7	16	8.08	8.46	9.2	9.7	10	11.5	12
pH (pH units)	313	313	0%	8.18	0.373	8.17	7	8.95	7.5	7.6	7.9	8.24	8.4	8.6	8.7
Residue Non-filterable (TSS; mg/L)	152	138	9%	24.8	42.3	10	0.5	260	2	2.5	4	7	24	66.3	128
Temperature (C)	174	174	0%	15.8	3.42	15.4	5	28	11	11.5	14	15.6	18	20	21
Turbidity (NTU)	220	220	0%	7.58	14.5	3	0.1	84	0.677	0.87	1.21	2.38	5.3	20.5	44.3
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	81	47	42%	23.4	27.8	8.17	1	110	1	1	1	10	40	60	80
Nitrogen - Nitrite, dissolved (NO_2)	148	11	93%	2.68	1.12	NA	1	9	2.18	2.5	2.5	2.5	2.5	2.5	5
Nitrogen Ammonia, dissolved	127	58	54%	12.8	20.8	6.14	2.5	117	2.5	2.5	2.5	2.5	12	30.4	52.1
Phosphorus, total (lake)	53	53	0%	53.7	108	33.4	4	800	9.2	13.4	22	33	52	77.6	102
Phosphorus, total (stream)	236	230	3%	39.8	58.2	NA	1.5	437	5	7	12	21	40.3	89	157
Major Ions (mg/L)															
Chloride, dissolved	231	227	2%	2.48	1.83	1.78	0.15	7.5	0.3	0.4	1.2	1.9	3.3	5.5	6.25
Fluoride, total	14	10	29%	0.0814	0.049	0.0705	0.025	0.19	0.0413	0.05	0.05	0.061	0.09	0.159	0.184
Sulfate, dissolved	185	182	2%	13.4	11	10.8	2.5	99	5	5.3	6.5	9.5	17.4	23.4	31.8
Metals (µg/L)															
Aluminum, total	16	14	13%	361	379	200	30	1420	30	40	77.5	275	495	750	955
Arsenic, total	4	2	50%	11.3	19.2	2.66	0.2	40	0.545	0.89	1.93	2.5	11.9	28.8	34.4
Boron, total	10	0	100%	17	6.32	15.2	5	20	5	5	20	20	20	20	20
Cadmium, total	1	1	0%	1	NA	1	1	1	1	1	1	1	1	1	1
Chromium, total	13	13	0%	8.17	7.8	4.79	0.2	27	1.28	2	2	5	10	18	22.8
Cobalt, total	10	1	90%	2.3	2.1	1.74	0.5	8	0.5	0.5	2	2	2	2.6	5.3
Copper, total	11	8	27%	3.05	5.84	1.28	0.5	20	0.5	0.5	0.75	1	1	6	13
Iron, total	26	26	0%	434	465	241	14	2080	26.3	43	118	265	630	910	1180
Lead, total	9	2	78%	0.722	0.507	0.63	0.5	2	0.5	0.5	0.5	0.5	0.5	1.2	1.6
Manganese, total	16	5	69%	6.63	2.28	6.3	5	10	5	5	5	5	9.25	10	10
Molybdenum, total	25	6	76%	5.88	9.72	2.8	0.1	50	0.25	0.35	2	5	5	10	10

Table 4.8. Summary of the available surface-water chemistry data for the Lower Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Nickel, total	5	0	100%	5.2	4.75	2.63	0.5	10	0.5	0.5	0.5	5	10	10	10
Selenium, total	1	1	0%	0.1	NA	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other (µg/L)															
Phenols	11	5	55%	2.91	3.81	1.9	1	14	1	1	1	1	3	3	8.5
Juvenile Rearing															
Conventionals															
Hardness (mg/L)	9	9	0%	46.1	2.78	46	41.5	48.3	41.7	42	44.2	47.9	48.2	48.2	48.3
pH (pH units)	47	47	0%	7.73	0.338	7.72	7.2	9.65	7.3	7.4	7.6	7.7	7.8	7.88	7.96
Temperature (C)	23	23	0%	4.65	2.65	3.98	1.5	11.5	1.5	1.6	3.25	3.5	6.25	8	8.45
Turbidity (NTU)	43	43	0%	2.37	3.91	1.27	0.14	23.9	0.38	0.394	0.655	1.2	1.96	6.03	7.1
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	28	28	0%	132	21.9	130	72	160	94.9	105	122	139	148	151	158
Nitrogen - Nitrite, dissolved (NO_2)	21	1	95%	2.55	0.65	2.47	1	5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	23	2	91%	2.89	1.33	2.73	2.5	8	2.5	2.5	2.5	2.5	2.5	2.5	5.65
Phosphorus, total (lake)	43	40	7%	12.6	13.4	9.19	1	84	1.75	4.2	7.5	9	12.5	19	30
Major Ions (mg/L)															
Chloride, dissolved	43	42	2%	1.5	1.36	1.31	0.25	10	0.909	1	1.2	1.3	1.5	1.6	1.79
Fluoride, total	9	9	0%	0.0667	0.0507	0.0576	0.04	0.2	0.04	0.04	0.05	0.05	0.05	0.096	0.148
Sulfate, dissolved	40	40	0%	9.09	1.25	8.99	4.9	11.7	7.33	7.99	8.58	9.05	10	10.5	10.6
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	39	39	0%	55.2	23.6	51.3	31.5	114	33.5	35	38.8	48.4	57.3	103	112
Dissolved Oxygen (mg/L)	37	37	0%	9.54	1.39	9.42	4.7	12	8.02	8.84	9.2	9.4	9.9	11.1	12
pH (pH units)	239	239	0%	8.13	0.299	8.12	7.2	8.95	7.59	7.7	7.9	8.2	8.3	8.4	8.5
Residue Non-filterable (TSS; mg/L)	158	154	3%	74.3	90.7	44.8	0.5	648	6.85	13.7	25.3	47	82	157	213
Temperature (C)	127	127	0%	12.6	3.73	12	5	28	6	8	10	13.5	15	16	16.5
Turbidity (NTU)	193	193	0%	21.4	34.3	10.6	0.5	320	1.92	2.8	4.9	8.5	24	54.6	77.6

Table 4.8. Summary of the available surface-water chemistry data for the Lower Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	38	31	18%	32.5	39.1	12.1	1	120	1	1	4.5	13	72.5	93	110
Nitrogen - Nitrite, dissolved (NO_2)	127	14	89%	2.87	1.3	NA	1	9	2.5	2.5	2.5	2.5	2.5	3	6
Nitrogen Ammonia, dissolved	102	39	62%	9.17	13.9	5.04	2.5	102	2.5	2.5	2.5	2.5	10.8	21.9	35.8
Phosphorus, total (lake)	28	27	4%	39.7	20.6	31.1	1	83	6.45	15.2	26	39	54	60.8	74
Phosphorus, total (stream)	168	168	0%	81	91.4	51.7	7	596	12	13.7	27	54	95.3	179	231
Major Ions (mg/L)															
Chloride, dissolved	131	130	1%	2.03	0.841	1.81	0.2	4.2	0.8	1.1	1.5	1.9	2.7	3.1	3.25
Fluoride, total	5	4	20%	0.0696	0.0203	0.0674	0.05	0.1	0.0516	0.0532	0.058	0.06	0.08	0.092	0.096
Sulfate, dissolved	119	117	2%	9.36	4.43	8.33	0.25	24	4.66	5.08	6.2	8.2	11.1	16.1	17.4
Metals (µg/L)															
Aluminum, total	11	11	0%	1040	777	803	230	2710	275	320	465	700	1440	1950	2330
Arsenic, total	2	2	0%	20.1	28.1	2.83	0.2	40	2.19	4.18	10.2	20.1	30.1	36	38
Boron, total	7	1	86%	25.7	15.1	23.4	20	60	20	20	20	20	20	36	48
Chromium, total	7	7	0%	5.57	3.91	4.52	2	12	2	2	3	4	7.5	10.8	11.4
Cobalt, total	7	1	86%	2.29	0.756	2.21	2	4	2	2	2	2	2	2.8	3.4
Copper, total	4	3	25%	5.88	9.44	2.11	0.5	20	0.575	0.65	0.875	1.5	6.5	14.6	17.3
Iron, total	14	14	0%	1330	1050	1050	250	4110	439	576	685	965	1790	2500	3180
Lead, total	3	1	67%	1	0.866	0.794	0.5	2	0.5	0.5	0.5	0.5	1.25	1.7	1.85
Manganese, total	5	2	60%	7	2.74	6.6	5	10	5	5	5	5	10	10	10
Molybdenum, total	13	2	85%	4.15	2.94	3.4	2	10	2	2	2	2	5	9	10
Selenium, total	1	1	0%	0.1	NA	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other (µg/L)															
Phenols	5	1	80%	1.2	0.447	1.15	1	2	1	1	1	1	1	1.6	1.8

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.9. Summary of the available surface-water chemistry data for the North Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	55	55	0%	39.4	20.0	37.0	23.5	166	25.3	27.7	32.6	35.6	37.6	49.9	58.9
Dissolved Oxygen (mg/L)	12	12	0%	9.34	0.908	9.30	8.20	11.0	8.31	8.41	8.65	9.10	9.98	10.4	10.7
pH (pH units)	117	117	0%	7.66	0.285	7.66	6.80	8.41	7.18	7.30	7.50	7.70	7.81	8.00	8.03
Residue Non-filterable (TSS; mg/L)	81	61	25%	15.3	14.9	8.86	0.500	64.0	1.00	2.00	2.50	11.0	21.0	33.0	49.0
Temperature (C)	36	36	0%	14.3	3.16	13.9	6.70	20.0	9.00	10.0	12.8	14.2	16.2	18.6	19.1
Turbidity (NTU)	80	80	0%	3.49	4.13	1.76	0.100	22.0	0.276	0.300	0.600	1.80	5.06	8.05	11.1
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	32	32	0%	38.5	21.8	32.8	11	80	16	17.2	20.8	26.5	60	70	70
Nitrogen - Nitrite, dissolved (NO_2)	28	1	96%	2.55	0.774	2.44	0.5	6	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	17	5	71%	25.6	38.7	7.48	2.5	100	2.5	2.5	2.5	2.5	50	100	100
Phosphorus, total (stream)	103	94	9%	15.1	13.7	10.4	1	72	1.5	3	6	11	19.5	31.4	44.2
Major Ions (mg/L)															
Chloride, dissolved	109	70	36%	0.432	0.532	0.322	0.0500	4.00	0.138	0.168	0.250	0.250	0.450	0.700	1.02
Fluoride, total	32	27	16%	0.0568	0.0361	0.0495	0.0200	0.180	0.0200	0.0300	0.0400	0.0500	0.0585	0.0970	0.132
Sulfate, dissolved	103	99	4%	6.03	3.64	5.43	1.50	33.0	2.50	2.80	4.75	5.60	6.75	7.96	9.09
Metals (µg/L)															
Aluminum, total	35	24	31%	387	451	174	30	1770	30	30	30	210	500	956	1380
Arsenic, total	3	1	67%	1.7	1.39	0.855	0.1	2.5	0.34	0.58	1.3	2.5	2.5	2.5	2.5
Boron, total	33	0	100%	10.5	7.33	8.28	5	20	5	5	5	5	20	20	20
Cadmium, total	2	2	0%	7.5	3.54	7.07	5	10	5.25	5.5	6.25	7.5	8.75	9.5	9.75
Chromium, total	9	9	0%	9.58	6.25	5.95	0.2	20	0.92	1.64	7	10	14	16	18
Cobalt, total	17	3	82%	3.53	3.95	2.32	0.5	13	0.5	1.4	2	2	2	10.8	12.2
Copper, total	8	4	50%	4.63	7.14	1.65	0.5	21	0.5	0.5	0.5	0.75	6.25	11.2	16.1
Iron, total	43	41	5%	497	547	227	25	2290	29.2	31.8	59.5	310	675	1400	1520
Lead, total	7	4	43%	19.4	31.3	2.86	0.5	70	0.5	0.5	0.5	1	31.5	64	67
Manganese, total	32	19	41%	11.2	16.8	6.03	0.5	86	0.775	2.1	5	5	9.25	21.9	40.4
Molybdenum, total	41	5	88%	4.64	4	3.42	0.1	20	0.7	2	2	5	5	5	10
Nickel, total	23	0	100%	9.17	2.74	7.71	0.5	10	1.45	10	10	10	10	10	10

Table 4.9. Summary of the available surface-water chemistry data for the North Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Selenium, total	2	2	0%	30.1	42.4	2.45	0.1	60	3.1	6.09	15.1	30.1	45	54	57
Spawning & Incubation															
Conventionals															
pH (pH units)	7	7	0%	8.14	0.151	8.14	7.90	8.40	7.96	8.02	8.10	8.10	8.20	8.28	8.34
Residue Non-filterable (TSS; mg/L)	5	4	20%	5.60	6.54	3.48	1.00	17.0	1.20	1.40	2.00	3.00	5.00	12.2	14.6
Turbidity (NTU)	6	6	0%	1.78	1.85	1.06	0.300	4.90	0.300	0.300	0.425	1.05	2.65	4.00	4.45
Nutrients (µg/L)															
Phosphorus, total (stream)	7	7	0%	11.9	7.95	9.86	3	28	4.5	6	8.5	10	12.5	20.2	24.1
Major Ions (mg/L)															
Chloride, dissolved	6	6	0%	1.60	0.490	1.54	1.10	2.20	1.10	1.10	1.15	1.60	1.98	2.10	2.15
Sulfate, dissolved	6	6	0%	12.0	3.96	11.5	8.00	18.5	8.28	8.55	9.20	11.0	13.9	16.4	17.5
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	23	23	0%	34.8	7.94	34.0	22.1	54.1	23.6	24.3	30.2	35.9	37.5	41.3	50.2
Dissolved Oxygen (mg/L)	1	1	0%	11.0	NA	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
pH (pH units)	72	72	0%	7.68	0.229	7.67	6.80	8.10	7.20	7.40	7.60	7.70	7.80	7.90	7.93
Residue Non-filterable (TSS; mg/L)	57	52	9%	24.0	24.3	14.9	1.00	104	2.00	2.50	12.0	16.0	26.0	54.8	77.8
Temperature (C)	20	20	0%	9.80	2.27	9.57	6.70	16.1	6.99	7.90	8.38	9.25	10.4	12.3	13.2
Turbidity (NTU)	43	43	0%	3.94	4.08	2.54	0.200	17.0	0.600	0.828	1.40	2.40	5.45	8.20	14.4
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	13	13	0%	37.5	16.9	34.1	19	73	19.6	20.2	23	36	45	57	64.6
Nitrogen - Nitrite, dissolved (NO_2)	17	2	88%	2.5	1.08	2.27	0.5	6	0.9	1.9	2.5	2.5	2.5	2.5	3.2
Nitrogen Ammonia, dissolved	17	7	59%	26.2	55	5.94	2.5	200	2.5	2.5	2.5	2.5	5	100	120
Phosphorus, total (stream)	67	67	0%	22.4	19	16.8	3	95	4	5	11	16	28.5	38.2	65.7

Table 4.9. Summary of the available surface-water chemistry data for the North Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Major Ions (mg/L)															
Chloride, dissolved	69	40	42%	0.393	0.393	0.299	0.0500	2.50	0.112	0.150	0.200	0.250	0.500	0.600	1.10
Fluoride, total	19	14	26%	0.0499	0.0319	0.0441	0.0200	0.170	0.0200	0.0280	0.0350	0.0500	0.0500	0.0620	0.0800
Sulfate, dissolved	68	68	0%	5.06	1.91	4.73	1.50	13.1	2.50	2.77	4.30	4.90	5.73	7.53	8.06
Metals (µg/L)															
Aluminum, total	26	25	4%	633	512	437	30	1770	105	150	263	440	863	1490	1570
Arsenic, total	1	1	0%	0.1	NA	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Boron, total	23	1	96%	14.1	16.1	9.7	5	80	5	5	5	5	20	20	20
Cadmium, total	2	2	0%	6	1.41	5.92	5	7	5.1	5.2	5.5	6	6.5	6.8	6.9
Chromium, total	3	3	0%	9.33	3.06	8.96	6	12	6.4	6.8	8	10	11	11.6	11.8
Cobalt, total	13	4	69%	5.15	6.32	3.31	2	23	2	2	2	2	4	11.6	16.4
Copper, total	4	3	25%	5.13	3.22	3.46	0.5	8	1.33	2.15	4.63	6	6.5	7.4	7.7
Iron, total	28	28	0%	770	688	453	3	2630	61.6	138	299	579	1000	1760	2230
Lead, total	3	3	0%	41	32.9	22.1	3	60	8.7	14.4	31.5	60	60	60	60
Manganese, total	18	13	28%	14.7	11.8	10.8	2	42	4.55	5	5	12	19.8	31.3	39.5
Molybdenum, total	26	1	96%	4.27	2.81	3.68	2	16	2	2	2	5	5	5	5
Nickel, total	13	0	100%	10	<0.001	10	10	10	10	10	10	10	10	10	10
Selenium, total	1	1	0%	0.1	NA	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.10. Summary of the available surface-water chemistry data for the South Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	41	41	0%	38.7	9.92	38.0	31.6	95.2	32.8	33.2	34.0	36.7	40.7	42.2	42.5
Dissolved Oxygen (mg/L)	21	21	0%	8.72	1.71	8.40	2.00	10.3	8.00	8.20	8.30	8.80	9.80	10.0	10.2
pH (pH units)	176	176	0%	7.81	0.198	7.81	7.30	8.30	7.40	7.60	7.70	7.80	7.90	8.00	8.10
Residue Non-filterable (TSS; mg/L)	86	72	16%	7.22	9.12	4.94	1.00	73.0	2.00	2.00	2.50	4.50	8.00	14.5	18.0
Temperature (C)	39	39	0%	17.4	2.92	17.1	10.0	22.5	12.9	13.8	15.3	18.0	19.0	21.0	21.9
Turbidity (NTU)	121	121	0%	1.84	1.37	1.45	0.200	6.60	0.510	0.600	0.900	1.41	2.30	4.00	4.90
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	40	29	28%	28.2	22.5	20.7	5	94	6.9	10	10	20	39.3	59.8	71.1
Nitrogen - Nitrite, dissolved (NO_2)	124	1	99%	2.5	0.289	NA	0.5	5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	24	11	54%	6.98	8.14	4.65	2.5	35	2.5	2.5	2.5	2.5	6.25	18.9	21.9
Phosphorus, total (stream)	173	169	2%	11.7	9.2	NA	1.5	63	4	5	7	9	13	19.8	30.2
Major Ions (mg/L)															
Chloride, dissolved	114	67	41%	0.588	0.727	0.440	0.150	6.60	0.250	0.250	0.250	0.500	0.600	0.800	1.54
Fluoride, total	18	18	0%	0.0500	0.0124	0.0488	0.0300	0.0900	0.0385	0.0400	0.0425	0.0500	0.0500	0.0600	0.0645
Sulfate, dissolved	97	94	3%	6.43	4.17	6.01	2.50	45.0	5.00	5.16	5.40	5.70	6.30	7.70	9.12
Metals (µg/L)															
Aluminum, total	49	44	10%	191	162	137	30	690	30	38	80	140	260	442	546
Arsenic, total	2	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Boron, total	35	1	97%	12	12.4	8.67	5	70	5	5	5	5	20	20	20
Cadmium, total	2	2	0%	6.5	0.707	6.48	6	7	6.05	6.1	6.25	6.5	6.75	6.9	6.95
Chromium, total	7	7	0%	14.7	12.2	10.8	2	40	3.8	5.6	9	10	16.5	26.2	33.1
Cobalt, total	19	6	68%	4.68	4.33	3.34	2	14	2	2	2	2	7.5	12.2	13.1
Copper, total	5	4	20%	7.7	6.36	4.84	0.5	18	1.6	2.7	6	7	7	13.6	15.8
Iron, total	54	54	0%	232	180	182	20	820	62.6	88.6	113	172	270	467	640
Lead, total	2	1	50%	30.3	42.1	5.48	0.5	60	3.48	6.45	15.4	30.3	45.1	54.1	57
Manganese, total	23	22	4%	11	6.98	9.69	4	36	5.1	6	7.5	9	11.5	18.6	22.7
Molybdenum, total	56	3	95%	4.19	1.7	3.61	0.25	10	1.73	2	2	5	5	5	5
Nickel, total	23	1	96%	13.7	18.8	10.7	5	100	10	10	10	10	10	10	10

Table 4.10. Summary of the available surface-water chemistry data for the South Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Selenium, total	1	1	0%	60	NA	60	60	60	60	60	60	60	60	60	60
Other (µg/L)															
Phenols	2	1	50%	1.5	0.707	1.41	1	2	1.05	1.1	1.25	1.5	1.75	1.9	1.95
Juvenile Rearing															
Conventionals															
Hardness (mg/L)	114	114	0%	36.5	9.30	35.4	20.1	66.7	25.2	26.0	29.5	34.5	41.9	49.9	52.3
Dissolved Oxygen (mg/L)	172	172	0%	10.5	1.48	10.3	6.60	15.0	8.60	8.80	9.28	10.2	11.6	12.4	13.0
pH (pH units)	1057	1057	0%	7.69	0.340	7.68	6.60	11.6	7.10	7.30	7.50	7.70	7.90	8.00	8.10
Residue Non-filterable (TSS; mg/L)	75	52	31%	4.03	11.4	1.49	0.500	85.0	0.500	0.500	0.500	1.00	2.75	4.00	14.2
Temperature (C)	527	527	0%	12.6	6.69	10.3	0.500	26.0	3.00	3.56	5.50	13.5	18.1	21.0	22.0
Turbidity (NTU)	513	513	0%	0.702	1.04	0.501	0.100	13.1	0.200	0.200	0.300	0.420	0.700	1.20	1.90
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	181	119	34%	57.7	45.9	21	1	168	1	1	2	70	96	113	120
Nitrogen - Nitrite, dissolved (NO_2)	340	17	95%	2.56	1.74	NA	0.5	29	1	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	328	134	59%	10.2	24.3	NA	2.5	200	2.5	2.5	2.5	2.5	8	17.3	28.6
Phosphorus, total (lake)	1047	829	21%	5.42	7.44	NA	1	114	1	1	3	4	6	10	13
Phosphorus, total (stream)	70	59	16%	6.69	7.02	4.92	1	53	1.5	1.5	3	5	8	11.2	16.1
Major Ions (mg/L)															
Chloride, dissolved	804	501	38%	0.647	0.732	0.495	0.0500	14.0	0.250	0.250	0.250	0.500	0.800	1.10	1.30
Fluoride, total	7	7	0%	0.0300	0.0115	0.0283	0.0200	0.0500	0.0200	0.0200	0.0200	0.0300	0.0350	0.0440	0.0470
Sulfate, dissolved	723	703	3%	5.99	1.82	5.74	1.50	22.7	3.22	4.10	5.10	5.80	6.90	7.90	8.59
Metals (µg/L)															
Aluminum, total	65	43	34%	93.9	343	32.4	4.1	2750	7.66	10	10	30	50	96	218
Arsenic, total	10	7	30%	0.371	0.751	0.16	0.05	2.5	0.05	0.05	0.1	0.155	0.2	0.43	1.47
Boron, total	42	1	98%	38.2	58.7	11.3	1	300	1	2.65	4	4	100	100	100
Cadmium, total	16	8	50%	1.95	5.41	0.0431	0.005	20	0.005	0.005	0.005	0.005	0.225	5.15	12.5
Chromium, total	13	6	54%	8.48	15.6	0.594	0.05	50	0.08	0.1	0.1	0.1	10	27.8	38

Table 4.10. Summary of the available surface-water chemistry data for the South Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Cobalt, total	16	7	56%	13.3	49.8	0.153	0.0025	200	0.0025	0.0025	0.0158	0.06	2	2	51.5
Copper, total	30	11	63%	0.963	1.15	0.684	0.35	5	0.413	0.499	0.5	0.5	0.53	2	3.46
Iron, total	106	85	20%	78.8	108	45.3	5	800	9.25	10	20	50	100	170	208
Lead, total	29	5	83%	0.63	0.907	0.326	0.005	5	0.0082	0.0426	0.5	0.5	0.5	0.5	1.4
Manganese, total	51	20	61%	7.01	5.94	4.23	0.5	30	0.5	0.823	1.19	10	10	10	11.5
Mercury, total	7	5	29%	0.04	0.0283	0.0301	0.01	0.08	0.01	0.01	0.015	0.04	0.06	0.074	0.077
Molybdenum, total	103	25	76%	3.19	2.04	2.25	0.25	10	0.435	0.5	0.85	2.5	5	5	5
Nickel, total	48	5	90%	4.27	1.57	3.7	0.27	10	0.621	3.09	4	5	5	5	5
Selenium, total	9	4	56%	0.164	0.0829	0.148	0.1	0.3	0.1	0.1	0.1	0.1	0.2	0.284	0.292
Silver, total	9	2	78%	0.0447	0.0998	0.0142	0.0025	0.31	0.0055	0.0085	0.01	0.01	0.01	0.086	0.198
Spawning & Incubation															
Conventionals															
Hardness (mg/L)	746	746	0%	129	78.3	98.4	9.10	272	25.6	31.0	49.7	125	206	222	230
Dissolved Oxygen (mg/L)	748	747	0%	13.3	51.0	11.0	0.0500	1400	8.24	8.90	10.0	11.2	13.0	14.0	15.0
pH (pH units)	2375	2375	0%	7.85	0.413	7.84	5.90	11.6	7.10	7.30	7.60	7.88	8.19	8.30	8.40
Residue Non-filterable (TSS; mg/L)	1224	976	20%	19.0	52.9	4.22	0.100	799	0.500	0.500	1.00	3.00	11.0	50.7	88.8
Temperature (C)	1493	1434	4%	8.80	6.43	5.35	0.0500	25.5	0.400	1.00	3.50	7.50	13.5	18.7	20.6
Turbidity (NTU)	1445	1423	2%	6.12	16.4	1.52	0.0500	200	0.200	0.300	0.500	1.20	3.30	15.5	30.8
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	335	277	17%	83.4	72.3	NA	1	440	1	2	22	70	116	192	229
Nitrogen - Nitrite, dissolved (NO_2)	649	116	82%	2.9	2.42	NA	0.5	42	1	2	2.5	2.5	2.5	5	5
Nitrogen Ammonia, dissolved	958	461	52%	13.5	28.8	NA	2.5	529	2.5	2.5	2.5	6	12	31	49
Phosphorus, total (lake)	814	646	21%	5.41	8.05	NA	1	114	1	1	3	4	6	9	13
Phosphorus, total (stream)	1368	1317	4%	72.5	80.7	NA	1	1060	3	4	11	62	90	146	207
Major Ions (mg/L)															
Chloride, dissolved	1283	946	26%	1.66	1.91	0.923	0.0500	19.0	0.250	0.250	0.250	0.800	2.80	4.40	4.90
Fluoride, total	117	117	0%	0.135	0.0603	0.117	0.0100	0.350	0.0280	0.0560	0.100	0.140	0.170	0.200	0.224
Sulfate, dissolved	1107	1062	4%	13.8	15.3	8.74	1.50	73.1	2.50	3.70	5.20	6.70	12.4	43.7	48.0

Table 4.10. Summary of the available surface-water chemistry data for the South Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L)															
Aluminum, total	582	551	5%	422	867	NA	0.9	9210	11.3	30	60	140	337	1110	1930
Arsenic, total	342	326	5%	1.16	2.72	NA	0.005	50	0.3	0.5	0.8	1	1.12	1.32	1.8
Boron, total	261	141	46%	41	154	NA	0.05	1600	4	4	4	11	16	25	100
Cadmium, total	362	329	9%	0.231	1.29	NA	0.0025	20	0.005	0.008	0.02	0.1	0.1	0.3	0.5
Chromium, total	477	428	10%	6.53	105	NA	0.0025	2290	0.1	0.142	0.244	0.5	1.28	3.54	6.48
Cobalt, total	473	444	6%	0.929	9.2	NA	0.001	200	0.0444	0.0874	0.132	0.287	0.5	1.39	2
Copper, total	506	463	8%	3.76	12.9	NA	0.06	165	0.5	0.5	0.8	1.2	2.2	5.65	11.8
Iron, total	734	698	5%	669	1300	NA	0.25	14900	20	50	161	275	585	1570	2780
Lead, total	496	300	40%	0.548	1.03	NA	0.005	9.1	0.0268	0.045	0.1	0.2	0.5	1.4	2.33
Manganese, total	557	501	10%	51.3	45.8	NA	0.5	405	3	8.49	29	45.4	63.2	86.6	121
Mercury, total	101	97	4%	41.6	202	6.98	0.01	2040	0.04	0.06	7	10	24	60	80
Molybdenum, total	667	478	28%	2.43	2.36	NA	0.0025	30	0.443	0.6	1.36	2	2.5	5	5
Nickel, total	518	408	21%	2.25	2.38	NA	0.1	20	0.4	0.5	0.69	1.2	4	5	5.52
Selenium, total	321	289	10%	0.766	4.45	NA	0.02	80	0.1	0.1	0.32	0.5	0.66	0.8	0.9
Silver, total	322	159	51%	0.293	4.22	NA	0.0005	75.7	0.0005	0.002	0.007	0.021	0.05	0.1	0.2
Other (µg/L)															
Cyanide WAD	128	10	92%	0.295	0.206	NA	0.25	2	0.25	0.25	0.25	0.25	0.25	0.25	0.5
Phenols	6	3	50%	2.17	1.33	1.82	1	4	1	1	1	2	3	3.5	3.75
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	17	17	0%	42.8	14.0	41.5	34.4	95.2	34.8	35.1	36.8	39.4	41.8	46.0	56.3
Dissolved Oxygen (mg/L)	10	10	0%	10.1	1.59	9.98	7.34	12.2	8.00	8.65	9.25	9.85	11.5	12.1	12.2
pH (pH units)	97	97	0%	7.78	0.185	7.78	7.30	8.59	7.48	7.60	7.70	7.80	7.90	7.92	8.04
Residue Non-filterable (TSS; mg/L)	60	54	10%	11.1	10.5	8.50	2.50	73.0	2.50	3.85	6.00	8.00	13.3	21.0	25.2
Temperature (C)	26	26	0%	11.4	2.87	11.0	7.00	18.0	7.00	7.50	9.63	10.5	13.8	14.5	15.8
Turbidity (NTU)	56	56	0%	3.24	1.75	2.80	0.700	7.40	1.30	1.48	1.85	2.65	4.14	6.10	6.45
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	19	18	5%	58.9	22.7	47.2	1	94	13.6	34.2	52.5	60	71.5	81.6	85
Nitrogen - Nitrite, dissolved (NO_2)	62	1	98%	3.56	8.58	2.57	0.5	70	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Table 4.10. Summary of the available surface-water chemistry data for the South Thompson River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Nutrients (µg/L; continued)															
Nitrogen Ammonia, dissolved	23	13	43%	5.61	3.35	4.71	2.5	14	2.5	2.5	2.5	6	7	9.8	10.9
Phosphorus, total (stream)	96	95	1%	16	10.6	13.3	1.5	63	5	7	10	13	20	29	35.5
Major Ions (mg/L)															
Chloride, dissolved	70	44	37%	0.612	0.821	0.451	0.150	6.60	0.150	0.250	0.250	0.500	0.600	0.910	1.47
Fluoride, total	12	12	0%	0.0550	0.0124	0.0539	0.0400	0.0900	0.0455	0.0500	0.0500	0.0500	0.0600	0.0600	0.0735
Sulfate, dissolved	59	58	2%	6.82	5.19	6.27	2.50	45.0	5.29	5.50	5.60	5.80	6.40	7.54	8.32
Metals (µg/L)															
Aluminum, total	33	31	6%	324	257	240	30	1240	60	100	180	220	490	674	718
Boron, total	25	0	100%	11.6	7.6	9.2	5	20	5	5	5	5	20	20	20
Cadmium, total	2	2	0%	7	1.41	6.93	6	8	6.1	6.2	6.5	7	7.5	7.8	7.9
Chromium, total	6	6	0%	10.2	7.78	7.39	2	21	2.25	2.5	4.25	8.5	15.8	19.5	20.3
Cobalt, total	14	3	79%	4.43	5.23	2.97	2	19	2	2	2	2	2	11.1	14.5
Copper, total	4	4	0%	9.75	5.5	8.86	7	18	7	7	7	7	9.75	14.7	16.4
Iron, total	33	33	0%	379	274	309	110	1180	132	144	213	260	479	780	928
Manganese, total	14	14	0%	12.2	6.45	10.8	4	28	5.3	6.3	8.25	10	15.3	19.4	22.8
Molybdenum, total	34	2	94%	4.35	3.15	3.68	0.9	20	2	2	2	5	5	5	5
Nickel, total	14	1	93%	16.4	24.1	11.8	10	100	10	10	10	10	10	10	41.5
Other (µg/L)															
Phenols	1	0	100%	1	NA	1	1	1	1	1	1	1	1	1	1

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.11. **Summary of the available surface-water chemistry data for the Chilko River Area of Interest.**

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	20	20	0%	30.7	6.63	30.2	26.8	55.5	26.8	27.0	27.6	28.1	29.9	37.2	38.5
Dissolved Oxygen (mg/L)	2	2	0%	10.7	0.707	10.7	10.2	11.2	10.3	10.3	10.5	10.7	11.0	11.1	11.2
pH (pH units)	21	21	0%	7.50	0.506	7.48	6.00	7.90	6.20	7.00	7.50	7.70	7.80	7.80	7.80
Residue Non-filterable (TSS; mg/L)	14	14	0%	10.5	18.5	5.17	1.00	73.0	1.65	2.00	2.25	4.00	9.00	14.1	35.3
Temperature (C)	7	7	0%	13.0	1.38	12.9	10.5	15.0	11.1	11.7	12.8	13.0	13.5	14.4	14.7
Turbidity (NTU)	19	19	0%	13.7	13.0	9.80	1.10	47.4	5.15	5.86	6.38	9.30	11.8	36.4	42.5
Nutrients (µg/L)															
Nitrogen - Nitrite, dissolved (NO_2)	2	0	100%	1.75	1.06	1.58	1	2.5	1.08	1.15	1.38	1.75	2.13	2.35	2.43
Phosphorus, total (stream)	25	22	12%	27.2	34.9	14.2	1	152	1	2.2	12	16	22	65.8	95.4
Major Ions (mg/L)															
Chloride, dissolved	2	1	50%	0.425	0.247	0.387	0.250	0.600	0.268	0.285	0.338	0.425	0.513	0.565	0.583
Sulfate, dissolved	22	21	5%	6.38	3.26	5.47	0.250	19.5	4.53	5.01	5.38	6.05	6.60	6.99	7.48
Metals (µg/L)															
Aluminum, total	12	12	0%	415	350	259	2.6	1460	152	276	296	345	382	507	942
Arsenic, total	15	14	7%	0.41	0.191	0.357	0.05	0.8	0.225	0.3	0.3	0.4	0.45	0.68	0.8
Boron, total	2	2	0%	13.5	0.707	13.5	13	14	13.1	13.1	13.3	13.5	13.8	13.9	14
Cadmium, total	15	5	67%	0.00933	0.00942	0.00724	0.005	0.04	0.005	0.005	0.005	0.005	0.01	0.016	0.026
Chromium, total	15	4	73%	0.22	0.224	0.155	0.1	0.7	0.1	0.1	0.1	0.1	0.2	0.62	0.7
Cobalt, total	15	13	13%	0.297	0.405	0.113	0.0025	1.28	0.0025	0.0155	0.087	0.184	0.204	0.902	1.26
Copper, total	17	17	0%	2.8	3.1	1.93	0.87	11	0.87	0.87	1.28	1.48	2	6.78	10.2
Iron, total	2	2	0%	561	290	522	356	766	377	397	459	561	664	725	746
Lead, total	17	15	12%	0.879	1.93	0.197	0.005	6	0.049	0.066	0.09	0.13	0.5	2.73	6
Manganese, total	16	15	6%	17.3	18.9	12.6	5	66.2	6.63	7.29	8.81	10.5	13.8	41.1	64.3
Molybdenum, total	15	14	7%	0.93	0.286	0.771	0.025	1.36	0.47	0.752	0.965	0.98	1.03	1.05	1.14
Nickel, total	14	12	14%	0.628	0.887	0.296	0.025	2.7	0.025	0.0685	0.223	0.295	0.448	2.08	2.68
Selenium, total	15	1	93%	0.107	0.0258	0.105	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.13
Silver, total	15	0	100%	0.01	2.11E-10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 4.11. Summary of the available surface-water chemistry data for the Chilko River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Juvenile Rearing															
Conventionals															
Hardness (mg/L)	7	7	0%	23.9	2.84	23.8	21.0	28.3	21.1	21.2	21.7	23.2	25.9	27.5	27.9
Dissolved Oxygen (mg/L)	6	6	0%	10.3	1.59	10.2	8.80	12.8	8.85	8.90	9.10	9.90	11.3	12.2	12.5
pH (pH units)	18	18	0%	7.36	0.273	7.35	6.90	7.70	6.99	7.00	7.13	7.35	7.60	7.70	7.70
Residue Non-filterable (TSS; mg/L)	11	10	9%	9.36	8.49	6.58	2.00	26.0	2.00	2.00	4.00	6.00	12.0	24.0	25.0
Temperature (C)	4	4	0%	8.00	4.45	6.28	1.50	11.5	2.63	3.75	7.13	9.50	10.4	11.1	11.3
Turbidity (NTU)	6	6	0%	13.6	4.94	12.8	6.50	21.0	7.88	9.25	12.0	12.5	16.0	19.0	20.0
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	4	2	50%	45	63.5	23	10	140	10	10	10	15	50	104	122
Nitrogen - Nitrite, dissolved (NO_2)	12	2	83%	2.42	0.469	2.35	1	3	1.83	2.5	2.5	2.5	2.5	2.5	2.73
Phosphorus, total (stream)	11	11	0%	12.2	5.95	11.1	6	24	6.5	7	9	10	12	23	23.5
Major Ions (mg/L)															
Sulfate, dissolved	17	17	0%	7.21	1.22	7.11	5.50	9.50	5.90	6.00	6.20	7.00	7.80	9.24	9.34
Metals (µg/L)															
Aluminum, total	10	10	0%	1550	1030	1320	660	3490	692	723	1080	1170	1440	3410	3450
Arsenic, total	8	4	50%	0.75	0.267	0.707	0.5	1	0.5	0.5	0.5	0.75	1	1	1
Boron, total	10	3	70%	27	25.6	16.8	4	76	4	4	8	20	30.5	68.8	72.4
Chromium, total	4	4	0%	3	1.41	2.78	2	5	2	2	2	2.5	3.5	4.4	4.7
Cobalt, total	10	1	90%	1.95	0.762	1.86	1.5	4	1.5	1.5	1.5	1.75	2	2.2	3.1
Copper, total	1	1	0%	1	NA	1	1	1	1	1	1	1	1	1	1
Iron, total	11	11	0%	1220	710	1080	562	2610	599	635	863	960	1170	2590	2600
Lead, total	1	0	100%	0.5	NA	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Molybdenum, total	11	1	91%	1.99	0.0302	1.99	1.9	2	1.95	2	2	2	2	2	2
Silver, total	4	0	100%	0.05	NA	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Spawning & Incubation															
Conventionals															
Hardness (mg/L)	5	5	0%	24.5	3.27	24.3	21.0	28.3	21.1	21.1	21.3	24.8	26.9	27.7	28.0
Dissolved Oxygen (mg/L)	5	5	0%	10.6	1.57	10.5	9.00	12.8	9.08	9.16	9.40	10.4	11.6	12.3	12.6

Table 4.11. Summary of the available surface-water chemistry data for the Chilko River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Conventionals (continued)															
pH (pH units)	16	16	0%	7.34	0.283	7.34	6.90	7.70	6.98	7.00	7.10	7.35	7.63	7.70	7.70
Residue Non-filterable (TSS; mg/L)	11	10	9%	9.36	8.49	6.58	2.00	26.0	2.00	2.00	4.00	6.00	12.0	24.0	25.0
Temperature (C)	3	3	0%	7.67	5.39	5.57	1.50	11.5	2.35	3.20	5.75	10.0	10.8	11.2	11.4
Turbidity (NTU)	4	4	0%	15.5	4.36	15.1	12.0	21.0	12.0	12.0	12.0	14.5	18.0	19.8	20.4
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	3	2	33%	56.7	72.3	30.4	10	140	11	12	15	20	80	116	128
Nitrogen - Nitrite, dissolved (NO_2)	11	2	82%	2.41	0.491	2.34	1	3	1.75	2.5	2.5	2.5	2.5	2.5	2.75
Phosphorus, total (stream)	10	10	0%	12.7	6	11.6	6	24	6.9	7.8	10	11	12	23.1	23.6
Major Ions (mg/L)															
Sulfate, dissolved	15	15	0%	7.28	1.27	7.18	5.50	9.50	5.85	6.00	6.35	7.00	8.00	9.26	9.36
Metals (µg/L)															
Aluminum, total	10	10	0%	1550	1030	1320	660	3490	692	723	1080	1170	1440	3410	3450
Arsenic, total	8	4	50%	0.75	0.267	0.707	0.5	1	0.5	0.5	0.5	0.75	1	1	1
Boron, total	10	3	70%	27	25.6	16.8	4	76	4	4	8	20	30.5	68.8	72.4
Chromium, total	4	4	0%	3	1.41	2.78	2	5	2	2	2	2.5	3.5	4.4	4.7
Cobalt, total	10	1	90%	1.95	0.762	1.86	1.5	4	1.5	1.5	1.5	1.75	2	2.2	3.1
Copper, total	1	1	0%	1	NA	1	1	1	1	1	1	1	1	1	1
Iron, total	11	11	0%	1220	710	1080	562	2610	599	635	863	960	1170	2590	2600
Lead, total	1	0	100%	0.5	NA	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Molybdenum, total	11	1	91%	1.99	0.0302	1.99	1.9	2	1.95	2	2	2	2	2	2
Silver, total	4	0	100%	0.05	NA	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	12	12	0%	34.4	10.7	33.1	26.8	57.3	27.2	27.5	27.8	29.7	33.9	53.7	56.3
Dissolved Oxygen (mg/L)	1	1	0%	11.2	NA	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
pH (pH units)	10	10	0%	7.57	0.564	7.55	6.00	7.90	6.68	7.35	7.63	7.80	7.80	7.81	7.86
Residue Non-filterable (TSS; mg/L)	8	8	0%	15.6	23.5	8.60	2.00	73.0	2.70	3.40	5.50	8.00	10.5	32.4	52.7
Temperature (C)	3	3	0%	13.7	1.15	13.6	13.0	15.0	13.0	13.0	13.0	13.0	14.0	14.6	14.8
Turbidity (NTU)	11	11	0%	17.7	15.7	12.8	3.86	47.4	5.17	6.48	7.45	11.1	23.7	42.0	44.7

Table 4.11. Summary of the available surface-water chemistry data for the Chilko River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Nutrients (µg/L)															
Phosphorus, total (stream)	11	9	18%	0.0405	0.0469	0.0170	0.00100	0.152	0.00100	0.00100	0.0105	0.0230	0.0505	0.0990	0.126
Major Ions (mg/L)															
Sulfate, dissolved	11	11	0%	5.99	0.936	5.92	4.30	7.50	4.65	5.00	5.45	5.90	6.60	7.00	7.25
Metals (µg/L)															
Aluminum, total	8	8	0%	485	407	397	172	1460	210	248	297	371	432	801	1130
Arsenic, total	9	9	0%	0.522	0.172	0.499	0.3	0.8	0.34	0.38	0.4	0.5	0.5	0.8	0.8
Boron, total	1	1	0%	14	NA	14	14	14	14	14	14	14	14	14	14
Cadmium, total	9	5	44%	0.0122	0.0115	0.00926	0.005	0.04	0.005	0.005	0.005	0.01	0.01	0.024	0.032
Chromium, total	9	4	56%	0.3	0.265	0.208	0.1	0.7	0.1	0.1	0.1	0.1	0.5	0.7	0.7
Cobalt, total	9	9	0%	0.44	0.473	0.294	0.135	1.28	0.139	0.144	0.165	0.201	0.381	1.26	1.27
Copper, total	11	11	0%	3.54	3.68	2.32	0.87	11	0.93	0.99	1.18	1.48	4.46	10	10.5
Iron, total	1	1	0%	766	NA	766	766	766	766	766	766	766	766	766	766
Lead, total	11	11	0%	1.26	2.35	0.305	0.06	6	0.08	0.1	0.105	0.13	0.525	6	6
Manganese, total	10	9	10%	22.8	22.7	15.9	5	66.2	6.13	7.27	8.62	14.4	19.5	63.9	65
Molybdenum, total	9	9	0%	1.04	0.187	1.02	0.66	1.36	0.78	0.9	1.02	1.03	1.05	1.23	1.3
Nickel, total	9	9	0%	0.922	1.01	0.606	0.25	2.7	0.27	0.29	0.34	0.48	0.69	2.68	2.69
Selenium, total	9	1	89%	0.111	0.0333	0.108	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.12	0.16
Silver, total	9	0	100%	0.01	1.61E-10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.12. Summary of the available surface-water chemistry data for the Quesnel River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	23	23	0%	82.2	102	60.3	41.0	405	41.9	42.4	44.5	47.9	54.9	94.2	369
Dissolved Oxygen (mg/L)	3	3	0%	9.93	1.81	9.83	8.60	12.0	8.66	8.72	8.90	9.20	10.6	11.4	11.7
pH (pH units)	26	26	0%	7.88	0.268	7.87	7.33	8.20	7.40	7.48	7.75	7.99	8.10	8.16	8.20
Residue Non-filterable (TSS; mg/L)	19	18	5%	59.3	105	21.1	2.00	455	2.00	2.40	7.00	26.0	49.5	119	195
Temperature (C)	24	24	0%	15.4	3.20	15.1	10.3	21.7	11.2	12.1	13.1	14.0	18.1	19.5	20.0
Turbidity (NTU)	19	19	0%	12.2	14.2	4.92	0.300	52.0	0.390	0.480	0.900	9.00	14.5	31.2	37.6
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	4	4	0%	80	11.5	79.4	70	90	70	70	70	80	90	90	90
Nitrogen - Nitrite, dissolved (NO_2)	5	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	16	5	69%	4.22	3.14	3.52	2.5	13	2.5	2.5	2.5	2.5	5	8.5	10
Phosphorus, total (stream)	6	5	17%	4.58	2.97	3.87	1.5	10	1.88	2.25	3	4	5	7.5	8.75
Major Ions (mg/L)															
Chloride, dissolved	21	12	43%	0.721	0.722	0.490	0.150	2.60	0.250	0.250	0.250	0.400	0.700	1.70	2.20
Sulfate, dissolved	23	22	4%	37.5	85.0	13.7	2.50	320	5.72	5.92	6.35	11.0	16.0	30.6	265
Metals (µg/L)															
Aluminum, total	14	14	0%	655	1770	145	7	6780	15.5	28.4	81.3	125	319	558	2790
Arsenic, total	15	1	93%	0.127	0.247	0.068	0.05	1	0.05	0.05	0.05	0.05	0.05	0.17	0.475
Boron, total	13	10	23%	573	582	189	5	2220	5	5	50	570	730	786	1370
Cadmium, total	2	2	0%	0.35	0.0707	0.346	0.3	0.4	0.305	0.31	0.325	0.35	0.375	0.39	0.395
Chromium, total	13	5	62%	1.85	2.34	1.03	0.5	8	0.5	0.5	0.5	0.5	3	4.6	6.2
Cobalt, total	6	0	100%	0.833	0.516	0.721	0.5	1.5	0.5	0.5	0.5	0.5	1.25	1.5	1.5
Copper, total	19	11	42%	3.11	5.29	1.55	0.5	24	0.5	0.5	0.5	2	3	5	6.9
Iron, total	19	17	11%	813	2550	188	2.5	11300	45.3	88.4	133	180	254	610	1980
Lead, total	15	0	100%	0.5	NA	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Manganese, total	19	16	16%	34.1	73.2	15.7	2.5	331	4.75	5.8	9.5	13	28	44	83.5
Mercury, total	1	1	0%	145	NA	145	145	145	145	145	145	145	145	145	145
Molybdenum, total	18	5	72%	9.61	10.2	5.68	2.5	31	2.5	2.5	2.5	2.5	15.8	25	25.9
Nickel, total	18	7	61%	2.97	3.11	1.57	0.5	11	0.5	0.5	0.5	1.25	5	6.3	7.6

Table 4.12. Summary of the available surface-water chemistry data for the Quesnel River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Selenium, total	16	1	94%	0.3	0.147	0.281	0.25	0.8	0.25	0.25	0.25	0.25	0.25	0.375	0.575
Silver, total	13	0	100%	0.05	NA	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Other (µg/L)															
Cyanide WAD	13	0	100%	2.5	0.0000000672	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Juvenile Rearing															
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	318	171	46%	62	33.8	NA	10	150	21.9	25	34.5	55	89.3	120	130
Nitrogen - Nitrite, dissolved (NO_2)	318	125	61%	1.64	0.975	NA	1	9	1	1	1	1	2	3	3
Phosphorus, total (lake)	318	134	58%	2.62	2.99	NA	1	23	1	1	1	1	3	6	8
Spawning & Incubation															
Conventionals															
Hardness (mg/L)	56	56	0%	52.7	10.0	51.8	34.9	71.0	39.8	40.6	44.2	51.4	62.0	66.4	69.0
Dissolved Oxygen (mg/L)	56	56	0%	29.2	132	12.2	8.00	1000	8.00	8.50	9.73	11.5	13.0	15.5	18.0
pH (pH units)	96	96	0%	7.81	0.257	7.81	6.80	8.20	7.10	7.60	7.72	7.90	7.93	8.00	8.10
Residue Non-filterable (TSS; mg/L)	86	72	16%	9.81	20.3	3.21	0.500	145	0.500	0.500	1.00	2.00	8.00	25.0	44.5
Temperature (C)	68	52	24%	5.73	5.88	1.60	0.0500	18.0	0.0500	0.0500	0.400	4.00	10.1	15.0	16.7
Turbidity (NTU)	97	97	0%	3.91	6.27	1.78	0.400	38.6	0.480	0.560	0.700	1.30	3.70	13.1	17.3
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	91	74	19%	47.6	36.2	25.5	1	149	1	3	10	52	76	85	109
Nitrogen - Nitrite, dissolved (NO_2)	92	40	57%	2.03	1.55	1.63	1	7	1	1	1	1	2.25	4	6
Nitrogen Ammonia, dissolved	59	20	66%	11.3	19.9	5.03	2.5	101	2.5	2.5	2.5	2.5	10.5	32.6	43.1
Phosphorus, total (stream)	48	48	0%	22.6	29.4	14.1	4	139	5.44	6.45	7.78	9.85	24.2	44.5	91.1
Major Ions (mg/L)															
Chloride, dissolved	38	26	32%	0.697	0.381	0.584	0.250	1.50	0.250	0.250	0.250	0.700	1.00	1.13	1.25

Table 4.12. Summary of the available surface-water chemistry data for the Quesnel River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L)															
Aluminum, total	26	26	0%	214	413	72.9	13.9	2060	19.5	20.6	25.1	32.8	302	485	529
Arsenic, total	28	28	0%	0.313	0.134	0.294	0.21	0.88	0.224	0.23	0.23	0.26	0.35	0.44	0.447
Boron, total	28	28	0%	4.6	1.42	4.36	2.1	6.5	2.24	2.37	3.65	4.85	5.85	6.26	6.47
Cadmium, total	28	28	0%	0.0155	0.0149	0.012	0.003	0.081	0.00535	0.006	0.008	0.01	0.0175	0.0283	0.031
Chromium, total	28	28	0%	0.581	0.882	0.325	0.111	4.63	0.116	0.127	0.145	0.2	0.809	1.18	1.22
Cobalt, total	28	28	0%	0.184	0.321	0.0883	0.021	1.68	0.0281	0.032	0.0408	0.0485	0.248	0.38	0.424
Copper, total	10	10	0%	1.13	0.632	1	0.63	2.26	0.648	0.666	0.723	0.79	1.23	2.26	2.26
Iron, total	28	28	0%	373	547	220	72.3	2890	79.5	90.7	108	151	551	720	744
Lead, total	10	9	10%	0.0607	0.0813	0.0287	0.003	0.214	0.00633	0.0102	0.0178	0.022	0.044	0.212	0.213
Manganese, total	10	10	0%	13	9.06	11	6.59	31.6	7.01	7.44	7.8	8.53	11.6	28.4	30
Molybdenum, total	28	28	0%	0.829	0.115	0.821	0.531	1.08	0.647	0.701	0.751	0.842	0.913	0.938	0.966
Nickel, total	10	10	0%	0.755	0.518	0.64	0.41	1.74	0.41	0.41	0.44	0.455	0.795	1.67	1.7
Selenium, total	28	28	0%	0.299	0.051	0.295	0.2	0.46	0.244	0.25	0.268	0.29	0.313	0.349	0.383
Silver, total	28	23	18%	0.0053	0.00729	0.00278	5E-04	0.037	0.0005	0.0005	0.001	0.003	0.0055	0.0109	0.013
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	17	17	0%	58.7	25.4	55.7	43.0	152	43.0	43.2	48.0	55.2	56.8	65.8	92.5
pH (pH units)	17	17	0%	7.82	0.243	7.81	7.33	8.17	7.43	7.47	7.68	7.86	7.94	8.11	8.13
Residue Non-filterable (TSS; mg/L)	18	18	0%	42.5	44.4	23.8	2.00	166	2.85	6.50	11.3	24.5	62.0	102	116
Temperature (C)	17	17	0%	12.3	4.00	11.6	6.00	18.0	7.68	8.22	8.60	12.0	16.2	18.0	18.0
Turbidity (NTU)	11	11	0%	17.7	10.3	14.5	4.10	36.0	5.20	6.30	9.20	16.0	24.5	30.0	33.0
Nutrients (µg/L)															
Nitrogen - Nitrite, dissolved (NO_2)	1	0	100%	2.5	NA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nitrogen Ammonia, dissolved	10	2	80%	4.3	3.97	3.38	2.5	14	2.5	2.5	2.5	2.5	2.5	9.5	11.8
Phosphorus, total (stream)	1	1	0%	3	NA	3	3	3	3	3	3	3	3	3	3
Major Ions (mg/L)															
Chloride, dissolved	17	3	82%	0.312	0.362	0.246	0.150	1.70	0.150	0.150	0.150	0.250	0.250	0.300	0.580
Sulfate, dissolved	17	17	0%	12.5	9.56	10.4	5.00	44.0	5.80	6.00	7.00	9.00	13.0	20.2	28.8

Table 4.12. Summary of the available surface-water chemistry data for the Quesnel River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L)															
Aluminum, total	10	10	0%	194	291	92.4	7	993	17.8	28.6	47	106	180	326	660
Arsenic, total	16	4	75%	0.8	1.56	0.179	0.05	5.9	0.05	0.05	0.05	0.05	0.513	2.2	3.35
Boron, total	11	6	45%	289	315	60.3	5	800	5	5	5	230	535	730	765
Cadmium, total	1	1	0%	0.43	NA	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Chromium, total	11	2	82%	0.627	0.297	0.585	0.5	1.4	0.5	0.5	0.5	0.5	0.5	1	1.2
Cobalt, total	8	2	75%	0.646	0.559	0.52	0.17	2	0.286	0.401	0.5	0.5	0.5	0.95	1.48
Copper, total	17	7	59%	2.09	2.41	1.17	0.5	9	0.5	0.5	0.5	0.5	3	4.7	5.8
Iron, total	17	16	6%	291	348	157	2.5	1420	24.5	50.4	131	180	250	669	890
Lead, total	11	0	100%	0.5	NA	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Manganese, total	16	13	19%	15.6	12.4	11.1	2.5	41	2.5	2.5	8.25	12	20.3	34	38
Molybdenum, total	17	2	88%	4.03	4.35	3.1	2.5	17	2.5	2.5	2.5	2.5	2.5	7.1	14.6
Nickel, total	17	7	59%	42.5	169	1.39	0.5	700	0.5	0.5	0.5	0.5	3	4	143
Selenium, total	17	2	88%	0.388	0.391	0.313	0.25	1.8	0.25	0.25	0.25	0.25	0.25	0.62	1
Silver, total	11	0	100%	0.05	NA	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Other (µg/L)															
Cyanide WAD	11	0	100%	2.5	5.21E-08	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.13. Summary of the available surface-water chemistry data for the Nechako River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	233	233	0%	46.3	5.30	46.0	25.1	59.6	37.2	39.3	44.0	46.8	49.6	52.9	54.9
Dissolved Oxygen (mg/L)	117	117	0%	9.38	1.04	9.33	7.50	13.4	8.08	8.20	8.50	9.20	10.0	10.7	11.3
pH (pH units)	285	285	0%	7.78	0.307	7.77	6.16	8.15	7.10	7.50	7.70	7.87	7.97	8.00	8.10
Residue Non-filterable (TSS; mg/L)	88	77	13%	8.82	6.77	6.27	0.500	30.0	2.00	2.00	3.00	7.00	13.0	18.3	22.7
Temperature (C)	233	233	0%	16.6	3.76	16.1	8.00	25.7	10.1	11.7	14.0	17.0	19.1	21.3	22.7
Turbidity (NTU)	242	241	0%	4.11	4.21	2.66	0.0500	30.0	0.500	0.800	1.44	2.80	5.27	9.00	12.0
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	63	50	21%	7.19	13.6	3.79	1	100	1	1	2	3	8	11.8	22.6
Nitrogen - Nitrite, dissolved (NO_2)	105	40	62%	3.14	1.8	2.7	0.5	14	1	1	2.5	2.5	5	5	5
Nitrogen Ammonia, dissolved	51	20	61%	20.1	45.1	5.67	2.5	200	2.5	2.5	2.5	2.5	9	100	100
Phosphorus, total (stream)	134	131	2%	28.4	30.3	20.2	1	211	7	9	12	21	31	47	82.8
Major Ions (mg/L)															
Chloride, dissolved	253	206	19%	0.499	0.661	0.411	0.100	9.80	0.250	0.250	0.300	0.400	0.500	0.798	1.10
Fluoride, total	59	48	19%	0.0512	0.0288	0.0453	0.0100	0.160	0.0250	0.0290	0.0365	0.0400	0.0500	0.0920	0.112
Sulfate, dissolved	132	131	1%	3.94	0.806	3.83	0.250	7.00	3.00	3.10	3.48	3.90	4.40	4.99	5.30
Metals (µg/L)															
Aluminum, total	170	168	1%	270	232	183	1	1290	40.7	51.2	91.2	222	379	558	742
Arsenic, total	181	180	1%	0.413	0.156	NA	0.05	1.5	0.2	0.3	0.3	0.4	0.5	0.57	0.68
Boron, total	45	44	2%	2.73	0.994	2.38	0.05	4.2	0.92	1.5	2.1	2.9	3.5	3.86	3.98
Cadmium, total	109	109	0%	0.1	0.199	NA	0.001	2	0.006	0.007	0.013	0.1	0.1	0.2	0.26
Chromium, total	160	156	3%	1.16	2.72	NA	0.1	20.7	0.199	0.205	0.3	0.543	0.983	1.41	2.45
Cobalt, total	152	147	3%	0.247	0.169	NA	0.041	0.8	0.0538	0.0951	0.1	0.2	0.363	0.5	0.552
Copper, total	178	177	1%	11.2	65.8	NA	0.1	729	0.957	1.01	1.3	1.68	2.3	7.33	30
Iron, total	200	200	0%	379	287	281	1.3	1470	82.4	105	158	300	527	810	914
Lead, total	178	129	28%	0.699	2.04	NA	0.035	18.8	0.0734	0.1	0.1	0.3	0.5	1	1.62
Manganese, total	186	177	5%	23.8	13.4	NA	4	74.8	5.5	10	12	21	31.8	40	50.2
Mercury, total	37	37	0%	32.8	84.4	19	6	530	8.4	10	20	20	20	30	34
Molybdenum, total	176	154	13%	2.68	5.61	NA	0.05	70	1	1.1	1.3	1.7	2.3	5	5

Table 4.13. Summary of the available surface-water chemistry data for the Nechako River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Nickel, total	151	148	2%	2.04	7.24	NA	0.1	90	0.6	0.7	0.905	1.3	1.9	2.3	2.95
Selenium, total	175	111	37%	0.106	0.126	NA	0.025	1.2	0.025	0.05	0.05	0.09	0.1	0.2	0.2
Silver, total	114	67	41%	0.608	4.33	NA	0.0005	40.3	0.0005	0.001	0.004	0.05	0.1	0.1	0.1
Other (µg/L)															
Phenols	18	7	61%	2.56	3.99	1.63	1	18	1	1	1	1	2	4	6.1
Juvenile Rearing															
Conventionals															
Hardness (mg/L)	6	6	0%	36.5	2.08	36.4	33.8	39.7	34.2	34.6	35.4	36.1	37.5	38.8	39.3
pH (pH units)	6	6	0%	7.71	0.0619	7.71	7.63	7.80	7.64	7.64	7.66	7.71	7.74	7.77	7.79
Residue Non-filterable (TSS; mg/L)	17	0	100%	2.29	0.254	2.28	2.00	2.50	2.00	2.00	2.00	2.50	2.50	2.50	2.50
Turbidity (NTU)	17	17	0%	0.322	0.173	0.283	0.0900	0.800	0.138	0.174	0.200	0.300	0.430	0.482	0.560
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	12	12	0%	48.3	19.3	38.7	2	67	15.8	27.7	40	54.5	63	65.7	66.5
Nitrogen - Nitrite, dissolved (NO_2)	12	0	100%	1.5	0.739	1.36	1	2.5	1	1	1	1	2.5	2.5	2.5
Phosphorus, total (lake)	18	18	0%	6.11	1.78	5.89	4	10	4	4	5	6	6.75	8.6	10
Major Ions (mg/L)															
Chloride, dissolved	12	11	8%	0.492	0.145	0.470	0.250	0.700	0.290	0.323	0.375	0.550	0.600	0.600	0.645
Fluoride, total	4	4	0%	0.0475	0.00500	0.0473	0.0400	0.0500	0.0415	0.0430	0.0475	0.0500	0.0500	0.0500	0.0500
Sulfate, dissolved	12	12	0%	4.89	0.766	4.84	3.80	6.10	3.91	4.03	4.38	4.70	5.55	5.97	6.05
Metals (µg/L)															
Aluminum, total	6	0	100%	30	NA	30	30	30	30	30	30	30	30	30	30
Arsenic, total	15	12	20%	0.317	0.141	0.29	0.1	0.6	0.163	0.214	0.25	0.28	0.3	0.56	0.6
Boron, total	17	1	94%	12.8	10.6	8.36	1	25	1.8	3.8	5	5	25	25	25
Cadmium, total	11	7	36%	0.077	0.152	0.015	0.0025	0.5	0.0025	0.0025	0.0025	0.006	0.0445	0.2	0.35
Chromium, total	12	7	42%	2.53	3.83	0.346	0.05	9	0.05	0.05	0.05	0.1	4.63	8.9	9
Cobalt, total	10	10	0%	0.619	1.89	0.0307	0.007	6	0.0079	0.0088	0.0103	0.018	0.0358	0.641	3.32
Copper, total	9	9	0%	0.999	0.465	0.927	0.61	2.1	0.634	0.658	0.74	0.79	1.2	1.39	1.74

Table 4.13. Summary of the available surface-water chemistry data for the Nechako River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Iron, total	17	17	0%	31.2	26.9	22.6	7	111	7	7.6	10	24	43	58.4	69.4
Lead, total	16	14	13%	6.36	22.4	0.177	0.0025	90	0.00438	0.0055	0.0158	0.45	0.9	3.75	27.4
Manganese, total	17	16	6%	2.56	1.96	1.82	0.32	7.37	0.384	0.46	1	2	3.4	4.8	6.27
Molybdenum, total	17	9	47%	6.05	2.46	5.72	3.1	14.3	4.24	4.81	5	5	6.38	7.67	9.9
Nickel, total	17	9	47%	5	4.86	2.11	0.32	10	0.384	0.442	0.52	0.71	10	10	10
Selenium, total	15	8	47%	0.269	0.293	0.14	0.04	1	0.04	0.044	0.05	0.1	0.5	0.5	0.65
Silver, total	9	1	89%	0.005	0.00336	0.00381	0.0025	0.01	0.0025	0.0025	0.0025	0.0025	0.007	0.01	0.01
Spawning & Incubation															
Conventionals															
Hardness (mg/L)	4	4	0%	28.3	2.07	28.2	25.9	30.7	26.1	26.4	27.0	28.2	29.4	30.2	30.4
Dissolved Oxygen (mg/L)	46	46	0%	11.3	2.37	10.9	1.90	15.0	9.30	9.70	10.1	11.0	12.8	14.0	14.9
pH (pH units)	128	128	0%	7.62	0.252	7.62	6.80	8.30	7.20	7.30	7.50	7.60	7.80	7.90	8.00
Residue Non-filterable (TSS; mg/L)	15	15	0%	10.7	19.9	4.41	2.00	63.0	2.00	2.00	2.50	3.00	4.00	36.4	58.1
Temperature (C)	33	28	15%	4.69	3.92	1.97	0.0500	13.5	0.0500	0.0500	1.00	5.00	7.50	9.80	11.0
Turbidity (NTU)	24	24	0%	1.97	3.46	1.29	0.400	18.0	0.615	0.700	0.950	1.25	1.53	2.36	2.77
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	13	8	38%	26.7	36.9	10.1	1	140	1	1	1	18	33	40	80
Nitrogen - Nitrite, dissolved (NO_2)	122	42	66%	2.34	1.92	NA	0.5	14	0.5	0.5	1	2.5	2.5	3	4
Nitrogen Ammonia, dissolved	15	3	80%	6	8.42	3.71	2.5	33	2.5	2.5	2.5	2.5	2.5	13.8	20.4
Phosphorus, total (stream)	46	46	0%	12	15.6	9.2	4	93	4.5	6	7	8	11	14.5	17.3
Major Ions (mg/L)															
Chloride, dissolved	61	21	66%	0.408	0.260	0.352	0.250	1.40	0.250	0.250	0.250	0.250	0.500	0.800	0.900
Sulfate, dissolved	2	2	0%	2.50	0.283	2.49	2.30	2.70	2.32	2.34	2.40	2.50	2.60	2.66	2.68
Metals (µg/L)															
Aluminum, total	21	19	10%	62.9	59.8	45.5	10	250	10	20	30	40	60	150	180
Iron, total	21	21	0%	122	93.4	98.6	50	350	50	50	60	80	150	260	330
Manganese, total	3	2	33%	11.7	7.64	10	5	20	5.5	6	7.5	10	15	18	19
Molybdenum, total	21	1	95%	5.24	1.09	5.17	5	10	5	5	5	5	5	5	5

Table 4.13. Summary of the available surface-water chemistry data for the Nechako River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	131	131	0%	47.9	8.21	47.4	25.1	106	41.4	44.0	45.3	47.6	49.7	52.0	54.8
Dissolved Oxygen (mg/L)	68	68	0%	9.88	1.56	9.78	7.50	18.4	8.40	8.50	9.00	9.80	10.2	11.4	11.5
pH (pH units)	145	145	0%	7.73	0.370	7.72	5.77	8.20	6.92	7.40	7.70	7.80	7.92	8.00	8.02
Residue Non-filterable (TSS; mg/L)	56	55	2%	48.3	194	18.9	2.00	1470	4.75	8.50	11.0	19.0	28.5	44.0	65.5
Temperature (C)	131	131	0%	14.4	4.66	13.6	4.00	25.0	8.00	9.00	11.7	14.0	17.0	21.9	23.1
Turbidity (NTU)	136	136	0%	12.8	24.7	6.80	0.100	256	1.08	1.70	3.59	7.04	13.1	26.0	37.7
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	38	29	24%	6.79	7.72	4.24	1	40	1	1	2	3.5	9.75	11.6	20.1
Nitrogen - Nitrite, dissolved (NO_2)	46	18	61%	2.99	1.5	2.54	0.5	5	1	1	2.5	2.5	5	5	5
Nitrogen Ammonia, dissolved	28	16	43%	13.8	25	6.48	2.5	100	2.5	2.5	2.5	5.5	11.3	20	74.4
Phosphorus, total (stream)	70	70	0%	75.9	158	46.3	2	1320	15.3	19	30.3	41	76.5	112	166
Major Ions (mg/L)															
Chloride, dissolved	134	118	12%	0.644	0.854	0.516	0.100	9.80	0.250	0.250	0.400	0.500	0.623	1.00	1.34
Fluoride, total	28	22	21%	0.0568	0.0347	0.0468	0.00500	0.160	0.0153	0.0250	0.0400	0.0500	0.0650	0.103	0.123
Sulfate, dissolved	73	72	1%	3.73	0.971	3.51	0.250	6.00	2.56	2.82	3.40	3.70	4.20	4.86	5.28
Metals (µg/L)															
Aluminum, total	95	95	0%	622	454	471	2	2170	158	201	320	490	807	1230	1590
Arsenic, total	93	92	1%	0.532	0.205	0.493	0.11	1.2	0.3	0.3	0.4	0.5	0.65	0.8	0.916
Boron, total	24	24	0%	2.95	1.75	2.62	0.9	10.2	1.09	1.63	2.18	2.9	3.35	3.57	3.77
Cadmium, total	72	72	0%	0.124	0.147	0.0731	0.001	1.1	0.0126	0.018	0.0268	0.1	0.2	0.2	0.3
Chromium, total	87	87	0%	1.65	1.58	1.21	0.115	10	0.419	0.538	0.7	1.1	2	3.5	5.07
Cobalt, total	81	81	0%	0.512	0.34	0.41	0.033	1.8	0.1	0.2	0.273	0.45	0.627	0.9	1.2
Copper, total	94	94	0%	5.08	8.81	2.97	0.53	54.6	1.34	1.4	1.7	2.49	4.08	7.94	21.6
Iron, total	106	106	0%	918	627	723	2.2	3610	302	357	515	776	1140	1700	2270
Lead, total	94	76	19%	0.598	0.568	NA	0.024	3.5	0.1	0.119	0.2	0.4	0.7	1.4	1.7
Manganese, total	98	95	3%	42.2	20.2	37.1	5	115	18.8	22.8	29.3	37.1	51.2	66.8	82.5
Mercury, total	24	24	0%	16.6	6.94	15	6	30	6	7.2	10	20	20	20	28.5
Molybdenum, total	94	82	13%	3.31	7.05	2.37	0.072	70	1.5	1.6	1.86	2.3	2.88	5	5

Table 4.13. Summary of the available surface-water chemistry data for the Nechako River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Nickel, total	82	82	0%	2.38	1.11	2.12	0.06	6.1	1.2	1.3	1.65	2.1	2.8	3.88	4.58
Selenium, total	90	59	34%	0.106	0.0736	NA	0.025	0.4	0.0363	0.05	0.05	0.08	0.188	0.2	0.2
Silver, total	57	37	35%	1.16	6.1	0.0304	0.001	40.3	0.0038	0.0046	0.007	0.05	0.05	0.1	0.16
Other (µg/L)															
Phenols	11	4	64%	2	1.67	1.57	1	6	1	1	1	1	2.5	4	5

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.14. Summary of the available surface-water chemistry data for the Bowron River Area of Interest.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Juvenile Rearing															
Conventionals															
pH (pH units)	48	48	0%	7.50	0.368	7.49	6.90	7.90	6.90	6.90	7.35	7.60	7.80	7.80	7.87
Residue Non-filterable (TSS; mg/L)	44	16	64%	0.886	0.799	0.718	0.500	4.00	0.500	0.500	0.500	0.500	1.00	1.70	2.00
Turbidity (NTU)	48	48	0%	0.610	0.236	0.571	0.300	1.40	0.335	0.400	0.400	0.500	0.800	0.860	1.00
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	43	38	12%	61.9	27.3	45.6	1	127	1.65	22.4	50.5	65	79.5	88.8	97
Nitrogen - Nitrite, dissolved (NO_2)	48	13	73%	1.52	0.758	1.37	1	3	1	1	1	1	2	3	3
Phosphorus, total (lake)	48	46	4%	8.29	12.2	5.54	1	74	3	3	4	5	7	13.1	22

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.15. Summary of the available surface-water chemistry data for reference areas within the Fraser River Basin.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Adult Upstream Migration															
Conventionals															
Hardness (mg/L)	200	200	0%	60.1	6.44	59.7	19.4	80.2	51.5	53.5	56.2	60	63.7	68.5	70.2
Dissolved Oxygen (mg/L)	38	38	0%	9.56	0.498	9.54	8.4	11	8.79	8.87	9.2	9.65	9.9	10	10
pH (pH units)	193	193	0%	7.89	0.223	7.88	6.9	8.2	7.4	7.7	7.87	7.94	8	8.05	8.1
Residue Non-filterable (TSS; mg/L)	76	33	57%	6.21	3.02	5.75	2.5	21	5	5	5	5	5	10	11.5
Temperature (C)	198	198	0%	9.95	2.43	9.6	2	16	6	7	8.5	10	11.5	13	14
Turbidity (NTU)	203	203	0%	2.81	2.69	2.09	0.05	22.1	0.555	0.892	1.4	2.17	3.34	4.84	6.49
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	57	57	0%	43	21.7	37.2	7	85	14.6	19.6	26	37	60	76	82.2
Nitrogen - Nitrite, dissolved (NO_2)	57	33	42%	3.75	3.11	2.85	1	22	1	1	1	5	5	5	5
Phosphorus, total (stream)	111	105	5%	6.93	10.4	4.98	1	103	1.15	2	3.8	5	7	11	14
Major Ions (mg/L)															
Chloride, dissolved	203	156	23%	0.426	1.2	0.312	0.1	17	0.2	0.2	0.25	0.3	0.4	0.5	0.6
Fluoride, total	34	34	0%	0.0297	0.019	0.0256	0.01	0.1	0.01	0.01	0.02	0.03	0.03	0.04	0.064
Sulfate, dissolved	142	142	0%	12.2	2.23	12	7.6	19	8.91	9.4	10.6	12.1	14	15	16
Metals (µg/L)															
Aluminum, total	133	133	0%	152	71.8	139	43.3	522	78.2	89.6	111	135	167	232	290
Arsenic, total	119	99	17%	0.153	0.261	NA	0.02	2.2	0.05	0.05	0.08	0.1	0.14	0.2	0.21
Boron, total	37	26	30%	0.688	0.483	0.382	0.05	1.4	0.05	0.05	0.05	0.9	1.1	1.2	1.3
Cadmium, total	76	72	5%	0.122	0.467	NA	5E-04	4	0.000875	0.0025	0.004	0.1	0.1	0.1	0.2
Chromium, total	146	123	16%	0.538	1.52	NA	0.045	16.9	0.0723	0.086	0.1	0.2	0.4	1.15	1.85
Cobalt, total	146	146	0%	0.377	0.178	NA	0.1	1.2	0.184	0.2	0.3	0.367	0.433	0.6	0.7
Copper, total	166	164	1%	2.82	9.35	NA	0.1	108	0.5	0.5	0.7	0.815	1.3	3.9	9.6
Iron, total	174	174	0%	153	114	126	36	758	54.7	63.4	87	118	172	276	401
Lead, total	166	105	37%	0.317	0.386	NA	0.029	2.8	0.0773	0.1	0.1	0.2	0.388	0.7	0.9
Manganese, total	166	159	4%	12	4.82	NA	1	31.6	5.55	6.7	8.8	11.2	14.1	17.3	20.4
Mercury, total	28	28	0%	18.1	12	15.3	6	50	7.05	9.7	10	18	20	28.5	48.6
Molybdenum, total	146	93	36%	0.076	0.0487	NA	0.034	0.5	0.047	0.05	0.05	0.0515	0.1	0.1	0.1
Nickel, total	138	138	0%	2.47	0.814	NA	0.7	5.6	1.39	1.67	1.9	2.4	2.85	3.48	3.75

Table 4.15. Summary of the available surface-water chemistry data for reference areas within the Fraser River Basin.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Selenium, total	119	39	67%	0.086	0.117	NA	0.025	0.97	0.025	0.025	0.05	0.05	0.1	0.2	0.223
Silver, total	100	38	62%	0.0489	0.0684	NA	5E-04	0.6	0.0005	0.0005	0.001	0.05	0.05	0.1	0.1
Smolt Outmigration															
Conventionals															
Hardness (mg/L)	94	94	0%	68.3	6.62	68	53.9	82.1	57.1	59.9	63.4	68.6	73.3	76.6	78.9
Dissolved Oxygen (mg/L)	18	18	0%	10.1	0.946	10	6.8	11	9.35	9.87	9.93	10	10.8	11	11
pH (pH units)	92	92	0%	7.86	0.291	7.86	6.6	8.22	7.21	7.4	7.88	7.95	8	8.1	8.1
Residue Non-filterable (TSS; mg/L)	31	12	61%	5.16	1.82	4.89	2.5	10	2.5	2.5	5	5	5	5	10
Temperature (C)	96	96	0%	6.84	2.38	6.37	1.5	12.5	3.38	4	5	7	8	10	11.3
Turbidity (NTU)	96	96	0%	1.29	1.18	0.83	0.07	6.3	0.168	0.2	0.4	0.925	1.93	2.55	3.63
Nutrients (µg/L)															
Nitrate (NO_3), dissolved	28	28	0%	71.9	12.2	70.6	30	94	55.8	59.7	67	72	80	83.3	84.7
Nitrogen - Nitrite, dissolved (NO_2)	28	13	54%	3.73	4.01	2.62	1	22	1	1	1	2.5	5	5	5
Phosphorus, total (stream)	50	43	14%	4.21	3.63	3.3	1	20	1	1	2	4	5	7	7.78
Major Ions (mg/L)															
Chloride, dissolved	96	80	17%	0.646	1.71	0.436	0.1	17	0.245	0.25	0.3	0.4	0.553	0.7	0.9
Fluoride, total	13	13	0%	0.0269	0.0184	0.0227	0.01	0.08	0.01	0.01	0.02	0.02	0.03	0.038	0.056
Sulfate, dissolved	65	65	0%	13.3	2.45	13	8.6	19	9.44	10.1	11.7	13	14.9	16.4	17.8
Metals (µg/L)															
Aluminum, total	61	61	0%	85.5	44.6	74.9	32	218	35	40	47.3	73.3	119	144	163
Boron, total	18	14	22%	0.744	0.516	0.45	0.05	1.5	0.05	0.05	0.3	0.8	1.1	1.4	1.42
Cadmium, total	29	28	3%	0.106	0.266	0.0148	5E-04	1.1	0.0014	0.0028	0.004	0.005	0.1	0.1	0.64
Chromium, total	67	51	24%	0.584	1.23	0.218	0.031	8.8	0.0496	0.0574	0.1	0.169	0.4	1.58	2.27
Cobalt, total	67	64	4%	0.23	0.121	0.198	0.05	0.6	0.1	0.1	0.128	0.2	0.3	0.4	0.403
Copper, total	75	74	1%	3.4	14.1	1.05	0.1	122	0.394	0.454	0.5	0.8	1.5	3.9	10.5
Iron, total	79	79	0%	98.4	82.9	75.2	17.8	615	22.8	24.7	40.2	86.1	125	170	203
Lead, total	75	44	41%	0.288	0.373	0.162	0.014	2	0.0278	0.0556	0.1	0.1	0.3	0.8	1.03
Manganese, total	75	72	4%	8.29	3.56	7.39	1	17.5	2.94	3.82	5.5	8.3	10.2	12.9	14

Table 4.15. Summary of the available surface-water chemistry data for reference areas within the Fraser River Basin.

Life Stage/Class/Analyte	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Metals (µg/L; continued)															
Mercury, total	12	12	0%	15.3	5.55	14.3	7	21	8.1	9.1	10	18.5	20	20	20.5
Molybdenum, total	67	41	39%	0.0761	0.0385	0.0693	0.043	0.2	0.05	0.05	0.05	0.053	0.1	0.1	0.17
Nickel, total	63	63	0%	2.01	0.708	1.88	0.7	3.6	1	1.1	1.5	2	2.5	2.88	3.19
Selenium, total	54	20	63%	0.0715	0.0555	0.0564	0.025	0.3	0.025	0.025	0.025	0.05	0.1	0.114	0.2
Silver, total	45	17	62%	0.0382	0.0351	0.011	5E-04	0.1	0.0005	0.0005	0.001	0.05	0.05	0.1	0.1

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.

No data were available for the following areas of interest within the Fraser River Basin: Harrison River, Nahatlatch, Seton-Portage.
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.16. Summary of the available sediment chemistry data for the Fraser River Basin.

Area of Interest/ Chemical Class/Analyte	n	n Detect	% Non-Detect	Mean	Standard Deviation	Geometric Mean	Min	Max	Distribution 5th	10th	25th	50th	75th	90th	95th
Lower Fraser River															
Metals (mg/kg)															
Arsenic	39	37	5.13%	5.87	1.57	5.68	4.00	10.00	4.09	4.16	4.79	5.41	6.71	8.20	8.85
Cadmium	39	37	5.13%	0.306	0.284	0.269	0.140	2.000	0.182	0.200	0.216	0.260	0.295	0.354	0.400
Chromium	58	58	0.00%	41.1	13.0	38.7	17.0	61.7	20.9	21.0	33.0	44.3	50.8	56.8	58.1
Copper	58	58	0.00%	33.1	10.2	31.2	14.0	52.0	15.9	17.0	25.2	36.0	39.2	43.4	47.3
Iron	58	58	0.00%	30500	8290	29200	15200	46900	16900	17400	26100	31600	35100	40900	44600
Lead	59	50	15.25%	10.0	6.24	8.74	3.40	37.0	4.97	5.00	6.50	9.00	10.6	20.0	20.2
Mercury	54	49	9.26%	0.058	0.017	0.055	0.025	0.090	0.025	0.033	0.049	0.059	0.070	0.080	0.090
Nickel	58	58	0.00%	42.9	8.8	42.0	28.0	57.0	30.0	31.0	35.1	41.5	50.1	55.0	56.3
Selenium	4	1	75.00%	0.338	0.175	0.311	0.250	0.600	0.250	0.250	0.250	0.250	0.338	0.495	0.548
Silver	25	21	16.00%	0.124	0.050	0.114	0.050	0.220	0.050	0.050	0.110	0.120	0.140	0.192	0.208
Zinc	58	58	0.00%	74.4	22.0	70.7	34.0	118.0	38.7	39.7	63.3	75.7	88.2	102.3	106.2
Pesticides (mg/kg)															
Aldrin	31	31	0	0.0003	0.0001	0.0003	0.0003	0.0008	0.0003	0.0003	0.0003	0.0003	0.0005	0.0005	0.0005
Chlordane (total)	31	31	0.00%	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Dieldrin	31	0	100.00%	0.0003	0.0001	0.0003	0.0003	0.0005	0.0003	0.0003	0.0003	0.0003	0.0005	0.0005	0.0005
Endosulfan A	31	0	100.00%	0.0003	0.0001	0.0003	0.0003	0.0005	0.0003	0.0003	0.0003	0.0003	0.0005	0.0005	0.0005
Endosulfan B	31	0	100.00%	0.0003	0.0001	0.0003	0.0003	0.0005	0.0003	0.0003	0.0003	0.0003	0.0005	0.0005	0.0005
Endrin	31	0	100.00%	0.0003	0.0	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Heptachlor epoxide	21	0	100.00%	0.0003	0.0	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Lindane	31	0	100.00%	0.0003	0.0001	0.0003	0.0003	0.0005	0.0003	0.0003	0.0003	0.0003	0.0005	0.0005	0.0005
Methoxychlor	31	2	93.55%	0.0015	0.0009	0.0011	0.0003	0.0025	0.0003	0.0003	0.0008	0.0015	0.0025	0.0025	0.0025
Sum DDD	31	21	32.26%	0.0005	0.0	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Sum DDE	31	22	29.03%	0.0004	0.0001	0.0004	0.0003	0.001	0.0003	0.0003	0.0003	0.001	0.001	0.001	0.001
Sum DDT	31	22	29.03%	0.001	0.0	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Plastics-Related Chemicals (mg/kg)															
Diethyl phthalate	10	2	80.00%	0.063	0.028	0.059	0.050	0.120	0.050	0.050	0.050	0.050	0.050	0.111	0.116
Bis (2-ethylhexyl) phthala	10	10	0.00%	0.573	0.456	0.408	0.110	1.440	0.115	0.119	0.190	0.505	0.703	1.242	1.341

Table 4.16. Summary of the available sediment chemistry data for the Fraser River Basin.

Area of Interest/ Chemical Class/Analyte	n	n Detect	% Non-Detect	Mean	Standard Deviation	Geometric Mean	Min	Max	Distribution						
									5th	10th	25th	50th	75th	90th	95th
Lower Fraser River (continued)															
Polychlorinated Biphenyls (PCBs; mg/kg)															
PCBs (total)	74	21	71.62%	0.0067	0.0041	0.0042	0.0002	0.010	0.0003	0.0005	0.0015	0.0100	0.0100	0.0100	0.0100
Polycyclic Aromatic Hydrocarbons (mg/kg)															
Acenaphthene	31	15	51.61%	0.002	0.002	0.001	0.000	0.010	0.0003	0.0003	0.001	0.002	0.003	0.003	0.004
Acenaphthylene	31	7	77.42%	0.001	0.001	0.001	0.000	0.005	0.0003	0.0003	0.000	0.001	0.003	0.003	0.003
Anthracene	37	21	43.24%	0.005	0.007	0.004	0.001	0.039	0.001	0.002	0.003	0.003	0.005	0.010	0.014
Benz(a)anthracene	37	24	35.14%	0.019	0.028	0.009	0.001	0.120	0.002	0.003	0.005	0.007	0.019	0.053	0.083
Benzo(a)pyrene	37	23	37.84%	0.016	0.023	0.009	0.001	0.100	0.001	0.002	0.005	0.010	0.014	0.025	0.071
Chrysene	37	22	40.54%	0.019	0.027	0.010	0.003	0.140	0.003	0.005	0.005	0.008	0.021	0.039	0.057
Dibenz(a,h)anthracne	37	14	62.16%	0.019	0.062	0.003	0.0003	0.370	0.0003	0.0003	0.0005	0.002	0.010	0.026	0.067
Fluoranthene	37	24	35.14%	0.026	0.028	0.015	0.004	0.120	0.005	0.005	0.005	0.017	0.032	0.063	0.082
Fluorene	37	26	29.73%	0.004	0.004	0.003	0.001	0.023	0.001	0.001	0.002	0.003	0.005	0.009	0.010
Naphthalene	37	22	40.54%	0.008	0.021	0.005	0.003	0.130	0.003	0.003	0.003	0.004	0.006	0.010	0.011
Phenanthrene	37	23	37.84%	0.017	0.027	0.009	0.003	0.150	0.003	0.003	0.003	0.009	0.017	0.036	0.057
Pyrene	37	22	40.54%	0.022	0.026	0.013	0.002	0.130	0.005	0.005	0.005	0.011	0.028	0.051	0.070
Harrison River															
Metals (mg/kg)															
Chromium	1	1	0.00%	26	NA	26	26	26	26	26	26	26	26	26	26
Copper	1	1	0.00%	63	NA	63	63	63	63	63	63	63	63	63	63
Iron	1	1	0.00%	32600	NA	32600	32600	32600	32600	32600	32600	32600	32600	32600	32600
Lead	1	1	0.00%	31	NA	31	31	31	31	31	31	31	31	31	31
Mercury	1	0	100.00%	0.025	NA	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Nickel	1	1	0.00%	23	NA	23	23	23	23	23	23	23	23	23	23
Zinc	1	1	0.00%	98	NA	98	98	98	98	98	98	98	98	98	98
Lower Thompson River															
Metals (mg/kg)															
Mercury	1	1	0.00%	0.060	NA	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060

Table 4.16. Summary of the available sediment chemistry data for the Fraser River Basin.

Area of Interest/ Chemical Class/Analyte	n	n Detect	% Non-Detect	Mean	Standard Deviation	Geometric Mean	Min	Max	Distribution						
									5th	10th	25th	50th	75th	90th	95th
South Thompson River															
Metals (mg/kg)															
Chromium	1	1	0.00%	41.0	NA	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0
Copper	1	1	0.00%	41.0	NA	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0
Iron	1	1	0.00%	38100	NA	38100	38100	38100	38100	38100	38100	38100	38100	38100	38100
Lead	1	0	100.00%	5.00	NA	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Mercury	1	1	0.00%	0.070	NA	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
Nickel	1	1	0.00%	61.0	NA	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0
Zinc	1	1	0.00%	109	NA	109	109	109	109	109	109	109	109	109	109

n = number of samples; detect = detected; SD = standard deviation; NA = no data available; TSS = total suspended solids.
No data were available for the following areas of interest within the Fraser River Basin:
Upper Fraser River, Pitt River, Cultus Lake, Kakawa Lake, Nahatlatch River, Seton-Portage, North Thompson River, Chilko River, Quesnel River, Nechako River, Bowron River, Reference
One-half the detection limit was substituted for non-detect values in the distribution calculations.
The minimum value shown is the lower of one-half the detection limit or the lowest detectable measurement.
The maximum value shown is the higher of one-half the detection limit or the highest detectable measurement.

Table 4.17. Summary of usable[1] surface-water chemistry data used to evaluate potential effects of chemicals of potential concern in the Fraser River Basin.

Chemical of Potential Concern Class	Water Quality Data Available for One or More AoI			
	Spawning & Incubation	Juvenile Rearing	Smolt Outmigration	Adult Upstream Migration
Conventional Variables	**Yes**	**Yes**	**Yes**	**Yes**
Microbiological Variables	No	No	No	No
Major Ions	**Yes**	**Yes**	**Yes**	**Yes**
Nutrients	**Yes**	**Yes**	**Yes**	**Yes**
Metals	**Yes**	**Yes**	**Yes**	**Yes**
Organometallics	No	No	No	No
Cyanides	**Yes**	No	**Yes**	**Yes**
Mono Aromatic Hydrocarbons (MAHs)	No	No	No	No
Polycyclic Aromatic Hydrocarbons (PAHs)	No	No	No	No
Phenolic Compounds	**Yes**	**Yes**	**Yes**	**Yes**
Chlorinated Phenolic Compounds	No	No	**Yes**	**Yes**
Polychlorinated Biphenyls (PCBs)	No	No	No	No
Polychlorinated Dibenzo-*p*- Dioxins (PCDDs)	No	No	No	No
Polychlorinated Dibenzofurans (PCDFs)	No	No	No	No
Resin Acids	No	No	No	No
Fatty Acids	No	No	No	No
Petroleum Hydrocarbons	No	No	No	No
Pesticides	No	No	No	No
Wood Preservation Chemicals	No	No	No	No
Surfactants	No	No	No	No
Pharmaceuticals	No	No	No	No
Personal Care Products	No	No	No	No
Steroids, Hormones, and Hormone Mimickers	No	No	No	No
Disinfectants	No	No	No	No
Fire Retardants	No	No	No	No
Plastics-Related Chemicals	No	No	No	No

…footnotes continued on the next page

Table 4.17. Summary of usable[1] surface-water chemistry data used to evaluate potential effects of chemicals of potential concern in the Fraser River Basin.

Chemical of Potential Concern Class	Water Quality Data Available for One or More AoI			
	Spawning & Incubation	Juvenile Rearing	Smolt Outmigration	Adult Upstream Migration

[1] Usable Data defined using the following criteria:

At least one measurement was available with a detected result or detection limit was less than TSV for an undetected result.
A toxicity screening value is available from CCME, BCMOE or USEPA;
When ancillary parameters were required to calculate a TSV, they must also be measured in the same sample (e.g., temperature and pH are required to calculated a sample-specific TSV for ammonia);

Table 4.18. Summary of usable[1] sediment chemistry data used to evaluate potential hazards to sockeye salmon in the Fraser River Basin.

Chemical of Potential Concern Class	Sediment Quality Data Available for One or More Area of Interest
Metals	**Yes**
Organometallics	No
Cyanides	No
Mono Aromatic Hydrocarbons (MAHs)	No
Polycyclic Aromatic Hydrocarbons (PAHs)	**Yes**
Phenolic Compounds	No
Chlorinated Phenolic Compounds	No
Polychlorinated Biphenyls (PCBs)	**Yes**
Polychlorinated Dibenzo-*p*- Dioxins (PCDDs)	No
Polychlorinated Dibenzofurans (PCDFs)	No
Resin Acids	No
Fatty Acids	No
Petroleum Hydrocarbons	No
Pesticides	**Yes**
Wood Preservation Chemicals	No
Surfactants	No
Pharmaceuticals	No
Personal Care Products	No
Steroids, Hormones, and Hormone Mimickers	No
Disinfectants	No
Fire Retardants	No
Plastics-Related Chemicals	**Yes**

[1] Usable Data defined using the following criteria:
A toxicity screening value is available from MacDonald (1994, 2000a; 2000b); CCME (1999); or Nagpal *et al.* (2006).
At least one measurement was available with a detected result or the detection limit was less than the toxicity screening value for an undetected result.

Table 4.19. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Lower Fraser River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	ND	ND	ND	0	**1.05**	**1.08**	**3.42**
Residue Non-filterable (TSS)	ND	ND	ND	ND	**26.6**	**17**	**10.6**	**12.1**
Turbidity	ND	ND	ND	ND	**65**	**73.5**	**35.5**	**195**
Nutrients								
Ammonia, dissolved	ND	ND	ND	ND	0.0143	0.0045	0.61	0.101
Nitrate (NO_3), dissolved	ND	ND	ND	ND	ND	0.0572	ND	0.0369
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0.517	0.167	0.0417	0.667
Phosphorus, total (stream)	ND	ND	ND	ND	**124**	**155**	**89**	**90.6**
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	0.0104	0.00783	0.0148	0.0139
Fluoride, total	ND	ND	ND	ND	ND	0.233	ND	0.35
Sulfate, dissolved	ND	ND	ND	ND	0.075	0.076	0.1	0.14
Metals								
Aluminum, total	ND	ND	ND	ND	**49.2**	**91.7**	**34**	**181**
Arsenic, total	ND	ND	ND	ND	0.76	0.46	0.32	0.418
Boron, total	ND	ND	ND	ND	ND	0.00342	ND	0.0825
Cadmium, total	ND	ND	ND	ND	**23.5**	**94.1**	**23.5**	**82.4**
Chromium, total	ND	ND	ND	ND	**9.8**	**15.1**	**28.7**	**44**
Cobalt, total	ND	ND	ND	ND	ND	**1.73**	ND	**2.29**
Copper, total	ND	ND	ND	ND	**47.8**	**10.4**	**79.5**	**11**
Iron, total	ND	ND	ND	ND	**93.3**	**45**	**28.3**	**54.7**

Table 4.19. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Lower Fraser River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Lead, total	ND	ND	ND	ND	**8**	**7**	**8**	**6.01**
Manganese, total	ND	ND	ND	ND	0.425	0.376	0.231	0.41
Mercury, total	ND	ND	ND	ND	**4000**	**4000**	**2000**	**1000**
Molybdenum, total	ND	ND	ND	ND	0.0685	0.0137	0.411	0.0274
Nickel, total	ND	ND	ND	ND	0.428	0.856	0.516	**1.32**
Selenium, total	ND	ND	ND	ND	0.6	0.4	0.2	0.4
Silver, total	ND	ND	ND	ND	ND	**22**	ND	**7**
Chlorophenols								
Dichlorophenol	ND	ND	ND	ND	ND	0.0125	ND	0.0125
Monochlorophenol	ND	ND	ND	ND	ND	0.00357	ND	0.00357
Pentachlorophenol	ND	ND	ND	ND	ND	0.05	ND	0.05
Tetrachlorophenol	ND	ND	ND	ND	ND	0.025	ND	0.025
Trichlorophenol	ND	ND	ND	ND	ND	0.00139	ND	0.00139

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.20. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Upper Fraser River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	ND	ND	ND	0	0	**1.12**	0
Residue Non-filterable (TSS)	ND	ND	ND	ND	**26.4**	**19.8**	**26.4**	**12.8**
Turbidity	ND	ND	ND	ND	**80**	**125**	**80**	**178**
Nutrients								
Ammonia, dissolved	ND	ND	ND	ND	0.0319	0.0121	0.0384	0.0188
Nitrate (NO_3), dissolved	ND	ND	ND	ND	0.0793	0.0876	0.0414	0.0407
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0.0417	0.1	0.0417	0.15
Phosphorus, total (stream)	ND	ND	ND	ND	**228**	**158**	**228**	**98.2**
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	0.0478	0.0422	0.0478	**2.59**
Fluoride, total	ND	ND	ND	ND	ND	0.333	ND	0.233
Sulfate, dissolved	ND	ND	ND	ND	0.087	0.087	0.145	0.121
Metals								
Aluminum, total	ND	ND	ND	ND	**75**	**127**	**77**	**114**
Arsenic, total	ND	ND	ND	ND	**1.34**	0.562	**1.34**	0.562
Boron, total	ND	ND	ND	ND	ND	0.0025	ND	0.00367
Cadmium, total	ND	ND	ND	ND	**64.7**	**112**	**58.8**	**159**
Chromium, total	ND	ND	ND	ND	**30**	**26.1**	**15**	**19.1**
Cobalt, total	ND	ND	ND	ND	**1.23**	**2.43**	**1.08**	**2.6**
Copper, total	ND	ND	ND	ND	**53.8**	**13.6**	**59**	**12.2**
Iron, total	ND	ND	ND	ND	**147**	**62.3**	**147**	**100**
Lead, total	ND	ND	ND	ND	**6.3**	**9.3**	**6.3**	**8.1**

Table 4.20. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Upper Fraser River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Manganese, total	ND	ND	ND	ND	0.606	0.485	0.606	0.498
Mercury, total	ND	ND	ND	ND	**4500**	**4550**	**3000**	**4550**
Molybdenum, total	ND	ND	ND	ND	0.274	0.0137	0.274	0.0127
Nickel, total	ND	ND	ND	ND	0.44	**1.14**	0.44	0.88
Selenium, total	ND	ND	ND	ND	0.6	0.3	0.6	0.6
Silver, total	ND	ND	ND	ND	ND	1	ND	**8**
Chlorophenols								
Dichlorophenol	ND	ND	ND	ND	ND	0.0125	ND	0.0125
Monochlorophenol	ND	ND	ND	ND	ND	0.00357	ND	0.00357
Pentachlorophenol	ND	ND	ND	ND	ND	0.05	ND	0.05
Tetrachlorophenol	ND	ND	ND	ND	ND	0.025	ND	0.025
Trichlorophenol	ND	ND	ND	ND	ND	0.00139	ND	0.00139
Other								
Cyanide (WAD)	ND	ND	ND	ND	ND	ND	ND	0.05
Phenols	ND	ND	ND	ND	**2.5**	ND	**2.5**	ND

ND = no data; WAD = weak acid dissociiable; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.21. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Pitt River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	ND	0	0	0	ND	0	0
Residue Non-filterable (TSS)	ND	ND	ND	0.52	**1.52**	ND	**2.96**	**6.16**
Turbidity	ND	ND	ND	**3.1**	**11.5**	ND	**19**	**18**
Nutrients								
Ammonia, dissolved	ND	ND	ND	0.00878	0.00418	ND	0.0352	ND
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	0.0833	0.0417	ND	0.0417	0.1
Metals								
Aluminum, total	ND	ND	ND	ND	**12**	ND	**18.2**	ND
Iron, total	ND	ND	ND	ND	**5.23**	ND	**8.43**	ND
Molybdenum, total	ND	ND	ND	ND	0.0685	ND	0.0685	ND
Chlorophenols								
Pentachlorophenol	ND	ND	ND	ND	ND	ND	0.1	0.1
Tetrachlorophenol	ND	ND	ND	ND	ND	ND	0.05	0.05
Trichlorophenol	ND	ND	ND	ND	ND	ND	0.00278	0.00278

ND = no data; TSS = total suspended solids.

Only chemicals of potential concern for which usable data were available in an area of interest were reported.

Bolded values indicate hazard quotients >1.0.

Pre-1990 includes 1990.

[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.22. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Cultus Lake Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	**Post-1990**	**Pre-1990**	**Post-1990**	**Pre-1990**	**Post-1990**	**Pre-1990**	**Post-1990**
Conventionals								
pH[1]	0	ND	0	ND	ND	0	0	0
Residue Non-filterable (TSS)	0.84	ND	0.84	ND	ND	**2.32**	ND	**2.04**
Turbidity	**8**	0.325	**8**	0.325	ND	**16.8**	ND	**90**
Nutrients								
Ammonia, dissolved	0.0409	ND	0.0409	ND	ND	ND	ND	0.0515
Nitrate (NO_3), dissolved	0.0241	ND	0.0241	ND	ND	**1.36**	ND	**1.45**
Nitrogen-Nitrite, dissolved (NO_2)	0.0417	ND	0.0417	ND	ND	**3.95**	ND	**3.95**
Phosphorus, total (lake)	**1.67**	**5**	**3.33**	**5**	ND	ND	ND	ND
Phosphorus, total (stream)	ND	ND	ND	ND	ND	**63.2**	ND	**38**
Major Ions								
Chloride, dissolved	0.0152	ND	0.0152	ND	ND	0.0735	ND	0.0783
Sulfate, dissolved	0.246	ND	0.246	ND	ND	0.24	ND	0.3
Metals								
Aluminum, total	ND	ND	ND	ND	ND	**3.63**	ND	**2.5**
Arsenic, total	ND	ND	ND	ND	ND	0.264	ND	0.256
Boron, total	ND	ND	ND	ND	ND	0.0382	ND	0.0717
Cadmium, total	ND	ND	ND	ND	ND	0.706	ND	0.647
Chromium, total	ND	ND	ND	ND	ND	**12.2**	ND	**24**
Cobalt, total	ND	ND	ND	ND	ND	0.835	ND	0.375
Copper, total	**5.5**	ND	**5.5**	ND	ND	0.693	ND	0.4
Iron, total	**3.67**	ND	**3.67**	ND	ND	**8.83**	ND	**5.53**
Lead, total	0.5	ND	0.5	ND	ND	0.0528	ND	0.114
Manganese, total	0.0106	ND	0.0106	ND	ND	0.127	ND	0.0787

Table 4.22. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Cultus Lake Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Molybdenum, total	ND	ND	ND	ND	ND	0.00912	ND	0.0274
Nickel, total	0.154	ND	0.154	ND	ND	0.685	ND	0.235
Selenium, total	ND	ND	ND	ND	ND	0.2	ND	0.24
Silver, total	ND	ND	ND	ND	ND	0.05	ND	0.03
Other								
Phenols	1	ND	1	ND	ND	ND	ND	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.23. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Kakawa Lake Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	ND	ND	ND	0	ND	0	ND
Residue Non-filterable (TSS)	ND	ND	ND	ND	0.56	ND	0.56	ND
Turbidity	ND	ND	ND	ND	**14**	ND	**1.65**	ND
Nutrients								
Ammonia, dissolved	ND	ND	ND	ND	0.00784	ND	0.00856	ND
Nitrate (NO_3), dissolved	ND	ND	ND	ND	0.0345	ND	0.0345	ND
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0.0417	ND	0.3	ND
Phosphorus, total (stream)	ND	ND	ND	ND	**7.8**	ND	**3.2**	ND
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	0.00304	ND	0.00435	ND
Sulfate, dissolved	ND	ND	ND	ND	0.064	ND	0.106	ND
Metals								
Arsenic, total	ND	ND	ND	ND	ND	ND	0.5	ND
Copper, total	ND	ND	ND	ND	**1.5**	ND	**1.5**	ND
Iron, total	ND	ND	ND	ND	**1.67**	ND	**1.67**	ND
Lead, total	ND	ND	ND	ND	**2**	ND	**2**	ND
Manganese, total	ND	ND	ND	ND	0.0722	ND	0.0289	ND
Molybdenum, total	ND	ND	ND	ND	ND	ND	0.00822	ND
Nickel, total	ND	ND	ND	ND	0.4	ND	0.2	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.24. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Lower Thompson River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	ND	ND	**1.07**	0	0	0	0
Residue Non-filterable (TSS)	ND	ND	ND	ND	**18.1**	**25.9**	**3.8**	**10.4**
Turbidity	ND	ND	ND	**12**	**27**	**160**	**23.5**	**42**
Nutrients								
Ammonia, dissolved	ND	ND	ND	0.0332	0.124	0.172	0.533	0.256
Nitrate (NO_3), dissolved	ND	ND	ND	0.0552	0.0414	0.00724	0.0379	0.0176
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	0.0833	0.133	0.15	0.0833	0.15
Phosphorus, total (lake)	ND	ND	ND	**5.6**	**3.73**	**5.53**	**3.73**	**53.3**
Phosphorus, total (stream)	ND	ND	ND	ND	**87.4**	**119**	**87.4**	**40.4**
Major Ions								
Chloride, dissolved	ND	ND	ND	0.0435	0.0126	0.0183	0.0196	0.0326
Fluoride, total	ND	ND	ND	1	0.5	ND	0.95	0.3
Sulfate, dissolved	ND	ND	ND	0.117	0.24	0.21	0.99	0.482
Metals								
Aluminum, total	ND	ND	ND	ND	**19.5**	**27.1**	**7**	**14.2**
Arsenic, total	ND	ND	ND	ND	0.04	**8**	0.5	**8**
Boron, total	ND	ND	ND	ND	ND	0.05	ND	0.0167
Cadmium, total	ND	ND	ND	ND	ND	ND	**58.8**	ND
Chromium, total	ND	ND	ND	ND	**10**	**12**	**10**	**27**
Cobalt, total	ND	ND	ND	ND	ND	1	0.125	**2**
Copper, total	ND	ND	ND	ND	**10**	ND	**10**	**3**
Iron, total	ND	ND	ND	ND	**8.93**	**13.7**	**2.9**	**6.93**
Lead, total	ND	ND	ND	ND	**2**	ND	**2**	ND

Table 4.24. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Lower Thompson River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient: Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Manganese, total	ND	ND	ND	ND	0.0133	ND	0.0136	0.00896
Molybdenum, total	ND	ND	ND	ND	0.137	0.0274	0.685	0.0685
Nickel, total	ND	ND	ND	ND	ND	ND	0.2	0.154
Selenium, total	ND	ND	ND	ND	0.1	ND	0.1	ND
Other								
Phenols	ND	ND	ND	ND	0.5	ND	**3.5**	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.25. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the North Thompson River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	0	ND	ND	0	0	**1.07**	0
Residue Non-filterable (TSS)	ND	0.68	ND	ND	**4.04**	**4.16**	**2.48**	**2.56**
Turbidity	ND	**2.45**	ND	ND	**7.5**	**8.5**	**6**	**11**
Nutrients								
Ammonia, dissolved	ND	ND	ND	ND	0.258	0.00584	0.0954	0.00983
Nitrate (NO_3), dissolved	ND	ND	ND	ND	ND	0.0252	0.0276	0.0214
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0.0417	0.1	0.0417	0.1
Phosphorus, total (stream)	ND	**5.6**	ND	ND	**17.8**	**19**	**14.4**	**14.2**
Major Ions								
Chloride, dissolved	ND	0.00957	ND	ND	0.00522	0.0109	0.0135	0.0174
Fluoride, total	ND	ND	ND	ND	0.85	0.35	0.9	0.35
Sulfate, dissolved	ND	0.185	ND	ND	0.078	0.131	0.098	0.33
Metals								
Aluminum, total	ND	ND	ND	ND	**17.7**	**15.4**	**17.7**	**14.3**
Arsenic, total	ND	ND	ND	ND	0.02	ND	0.5	ND
Boron, total	ND	ND	ND	ND	ND	0.0667	ND	0.0167
Cadmium, total	ND	ND	ND	ND	ND	**412**	**588**	**294**
Chromium, total	ND	ND	ND	ND	ND	**12**	**20**	**15**
Cobalt, total	ND	ND	ND	ND	ND	**5.75**	0.125	**3.25**
Copper, total	ND	ND	ND	ND	0.25	**4**	0.5	**10.5**
Iron, total	ND	ND	ND	ND	**7.63**	**8.77**	**7.63**	**5.37**
Lead, total	ND	ND	ND	ND	**3**	**60**	**3**	**60**
Manganese, total	ND	ND	ND	ND	0.00665	0.0582	0.00669	0.0645

Table 4.25. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the North Thompson River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Molybdenum, total	ND	ND	ND	ND	0.0685	0.219	0.274	0.137
Nickel, total	ND	ND	ND	ND	ND	0.4	0.02	0.4
Selenium, total	ND	ND	ND	ND	0.1	ND	0.1	**60**

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.26. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the South Thompson River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	**Post-1990**	**Pre-1990**	**Post-1990**	**Pre-1990**	**Post-1990**	**Pre-1990**	**Post-1990**
Conventionals								
pH[1]	**1.16**	**1.13**	**1.16**	0	0	0	**1.07**	0
Residue Non-filterable (TSS)	**32**	**24.8**	**3.4**	0.1	1	**2.92**	0.72	**2.92**
Turbidity	**95**	**100**	**1.85**	**6.55**	**3.35**	**3.7**	**3.15**	**3.3**
Nutrients								
Ammonia, dissolved	0.343	0.578	0.0843	0.633	0.0121	0.00968	0.126	0.0118
Nitrate (NO_3), dissolved	0.103	0.152	0.0414	0.0579	0.0207	0.0324	0.0172	0.0324
Nitrogen-Nitrite, dissolved (NO_2)	0.133	0.7	0.0417	0.483	**1.17**	0.0417	0.0833	0.0417
Phosphorus, total (lake)	**7.6**	**6.2**	**7.6**	**6.2**	ND	ND	ND	ND
Phosphorus, total (stream)	**212**	**122**	**10.6**	0.2	**12.6**	**9.4**	**12.6**	**9**
Major Ions								
Chloride, dissolved	0.027	0.0826	0.0109	0.0609	0.00304	0.0287	0.01	0.0287
Fluoride, total	ND	**1.17**	ND	0.25	ND	0.3	ND	0.3
Sulfate, dissolved	0.631	0.731	0.105	0.227	0.077	0.45	0.077	0.45
Metals								
Aluminum, total	**61.9**	**92.1**	**27.5**	0.7	**5.2**	**12.4**	**3.2**	**6.9**
Arsenic, total	**1.6**	**10**	0.5	0.04	ND	ND	0.5	ND
Boron, total	0.5	**1.33**	0.25	0.0167	ND	0.0167	ND	0.0583
Cadmium, total	**1180**	**129**	**1180**	0.294	ND	**471**	ND	**412**
Chromium, total	**2290**	**23**	**50**	**19**	ND	**21**	**40**	**17**
Cobalt, total	**50**	**1.85**	**50**	0.5	ND	**4.75**	ND	**3.5**
Copper, total	**41.3**	**12.2**	**2.5**	**2.33**	ND	**9**	0.25	**9**
Iron, total	**35**	**49.7**	**2.67**	0.48	**2.2**	**3.93**	**1.47**	**2.73**

Table 4.26. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the South Thompson River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Lead, total	**7**	**9.1**	**5**	0.19	ND	ND	0.5	**60**
Manganese, total	0.378	0.484	0.0403	0.0295	ND	0.0346	0.0133	0.0431
Mercury, total	**102000**	**5300**	**4**	ND	ND	ND	ND	ND
Molybdenum, total	0.411	0.0812	0.137	0.0685	0.0685	0.274	0.137	0.0685
Nickel, total	0.8	0.684	0.2	0.4	ND	**4**	0.2	**4**
Selenium, total	**5**	**80**	ND	0.3	ND	ND	ND	**60**
Silver, total	ND	**757**	ND	**3.1**	ND	ND	ND	ND
Other								
Cyanide (WAD)	ND	0.4	ND	ND	ND	ND	ND	ND
Phenols	1	ND	ND	ND	0.25	ND	0.5	ND

ND = no data; WAD = weak acid dissociiable; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.27. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Chilko River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon.

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	0	0	**1.02**	0	**1.08**	0	**1.08**	**1.05**
Residue Non-filterable (TSS)	0.08	**1.04**	0.08	**1.04**	ND	**2.92**	0.48	**2.92**
Turbidity	**10.5**	ND	**10.5**	ND	**21**	**23.7**	**21**	**23.7**
Nutrients								
Nitrate (NO_3), dissolved	0.0483	ND	0.0483	ND	ND	ND	ND	ND
Nitrogen-Nitrite, dissolved (NO_2)	0.05	0.0417	0.05	0.0417	ND	ND	0.0417	0.0167
Phosphorus, total (stream)	**2.4**	**4.8**	**2.4**	**4.8**	**30.4**	**11.6**	**30.4**	**8.6**
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	ND	ND	0.00261	0.00109
Sulfate, dissolved	0.078	0.095	0.078	0.095	0.075	0.066	0.195	0.069
Metals								
Aluminum, total	ND	**34.9**	ND	**34.9**	ND	**14.6**	ND	**14.6**
Arsenic, total	ND	0.2	ND	0.2	ND	0.16	ND	0.16
Boron, total	ND	0.0633	ND	0.0633	ND	0.0117	ND	0.0117
Cadmium, total	ND	ND	ND	ND	ND	**2.35**	ND	**2.35**
Chromium, total	ND	**5**	ND	**5**	ND	0.7	ND	0.7
Cobalt, total	ND	1	ND	1	ND	0.32	ND	0.32
Copper, total	0.5	ND	0.5	ND	**5.5**	**2.32**	**5.5**	**2.32**
Iron, total	**2.67**	**8.7**	**2.67**	**8.7**	ND	**2.55**	ND	**2.55**
Lead, total	0.5	ND	0.5	ND	**6**	0.55	**6**	0.55
Manganese, total	ND	ND	ND	ND	0.00589	0.0911	0.0136	0.0911
Molybdenum, total	0.026	0.0274	0.026	0.0274	ND	0.0186	ND	0.0186
Nickel, total	ND	ND	ND	ND	ND	0.108	ND	0.108

Table 4.27. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Chilko River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon.

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Selenium, total	ND	ND	ND	ND	ND	0.2	ND	0.2
Silver, total	ND	0.5	ND	0.5	ND	0.1	ND	0.1

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.28. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Quesnel River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	0	ND	ND	0	0	0	0
Residue Non-filterable (TSS)	ND	**5.8**	ND	ND	0.08	**6.64**	0.08	**18.2**
Turbidity	ND	**19.3**	ND	ND	ND	**18**	0.45	**26**
Nutrients								
Ammonia, dissolved	ND	0.111	ND	ND	ND	0.026	0.0206	0.026
Nitrate (NO_3), dissolved	ND	0.0514	ND	0.0517	ND	ND	0.031	ND
Nitrogen-Nitrite, dissolved (NO_2)	ND	0.117	ND	0.15	0.0417	ND	0.0417	ND
Phosphorus, total (lake)	ND	ND	ND	**5**	ND	ND	ND	ND
Phosphorus, total (stream)	ND	**27.8**	ND	ND	0.6	ND	**2**	ND
Major Ions								
Chloride, dissolved	ND	0.00652	ND	ND	ND	0.00739	0.00652	0.0113
Sulfate, dissolved	ND	ND	ND	ND	ND	0.44	0.067	**3.2**
Metals								
Aluminum, total	ND	**20.6**	ND	ND	ND	**9.93**	0.2	**67.8**
Arsenic, total	ND	0.176	ND	ND	ND	**1.18**	ND	0.2
Boron, total	ND	0.00542	ND	ND	ND	0.667	ND	**1.85**
Cadmium, total	ND	**4.76**	ND	ND	ND	**25.3**	ND	**23.5**
Chromium, total	ND	**4.63**	ND	ND	ND	**1.4**	ND	**8**
Cobalt, total	ND	0.42	ND	ND	ND	0.5	ND	0.375
Copper, total	ND	**1.13**	ND	ND	ND	**4.5**	0.25	**12**
Iron, total	ND	**9.63**	ND	ND	ND	**4.73**	0.167	**37.7**
Lead, total	ND	0.214	ND	ND	ND	0.5	0.5	0.5
Manganese, total	ND	0.0405	ND	ND	ND	0.0501	0.0123	0.322

Table 4.28. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Quesnel River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Mercury, total	ND	ND	ND	ND	ND	ND	ND	**7250**
Molybdenum, total	ND	0.0148	ND	ND	ND	0.233	ND	0.425
Nickel, total	ND	0.0696	ND	ND	ND	**28**	ND	0.28
Selenium, total	ND	0.46	ND	ND	ND	**1.8**	ND	0.8
Silver, total	ND	0.37	ND	ND	ND	0.5	ND	0.5
Other								
Cyanide (WAD)	ND	ND	ND	ND	ND	0.5	ND	0.5

ND = no data; WAD = weak acid dissociiable; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.29. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Nechako River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	0	0	ND	0	0	**1.13**	0	**1.06**
Residue Non-filterable (TSS)	**2.52**	0.16	ND	0.1	**58.8**	**3.64**	0.96	**1.2**
Turbidity	**9**	0.2	ND	0.4	**128**	**43.4**	**3.6**	**15**
Nutrients								
Ammonia, dissolved	0.0177	0.0147	ND	ND	0.163	0.0198	0.225	0.0342
Nitrate (NO_3), dissolved	0.0138	0.0483	ND	0.0231	0.00345	0.0138	0.00345	0.0345
Nitrogen-Nitrite, dissolved (NO_2)	0.05	0.233	ND	0.0417	0.0417	0.0833	0.0417	0.233
Phosphorus, total (lake)	ND	ND	ND	**3.33**	ND	ND	ND	ND
Phosphorus, total (stream)	**18.6**	**1.8**	ND	ND	**264**	**60**	**15.2**	**42.2**
Major Ions								
Chloride, dissolved	0.00609	0.00478	ND	0.00304	0.00609	0.0426	0.00522	0.0426
Fluoride, total	ND	ND	ND	0.25	0.8	0.65	0.8	0.65
Sulfate, dissolved	0.027	ND	ND	0.061	0.06	0.056	0.058	0.07
Metals								
Aluminum, total	**2.5**	ND	ND	0.3	**8.79**	**53.2**	**6.39**	**53.2**
Arsenic, total	ND	ND	ND	0.12	0.16	0.24	0.3	0.2
Boron, total	ND	ND	ND	0.0208	ND	0.0085	ND	0.0035
Cadmium, total	ND	ND	ND	**29.4**	**64.7**	**23.5**	**118**	**11.8**
Chromium, total	ND	ND	ND	**9**	**10**	**4.3**	**20.7**	**2.4**
Cobalt, total	ND	ND	ND	**1.5**	0.2	0.45	0.15	0.2
Copper, total	ND	ND	ND	**1.05**	**27.3**	**2.55**	**365**	**2.75**
Iron, total	**1.17**	ND	ND	0.37	**5.3**	**12**	**3.33**	**4.9**
Lead, total	ND	ND	ND	**90**	**3.5**	**2.2**	**18.8**	**1.6**

Table 4.29. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Nechako River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Manganese, total	0.0278	ND	ND	0.00978	0.08	0.143	0.0525	0.095
Mercury, total	ND	ND	ND	ND	**1500**	**500**	**2500**	**26500**
Molybdenum, total	0.137	ND	ND	0.196	0.959	0.0573	0.959	0.0555
Nickel, total	ND	ND	ND	0.4	0.14	0.244	**3.6**	0.18
Selenium, total	ND	ND	ND	1	0.4	0.2	1	**1.2**
Silver, total	ND	ND	ND	0.1	ND	**403**	ND	**403**
Other								
Phenols	ND	ND	ND	ND	0.5	**1.5**	**4.5**	1

ND = no data; TSS = total suspended solids.

Only chemicals of potential concern for which usable data were available in an area of interest were reported.

Bolded values indicate hazard quotients >1.0.

Pre-1990 includes 1990.

[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.30. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants within the Bowron River Area of Interest (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	ND	ND	0	ND	ND	ND	ND
Residue Non-filterable (TSS)	ND	ND	ND	0.16	ND	ND	ND	ND
Turbidity	ND	ND	ND	0.7	ND	ND	ND	ND
Nutrients								
Nitrate (NO_3), dissolved	ND	ND	ND	0.0438	ND	ND	ND	ND
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	0.05	ND	ND	ND	ND
Phosphorus, total (lake)	ND	ND	ND	**5**	ND	ND	ND	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.31. Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants in the reference areas within the Fraser River Basin (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH[1]	ND	ND	ND	ND	0	0	0	0
Residue Non-filterable (TSS)	ND	ND	ND	ND	0.2	0.4	0.84	0.52
Turbidity	ND	ND	ND	ND	**2**	**3.15**	**4.25**	**11.1**
Nutrients								
Nitrate (NO_3), dissolved	ND	ND	ND	ND	ND	0.0324	ND	0.0293
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	ND	0.367	ND	0.367
Phosphorus, total (stream)	ND	ND	ND	ND	**3.8**	**4**	**5.2**	**20.6**
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	0.00217	0.0739	0.00174	0.0739
Fluoride, total	ND	ND	ND	ND	ND	0.267	ND	0.333
Sulfate, dissolved	ND	ND	ND	ND	0.133	0.19	0.122	0.19
Metals								
Aluminum, total	ND	ND	ND	ND	0.35	**2.18**	**1.81**	**5.22**
Arsenic, total	ND	ND	ND	ND	0.22	0.04	0.34	0.44
Boron, total	ND	ND	ND	ND	ND	0.00125	ND	0.00117
Cadmium, total	ND	ND	ND	ND	**64.7**	**5.88**	**235**	**11.8**
Chromium, total	ND	ND	ND	ND	**2.6**	**8.8**	**5.2**	**16.9**
Cobalt, total	ND	ND	ND	ND	0.1	0.15	0.15	0.3
Copper, total	ND	ND	ND	ND	**60.8**	**4.95**	**54**	**4.95**
Iron, total	ND	ND	ND	ND	**2.05**	0.893	**2.07**	**2.53**
Lead, total	ND	ND	ND	ND	**1.1**	0.4	**2.8**	0.8
Manganese, total	ND	ND	ND	ND	0.0164	0.0197	0.0182	0.036
Mercury, total	ND	ND	ND	ND	**1000**	**1050**	**2500**	**2300**

Table 4.31. **Evaluation of potential hazards in surface water posed to sockeye salmon exposed to contaminants in the reference areas within the Fraser River Basin (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon).**

Chemical of Potential Concern	Maximum Hazard Quotient							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Molybdenum, total	ND	ND	ND	ND	0.000685	0.00274	0.00137	0.00685
Nickel, total	ND	ND	ND	ND	0.044	0.116	0.08	0.172
Selenium, total	ND	ND	ND	ND	0.3	0.2	0.3	0.97
Silver, total	ND	ND	ND	ND	ND	1	ND	**6**

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which usable data were available in an area of interest were reported.
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Table 4.32. Frequency of exceedance of the selected toxicity screening values for surface water in the Lower Fraser River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	ND	ND	ND	0% (33)	1% (92)	12% (110)	2% (222)
Residue Non-filterable (TSS)	ND	ND	ND	ND	94% (35)	100% (7)	75% (69)	100% (19)
Turbidity	ND	ND	ND	ND	100% (34)	98% (86)	97% (60)	97% (174)
Nutrients								
Ammonia, dissolved	ND	ND	ND	ND	0% (2)	0% (1)	0% (11)	0% (24)
Nitrate (NO_3), dissolved	ND	ND	ND	ND	ND	0% (34)	ND	0% (63)
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0% (2)	0% (34)	0% (10)	0% (73)
Phosphorus, total (stream)	ND	ND	ND	ND	100% (27)	95% (64)	100% (53)	97% (144)
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	0% (35)	0% (86)	0% (63)	0% (176)
Fluoride, total	ND	ND	ND	ND	ND	0% (23)	ND	0% (45)
Sulfate, dissolved	ND	ND	ND	ND	0% (34)	0% (35)	0% (61)	0% (73)
Metals								
Aluminum, total	ND	ND	ND	ND	100% (3)	99% (72)	100% (9)	94% (161)
Arsenic, total	ND	ND	ND	ND	0% (16)	0% (44)	0% (43)	0% (93)
Boron, total	ND	ND	ND	ND	ND	0% (20)	ND	0% (53)
Cadmium, total	ND	ND	ND	ND	100% (5)	99% (71)	100% (8)	98% (148)
Chromium, total	ND	ND	ND	ND	80% (5)	99% (71)	100% (17)	88% (162)
Cobalt, total	ND	ND	ND	ND	ND	15% (71)	ND	5% (165)
Copper, total	ND	ND	ND	ND	100% (16)	100% (64)	86% (43)	87% (137)
Iron, total	ND	ND	ND	ND	100% (17)	99% (71)	98% (58)	95% (165)
Lead, total	ND	ND	ND	ND	81% (16)	80% (64)	49% (43)	58% (137)
Manganese, total	ND	ND	ND	ND	0% (16)	0% (64)	0% (43)	0% (137)

Table 4.32. Frequency of exceedance of the selected toxicity screening values for surface water in the Lower Fraser River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Mercury, total	ND	ND	ND	ND	100% (15)	100% (6)	100% (41)	100% (11)
Molybdenum, total	ND	ND	ND	ND	0% (4)	0% (71)	0% (25)	0% (165)
Nickel, total	ND	ND	ND	ND	0% (5)	0% (64)	0% (12)	1% (137)
Selenium, total	ND	ND	ND	ND	0% (16)	0% (40)	0% (43)	0% (87)
Silver, total	ND	ND	ND	ND	ND	4% (51)	ND	4% (114)
Chlorophenols								
Dichlorophenols	ND	ND	ND	ND	ND	0% (3)	ND	0% (11)
Monochlorophenols	ND	ND	ND	ND	ND	0% (3)	ND	0% (11)
Pentachlorophenol	ND	ND	ND	ND	ND	0% (3)	ND	0% (10)
Tetrachlorophenols	ND	ND	ND	ND	ND	0% (3)	ND	0% (11)
Trichlorophenols	ND	ND	ND	ND	ND	0% (3)	ND	0% (11)

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.33. Frequency of exceedance of the selected toxicity screening values for surface water in the Upper Fraser River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	ND	ND	ND	0% (47)	0% (91)	4% (84)	0% (170)
Residue Non-filterable (TSS)	ND	ND	ND	ND	100% (31)	100% (24)	89% (55)	84% (51)
Turbidity	ND	ND	ND	ND	100% (31)	99% (88)	98% (56)	99% (163)
Nutrients								
Ammonia, dissolved	ND	ND	ND	ND	0% (9)	0% (9)	0% (17)	0% (18)
Nitrate (NO_3), dissolved	ND	ND	ND	ND	0% (7)	0% (32)	0% (9)	0% (61)
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0% (11)	0% (32)	0% (17)	0% (61)
Phosphorus, total (stream)	ND	ND	ND	ND	100% (35)	100% (34)	97% (63)	93% (70)
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	0% (42)	0% (89)	0% (77)	1% (164)
Fluoride, total	ND	ND	ND	ND	ND	0% (22)	ND	0% (40)
Sulfate, dissolved	ND	ND	ND	ND	0% (33)	0% (35)	0% (60)	0% (68)
Metals								
Aluminum, total	ND	ND	ND	ND	100% (21)	99% (72)	100% (37)	99% (137)
Arsenic, total	ND	ND	ND	ND	4% (23)	0% (47)	3% (40)	0% (89)
Boron, total	ND	ND	ND	ND	ND	0% (24)	ND	0% (47)
Cadmium, total	ND	ND	ND	ND	100% (11)	100% (72)	100% (17)	97% (134)
Chromium, total	ND	ND	ND	ND	100% (17)	99% (73)	92% (26)	91% (140)
Cobalt, total	ND	ND	ND	ND	50% (4)	18% (73)	13% (8)	6% (140)
Copper, total	ND	ND	ND	ND	100% (23)	99% (68)	93% (40)	83% (128)
Iron, total	ND	ND	ND	ND	100% (39)	99% (73)	99% (69)	98% (140)
Lead, total	ND	ND	ND	ND	70% (23)	65% (68)	58% (40)	38% (128)
Manganese, total	ND	ND	ND	ND	0% (23)	0% (68)	0% (39)	0% (128)
Mercury, total	ND	ND	ND	ND	100% (17)	100% (10)	100% (28)	100% (12)

Table 4.33. Frequency of exceedance of the selected toxicity screening values for surface water in the Upper Fraser River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Molybdenum, total	ND	ND	ND	ND	0% (20)	0% (73)	0% (37)	0% (140)
Nickel, total	ND	ND	ND	ND	0% (10)	1% (68)	0% (20)	0% (128)
Selenium, total	ND	ND	ND	ND	0% (23)	0% (45)	0% (40)	0% (84)
Silver, total	ND	ND	ND	ND	ND	0% (54)	ND	2% (102)
Chlorophenols								
Dichlorophenol	ND	ND	ND	ND	ND	0% (9)	ND	0% (27)
Monochlorophenol	ND	ND	ND	ND	ND	0% (9)	ND	0% (27)
Pentachlorophenol	ND	ND	ND	ND	ND	0% (9)	ND	0% (27)
Tetrachlorophenol	ND	ND	ND	ND	ND	0% (9)	ND	0% (27)
Trichlorophenol	ND	ND	ND	ND	ND	0% (9)	ND	0% (27)
Other								
Cyanide (weak acid dissociable)	ND	ND	ND	ND	ND	ND	ND	0% (1)
Phenols	ND	ND	ND	ND	13% (15)	ND	17% (29)	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.34. Frequency of exceedance of the selected toxicity screening values for surface water in the Pitt River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	ND	0% (5)	0% (15)	0% (2)	ND	0% (11)	0% (19)
Residue Non-filterable (TSS)	ND	ND	ND	0% (11)	50% (2)	ND	40% (10)	70% (10)
Turbidity	ND	ND	ND	25% (16)	50% (2)	ND	60% (10)	100% (10)
Nutrients								
Ammonia, dissolved	ND	ND	ND	0% (5)	0% (2)	ND	0% (9)	ND
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	0% (15)	0% (2)	ND	0% (10)	0% (20)
Metals								
Aluminum, total	ND	ND	ND	ND	50% (2)	ND	80% (10)	ND
Iron, total	ND	ND	ND	ND	50% (2)	ND	60% (10)	ND
Molybdenum, total	ND	ND	ND	ND	0% (2)	ND	0% (10)	ND
Chlorophenols								
Pentachlorophenol	ND	ND	ND	ND	ND	ND	0% (1)	0% (3)
Tetrachlorophenol	ND	ND	ND	ND	ND	ND	0% (1)	0% (3)
Trichlorophenol	ND	ND	ND	ND	ND	ND	0% (1)	0% (3)

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.35. Frequency of exceedance of the selected toxicity screening values for surface water in the Cultus Lake Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	0% (30)	ND	0% (40)	ND	ND	0% (21)	0% (1)	0% (60)
Residue Non-filterable (TSS)	0% (24)	ND	0% (30)	ND	ND	17% (12)	ND	3% (36)
Turbidity	7% (28)	0% (5)	5% (37)	0% (5)	ND	100% (21)	ND	91% (55)
Nutrients								
Ammonia, dissolved	0% (14)	ND	0% (20)	ND	ND	ND	ND	0% (1)
Nitrate (NO_3), dissolved	0% (7)	ND	0% (12)	ND	ND	38% (21)	ND	31% (55)
Nitrogen-Nitrite, dissolved (NO_2)	0% (20)	ND	0% (26)	ND	ND	5% (21)	ND	3% (60)
Phosphorus, total (lake)	39% (38)	33% (9)	52% (60)	33% (9)	ND	ND	ND	ND
Phosphorus, total (stream)	ND	ND	ND	ND	ND	100% (10)	ND	100% (44)
Major Ions								
Chloride, dissolved	0% (19)	ND	0% (25)	ND	ND	0% (21)	ND	0% (42)
Sulfate, dissolved	0% (18)	ND	0% (25)	ND	ND	0% (19)	ND	0% (39)
Metals								
Aluminum, total	ND	ND	ND	ND	ND	100% (5)	ND	38% (13)
Arsenic, total	ND	ND	ND	ND	ND	0% (6)	ND	0% (20)
Boron, total	ND	ND	ND	ND	ND	0% (6)	ND	0% (25)
Cadmium, total	ND	ND	ND	ND	ND	0% (6)	ND	0% (20)
Chromium, total	ND	ND	ND	ND	ND	100% (6)	ND	39% (23)
Cobalt, total	ND	ND	ND	ND	ND	0% (6)	ND	0% (25)
Copper, total	15% (13)	ND	12% (17)	ND	ND	0% (5)	ND	0% (8)
Iron, total	8% (12)	ND	7% (14)	ND	ND	100% (6)	ND	100% (25)
Lead, total	0% (6)	ND	0% (6)	ND	ND	0% (5)	ND	0% (8)
Manganese, total	0% (1)	ND	0% (3)	ND	ND	0% (5)	ND	0% (8)
Molybdenum, total	ND	ND	ND	ND	ND	0% (6)	ND	0% (25)

Table 4.35. Frequency of exceedance of the selected toxicity screening values for surface water in the Cultus Lake Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Nickel, total	0% (3)	ND	0% (5)	ND	ND	0% (5)	ND	0% (8)
Selenium, total	ND	ND	ND	ND	ND	0% (6)	ND	0% (20)
Silver, total	ND	ND	ND	ND	ND	0% (6)	ND	0% (20)
Other								
Phenols	0% (12)	ND	0% (14)	ND	ND	ND	ND	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.36. Frequency of exceedance of the selected toxicity screening values for surface water in the Kakawa Lake Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	ND	ND	ND	0% (6)	ND	0% (11)	ND
Residue Non-filterable (TSS)	ND	ND	ND	ND	0% (4)	ND	0% (8)	ND
Turbidity	ND	ND	ND	ND	50% (2)	ND	50% (2)	ND
Nutrients								
Ammonia, dissolved	ND	ND	ND	ND	0% (4)	ND	0% (7)	ND
Nitrate (NO_3), dissolved	ND	ND	ND	ND	0% (4)	ND	0% (7)	ND
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0% (6)	ND	0% (10)	ND
Phosphorus, total (stream)	ND	ND	ND	ND	75% (4)	ND	38% (8)	ND
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	0% (6)	ND	0% (11)	ND
Sulfate, dissolved	ND	ND	ND	ND	0% (5)	ND	0% (7)	ND
Metals								
Arsenic, total	ND	ND	ND	ND	ND	ND	0% (1)	ND
Copper, total	ND	ND	ND	ND	25% (4)	ND	14% (7)	ND
Iron, total	ND	ND	ND	ND	33% (3)	ND	33% (6)	ND
Lead, total	ND	ND	ND	ND	33% (3)	ND	17% (6)	ND
Manganese, total	ND	ND	ND	ND	0% (4)	ND	0% (7)	ND
Molybdenum, total	ND	ND	ND	ND	ND	ND	0% (1)	ND
Nickel, total	ND	ND	ND	ND	0% (4)	ND	0% (7)	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.37. Frequency of exceedance of the selected toxicity screening values for surface water in the Lower Thompson River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	ND	ND	2% (47)	0% (80)	0% (159)	0% (154)	0% (159)
Residue Non-filterable (TSS)	ND	ND	ND	ND	60% (43)	80% (115)	10% (59)	32% (93)
Turbidity	ND	ND	ND	23% (43)	96% (56)	93% (137)	53% (89)	59% (131)
Nutrients								
Ammonia, dissolved	ND	ND	ND	0% (23)	0% (13)	0% (89)	0% (37)	0% (90)
Nitrate (NO_3), dissolved	ND	ND	ND	0% (28)	0% (14)	0% (24)	0% (37)	0% (44)
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	0% (21)	0% (62)	0% (65)	0% (97)	0% (51)
Phosphorus, total (lake)	ND	ND	ND	26% (43)	100% (12)	94% (16)	100% (18)	83% (35)
Phosphorus, total (stream)	ND	ND	ND	ND	100% (70)	100% (98)	92% (130)	96% (106)
Major Ions								
Chloride, dissolved	ND	ND	ND	0% (43)	0% (29)	0% (102)	0% (97)	0% (134)
Fluoride, total	ND	ND	ND	0% (9)	0% (5)	ND	0% (12)	0% (2)
Sulfate, dissolved	ND	ND	ND	0% (40)	0% (26)	0% (93)	0% (67)	0% (118)
Metals								
Aluminum, total	ND	ND	ND	ND	100% (4)	100% (7)	67% (6)	60% (10)
Arsenic, total	ND	ND	ND	ND	0% (1)	100% (1)	0% (3)	100% (1)
Boron, total	ND	ND	ND	ND	ND	0% (7)	ND	0% (10)
Cadmium, total	ND	ND	ND	ND	ND	ND	100% (1)	ND
Chromium, total	ND	ND	ND	ND	100% (1)	100% (6)	80% (5)	100% (8)
Cobalt, total	ND	ND	ND	ND	ND	0% (7)	0% (2)	13% (8)
Copper, total	ND	ND	ND	ND	25% (4)	ND	10% (10)	100% (1)
Iron, total	ND	ND	ND	ND	86% (7)	100% (7)	31% (16)	60% (10)
Lead, total	ND	ND	ND	ND	33% (3)	ND	11% (9)	ND
Manganese, total	ND	ND	ND	ND	0% (5)	ND	0% (14)	0% (2)

Table 4.37. Frequency of exceedance of the selected toxicity screening values for surface water in the Lower Thompson River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Molybdenum, total	ND	ND	ND	ND	0% (6)	0% (7)	0% (15)	0% (10)
Nickel, total	ND	ND	ND	ND	ND	ND	0% (3)	0% (2)
Selenium, total	ND	ND	ND	ND	0% (1)	ND	0% (1)	ND
Other								
Phenols	ND	ND	ND	ND	0% (5)	ND	9% (11)	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.38. Frequency of exceedance of the selected toxicity screening values for surface water in the North Thompson River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	0% (7)	ND	ND	0% (28)	0% (44)	2% (58)	0% (59)
Residue Non-filterable (TSS)	ND	0% (5)	ND	ND	46% (13)	20% (44)	27% (22)	17% (59)
Turbidity	ND	33% (6)	ND	ND	50% (12)	61% (31)	54% (37)	44% (43)
Nutrients								
Ammonia, dissolved	ND	ND	ND	ND	0% (8)	0% (9)	0% (6)	0% (11)
Nitrate (NO_3), dissolved	ND	ND	ND	ND	ND	0% (13)	0% (11)	0% (21)
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0% (7)	0% (10)	0% (13)	0% (15)
Phosphorus, total (stream)	ND	86% (7)	ND	ND	100% (23)	82% (44)	86% (44)	73% (59)
Major Ions								
Chloride, dissolved	ND	0% (6)	ND	ND	0% (25)	0% (44)	0% (50)	0% (59)
Fluoride, total	ND	ND	ND	ND	0% (8)	0% (11)	0% (15)	0% (17)
Sulfate, dissolved	ND	0% (6)	ND	ND	0% (27)	0% (41)	0% (50)	0% (53)
Metals								
Aluminum, total	ND	ND	ND	ND	100% (3)	91% (23)	100% (2)	61% (33)
Arsenic, total	ND	ND	ND	ND	0% (1)	ND	0% (3)	ND
Boron, total	ND	ND	ND	ND	ND	0% (23)	ND	0% (33)
Cadmium, total	ND	ND	ND	ND	ND	100% (2)	100% (1)	100% (1)
Chromium, total	ND	ND	ND	ND	ND	100% (3)	67% (3)	100% (6)
Cobalt, total	ND	ND	ND	ND	ND	23% (13)	0% (2)	20% (15)
Copper, total	ND	ND	ND	ND	0% (1)	100% (3)	0% (5)	100% (3)
Iron, total	ND	ND	ND	ND	60% (5)	74% (23)	60% (10)	52% (33)
Lead, total	ND	ND	ND	ND	100% (1)	100% (2)	20% (5)	100% (2)
Manganese, total	ND	ND	ND	ND	0% (5)	0% (13)	0% (11)	0% (21)
Molybdenum, total	ND	ND	ND	ND	0% (3)	0% (23)	0% (8)	0% (33)

Table 4.38. Frequency of exceedance of the selected toxicity screening values for surface water in the North Thompson River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Nickel, total	ND	ND	ND	ND	ND	0% (13)	0% (2)	0% (21)
Selenium, total	ND	ND	ND	ND	0% (1)	ND	0% (1)	100% (1)

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.39. Frequency of exceedance of the selected toxicity screening values for surface water in the South Thompson River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	0% (871)	0% (1504)	0% (391)	0% (666)	0% (64)	0% (33)	1% (130)	0% (46)
Residue Non-filterable (TSS)	16% (503)	17% (721)	3% (71)	0% (4)	0% (27)	9% (33)	0% (40)	4% (46)
Turbidity	17% (313)	39% (1132)	2% (151)	6% (362)	66% (38)	67% (18)	25% (96)	48% (25)
Nutrients								
Ammonia, dissolved	0% (185)	0% (773)	0% (103)	0% (225)	0% (14)	0% (9)	0% (13)	0% (11)
Nitrate (NO_3), dissolved	0% (89)	0% (246)	0% (47)	0% (134)	0% (5)	0% (14)	0% (18)	0% (22)
Nitrogen-Nitrite, dissolved (NO_2)	0% (363)	0% (286)	0% (168)	0% (172)	2% (52)	0% (10)	0% (109)	0% (15)
Phosphorus, total (lake)	49% (285)	67% (529)	46% (330)	68% (717)	ND	ND	ND	ND
Phosphorus, total (stream)	74% (583)	92% (785)	46% (69)	0% (1)	98% (63)	85% (33)	88% (128)	78% (45)
Major Ions								
Chloride, dissolved	0% (450)	0% (833)	0% (178)	0% (626)	0% (37)	0% (33)	0% (68)	0% (46)
Fluoride, total	ND	2% (117)	ND	0% (7)	ND	0% (12)	ND	0% (18)
Sulfate, dissolved	0% (499)	0% (608)	0% (190)	0% (533)	0% (30)	0% (29)	0% (59)	0% (38)
Metals								
Aluminum, total	48% (108)	62% (474)	19% (32)	0% (33)	100% (8)	80% (25)	71% (14)	57% (35)
Arsenic, total	3% (76)	0% (266)	0% (1)	0% (9)	ND	ND	0% (2)	ND
Boron, total	0% (22)	0% (239)	0% (12)	0% (30)	ND	0% (25)	ND	0% (35)
Cadmium, total	100% (44)	74% (318)	100% (7)	0% (9)	ND	100% (2)	ND	100% (2)
Chromium, total	84% (43)	24% (434)	100% (3)	10% (10)	ND	100% (6)	100% (3)	100% (4)
Cobalt, total	6% (31)	0% (442)	100% (1)	0% (15)	ND	21% (14)	ND	32% (19)
Copper, total	32% (119)	17% (387)	4% (25)	20% (5)	ND	100% (4)	0% (1)	100% (4)
Iron, total	31% (257)	53% (477)	4% (74)	0% (32)	38% (8)	36% (25)	11% (19)	26% (35)
Lead, total	12% (113)	4% (383)	8% (24)	0% (5)	ND	ND	0% (1)	100% (1)

Table 4.39. Frequency of exceedance of the selected toxicity screening values for surface water in the South Thompson River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Manganese, total	0% (116)	0% (441)	0% (27)	0% (24)	ND	0% (14)	0% (1)	0% (22)
Mercury, total	92% (61)	100% (40)	57% (7)	ND	ND	ND	ND	ND
Molybdenum, total	0% (166)	0% (501)	0% (66)	0% (37)	0% (9)	0% (25)	0% (21)	0% (35)
Nickel, total	0% (77)	0% (441)	0% (24)	0% (24)	ND	7% (14)	0% (1)	5% (22)
Selenium, total	2% (63)	3% (258)	ND	0% (9)	ND	ND	ND	100% (1)
Silver, total	ND	6% (322)	ND	11% (9)	ND	ND	ND	ND
Other								
Cyanide (weak acid dissociable)	ND	0% (128)	ND	ND	ND	ND	ND	ND
Phenols	0% (6)	ND	ND	ND	0% (1)	ND	0% (2)	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.40. **Frequency of exceedance of the selected toxicity screening values for surface water in the Chilko River Area of Interest.**

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	0% (6)	0% (10)	13% (8)	0% (10)	50% (2)	0% (8)	13% (8)	8% (13)
Residue Non-filterable (TSS)	0% (1)	10% (10)	0% (1)	10% (10)	ND	13% (8)	0% (2)	8% (12)
Turbidity	100% (4)	ND	100% (6)	ND	100% (3)	100% (8)	88% (8)	100% (11)
Nutrients								
Nitrate (NO_3), dissolved	0% (3)	ND	0% (4)	ND	ND	ND	ND	ND
Nitrogen-Nitrite, dissolved (NO_2)	0% (5)	0% (6)	0% (6)	0% (6)	ND	ND	0% (1)	0% (1)
Phosphorus, total (stream)	100% (6)	100% (4)	100% (7)	100% (4)	100% (3)	63% (8)	100% (9)	75% (16)
Major Ions								
Chloride, dissolved	ND	ND	ND	ND	ND	ND	0% (1)	0% (1)
Sulfate, dissolved	0% (5)	0% (10)	0% (7)	0% (10)	0% (3)	0% (8)	0% (7)	0% (15)
Metals								
Aluminum, total	ND	100% (10)	ND	100% (10)	ND	100% (8)	ND	92% (12)
Arsenic, total	ND	0% (8)	ND	0% (8)	ND	0% (9)	ND	0% (15)
Boron, total	ND	0% (10)	ND	0% (10)	ND	0% (1)	ND	0% (2)
Cadmium, total	ND	ND	ND	ND	ND	22% (9)	ND	13% (15)
Chromium, total	ND	100% (4)	ND	100% (4)	ND	0% (9)	ND	0% (15)
Cobalt, total	ND	0% (10)	ND	0% (10)	ND	0% (9)	ND	0% (15)
Copper, total	0% (1)	ND	0% (1)	ND	100% (2)	22% (4)	67% (3)	14% (14)
Iron, total	100% (1)	100% (10)	100% (1)	100% (10)	ND	100% (1)	ND	100% (2)
Lead, total	0% (1)	ND	0% (1)	ND	100% (2)	0% (9)	67% (3)	0% (14)
Manganese, total	ND	ND	ND	ND	0% (1)	0% (9)	0% (2)	0% (14)
Molybdenum, total	0% (1)	0% (10)	0% (1)	0% (10)	ND	0% (9)	ND	0% (15)
Nickel, total	ND	ND	ND	ND	ND	0% (9)	ND	0% (14)

Table 4.40. Frequency of exceedance of the selected toxicity screening values for surface water in the Chilko River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Selenium, total	ND	ND	ND	ND	ND	0% (9)	ND	0% (15)
Silver, total	ND	0% (4)	ND	0% (4)	ND	0% (9)	ND	0% (15)

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.41. Frequency of exceedance of the selected toxicity screening values for surface water in the Quesnel River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	0% (96)	ND	ND	0% (1)	0% (16)	0% (8)	0% (18)
Residue Non-filterable (TSS)	ND	10% (86)	ND	ND	0% (1)	53% (17)	0% (2)	59% (17)
Turbidity	ND	33% (97)	ND	ND	ND	100% (11)	0% (6)	100% (13)
Nutrients								
Ammonia, dissolved	ND	0% (59)	ND	ND	ND	0% (10)	0% (3)	0% (13)
Nitrate (NO_3), dissolved	ND	0% (91)	ND	0% (318)	ND	ND	0% (4)	ND
Nitrogen-Nitrite, dissolved (NO_2)	ND	0% (92)	ND	0% (318)	0% (1)	ND	0% (5)	ND
Phosphorus, total (lake)	ND	ND	ND	85% (318)	ND	ND	ND	ND
Phosphorus, total (stream)	ND	96% (48)	ND	ND	0% (1)	ND	17% (6)	ND
Major Ions								
Chloride, dissolved	ND	0% (38)	ND	ND	ND	0% (17)	0% (3)	0% (18)
Sulfate, dissolved	ND	ND	ND	ND	ND	0% (17)	0% (5)	11% (18)
Metals								
Aluminum, total	ND	35% (26)	ND	ND	ND	50% (10)	0% (1)	62% (13)
Arsenic, total	ND	0% (28)	ND	ND	ND	6% (16)	ND	0% (15)
Boron, total	ND	0% (28)	ND	ND	ND	0% (11)	ND	8% (13)
Cadmium, total	ND	25% (28)	ND	ND	ND	100% (1)	ND	100% (2)
Chromium, total	ND	18% (28)	ND	ND	ND	9% (11)	ND	31% (13)
Cobalt, total	ND	0% (28)	ND	ND	ND	0% (8)	ND	0% (6)
Copper, total	ND	20% (10)	ND	ND	ND	35% (17)	0% (2)	41% (17)
Iron, total	ND	36% (28)	ND	ND	ND	18% (17)	0% (1)	22% (18)
Lead, total	ND	0% (10)	ND	ND	ND	0% (11)	0% (2)	0% (13)
Manganese, total	ND	0% (10)	ND	ND	ND	0% (16)	0% (2)	0% (17)
Mercury, total	ND	ND	ND	ND	ND	ND	ND	100% (1)

Table 4.41. Frequency of exceedance of the selected toxicity screening values for surface water in the Quesnel River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Molybdenum, total	ND	0% (28)	ND	ND	ND	0% (17)	ND	0% (18)
Nickel, total	ND	0% (10)	ND	ND	ND	6% (17)	ND	0% (18)
Selenium, total	ND	0% (28)	ND	ND	ND	6% (17)	ND	0% (16)
Silver, total	ND	0% (28)	ND	ND	ND	0% (11)	ND	0% (13)
Other								
Cyanide (weak acid dissociable)	ND	ND	ND	ND	ND	0% (11)	ND	0% (13)

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.42. Frequency of exceedance of the selected toxicity screening values for surface water in the Nechako River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	0% (74)	0% (54)	ND	0% (6)	0% (52)	2% (93)	0% (109)	1% (176)
Residue Non-filterable (TSS)	14% (14)	0% (1)	ND	0% (17)	23% (31)	36% (25)	0% (44)	7% (44)
Turbidity	13% (23)	0% (1)	ND	0% (17)	71% (45)	92% (91)	38% (80)	74% (162)
Nutrients								
Ammonia, dissolved	0% (1)	0% (14)	ND	ND	0% (16)	0% (12)	0% (24)	0% (27)
Nitrate (NO_3), dissolved	0% (4)	0% (9)	ND	0% (12)	0% (4)	0% (34)	0% (2)	0% (61)
Nitrogen-Nitrite, dissolved (NO_2)	0% (73)	0% (49)	ND	0% (12)	0% (12)	0% (34)	0% (31)	0% (74)
Phosphorus, total (lake)	ND	ND	ND	56% (18)	ND	ND	ND	ND
Phosphorus, total (stream)	100% (34)	75% (12)	ND	ND	100% (36)	97% (34)	97% (71)	98% (63)
Major Ions								
Chloride, dissolved	0% (36)	0% (25)	ND	0% (12)	0% (43)	0% (91)	0% (83)	0% (170)
Fluoride, total	ND	ND	ND	0% (4)	0% (6)	0% (22)	0% (14)	0% (45)
Sulfate, dissolved	0% (2)	ND	ND	0% (12)	0% (39)	0% (34)	0% (70)	0% (62)
Metals								
Aluminum, total	14% (21)	ND	ND	0% (6)	100% (18)	97% (77)	68% (31)	73% (139)
Arsenic, total	ND	ND	ND	0% (15)	0% (24)	0% (69)	0% (42)	0% (139)
Boron, total	ND	ND	ND	0% (17)	ND	0% (24)	ND	0% (45)
Cadmium, total	ND	ND	ND	45% (11)	100% (7)	89% (65)	100% (12)	67% (97)
Chromium, total	ND	ND	ND	33% (12)	91% (11)	50% (76)	73% (15)	15% (145)
Cobalt, total	ND	ND	ND	10% (10)	0% (5)	0% (76)	0% (7)	0% (145)
Copper, total	ND	ND	ND	11% (9)	100% (23)	48% (71)	68% (44)	22% (134)
Iron, total	10% (21)	ND	ND	0% (17)	97% (30)	93% (76)	36% (55)	54% (145)
Lead, total	ND	ND	ND	13% (16)	30% (23)	11% (71)	32% (44)	2% (134)
Manganese, total	0% (3)	ND	ND	0% (17)	0% (27)	0% (71)	0% (52)	0% (134)

Table 4.42. Frequency of exceedance of the selected toxicity screening values for surface water in the Nechako River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Mercury, total	ND	ND	ND	ND	100% (17)	100% (7)	100% (29)	100% (8)
Molybdenum, total	0% (21)	ND	ND	0% (17)	0% (18)	0% (76)	0% (31)	0% (145)
Nickel, total	ND	ND	ND	0% (17)	0% (11)	0% (71)	6% (17)	0% (134)
Selenium, total	ND	ND	ND	0% (15)	0% (23)	0% (67)	0% (42)	1% (133)
Silver, total	ND	ND	ND	0% (9)	ND	5% (57)	ND	4% (114)
Other								
Phenols	ND	ND	ND	ND	0% (7)	25% (4)	9% (11)	0% (7)

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.43. Frequency of exceedance of the selected toxicity screening values for surface water in the Bowron River Area of Interest.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	ND	ND	0% (48)	ND	ND	ND	ND
Residue Non-filterable (TSS)	ND	ND	ND	0% (44)	ND	ND	ND	ND
Turbidity	ND	ND	ND	0% (48)	ND	ND	ND	ND
Nutrients								
Nitrate (NO_3), dissolved	ND	ND	ND	0% (43)	ND	ND	ND	ND
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	0% (48)	ND	ND	ND	ND
Phosphorus, total (lake)	ND	ND	ND	52% (48)	ND	ND	ND	ND

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.44. Frequency of exceedance of the selected toxicity screening values for surface water in reference area within the Fraser River Basin.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals								
pH	ND	ND	ND	ND	0% (13)	0% (79)	0% (28)	0% (165)
Residue Non-filterable (TSS)	ND	ND	ND	ND	0% (6)	0% (25)	0% (20)	0% (56)
Turbidity	ND	ND	ND	ND	12% (17)	25% (79)	55% (38)	54% (165)
Nutrients								
Nitrate (NO_3), dissolved	ND	ND	ND	ND	ND	0% (28)	ND	0% (57)
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	ND	0% (28)	ND	0% (57)
Phosphorus, total (stream)	ND	ND	ND	ND	18% (17)	18% (33)	42% (38)	40% (73)
Major Ions								
Bolded values indicate hazard quotier	ND	ND	ND	ND	0% (17)	0% (79)	0% (38)	0% (165)
Fluoride, total	ND	ND	ND	ND	ND	0% (13)	ND	0% (34)
Sulfate, dissolved	ND	ND	ND	ND	0% (17)	0% (48)	0% (38)	0% (104)
Metals								
Aluminum, total	ND	ND	ND	ND	0% (1)	38% (60)	100% (1)	84% (132)
Arsenic, total	ND	ND	ND	ND	0% (17)	0% (37)	0% (37)	0% (82)
Boron, total	ND	ND	ND	ND	ND	0% (18)	ND	0% (37)
Cadmium, total	ND	ND	ND	ND	100% (3)	31% (26)	100% (5)	48% (71)
Chromium, total	ND	ND	ND	ND	60% (5)	11% (62)	67% (9)	8% (137)
Cobalt, total	ND	ND	ND	ND	0% (5)	0% (62)	0% (9)	0% (137)
Copper, total	ND	ND	ND	ND	59% (17)	7% (58)	59% (37)	3% (129)
Iron, total	ND	ND	ND	ND	6% (17)	0% (62)	16% (37)	6% (137)
Lead, total	ND	ND	ND	ND	6% (17)	0% (58)	16% (37)	0% (129)
Manganese, total	ND	ND	ND	ND	0% (17)	0% (58)	0% (37)	0% (129)
Mercury, total	ND	ND	ND	ND	100% (4)	100% (8)	100% (11)	100% (17)
Molybdenum, total	ND	ND	ND	ND	0% (5)	0% (62)	0% (9)	0% (137)

Table 4.44. Frequency of exceedance of the selected toxicity screening values for surface water in reference area within the Fraser River Basin.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (continued)								
Nickel, total	ND	ND	ND	ND	0% (5)	0% (58)	0% (9)	0% (129)
Selenium, total	ND	ND	ND	ND	0% (17)	0% (37)	0% (37)	0% (82)
Silver, total	ND	ND	ND	ND	ND	0% (45)	ND	2% (100)

ND = no data; TSS = total suspended solids.
Only chemicals of potential concern for which data were available in an area of interest were reported.
Pre-1990 includes 1990.

Table 4.45. Summary of hazards posed to sockeye salmon exposed to surface water during spawning and incubation life stages within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	**Upper Fraser River**	**Pitt River**	**Harrison River**	**Cultus Lake**	**Kakawa Lake**	**Nahatlatch**	**Seton-Portage**	**Lower Thompson River**	**North Thompson River**	**South Thompson River**	**Chilko River**	**Quesnel River**	**Nechako River**	**Bowron River**	**Reference**	**Fraser River Basin**
Conventionals																	
pH[1]	ND	ND	ND	ND	0	ND	ND	ND	ND	0	**1.16**	0	0	0	ND	ND	**1.16**
Residue Non-filterable (TSS)	ND	ND	ND	ND	0.840	ND	ND	ND	ND	0.680	**32.0**	**1.04**	**5.80**	**2.52**	ND	ND	**32.0**
Turbidity	ND	ND	ND	ND	**8.00**	ND	ND	ND	ND	**2.45**	**100**	**10.5**	**19.3**	**9.00**	ND	ND	**100**
Nutrients																	
Ammonia, dissolved	ND	ND	ND	ND	0.0409	ND	ND	ND	ND	ND	0.578	ND	0.111	0.0177	ND	ND	0.578
Nitrate (NO_3), dissolved	ND	ND	ND	ND	0.0241	ND	ND	ND	ND	ND	0.152	0.0483	0.0514	0.0483	ND	ND	0.152
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	ND	ND	0.0417	ND	ND	ND	ND	ND	0.700	0.0500	0.117	0.233	ND	ND	0.700
Phosphorus, total (lake)	ND	ND	ND	ND	**5.00**	ND	ND	ND	ND	ND	**7.60**	ND	ND	ND	ND	ND	**7.60**
Phosphorus, total (stream)	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.60	**212**	**4.80**	**27.8**	**18.6**	ND	ND	**212**
Major Ions																	
Chloride, dissolved	ND	ND	ND	ND	0.0152	ND	ND	ND	ND	0.00957	0.0826	ND	0.00652	0.00609	ND	ND	0.0826
Fluoride, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**1.17**	ND	ND	ND	ND	ND	**1.17**
Sulfate, dissolved	ND	ND	ND	ND	0.246	ND	ND	ND	ND	0.185	0.731	0.0950	ND	0.0270	ND	ND	0.731
Metals																	
Aluminum, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**92.1**	**34.9**	**20.6**	**2.50**	ND	ND	**92.1**
Arsenic, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**10.0**	0.200	0.176	ND	ND	ND	**10.0**
Boron, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**1.33**	0.0633	0.00542	ND	ND	ND	**1.33**

Table 4.45. Summary of hazards posed to sockeye salmon exposed to surface water during spawning and incubation life stages within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Metals (continued)																	
Cadmium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**1180**	ND	**4.76**	ND	ND	ND	**1180**
Chromium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**2290**	**5.00**	**4.63**	ND	ND	ND	**2290**
Cobalt, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**50.0**	1.00	0.420	ND	ND	ND	**50.0**
Copper, total	ND	ND	ND	ND	**5.50**	ND	ND	ND	ND	ND	**41.3**	0.500	**1.13**	ND	ND	ND	**41.3**
Iron, total	ND	ND	ND	ND	**3.67**	ND	ND	ND	ND	ND	**49.7**	**8.70**	**9.63**	**1.17**	ND	ND	**49.7**
Lead, total	ND	ND	ND	ND	0.500	ND	ND	ND	ND	ND	**9.10**	0.500	0.214	ND	ND	ND	**9.10**
Manganese, total	ND	ND	ND	ND	0.0106	ND	ND	ND	ND	ND	0.484	ND	0.0405	0.0278	ND	ND	0.484
Mercury, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**102000**	ND	ND	ND	ND	ND	**102000**
Molybdenum, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.411	0.0274	0.0148	0.137	ND	ND	0.411
Nickel, total	ND	ND	ND	ND	0.154	ND	ND	ND	ND	ND	0.800	ND	0.0696	ND	ND	ND	0.800
Selenium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**80.0**	ND	0.460	ND	ND	ND	**80.0**
Silver, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**757**	0.500	0.370	ND	ND	ND	**757**
Other																	
Cyanide (WAD)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.400	ND	ND	ND	ND	ND	0.400
Phenols	ND	ND	ND	ND	1.00	ND	ND	ND	ND	ND	1.00	ND	ND	ND	ND	ND	1.00

ND = no data; WAD = weak acid dissociable; TSS = total suspended solids.

[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Bolded values indicate hazard quotients >1.0.

Table 4.46. Summary of hazards posed to sockeye salmon exposed to surface water during the juvenile rearing life stage within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals																	
pH[1]	ND	ND	0	ND	0	ND	ND	ND	**1.07**	ND	**1.16**	**1.02**	ND	0	0	ND	**1.16**
Residue Non-filterable (TSS)	ND	ND	0.520	ND	0.840	ND	ND	ND	ND	ND	**3.40**	**1.04**	ND	0.100	0.160	ND	**3.40**
Turbidity	ND	ND	**3.10**	ND	**8.00**	ND	ND	ND	**12.0**	ND	**6.55**	**10.5**	ND	0.400	0.700	ND	**12.0**
Nutrients																	
Ammonia, dissolved	ND	ND	0.00878	ND	0.0409	ND	ND	ND	0.0332	ND	0.633	ND	ND	ND	ND	ND	0.633
Nitrate (NO_3), dissolved	ND	ND	ND	ND	0.0241	ND	ND	ND	0.0552	ND	0.0579	0.0483	0.0517	0.0231	0.0438	ND	0.0579
Nitrogen-Nitrite, dissolved (NO_2)	ND	ND	0.0833	ND	0.0417	ND	ND	ND	0.0833	ND	0.483	0.0500	0.150	0.0417	0.0500	ND	0.483
Phosphorus, total (lake)	ND	ND	ND	ND	**5.00**	ND	ND	ND	**5.60**	ND	**7.60**	ND	**5.00**	**3.33**	**5.00**	ND	**7.60**
Phosphorus, total (stream)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**10.6**	**4.80**	ND	ND	ND	ND	**10.6**
Major Ions																	
Chloride, dissolved	ND	ND	ND	ND	0.0152	ND	ND	ND	0.0435	ND	0.0609	ND	ND	0.00304	ND	ND	0.0609
Fluoride, total	ND	ND	ND	ND	ND	ND	ND	ND	1.00	ND	0.250	ND	ND	0.250	ND	ND	1.00
Sulfate, dissolved	ND	ND	ND	ND	0.246	ND	ND	ND	0.117	ND	0.227	0.0950	ND	0.0610	ND	ND	0.246
Metals																	
Aluminum, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**27.5**	**34.9**	ND	0.300	ND	ND	**34.9**
Arsenic, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.500	0.200	ND	0.120	ND	ND	0.500
Boron, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.250	0.0633	ND	0.0208	ND	ND	0.250

Table 4.46. Summary of hazards posed to sockeye salmon exposed to surface water during the juvenile rearing life stage within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Metals (continued)																	
Cadmium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**1180**	ND	ND	**29.4**	ND	ND	**1180**
Chromium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**50.0**	**5.00**	ND	**9.00**	ND	ND	**50.0**
Cobalt, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**50.0**	1.00	ND	**1.50**	ND	ND	**50.0**
Copper, total	ND	ND	ND	ND	**5.50**	ND	ND	ND	ND	ND	**2.50**	0.500	ND	**1.05**	ND	ND	**5.50**
Iron, total	ND	ND	ND	ND	**3.67**	ND	ND	ND	ND	ND	**2.67**	**8.70**	ND	0.370	ND	ND	**8.70**
Lead, total	ND	ND	ND	ND	0.500	ND	ND	ND	ND	ND	**5.00**	0.500	ND	**90.0**	ND	ND	**90.0**
Manganese, total	ND	ND	ND	ND	0.0106	ND	ND	ND	ND	ND	0.0403	ND	ND	0.00978	ND	ND	0.0403
Mercury, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**4.00**	ND	ND	ND	ND	ND	**4.00**
Molybdenum, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.137	0.0274	ND	0.196	ND	ND	0.196
Nickel, total	ND	ND	ND	ND	0.154	ND	ND	ND	ND	ND	0.400	ND	ND	0.400	ND	ND	0.400
Selenium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.300	ND	ND	1.00	ND	ND	1.00
Silver, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**3.10**	0.500	ND	0.100	ND	ND	**3.10**
Other																	
Phenols	ND	ND	ND	ND	1.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.00

ND = no data; WAD = weak acid dissociable; TSS = total suspended solids.

[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Bolded values indicate hazard quotients >1.0.

Table 4.47. Summary of hazards posed to sockeye salmon exposed to surface water during the smolt outmigration life stage within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals																	
pH[1]	**1.05**	0	0	ND	0	0	ND	ND	0	0	0	**1.08**	0	**1.13**	ND	0	**1.13**
Residue Non-filterable (TSS)	**26.6**	**26.4**	**1.52**	ND	**2.32**	0.560	ND	ND	**25.9**	**4.16**	**2.92**	**2.92**	**6.64**	**58.8**	ND	0.400	**58.8**
Turbidity	**73.5**	**125**	**11.5**	ND	**16.8**	**14.0**	ND	ND	**160**	**8.50**	**3.70**	**23.7**	**18.0**	**128**	ND	**3.15**	**160**
Nutrients																	
Ammonia, dissolved	0.0143	0.0319	0.00418	ND	ND	0.00784	ND	ND	0.172	0.258	0.0121	ND	0.0260	0.163	ND	ND	0.258
Nitrate (NO_3), dissolved	0.0572	0.0876	ND	ND	**1.36**	0.0345	ND	ND	0.0414	0.0252	0.0324	ND	ND	0.0138	ND	0.0324	**1.36**
Nitrogen-Nitrite, dissolved (NO_2)	0.517	0.100	0.0417	ND	**3.95**	0.0417	ND	ND	0.150	0.100	**1.17**	ND	0.0417	0.0833	ND	0.367	**3.95**
Phosphorus, total (lake)	ND	ND	ND	ND	ND	ND	ND	ND	**5.53**	ND	ND	ND	ND	ND	ND	ND	**5.53**
Phosphorus, total (stream)	**155**	**228**	ND	ND	**63.2**	**7.80**	ND	ND	**119**	**19.0**	**12.6**	**30.4**	0.600	**264**	ND	**4.00**	**264**
Major Ions																	
Chloride, dissolved	0.0104	0.0478	ND	ND	0.0735	0.00304	ND	ND	0.0183	0.0109	0.0287	ND	0.00739	0.0426	ND	0.0739	0.0739
Fluoride, total	0.233	0.333	ND	ND	ND	ND	ND	ND	0.500	0.850	0.300	ND	ND	0.800	ND	0.267	0.850
Sulfate, dissolved	0.0760	0.0870	ND	ND	0.240	0.0640	ND	ND	0.240	0.131	0.450	0.0750	0.440	0.0600	ND	0.190	0.450
Metals																	
Aluminum, total	**91.7**	**127**	**12.0**	ND	**3.63**	ND	ND	ND	**27.1**	**17.7**	**12.4**	**14.6**	**9.93**	**53.2**	ND	**2.18**	**127**
Arsenic, total	0.760	**1.34**	ND	ND	0.264	ND	ND	ND	**8.00**	0.0200	ND	0.160	**1.18**	0.240	ND	0.220	**8.00**

Table 4.47. Summary of hazards posed to sockeye salmon exposed to surface water during the smolt outmigration life stage within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Metals (continued)																	
Boron, total	0.00342	0.00250	ND	ND	0.0382	ND	ND	ND	0.0500	0.0667	0.0167	0.0117	0.667	0.00850	ND	0.00125	0.667
Cadmium, total	**94.1**	**112**	ND	ND	0.706	ND	ND	ND	ND	**412**	**471**	**2.35**	**25.3**	**64.7**	ND	**64.7**	**471**
Chromium, total	**15.1**	**30**	ND	ND	**12.2**	ND	ND	ND	**12.0**	**12.0**	**21.0**	0.700	**1.40**	**10.0**	ND	**8.80**	**30.0**
Cobalt, total	**1.73**	**2.43**	ND	ND	0.835	ND	ND	ND	1.00	**5.75**	**4.75**	0.320	0.500	0.450	ND	0.150	**5.75**
Copper, total	**47.8**	**53.8**	ND	ND	0.693	**1.50**	ND	ND	**10.0**	**4.00**	**9.00**	**5.50**	**4.50**	**27.3**	ND	**60.8**	**60.8**
Iron, total	**93.3**	**147**	**5.23**	ND	**8.83**	**1.67**	ND	ND	**13.7**	**8.77**	**3.93**	**2.55**	**4.73**	**12.0**	ND	**2.05**	**147**
Lead, total	**8.00**	**9.30**	ND	ND	0.0528	**2.00**	ND	ND	**2.00**	**60.0**	ND	**6.00**	0.500	**3.50**	ND	**1.10**	**60.0**
Manganese, total	0.425	0.606	ND	ND	0.127	0.0722	ND	ND	0.0133	0.0582	0.0346	0.0911	0.0501	0.143	ND	0.0197	0.606
Mercury, total	**4000**	**4550**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**1500**	ND	**1050**	**4550**
Molybdenum, total	0.0685	0.274	0.0685	ND	0.00912	ND	ND	ND	0.137	0.219	0.274	0.0186	0.233	0.959	ND	0.00274	0.959
Nickel, total	0.856	**1.14**	ND	ND	0.685	0.400	ND	ND	ND	0.400	**4.00**	0.108	**28.0**	0.244	ND	0.116	**28.0**
Selenium, total	0.600	0.600	ND	ND	0.200	ND	ND	ND	0.100	0.100	ND	0.200	**1.80**	0.400	ND	0.300	**1.80**
Silver, total	**22.0**	1.00	ND	ND	0.0500	ND	ND	ND	ND	ND	ND	0.100	0.500	**403**	ND	1.00	**403**
Chlorophenols																	
Dichlorophenols	0.0125	0.0125	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0125
Monochlorophenols	0.00357	0.00357	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00357
Pentachlorophenol	0.0500	0.0500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0500
Tetrachlorophenols	0.0250	0.0250	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0250
Trichlorophenols	0.00139	0.00139	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00139

Table 4.47. Summary of hazards posed to sockeye salmon exposed to surface water during the smolt outmigration life stage within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Other																	
Cyanide (WAD)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.500	ND	ND	ND	0.500
Phenols	ND	**2.50**	ND	ND	ND	ND	ND	ND	0.500	ND	0.250	ND	ND	**1.50**	ND	ND	**2.50**

ND = no data; WAD = weak acid dissociable; TSS = total suspended solids.

[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Bolded values indicate hazard quotients >1.0.

Table 4.48. Summary of hazards posed to sockeye salmon exposed to surface water during the adult upstream migration life stage within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals																	
pH[1]	**3.42**	**1.12**	0	ND	0	0	ND	ND	0	**1.07**	**1.07**	**1.08**	0	**1.06**	ND	0	**3.42**
Residue Non-filterable (TSS)	**12.1**	**26.4**	**6.16**	ND	**2.04**	0.560	ND	ND	**10.4**	**2.56**	**2.92**	**2.92**	**18.2**	**1.20**	ND	0.840	**26.4**
Turbidity	**195**	**178**	**19.0**	ND	**90.0**	**1.65**	ND	ND	**42.0**	**11.0**	**3.30**	**23.7**	**26.0**	**15.0**	ND	**11.1**	**195**
Nutrients																	
Ammonia, dissolved	0.610	0.0384	0.0352	ND	0.0515	0.00856	ND	ND	0.533	0.0954	0.126	ND	0.0260	0.225	ND	ND	0.610
Nitrate (NO_3), dissolved	0.0369	0.0414	ND	ND	**1.45**	0.0345	ND	ND	0.0379	0.0276	0.0324	ND	0.0310	0.0345	ND	0.0293	**1.45**
Nitrogen-Nitrite, dissolved (NO_2)	0.667	0.150	0.100	ND	**3.95**	0.300	ND	ND	0.150	0.100	0.0833	0.0417	0.0417	0.233	ND	0.367	**3.95**
Phosphorus, total (lake)	ND	ND	ND	ND	ND	ND	ND	ND	**53.3**	ND	ND	ND	ND	ND	ND	ND	**53.3**
Phosphorus, total (stream)	**90.6**	**228**	ND	ND	**38.0**	**3.20**	ND	ND	**87.4**	**14.4**	**12.6**	**30.4**	**2.00**	**42.2**	ND	**20.6**	**228**
Major Ions																	
Chloride, dissolved	0.0148	**2.59**	ND	ND	0.0783	0.00435	ND	ND	0.0326	0.0174	0.0287	0.00261	0.0113	0.0426	ND	0.0739	**2.59**
Fluoride, total	0.350	0.233	ND	ND	ND	ND	ND	ND	0.950	0.900	0.300	ND	ND	0.800	ND	0.333	0.950
Sulfate, dissolved	0.140	0.145	ND	ND	0.300	0.106	ND	ND	0.990	0.330	0.450	0.195	**3.20**	0.0700	ND	0.190	**3.20**
Metals																	
Aluminum, total	**181**	**114**	**18.2**	ND	**2.50**	ND	ND	ND	**14.2**	**17.7**	**6.90**	**14.6**	**67.8**	**53.2**	ND	**5.22**	**181**
Arsenic, total	0.418	**1.34**	ND	ND	0.256	0.500	ND	ND	**8.00**	0.500	0.500	0.160	0.200	0.300	ND	0.440	**8.00**

Table 4.48. Summary of hazards posed to sockeye salmon exposed to surface water during the adult upstream migration life stage within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Metals (continued)																	
Boron, total	0.0825	0.00367	ND	ND	0.0717	ND	ND	ND	0.0167	0.0167	0.0583	0.0117	**1.85**	0.00350	ND	0.00117	**1.85**
Cadmium, total	**82.4**	**159**	ND	ND	0.647	ND	ND	ND	**58.8**	**588**	**412**	**2.35**	**23.5**	**118**	ND	**235**	**588**
Chromium, total	**44.0**	**19.1**	ND	ND	**24.0**	ND	ND	ND	**27.0**	**20.0**	**40.0**	0.700	**8.00**	**20.7**	ND	**16.9**	**44.0**
Cobalt, total	**2.29**	**2.60**	ND	ND	0.375	ND	ND	ND	**2.00**	**3.25**	**3.50**	0.320	0.375	0.200	ND	0.300	**3.50**
Copper, total	**79.5**	**59.0**	ND	ND	0.400	**1.50**	ND	ND	**10.0**	**10.5**	**9.00**	**5.50**	**12.0**	**365**	ND	**54.0**	**365**
Iron, total	**54.7**	**147**	**8.43**	ND	**5.53**	**1.67**	ND	ND	**6.93**	**7.63**	**2.73**	**2.55**	**37.7**	**4.90**	ND	**2.53**	**147**
Lead, total	**8.00**	**8.10**	ND	ND	0.114	**2.00**	ND	ND	**2.00**	**60.0**	**60.0**	**6.00**	0.500	**18.8**	ND	**2.80**	**60.0**
Manganese, total	0.410	0.606	ND	ND	0.0787	0.0289	ND	ND	0.0136	0.0645	0.0431	0.0911	0.322	0.0950	ND	0.0360	0.606
Mercury, total	**2000**	**4550**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**7250**	**26500**	ND	**2500**	**26500**
Molybdenum, total	0.411	0.274	0.0685	ND	0.0274	0.00822	ND	ND	0.685	0.274	0.137	0.0186	0.425	0.959	ND	0.00685	0.959
Nickel, total	**1.32**	0.880	ND	ND	0.235	0.200	ND	ND	0.200	0.400	**4.00**	0.108	0.280	**3.60**	ND	0.172	**4.00**
Selenium, total	0.400	0.600	ND	ND	0.240	ND	ND	ND	0.100	**60.0**	**60.0**	0.200	0.800	**1.20**	ND	0.970	**60.0**
Silver, total	**7.00**	**8.00**	ND	ND	0.0300	ND	ND	ND	ND	ND	ND	0.100	0.500	**403**	ND	**6.00**	**403**
Chlorophenols																	
Dichlorophenols	0.0125	0.0125	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0125
Monochlorophenols	0.00357	0.00357	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00357
Pentachlorophenol	0.0500	0.0500	0.100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.100
Tetrachlorophenols	0.0250	0.0250	0.0500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0500
Trichlorophenols	0.00139	0.00139	0.00278	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00278

Table 4.48. Summary of hazards posed to sockeye salmon exposed to surface water during the adult upstream migration life stage within the Fraser River Basin (maximum hazard quotients are reported for each chemical of potential concern).

Chemical of Potential Concern	Area of Interest																
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Other																	
Cyanide (WAD)	ND	0.0500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.500	ND	ND	ND	0.500
Phenols	ND	**2.50**	ND	ND	ND	ND	ND	ND	**3.50**	ND	0.500	ND	ND	**4.50**	ND	ND	**4.50**

ND = no data; WAD = weak acid dissociable; TSS = total suspended solids.

[1] For pH, a reported maximum hazard quotient of zero indicates that no measurements were outside the TSV range (i.e., all pH measurements were between 6.5 and 9.0).

Bolded values indicate hazard quotients >1.0.

Table 4.49. Summary of hazards posed to sockeye salmon exposed to surface water within the Fraser River Basin.

Chemical of Potential Concern	Maximum Hazard Quotient				
	Spawning & Incubation	Juvenile Rearing	Smolt Outmigration	Adult Upstream Migration	All Life Stages
Conventionals					
pH	**1.16**	**1.16**	**1.13**	**3.42**	**3.42**
Residue Non-filterable (TSS)	**32.0**	**3.40**	**58.8**	**26.4**	**58.8**
Turbidity	**100**	**12.0**	**160**	**195**	**195**
Nutrients					
Ammonia, dissolved	0.578	0.633	0.258	0.610	0.633
Nitrate (NO_3), dissolved	0.152	0.0579	**1.36**	**1.45**	**1.45**
Nitrogen-Nitrite, dissolved (NO_2)	0.700	0.483	**3.95**	**3.95**	**3.95**
Phosphorus, total (lake)	**7.60**	**7.60**	**5.53**	**53.3**	**53.3**
Phosphorus, total (stream)	**212**	**10.6**	**264**	**228**	**264**
Major Ions					
Chloride, dissolved	0.0826	0.0609	0.0739	**2.59**	**2.59**
Fluoride, total	**1.17**	1.00	0.850	0.950	**1.17**
Sulfate, dissolved	0.731	0.246	0.450	**3.20**	**3.20**
Metals					
Aluminum, total	**92.1**	**34.9**	**127**	**181**	**181**
Arsenic, total	**10.0**	0.500	**8.00**	**8.00**	**10.0**
Boron, total	**1.33**	0.250	0.667	**1.85**	**1.85**
Cadmium, total	**1180**	**1180**	**471**	**588**	**1180**
Chromium, total	**2290**	**50.0**	**30.0**	**44.0**	**2290**
Cobalt, total	**50.0**	**50.0**	**5.75**	**3.50**	**50.0**
Copper, total	**41.3**	**5.50**	**60.8**	**365**	**365**
Iron, total	**49.7**	**8.70**	**147**	**147**	**147**
Lead, total	**9.10**	**90.0**	**60.0**	**60.0**	**90.0**
Manganese, total	0.484	0.0403	0.606	0.606	0.606

Table 4.49. Summary of hazards posed to sockeye salmon exposed to surface water within the Fraser River Basin.

Chemical of Potential Concern	Maximum Hazard Quotient				
	Spawning & Incubation	Juvenile Rearing	Smolt Outmigration	Adult Upstream Migration	All Life Stages
Metals (continued)					
Mercury, total	**102000**	**4.00**	**4550**	**26500**	**102000**
Molybdenum, total	0.411	0.196	0.959	0.959	0.959
Nickel, total	0.800	0.400	**28.0**	**4.00**	**28.0**
Selenium, total	**80.0**	1.00	**1.80**	**60.0**	**80.0**
Silver, total	**757**	**3.10**	**403**	**403**	**757**
Chlorophenols					
Dichlorophenols	ND	ND	0.0125	0.0125	0.0125
Monochlorophenols	ND	ND	0.00357	0.00357	0.00357
Pentachlorophenol	ND	ND	0.0500	0.100	0.100
Tetrachlorophenols	ND	ND	0.0250	0.0500	0.0500
Trichlorophenols	ND	ND	0.00139	0.00278	0.00278
Other					
Phenols	1.00	1.00	**2.50**	**4.50**	**4.50**
Cyanide (WAD)	0.400	ND	0.500	0.500	0.500

ND = no data; WAD = weak acid dissociable; TSS = total suspended solids.
Bolded values indicate hazard quotients >1.0.

Table 4.50. Summary of water quality conditions in the Fraser River basin, showing the number of chemicals of potential concern (COPCs) with one or more exceedances of water quality guidelines.

Area of Interest	Number of COPCs with One or More Exceedances (Total Number of COPCs with One or More Usable Measurements)							
	Spawning & Incubation		Juvenile Rearing		Smolt Outmigration		Adult Upstream Migration	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Lower Fraser	0 (0)	0 (0)	0 (0)	0 (0)	**10 (20)**	**13 (30)**	**11 (20)**	**14 (30)**
Upper Fraser	0 (0)	0 (0)	0 (0)	0 (0)	**13 (23)**	**12 (30)**	**14 (23)**	**13 (31)**
Pitt River	0 (0)	0 (0)	0 (1)	**1 (5)**	**4 (8)**	0 (0)	**4 (11)**	**2 (7)**
Harrison River	***No Data Available***							
Cultus Lake	**4 (15)**	**1 (2)**	**4 (15)**	**1 (2)**	0 (0)	**8 (22)**	0 (1)	**8 (23)**
Kakawa Lake	0 (0)	0 (0)	0 (0)	0 (0)	**5 (14)**	0 (0)	**5 (16)**	0 (0)
Nahatlatch	***No Data Available***							
Seton-Portage	***No Data Available***							
Lower Thompson River	0 (0)	0 (0)	0 (0)	**3 (9)**	**9 (21)**	**8 (17)**	**11 (24)**	**10 (21)**
North Thompson River	0 (0)	**2 (6)**	0 (0)	0 (0)	**6 (17)**	**10 (21)**	**9 (22)**	**11 (22)**
South Thompson River	**15 (25)**	**18 (27)**	**13 (23)**	**5 (25)**	**5 (13)**	**10 (20)**	**6 (19)**	**12 (22)**
Chilko River	**3 (11)**	**5 (13)**	**4 (11)**	**5 (13)**	**5 (7)**	**7 (19)**	**5 (10)**	**8 (21)**
Quesnel River	0 (0)	**8 (22)**	0 (0)	**1 (3)**	0 (4)	**10 (21)**	**1 (14)**	**10 (22)**
Nechako River	**5 (13)**	**1 (8)**	0 (0)	**6 (23)**	**10 (24)**	**13 (26)**	**11 (24)**	**13 (26)**
Bowron River	0 (0)	0 (0)	0 (0)	**1 (6)**	0 (0)	0 (0)	0 (0)	0 (0)
Reference	0 (0)	0 (0)	0 (0)	0 (0)	**8 (19)**	**7 (24)**	**9 (19)**	**9 (24)**
Fraser River Basin	**15 (25)**	**18 (27)**	**13 (24)**	**13 (25)**	**16 (25)**	**20 (33)**	**16 (28)**	**22 (33)**

Pre-1990 includes 1990.
Bolded values indicate hazard quotients >1.0.

Table 4.51. Evaluation of potential hazards posed to sockeye salmon exposed to sediments within various areas of interest in the Fraser River Basin (maximum hazard quotients were reported for each chemical of potential concern).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Lower Fraser River		Harrison/Lillooet River		Lower Thompson River		South Thompson River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (mg/kg)								
Arsenic	0.82	1.02	ND	ND	ND	ND	ND	ND
Cadmium	0.32	**2.02**	ND	ND	ND	ND	ND	ND
Chromium	**1.25**	**1.42**	0.60	ND	ND	ND	0.94	ND
Copper	**1.40**	**1.65**	**1.99**	ND	ND	ND	**1.30**	ND
Iron	**1.75**	**2.21**	**1.54**	ND	ND	ND	**1.80**	ND
Lead	0.84	**1.03**	0.87	ND	ND	ND	0.14	ND
Mercury	0.50	0.43	0.14	ND	0.33	ND	0.39	ND
Nickel	**2.43**	**2.51**	**1.01**	ND	ND	ND	**2.69**	ND
Selenium	ND	0.30	ND	ND	ND	ND	ND	ND
Silver	ND	0.44	ND	ND	ND	ND	ND	ND
Zinc	0.88	0.98	0.81	ND	ND	ND	0.90	ND
Pesticides (mg/kg)								
Aldrin	0.25	0.38	ND	ND	ND	ND	ND	ND
Chlordane (total)	0.31	0.15	ND	ND	ND	ND	ND	ND
Dieldrin	0.26	0.13	ND	ND	ND	ND	ND	ND
Endosulfan A	0.17	0.09	ND	ND	ND	ND	ND	ND
Endosulfan B	0.04	0.02	ND	ND	ND	ND	ND	ND
Endrin	0.11	0.11	ND	ND	ND	ND	ND	ND
Heptachlor epoxide	ND	0.10	ND	ND	ND	ND	ND	ND
Lindane	0.21	0.11	ND	ND	ND	ND	ND	ND
Methoxychlor	0.13	0.13	ND	ND	ND	ND	ND	ND
Sum DDD	0.10	0.10	ND	ND	ND	ND	ND	ND
Sum DDE	0.16	0.16	ND	ND	ND	ND	ND	ND
Sum DDT	0.72	0.14	ND	ND	ND	ND	ND	ND

Table 4.51. Evaluation of potential hazards posed to sockeye salmon exposed to sediments within various areas of interest in the Fraser River Basin (maximum hazard quotients were reported for each chemical of potential concern).

Chemical of Potential Concern	Maximum Hazard Quotient							
	Lower Fraser River		Harrison/Lillooet River		Lower Thompson River		South Thompson River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Plastics-Related Chemicals (mg/kg)								
Bis (2-ethylhexyl) phthalate	**7.91**	ND	ND	ND	ND	ND	ND	ND
Diethyl phthalate	0.19	ND	ND	ND	ND	ND	ND	ND
Polychlorinated Biphenyls (PCBs; mg/kg)								
PCBs (total)	0.25	0.25	ND	ND	ND	ND	ND	ND
Polycyclic Aromatic Hydrocarbons (mg/kg)								
Acenaphthene	0.37	**1.49**	ND	ND	ND	ND	ND	ND
Acenaphthylene	0.85	0.65	ND	ND	ND	ND	ND	ND
Anthracene	0.04	0.68	ND	ND	ND	ND	ND	ND
Benz(a)anthracene	**1.11**	0.80	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	0.67	0.43	ND	ND	ND	ND	ND	ND
Chrysene	0.03	0.84	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	**11.21**	0.30	ND	ND	ND	ND	ND	ND
Fluoranthene	0.20	0.28	ND	ND	ND	ND	ND	ND
Fluorene	0.06	0.30	ND	ND	ND	ND	ND	ND
Naphthalene	0.74	0.08	ND	ND	ND	ND	ND	ND
Phenanthrene	0.01	0.74	ND	ND	ND	ND	ND	ND
Pyrene	0.03	0.67	ND	ND	ND	ND	ND	ND

ND = no data
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
Chemicals of potential concern with hazard quotients > 1.0 were identified as contaminants of concern.

Table 4.52. Frequency of exceedance of the selected toxicity screening values for sediment in each area of interest in the Fraser River Basin.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Lower Fraser River		Harrison/Lillooet River		Lower Thompson River		South Thompson River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (mg/kg)								
Arsenic	0% (10)	3% (29)	ND	ND	ND	ND	ND	ND
Cadmium	0% (10)	3% (29)	ND	ND	ND	ND	ND	ND
Chromium	33% (30)	68% (28)	0% (1)	ND	ND	ND	0% (1)	ND
Copper	67% (30)	68% (28)	100% (1)	ND	ND	ND	100% (1)	ND
Iron	67% (30)	100% (28)	100% (1)	ND	ND	ND	100% (1)	ND
Lead	0% (30)	3% (29)	0% (1)	ND	ND	ND	0% (1)	ND
Mercury	0% (30)	0% (24)	0% (1)	ND	0% (1)	ND	0% (1)	ND
Nickel	100% (30)	100% (28)	100% (1)	ND	ND	ND	100% (1)	ND
Selenium	ND	0% (4)	ND	ND	ND	ND	ND	ND
Silver	ND	0% (25)	ND	ND	ND	ND	ND	ND
Zinc	0% (30)	0% (28)	0% (1)	ND	ND	ND	0% (1)	ND
Pesticides (mg/kg)								
Aldrin	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Chlordane (total)	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Dieldrin	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Endosulfan A	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Endosulfan B	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Endrin	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Heptachlor epoxide	ND	0% (21)	ND	ND	ND	ND	ND	ND
Lindane	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Methoxychlor	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Sum DDD	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Sum DDE	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Sum DDT	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND

Table 4.52. Frequency of exceedance of the selected toxicity screening values for sediment in each area of interest in the Fraser River Basin.

Chemical of Potential Concern	Frequency of Exceedance of Toxicity Screening Values (total number of samples)							
	Lower Fraser River		Harrison/Lillooet River		Lower Thompson River		South Thompson River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Plastics-Related Chemicals (mg/kg)								
Bis (2-ethylhexyl) phthalate	70% (10)	ND	ND	ND	ND	ND	ND	ND
Diethyl phthalate	0% (10)	ND	ND	ND	ND	ND	ND	ND
Polychlorinated Biphenyls (PCBs; mg/kg)								
PCBs (total)	0% (32)	0% (42)	ND	ND	ND	ND	ND	ND
Polycyclic Aromatic Hydrocarbons (mg/kg)								
Acenaphthene	0% (10)	5% (21)	ND	ND	ND	ND	ND	ND
Acenaphthylene	0% (10)	0% (21)	ND	ND	ND	ND	ND	ND
Anthracene	0% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Benz(a)anthracene	10% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	0% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Chrysene	0% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	40% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Fluoranthene	0% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Fluorene	0% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Naphthalene	0% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Phenanthrene	0% (10)	0% (27)	ND	ND	ND	ND	ND	ND
Pyrene	0% (10)	0% (27)	ND	ND	ND	ND	ND	ND

ND = no data
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
Chemicals of potential concern with hazard quotients > 1.0 were identified as contaminants of concern.

Table 4.53. Identification of contaminants of concern in sediments for the various areas of interest in the Fraser River Basin (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon; shown in bold).

Chemical of Potential Concern	Area of Interest				Fraser River Basin
	Lower Fraser River	Harrison/Lillooet	Lower Thompson	South Thompson	
Metals (mg/kg)					
Arsenic	**1.02**	ND	ND	ND	**1.02**
Cadmium	**2.02**	ND	ND	ND	**2.02**
Chromium	**1.42**	0.60	ND	0.94	**1.42**
Copper	**1.65**	**1.99**	ND	**1.30**	**1.99**
Iron	**2.21**	**1.54**	ND	**1.80**	**2.21**
Lead	**1.03**	0.87	ND	0.14	**1.03**
Mercury	0.50	0.14	0.33	0.39	0.50
Nickel	**2.51**	**1.01**	ND	**2.69**	**2.69**
Selenium	0.30	ND	ND	ND	0.30
Silver	0.44	ND	ND	ND	0.44
Zinc	0.98	0.81	ND	0.90	0.98
Pesticides (mg/kg)					
Aldrin	0.38	ND	ND	ND	0.38
Chlordane (total)	0.31	ND	ND	ND	0.31
Dieldrin	0.26	ND	ND	ND	0.26
Endosulfan A	0.17	ND	ND	ND	0.17
Endosulfan B	0.04	ND	ND	ND	0.04
Endrin	0.11	ND	ND	ND	0.11
Heptachlor epoxide	0.10	ND	ND	ND	0.10
Lindane	0.21	ND	ND	ND	0.21
Methoxychlor	0.13	ND	ND	ND	0.13
Sum DDD	0.10	ND	ND	ND	0.10
Sum DDE	0.16	ND	ND	ND	0.16
Sum DDT	0.72	ND	ND	ND	0.72

Table 4.53. Identification of contaminants of concern in sediments for the various areas of interest in the Fraser River Basin (hazard quotients >1.0 were used to identify contaminants that pose potential hazards to sockeye salmon; shown in bold).

Chemical of Potential Concern	Area of Interest				Fraser River Basin
	Lower Fraser River	Harrison/Lillooet	Lower Thompson	South Thompson	
Plastics-Related Chemicals (mg/kg)					
Bis (2-ethylhexyl) phthalate	**7.91**	ND	ND	ND	**7.91**
Diethyl phthalate	0.19	ND	ND	ND	0.19
Polychlorinated Biphenyls (PCBs; mg/kg)					
PCBs (total)	0.25	ND	ND	ND	0.25
Polycyclic Aromatic Hydrocarbons (mg/kg)					
Acenaphthene	**1.49**	ND	ND	ND	**1.49**
Acenaphthylene	0.85	ND	ND	ND	0.85
Anthracene	0.68	ND	ND	ND	0.68
Benz(a)anthracene	**1.11**	ND	ND	ND	**1.11**
Benzo(a)pyrene	0.67	ND	ND	ND	0.67
Chrysene	0.84	ND	ND	ND	0.84
Dibenz(a,h)anthracene	**11.21**	ND	ND	ND	**11.21**
Fluoranthene	0.28	ND	ND	ND	0.28
Fluorene	0.30	ND	ND	ND	0.30
Naphthalene	0.74	ND	ND	ND	0.74
Phenanthrene	0.74	ND	ND	ND	0.74
Pyrene	0.67	ND	ND	ND	0.67

ND = no data
Bolded values indicate hazard quotients >1.0.
Pre-1990 includes 1990.
Chemicals of potential concern with hazard quotients > 1.0 were identified as contaminants of concern.

Table 5.1. Selected toxicity reference values (TRV) for evaluating the potential effects on sockeye salmon associated with exposure to contaminants of concern in surface water.

Contaminant of Concern	Selected TRV	Units	Hardness Range (mg/L of CaCO3)	Description of Procedure for Deriving the Toxicity Reference Value (TRV)	Reference
Conventionals					
Residue: Non-filterable (TSS)	25	mg/L	All	No basis for revising the TSV.	BCMOE (2010a)
Nutrients					
Nitrite, dissolved	0.06	mg nitrite-nitrogen/L	All	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)
Major Ions					
Chloride, dissolved	587	mg/L	All	The 54-d EC25 for rainbow trout biomass was divided by two to derive the TRV.	Rescan (2008)
Sulphate, dissolved	500	mg/L	All	The 96-h LC50 for rainbow trout was divided by 10 to derive the TRV.	BCMOE (2010a)
Metals					
Aluminum, total	5	µg/L	All; pH < 6.5	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)
	100	µg/L	All; pH ≥ 6.5	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)
Arsenic, total	55	µg/L	All	The 28-d LC50 for rainbow trout was divided by 10 to derive the TRV.	CCME (1999)
Cadmium, total	Equation[1]	µg/L	All	The intercept for coho salmon was used with the hardness-dependent FCV equation to derive the TRV.	USEPA (2001)
Chromium, total	1	µg/L	All	The Canadian water quality guideline for Cr(VI) was adopted as the TRV.	CCME (1999)
Cobalt, total	47	µg/L	All	The 28-d LC50 for rainbow trout was divided by 10 to derive the TRV.	BCMOE (2010a)
Copper, total	5.5	µg/L	≤ 60 mg/L	Species mean acute value for sockeye salmon was divided by 10 to derive the TRV.	USEPA (2007)

Table 5.1. Selected toxicity reference values (TRV) for evaluating the potential effects on sockeye salmon associated with exposure to contaminants of concern in surface water.

Contaminant of Concern	Selected TRV	Units	Hardness Range (mg/L of CaCO3)	Description of Procedure for Deriving the Toxicity Reference Value (TRV)	Reference
Metals (continued)					
Copper, total (continued)	5.5	µg/L	> 60 to ≤ 120 mg/L	Species mean acute value for sockeye salmon was divided by 10 to derive the TRV.	CCME (1999); USEPA (2007)
	11.0	µg/L	> 120 to ≤ 180 mg/L	TRV for water hardness < 60 mg/L was multiplied by two to derive the TRV.	CCME (1999)
	16.5	µg/L	> 180 mg/L	TRV for water hardness < 60 mg/L was multiplied by three to derive the TRV.	CCME (1999)
Iron, total	300	µg/L	All	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)
Lead, total	7.2	µg/L	≤ 60 mg/L	The 19-month MATC for rainbow trout in soft water was adopted as the TRV.	Davies *et al.* (1976)
	10.9	µg/L	> 60 to ≤ 120 mg/L	TRV interpolated from 19-month MATCs for rainbow trout in soft and hard water.	Davies *et al.* (1976)
	14.5	µg/L	> 120 to ≤ 180 mg/L	TRV interpolated from 19-month MATCs for rainbow trout in soft and hard water.	Davies *et al.* (1976)
	18.2	µg/L	> 180 mg/L	The 19-month MATC for rainbow trout in hard water was adopted as the TRV.	Davies *et al.* (1976)
Mercury, total	0.52	µg/L	All	Chronic toxicity threshold for brook trout was adopted as the TRV.	McKim *et al.* (1976)
Nickel, total	25	µg/L	≤ 60 mg/L	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)
	65	µg/L	> 60 to ≤ 120 mg/L	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)
	110	µg/L	> 120 to ≤ 180 mg/L	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)
	150	µg/L	> 180 mg/L	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)
Selenium, total	1	µg/L	All	No basis for revising the TSV; Generic TSV based on salmonid data.	CCME (1999)

Table 5.1. Selected toxicity reference values (TRV) for evaluating the potential effects on sockeye salmon associated with exposure to contaminants of concern in surface water.

Contaminant of Concern	Selected TRV	Units	Hardness Range (mg/L of CaCO3)	Description of Procedure for Deriving the Toxicity Reference Value (TRV)	Reference
Metals (continued)					
Silver, total	0.1	µg/L	All	No basis for revising the TSV; MATC for sainbow trout similar to TSV.	CCME (1999)
Phenols					
Phenols	7	µg/L	All	The 27-d LC50 for rainbow trout was divided by ten to derive the TRV.	CCME (1999)

d = day; h = hour; EC_{25} = effective concentration affecting 50% of the population; LC_{50} = lethal concentration affection 50% of the population;
TRV = toxicity reference value; FCV = final chronic value; Cr(VI) = chromium six; MATC = maximum acceptable toxicant concentration.
[1]Cadmium TRV = $e^{(0.74099*\ln(\text{hardness}) - 2.6299)}$; Coho Salmon ln(intercept) = -2.6299.

Table 5.2. Selected toxicity reference values (TRVs) for evaluating the potential effects on sockeye salmon associated with exposure to contaminants of concern in sediment.

Contaminant of Concern	Selected TRV			Reference
	TRV	Units (DW)	Type	
Metals				
Arsenic	33	mg/kg	PEC	MacDonald *et al.* 2000a
Cadmium	4.98	mg/kg	PEC	MacDonald *et al.* 2000a
Chromium	111	mg/kg	PEC	MacDonald *et al.* 2000a
Copper	149	mg/kg	PEC	MacDonald *et al.* 2000a
Lead	128	mg/kg	PEC	MacDonald *et al.* 2000a
Mercury	1.06	mg/kg	PEC	MacDonald *et al.* 2000a
Nickel	48.6	mg/kg	PEC	MacDonald *et al.* 2000a
Zinc	459	mg/kg	PEC	MacDonald *et al.* 2000a
Iron	43,766	µg/kg	SEL	Nagpal *et al.* 2006
Selenium	ND	ND	ND	NA
Silver	ND	ND	ND	NA
Pesticides				
Aldrin	80.0	µg/kg	SEL	Nagpal *et al.* 2006
Chlordane (Total)	17.6	µg/kg	PEC	MacDonald *et al.* 2000a
Dieldrin	61.8	µg/kg	PEC	MacDonald *et al.* 2000a
Endosulfan A	ND	ND	ND	NA
Endosulfan B	ND	ND	ND	NA
Endrin	207	µg/kg	PEC	MacDonald *et al.* 2000a
Heptachlor epoxide	16	µg/kg	PEC	MacDonald *et al.* 2000a
Lindane	4.99	µg/kg	PEC	MacDonald *et al.* 2000a
Methoxychlor	ND	ND	ND	NA
Sum DDD	28	µg/kg	PEC	MacDonald *et al.* 2000a
Sum DDE	31.3	µg/kg	PEC	MacDonald *et al.* 2000a
Sum DDT	62.9	µg/kg	PEC	MacDonald *et al.* 2000a
Total DDTs	572	µg/kg	PEC	MacDonald *et al.* 2000a
Toxaphene	ND	ND	ND	NA
Polycyclic Aromatic Hydrocarbons (PAHs)				
Acenapthalyene	128	µg/kg	PEL	CCME 1999
Acenapthene	88.9	µg/kg	PEL	CCME 1999
Anthracene	845	µg/kg	PEC	MacDonald *et al.* 2000a
Benz(a)anthracene	1050	µg/kg	PEC	MacDonald *et al.* 2000a
Benzo(a)pyrene	1450	µg/kg	PEC	MacDonald *et al.* 2000a
Chrysene	1290	µg/kg	PEC	MacDonald *et al.* 2000a
Dibenz(a,h)anthracene	135	µg/kg	PEL	CCME 1999
Fluoranthene	2230	µg/kg	PEC	MacDonald *et al.* 2000a
Fluorene	536	µg/kg	PEC	MacDonald *et al.* 2000a
Napthalene	561	µg/kg	PEC	MacDonald *et al.* 2000a
Phenanthrene	1170	µg/kg	PEC	MacDonald *et al.* 2000a
Pyrene	1520	µg/kg	PEC	MacDonald *et al.* 2000a
Total PAHs	22800	µg/kg	PEC	MacDonald *et al.* 2000a

Table 5.2. Selected toxicity reference values (TRVs) for evaluating the potential effects on sockeye salmon associated with exposure to contaminants of concern in sediment.

Contaminant of Concern	Selected TRV			Reference
	TRV	Units (DW)	Type	
Polychlorinated Biphenyls (PCBs)				
Total PCBs	0.40	µg/kg	PEC	MacDonald *et al.* 2000b
Plastics-Related Chemicals				
Diethyl phthalate	ND	ND	ND	NA
Bis (2-ethylhexyl) phthalate	2647	µg/kg	PEL	MacDonald 1994

DW = dry weight; ND = no data; NA = not applicable; PEL = probable effect level;
PEC = probable effect concentration.

Table 5.3. Exposure point concentrations for contaminants of concern in surface water for spawning and incubation areas within the Fraser River Basin.

Contaminant of Concern	Area of Interest													
	Lower Fraser River	Upper Fraser River	Pitt River	Cultus Lake	Kakawa Lake	Lower Thompson R.	North Thompson R.	South Thompson R.	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals (mg/L)														
Residue: Non-filterable (TSS)	ND	ND	ND	7.10	ND	ND	14.6	88.8	25.0	44.5	58.1	ND	ND	80.6
Nutrients (mg/L)														
Nitrogen - Nitrite, dissolved (NO2)	ND	ND	ND	0.003	ND	ND	ND	0.005	0.003	0.006	0.004	ND	ND	0.005
Major Ions (mg/L)														
Chloride, dissolved	ND	ND	ND	1.52	ND	ND	2.15	4.9	ND	1.25	0.9	ND	ND	4.90
Sulfate, dissolved	ND	ND	ND	23.8	ND	ND	17.5	48.0	9.36	ND	2.68	ND	ND	47.8
Metals (µg/L)														
Aluminum, total	ND	ND	ND	ND	ND	ND	ND	1930	3450	529	180	ND	ND	1940
Arsenic, total	ND	ND	ND	ND	ND	ND	ND	25.0	20.0	0.447	ND	ND	ND	25.0
Cadmium, total	ND	ND	ND	0.250	ND	ND	ND	1.00	ND	0.025	5.00	ND	ND	1.00
Chromium, total	ND	ND	ND	ND	ND	ND	ND	6.48	4.70	1.22	ND	ND	ND	6.18
Cobalt, total	ND	ND	ND	ND	ND	ND	ND	2.50	3.10	0.424	ND	ND	ND	2.50
Copper, total	ND	ND	ND	6.80	ND	ND	ND	9.63	1.00	2.26	ND	ND	ND	9.28
Iron, total	ND	ND	ND	605	ND	ND	ND	2780	2600	744	330	ND	ND	2690
Lead, total	ND	ND	ND	0.875	ND	ND	ND	2.32	0.500	0.213	ND	ND	ND	2.09
Mercury, total	ND	ND	ND	0.025	ND	ND	ND	36.8	ND	ND	ND	ND	ND	36.1
Nickel, total	ND	ND	ND	9.50	ND	ND	ND	5.52	ND	1.70	ND	ND	ND	5.55
Selenium, total	ND	ND	ND	ND	ND	ND	ND	0.900	ND	0.383	ND	ND	ND	0.900
Silver, total	ND	ND	ND	ND	ND	ND	ND	0.200	0.050	0.013	ND	ND	ND	0.135
Other (µg/L)														
Phenols	ND	ND	ND	3.45	ND	ND	ND	3.75	ND	ND	ND	ND	ND	4.00

ND = no data; R. = river.

Table 5.4. Exposure point concentrations for contaminants of concern in surface water for juvenile rearing areas within the Fraser River Basin.

	Area of Interest													
Contaminant of Concern	**Lower Fraser River**	**Upper Fraser River**	**Pitt River**	**Cultus Lake**	**Kakawa Lake**	**Lower Thompson R.**	**North Thompson R.**	**South Thompson R.**	**Chilko River**	**Quesnel River**	**Nechako River**	**Bowron River**	**Reference**	**Fraser River Basin**
Conventionals (mg/L)														
Residue: Non-filterable (TSS)	ND	ND	10	5.30	ND	ND	ND	14.2	25.0	ND	2.50	2.00	ND	12.0
Nutrients (mg/L)														
Nitrogen - Nitrite, dissolved (NO2)	ND	ND	0.0033	0.003	ND	0.0025	ND	0.0025	0.0027	0.003	0.0025	0.003	ND	0.003
Major Ions (mg/L)														
Chloride, dissolved	ND	ND	ND	1.78	ND	1.79	ND	1.30	ND	ND	0.645	ND	ND	1.48
Sulfate, dissolved	ND	ND	ND	23.6	ND	10.6	ND	8.59	9.34	ND	6.05	ND	ND	10.2
Metals (µg/L)														
Aluminum, total	ND	ND	ND	ND	ND	ND	ND	218	3449.5	ND	30.0	ND	ND	1210
Arsenic, total	ND	ND	ND	ND	ND	ND	ND	25.0	20.0	ND	0.600	ND	ND	25.0
Cadmium, total	ND	ND	ND	0.250	ND	ND	ND	3.50	ND	ND	3.00	ND	ND	3.00
Chromium, total	ND	ND	ND	ND	ND	ND	ND	38.0	4.70	ND	9.00	ND	ND	25.6
Cobalt, total	ND	ND	ND	ND	ND	ND	ND	2.65	3.10	ND	3.60	ND	ND	3.00
Copper, total	ND	ND	ND	5.40	ND	ND	ND	2.50	1.00	ND	1.74	ND	ND	2.95
Iron, total	ND	ND	ND	515	ND	ND	ND	208	2600	ND	69.4	ND	ND	948
Lead, total	ND	ND	ND	1.50	ND	ND	ND	1.40	0.500	ND	27.4	ND	ND	3.05
Mercury, total	ND	ND	ND	0.025	ND	ND	ND	0.049	ND	ND	ND	ND	ND	0.047
Nickel, total	ND	ND	ND	9.00	ND	ND	ND	5.00	ND	ND	10.0	ND	ND	10.0
Selenium, total	ND	ND	ND	ND	ND	ND	ND	0.292	ND	ND	0.650	ND	ND	0.500
Silver, total	ND	ND	ND	ND	ND	ND	ND	0.198	0.050	ND	0.010	ND	ND	0.050
Other (µg/L)														
Phenols	ND	ND	ND	3.35	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.35

ND = no data; R. = river.

Table 5.5. Exposure point concentrations for contaminants of concern in surface waters for smolt outmigration routes within the Fraser River Basin.

Contaminant of Concern	Area of Interest													
	Lower Fraser River	Upper Fraser River	Pitt River	Cultus Lake	Kakawa Lake	Lower Thompson R.	North Thompson R.	South Thompson R.	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals (mg/L)														
Residue: Non-filterable (TSS)	454	391	36.2	54.2	13.0	213	77.8	25.2	52.7	116	65.5	ND	10.0	239
Nutrients (mg/L)														
Nitrogen - Nitrite, dissolved (NO2)	0.009	0.005	0.0025	0.060	0.003	0.006	0.003	0.003	ND	0.003	0.005	ND	0.005	0.017
Major Ions (mg/L)														
Chloride, dissolved	1.90	1.85	ND	16.7	0.650	3.25	1.10	1.47	ND	0.580	1.34	ND	0.900	3.10
Sulfate, dissolved	7.10	8.17	ND	22.2	5.62	17.4	8.06	8.32	7.25	28.8	5.28	ND	17.8	17.0
Metals (µg/L)														
Aluminum, total	7090	7624	1140	320	ND	2330	1570	718	1130	660	1590	ND	163	5710
Arsenic, total	1.92	2.80	ND	1.31	ND	33.0	22.3	22.3	0.800	3.35	0.916	ND	0.235	20.0
Cadmium, total	1.41	1.20	ND	0.012	ND	ND	5.80	6.70	0.156	0.265	5.00	ND	0.500	3.00
Chromium, total	11.7	17.1	ND	9.86	ND	11.4	11.8	20.3	0.700	1.20	5.07	ND	2.27	12.0
Cobalt, total	5.20	6.36	ND	2.74	ND	3.40	11.8	11.4	1.27	5.00	1.20	ND	0.4028	5.20
Copper, total	22.1	24.1	ND	1.86	2.85	17.3	7.60	15.8	10.5	5.80	21.6	ND	10.5	20.9
Iron, total	9720	13500	1500	2360	480	3180	2230	928	766	890	2270	ND	203	9470
Lead, total	6.00	6.45	ND	0.205	1.93	1.93	60.0	ND	6.00	0.500	1.70	ND	1.03	5.92
Mercury, total	20.0	38.0	ND	ND	ND	0.025	ND	0.025	ND	0.025	28.5	ND	20.5	30.0
Nickel, total	18.2	20.3	ND	65.6	9.25	ND	10.0	41.5	2.69	143	4.58	ND	3.19	17.3
Selenium, total	0.400	0.300	ND	0.200	ND	0.100	0.100	ND	0.160	1.00	0.200	ND	0.200	0.300
Silver, total	0.100	0.100	ND	0.004	ND	ND	ND	ND	0.010	0.050	0.160	ND	0.100	0.100
Other (µg/L)														
Phenols	ND	8.60	ND	ND	ND	1.80	ND	1.00	ND	ND	5.00	ND	ND	6.90

ND = no data; R. = river.

Table 5.6. Exposure point concentrations for contaminants of concern in surface water for adult upstream migration routes within the Fraser River Basin.

Contaminant of Concern	Area of Interest													
	Lower Fraser River	Upper Fraser River	Pitt River	Cultus Lake	Kakawa Lake	Lower Thompson R.	North Thompson R.	South Thompson R.	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals (mg/L)														
Residue: Non-filterable (TSS)	203	221	81.8	13.3	13.0	128	49.0	18.0	35.3	195	22.7	ND	11.5	125.7
Nutrients (mg/L)														
Nitrogen - Nitrite, dissolved (NO2)	0.010	0.006	0.004	0.047	0.011	0.005	0.003	0.003	0.002	0.003	0.005	ND	0.005	0.024
Major Ions (mg/L)														
Chloride, dissolved	1.90	3.00	ND	17.0	0.850	6.25	1.02	1.54	0.583	2.20	1.10	ND	0.600	5.38
Sulfate, dissolved	10.0	11.0	ND	23.7	10.6	31.8	9.09	9.12	7.48	265	5.30	ND	16.0	20.3
Metals (µg/L)														
Aluminum, total	5250	4560	1540	196	ND	955	1380	546	942	2790	742	ND	290	3820
Arsenic, total	20.0	1.60	ND	20.0	2.50	30.0	21.3	21.3	0.800	5.00	0.680	ND	0.210	20.0
Cadmium, total	5.00	0.965	ND	0.008	0.250	3.00	3.00	5.70	0.103	0.340	5.00	ND	0.425	3.00
Chromium, total	11.4	9.93	ND	4.90	ND	22.8	18.0	33.1	0.700	6.20	2.45	ND	1.85	10.0
Cobalt, total	3.97	4.27	ND	1.50	ND	5.25	10.6	12.3	1.26	5.00	0.552	ND	0.700	4.25
Copper, total	15.9	16.0	ND	1.18	2.40	13.0	14.7	15.3	10.2	5.95	30.0	ND	9.60	16.2
Iron, total	7102	8250	2100	1320	500	1180	1520	640	746	1980	914	ND	401	5310
Lead, total	3.82	5.21	ND	0.433	1.85	1.75	67.0	57.0	6.00	0.500	1.62	ND	0.900	3.61
Mercury, total	34.5	30.0	ND	ND	ND	0.025	0.025	0.025	ND	0.025	30.0	ND	48.6	30.0
Nickel, total	14.2	15.1	ND	24.8	5.00	10.0	10.0	10.0	2.68	7.60	2.95	ND	3.75	11.2
Selenium, total	0.200	0.300	ND	0.231	ND	0.100	57.0	60.0	0.130	0.575	0.200	ND	0.223	0.250
Silver, total	0.100	0.100	ND	0.003	ND	ND	ND	ND	0.010	0.050	0.100	ND	0.100	0.100
Other (µg/L)														
Phenols	ND	6.60	ND	ND	ND	8.50	ND	1.95	ND	ND	6.10	ND	ND	7.15

ND = no data; R. = river.

Table 5.7. Exposure point concentrations for contaminants of concern in sediments for various Areas of Interest (AoIs) of the Fraser River Basin.

Contaminant of Concern	Exposure Point Concentration			
	Lower Fraser River AoI	Harrison River AoI	Lower Thompson River AoI	South Thompson River AoI
Metals (mg/kg)				
Cadmium	0.400	0.500	ND	0.500
Iron	44600	32600	ND	38100
Nickel	56.3	23	ND	61
Plastics-Related Chemicals (mg/kg)				
Bis (2-ethylhexyl) Phthalate	1.34	ND	ND	ND
Polycyclic Aromatic Hydrocarbons (mg/kg)				
Dibenz(a,h)anthracene	0.067	ND	ND	ND

ND = no data

Table 5.8. Exposure point concentrations for contaminants of concern in Weaver and Adams sockeye and Thompson chinook salmon populations in the Lower Fraser River and spawning grounds[1].

Contaminant of Concern	Fraser River Mouth		Spawning Grounds	
	Muscle	Roe	Muscle	Roe
Metals (µg/g)				
Mercury	0.025	0.010	0.063	0.015
Selenium	0.150	2.40	0.770	1.60
Chemical Mixtures				
∑TEQ[2]	13.20	7.58	33.86	4.43

[1] Data obtained from Siska Traditions Society (2009).

[2.] ∑TEQ is calculated as the the sum of the PCB, PCDD, and PCDF TEQ values.

Table 5.9. Hazard quotients of contaminants of concern in surface water for spawning and incubation areas in the Fraser River Basin.

Contaminant of Concern	Area of Interest													
	Lower Fraser River	Upper Fraser River	Pitt River	Cultus Lake	Kakawa Lake	Lower Thompson R.	North Thompson R.	South Thompson R.	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals (mg/L)														
Residue: Non-filterable (TSS)	ND	ND	ND	0.284	ND	ND	0.584	**3.55**	1.00	**1.78**	**2.32**	ND	ND	**3.22**
Nutrients														
Nitrogen - Nitrite, dissolved (NO_2)	ND	ND	ND	0.0417	ND	ND	ND	0.0833	0.0458	0.100	0.0667	ND	ND	0.0833
Major Ions														
Chloride, dissolved	ND	ND	ND	0.00259	ND	ND	0.00366	0.00835	ND	0.00212	0.00153	ND	ND	0.00835
Sulfate, dissolved	ND	ND	ND	0.0477	ND	ND	0.0349	0.0960	0.0187	ND	0.00536	ND	ND	0.0957
Metals														
Aluminum, total	ND	ND	ND	ND	ND	ND	ND	**19.3**	**34.5**	**5.29**	**1.80**	ND	ND	**19.4**
Arsenic, total	ND	ND	ND	ND	ND	ND	ND	0.455	0.364	0.00812	ND	ND	ND	0.455
Cadmium, total	ND	ND	ND	0.000139	ND	ND	ND	0.00109	ND	0.0000229	0.00617	ND	ND	0.00110
Chromium, total	ND	ND	ND	ND	ND	ND	ND	**6.48**	**4.70**	**1.22**	ND	ND	ND	**6.18**
Cobalt, total	ND	ND	ND	ND	ND	ND	ND	0.0532	0.0660	0.00901	ND	ND	ND	0.0532
Copper, total	ND	ND	ND	**1.24**	ND	ND	ND	**1.75**	0.182	0.411	ND	ND	ND	**1.69**
Iron, total	ND	ND	ND	**2.02**	ND	ND	ND	**9.26**	**8.67**	**2.48**	**1.10**	ND	ND	**8.96**
Lead, total	ND	ND	ND	0.0803	ND	ND	ND	0.322	0.0694	0.0296	ND	ND	ND	0.290
Mercury, total	ND	ND	ND	0.0481	ND	ND	ND	**70.9**	ND	ND	ND	ND	ND	**69.5**
Nickel, total	ND	ND	ND	0.146	ND	ND	ND	0.221	ND	0.0682	ND	ND	ND	0.222
Selenium, total	ND	ND	ND	ND	ND	ND	ND	0.900	ND	0.383	ND	ND	ND	0.900
Silver, total	ND	ND	ND	ND	ND	ND	ND	**2.00**	0.500	0.130	ND	ND	ND	**1.35**
Other														
Phenols	ND	ND	ND	0.493	ND	ND	ND	0.536	ND	ND	ND	ND	ND	0.571

ND = no data; R. = river; Bolded values indicate hazard quotients < 1.0.

Table 5.10. Hazard quotients of contaminants of concern in surface water for adult juvenile rearing areas in the Fraser River Basin.

Contaminant of Concern	Area of Interest													
	Lower Fraser River	Upper Fraser River	Pitt River	Cultus Lake	Kakawa Lake	Lower Thompson R.	North Thompson R.	South Thompson R.	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals (mg/L)														
Residue: Non-filterable (TSS)	ND	ND	0.400	0.212	ND	ND	ND	0.568	1.00	ND	0.100	0.0800	ND	0.478
Nutrients														
Nitrogen - Nitrite, dissolved (NO_2)	ND	ND	0.0542	0.0417	ND	0.0417	ND	0.0417	0.0454	0.0500	0.0417	0.0500	ND	0.0500
Major Ions														
Chloride, dissolved	ND	ND	ND	0.00303	ND	0.00305	ND	0.00221	ND	ND	0.00110	ND	ND	0.00253
Sulfate, dissolved	ND	ND	ND	0.0471	ND	0.0212	ND	0.0172	0.0187	ND	0.0121	ND	ND	0.0205
Metals														
Aluminum, total	ND	ND	ND	ND	ND	ND	ND	**2.18**	**34.5**	ND	0.300	ND	ND	**12.1**
Arsenic, total	ND	ND	ND	ND	ND	ND	ND	0.455	0.364	ND	0.0109	ND	ND	0.455
Cadmium, total	ND	ND	ND	0.000139	ND	ND	ND	0.00433	ND	ND	0.00337	ND	ND	0.00372
Chromium, total	ND	ND	ND	ND	ND	ND	ND	**38.0**	**4.70**	ND	**9.00**	ND	ND	**25.6**
Cobalt, total	ND	ND	ND	ND	ND	ND	ND	0.0564	0.0660	ND	0.0766	ND	ND	0.0638
Copper, total	ND	ND	ND	0.982	ND	ND	ND	0.455	0.182	ND	0.317	ND	ND	0.536
Iron, total	ND	ND	ND	**1.72**	ND	ND	ND	0.692	**8.67**	ND	0.231	ND	ND	**3.16**
Lead, total	ND	ND	ND	0.138	ND	ND	ND	0.194	0.0694	ND	**3.80**	ND	ND	0.424
Mercury, total	ND	ND	ND	0.0481	ND	ND	ND	0.0933	ND	ND	ND	ND	ND	0.0904
Nickel, total	ND	ND	ND	0.138	ND	ND	ND	0.200	ND	ND	0.400	ND	ND	0.400
Selenium, total	ND	ND	ND	ND	ND	ND	ND	0.292	ND	ND	0.650	ND	ND	0.500
Silver, total	ND	ND	ND	ND	ND	ND	ND	**1.98**	0.500	ND	0.100	ND	ND	0.500
Other														
Phenols	ND	ND	ND	0.479	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.479

ND = no data; R. = river; Bolded values indicate hazard quotients < 1.0.

Table 5.11. Hazard quotients of contaminants of concern in surface water for smolt outmigration routes in the Fraser River Basin.

Contaminant of Concern	Area of Interest													
	Lower Fraser River	Upper Fraser River	Pitt River	Cultus Lake	Kakawa Lake	Lower Thompson R.	North Thompson R.	South Thompson R.	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals (mg/L)														
Residue: Non-filterable (TSS)	**18.2**	**15.6**	**1.45**	**2.17**	0.518	**8.52**	**3.11**	**1.01**	**2.11**	**4.63**	**2.62**	ND	0.400	**9.56**
Nutrients														
Nitrogen - Nitrite, dissolved (NO_2)	0.154	0.0833	0.0417	1.00	0.0417	0.100	0.0533	0.0417	ND	0.0417	0.0833	ND	0.0833	0.283
Major Ions														
Chloride, dissolved	0.00324	0.00315	ND	0.0284	0.00111	0.00554	0.00187	0.00250	ND	0.000988	0.00227	ND	0.00153	0.00528
Sulfate, dissolved	0.0142	0.0163	ND	0.0444	0.0112	0.0347	0.0161	0.0166	0.0145	0.0576	0.0106	ND	0.0356	0.0340
Metals														
Aluminum, total	**70.9**	**76.2**	**11.4**	**3.20**	ND	**23.3**	**15.7**	**7.18**	**11.3**	**6.60**	**15.9**	ND	**1.63**	**57.1**
Arsenic, total	0.0349	0.0509	ND	0.0238	ND	0.600	0.405	0.405	0.0145	0.0609	0.0167	ND	0.00427	0.364
Cadmium, total	0.00116	0.000840	ND	0.00000417	ND	ND	0.00790	0.00671	0.000187	0.000217	0.00429	ND	0.000349	0.00294
Chromium, total	**11.7**	**17.1**	ND	**9.86**	ND	**11.4**	**11.8**	**20.3**	0.700	**1.20**	**5.07**	ND	**2.27**	**12.0**
Cobalt, total	0.111	0.135	ND	0.0583	ND	0.0723	0.251	0.243	0.0270	0.106	0.0255	ND	0.00857	0.111
Copper, total	**4.01**	**4.38**	ND	0.169	0.518	**3.15**	**1.38**	**2.87**	**1.91**	**1.05**	**3.93**	ND	**1.91**	**3.80**
Iron, total	**32.4**	**45.0**	**4.99**	**7.85**	**1.60**	**10.6**	**7.42**	**3.09**	**2.55**	**2.97**	**7.57**	ND	0.677	**31.6**
Lead, total	0.833	0.896	ND	0.0142	0.267	0.267	**8.33**	ND	0.833	0.0694	0.236	ND	0.143	0.822
Mercury, total	**38.5**	**73.1**	ND	ND	ND	0.0481	ND	0.0481	ND	0.0481	**54.8**	ND	**39.3**	**57.7**
Nickel, total	0.729	0.812	ND	0.596	0.370	ND	0.400	**1.66**	0.108	**5.73**	0.183	ND	0.128	0.691
Selenium, total	0.400	0.300	ND	0.200	ND	0.100	0.100	ND	0.160	1.000	0.200	ND	0.200	0.300
Silver, total	1.00	1.00	ND	0.0425	ND	ND	ND	ND	0.100	0.500	**1.60**	ND	1.00	1.00
Other														
Phenols	ND	**1.23**	ND	ND	ND	0.257	ND	0.143	ND	ND	0.714	ND	ND	0.986

ND = no data; R. = river; Bolded values indicate hazard quotients < 1.0.

Table 5.12. Hazard quotients of contaminants of concern in surface water for adult upstream migration routes in the Fraser River Basin.

Contaminant of Concern	Area of Interest													
	Lower Fraser River	Upper Fraser River	Pitt River	Cultus Lake	Kakawa Lake	Lower Thompson R.	North Thompson R.	South Thompson R.	Chilko River	Quesnel River	Nechako River	Bowron River	Reference	Fraser River Basin
Conventionals (mg/L)														
Residue: Non-filterable (TSS)	**8.13**	**8.83**	**3.27**	0.530	0.518	**5.13**	**1.96**	0.720	**1.41**	**7.80**	0.906	ND	0.460	**5.03**
Nutrients														
Nitrogen - Nitrite, dissolved (NO_2)	0.165	0.100	0.0646	0.790	0.184	0.0833	0.0417	0.0417	0.0404	0.0417	0.0833	ND	0.0833	0.392
Major Ions														
Chloride, dissolved	0.00324	0.00511	ND	0.0290	0.00145	0.0106	0.00174	0.00261	0.000992	0.00375	0.00187	ND	0.00102	0.00916
Sulfate, dissolved	0.0201	0.0220	ND	0.0473	0.0211	0.0636	0.0182	0.0182	0.0150	0.530	0.0106	ND	0.0320	0.0407
Metals														
Aluminum, total	**52.5**	**45.6**	**15.4**	**1.96**	ND	**9.55**	**13.8**	**5.46**	**9.42**	**27.9**	**7.42**	ND	**2.90**	**38.2**
Arsenic, total	0.364	0.0291	ND	0.364	0.0455	0.545	0.386	0.386	0.0145	0.0909	0.0124	ND	0.00382	0.364
Cadmium, total	0.00409	0.000684	ND	.0000027	0.000223	0.00328	0.00392	0.00581	0.000124	0.000298	0.00475	ND	0.000320	0.00292
Chromium, total	**11.4**	**9.93**	ND	**4.90**	ND	**22.8**	**18.0**	**33.1**	0.700	**6.20**	**2.45**	ND	**1.85**	**10.0**
Cobalt, total	0.0845	0.0907	ND	0.0319	ND	0.112	0.226	0.262	0.0268	0.106	0.0117	ND	0.0149	0.0904
Copper, total	**2.90**	**2.90**	ND	0.107	0.436	**2.36**	**2.67**	**2.77**	**1.85**	**1.08**	**5.45**	ND	**1.75**	**2.95**
Iron, total	**23.7**	**27.5**	**6.99**	**4.40**	**1.67**	**3.92**	**5.08**	**2.13**	**2.49**	**6.61**	**3.05**	ND	**1.34**	**17.7**
Lead, total	0.530	0.724	ND	0.0299	0.257	0.243	**9.31**	**7.92**	0.833	0.0694	0.224	ND	0.125	0.501
Mercury, total	**66.3**	**57.7**	ND	ND	ND	0.0481	0.0481	0.0481	ND	0.0481	**57.7**	ND	**93.5**	**57.7**
Nickel, total	0.566	0.604	ND	0.226	0.200	0.400	0.400	0.400	0.107	0.304	0.118	ND	0.150	0.447
Selenium, total	0.200	0.300	ND	0.231	ND	0.100	**57.0**	**60.0**	0.130	0.575	0.200	ND	0.223	0.250
Silver, total	1.00	1.00	ND	0.0253	ND	ND	ND	ND	0.100	0.500	1.00	ND	1.00	1.00
Other														
Phenols	ND	0.943	ND	ND	ND	**1.21**	ND	0.279	ND	ND	0.871	ND	ND	**1.02**

ND = no data; R. = river; TSS = total suspended solids; Bolded values indicate hazard quotients < 1.0.

Table 5.13. Frequency of exceedance of the selected toxicity threshold for surface water in spawning and incubation areas in the Fraser River Basin.

Contaminant of Concern	Area of Interest									
	Lower Fraser River		Upper Fraser River		Pitt River		Cultus Lake		Kakawa Lake	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)										
Residue: Non-filterable (TSS)	ND	ND	ND	ND	ND	ND	0% (24)	ND	ND	ND
Nutrients										
Nitrogen - Nitrite, dissolved (NO^2)	ND	ND	ND	ND	ND	ND	0% (20)	ND	ND	ND
Major Ions										
Chloride, dissolved	ND	ND	ND	ND	ND	ND	0% (19)	ND	ND	ND
Sulfate, dissolved	ND	ND	ND	ND	ND	ND	0% (18)	ND	ND	ND
Metals										
Aluminum, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium, total	ND	ND	ND	ND	ND	ND	0% (1)	ND	ND	ND
Chromium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper, total	ND	ND	ND	ND	ND	ND	8% (13)	ND	ND	ND
Iron, total	ND	ND	ND	ND	ND	ND	8% (12)	ND	ND	ND
Lead, total	ND	ND	ND	ND	ND	ND	0% (6)	ND	ND	ND
Mercury, total	ND	ND	ND	ND	ND	ND	0% (2)	ND	ND	ND
Nickel, total	ND	ND	ND	ND	ND	ND	0% (3)	ND	ND	ND
Selenium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Other										
Phenols	ND	ND	ND	ND	ND	ND	0% (12)	ND	ND	ND

ND = no data; TSS = total suspended solids.

Table 5.13. Frequency of exceedance of the selected toxicity threshold for surface water in spawning and incubation areas in the Fraser River Basin.

Contaminant of Concern	Lower Thompson River		North Thompson River		South Thompson River		Chilko River		Quesnel River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)										
Residue: Non-filterable (TSS)	ND	ND	ND	0% (5)	16% (503)	17% (721)	0% (1)	10% (10)	ND	10% (86)
Nutrients										
Nitrogen - Nitrite, dissolved (NO^2)	ND	ND	ND	ND	0% (363)	0% (286)	0% (5)	0% (6)	ND	0% (92)
Major Ions										
Chloride, dissolved	ND	ND	ND	0% (6)	0% (450)	0% (833)	ND	ND	ND	0% (38)
Sulfate, dissolved	ND	ND	ND	0% (6)	0% (499)	0% (608)	0% (5)	0% (10)	ND	ND
Metals										
Aluminum, total	ND	ND	ND	ND	48% (108)	62% (474)	ND	100% (10)	ND	35% (26)
Arsenic, total	ND	ND	ND	ND	0% (76)	0% (333)	ND	0% (10)	ND	0% (28)
Cadmium, total	ND	ND	ND	ND	3% (116)	3% (441)	ND	ND	ND	0% (10)
Chromium, total	ND	ND	ND	ND	84% (43)	24% (434)	ND	100% (4)	ND	18% (28)
Cobalt, total	ND	ND	ND	ND	3% (31)	0% (499)	ND	0% (10)	ND	0% (28)
Copper, total	ND	ND	ND	ND	19% (119)	5% (437)	0% (1)	ND	ND	0% (10)
Iron, total	ND	ND	ND	ND	31% (257)	53% (477)	100% (1)	100% (10)	ND	36% (28)
Lead, total	ND	ND	ND	ND	0% (113)	0% (385)	0% (1)	ND	ND	0% (10)
Mercury, total	ND	ND	ND	ND	30% (113)	100% (37)	ND	ND	ND	ND
Nickel, total	ND	ND	ND	ND	0% (77)	0% (441)	ND	ND	ND	0% (10)
Selenium, total	ND	ND	ND	ND	2% (63)	3% (258)	ND	ND	ND	0% (28)
Silver, total	ND	ND	ND	ND	ND	6% (322)	ND	0% (4)	ND	0% (28)
Other										
Phenols	ND	ND	ND	ND	0% (6)	ND	ND	ND	ND	ND

ND = no data; TSS = total suspended solids.

Table 5.13. Frequency of exceedance of the selected toxicity threshold for surface water in spawning and incubation areas in the Fraser River Basin.

Contaminant of Concern	Areas of Interest (AoIs)							
	Nechako River		Bowron River		Reference		Fraser River Basin	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)								
Residue: Non-filterable (TSS)	14% (14)	0% (1)	ND	ND	ND	ND	15% (542)	16% (823)
Nutrients								
Nitrogen - Nitrite, dissolved (NO^2)	0% (73)	0% (49)	ND	ND	ND	ND	0% (461)	0% (433)
Major Ions								
Chloride, dissolved	0% (36)	0% (25)	ND	ND	ND	ND	0% (505)	0% (902)
Sulfate, dissolved	0% (2)	ND	ND	ND	ND	ND	0% (524)	0% (624)
Metals								
Aluminum, total	14% (21)	ND	ND	ND	ND	ND	43% (129)	62% (510)
Arsenic, total	ND	ND	ND	ND	ND	ND	0% (76)	0% (371)
Cadmium, total	100% (3)	ND	ND	ND	ND	ND	5% (120)	3% (451)
Chromium, total	ND	ND	ND	ND	ND	ND	84% (43)	24% (466)
Cobalt, total	ND	ND	ND	ND	ND	ND	3% (31)	0% (537)
Copper, total	ND	ND	ND	ND	ND	ND	18% (133)	5% (447)
Iron, total	10% (21)	ND	ND	ND	ND	ND	29% (291)	53% (515)
Lead, total	ND	ND	ND	ND	ND	ND	0% (120)	0% (395)
Mercury, total	ND	ND	ND	ND	ND	ND	30% (115)	100% (37)
Nickel, total	ND	ND	ND	ND	ND	ND	0% (80)	0% (451)
Selenium, total	ND	ND	ND	ND	ND	ND	2% (63)	3% (286)
Silver, total	ND	ND	ND	ND	ND	ND	ND	5% (354)
Other								
Phenols	ND	ND	ND	ND	ND	ND	0% (18)	ND

ND = no data; TSS = total suspended solids.

Table 5.14. Frequency of exceedance of the selected toxicity threshold for surface water in juvenile rearing areas in the Fraser River Basin.

Contaminant of Concern	Areas of Interest (AoIs)									
	Lower Fraser River		Upper Fraser River		Pitt River		Cultus Lake		Kakawa Lake	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)										
Residue: Non- filterable (TSS)	ND	ND	ND	ND	ND	0% (11)	0% (30)	ND	ND	ND
Nutrients										
Nitrogen - Nitrite, dissolved (NO^2)	ND	ND	ND	ND	ND	0% (15)	0% (26)	ND	ND	ND
Major Ions										
Chloride, dissolved	ND	ND	ND	ND	ND	ND	0% (25)	ND	ND	ND
Sulfate, dissolved	ND	ND	ND	ND	ND	ND	0% (25)	ND	ND	ND
Metals										
Aluminum, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium, total	ND	ND	ND	ND	ND	ND	0% (1)	ND	ND	ND
Chromium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper, total	ND	ND	ND	ND	ND	ND	6% (17)	ND	ND	ND
Iron, total	ND	ND	ND	ND	ND	ND	7% (14)	ND	ND	ND
Lead, total	ND	ND	ND	ND	ND	ND	0% (8)	ND	ND	ND
Mercury, total	ND	ND	ND	ND	ND	ND	0% (3)	ND	ND	ND
Nickel, total	ND	ND	ND	ND	ND	ND	0% (5)	ND	ND	ND
Selenium, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver, total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Other										
Phenols	ND	ND	ND	ND	ND	ND	0% (14)	ND	ND	ND

ND = no data; TSS = total suspended solids.

Table 5.14. Frequency of exceedance of the selected toxicity threshold for surface water in juvenile rearing areas in the Fraser River Basin.

Contaminant of Concern	Areas of Interest							
	Lower Thompson River		North Thompson River		South Thompson River		Chilko River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)								
Residue: Non-filterable (TSS)	ND	ND	ND	ND	3% (71)	0% (4)	0% (1)	10% (10)
Nutrients								
Nitrogen - Nitrite, dissolved (NO^2)	ND	0% (21)	ND	ND	0% (168)	0% (172)	0% (6)	0% (6)
Major Ions								
Chloride, dissolved	ND	0% (43)	ND	ND	0% (178)	0% (626)	ND	ND
Sulfate, dissolved	ND	0% (40)	ND	ND	0% (190)	0% (533)	0% (7)	0% (10)
Metals								
Aluminum, total	ND	ND	ND	ND	19% (32)	0% (33)	ND	100% (10)
Arsenic, total	ND	ND	ND	ND	0% (1)	0% (33)	ND	0% (10)
Cadmium, total	ND	ND	ND	ND	9% (32)	8% (24)	ND	ND
Chromium, total	ND	ND	ND	ND	100% (3)	10% (10)	ND	100% (4)
Cobalt, total	ND	ND	ND	ND	100% (1)	0% (34)	ND	0% (10)
Copper, total	ND	ND	ND	ND	0% (25)	0% (23)	0% (1)	ND
Iron, total	ND	ND	ND	ND	4% (74)	0% (32)	100% (1)	100% (10)
Lead, total	ND	ND	ND	ND	0% (24)	0% (5)	0% (1)	ND
Mercury, total	ND	ND	ND	ND	0% (44)	ND	ND	ND
Nickel, total	ND	ND	ND	ND	0% (24)	0% (24)	ND	ND
Selenium, total	ND	ND	ND	ND	ND	0% (9)	ND	ND
Silver, total	ND	ND	ND	ND	ND	11% (9)	ND	0% (4)
Other								
Phenols	ND	ND	ND	ND	ND	ND	ND	ND

ND = no data; TSS = total suspended solids.

Table 5.14. Frequency of exceedance of the selected toxicity threshold for surface water in juvenile rearing areas in the Fraser River Basin.

Contaminant of Concern	Areas of Interest									
	Quesnel River		Nechako River		Bowron River		Reference		Fraser River Basin	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)										
Residue: Non-filterable (TSS)	ND	ND	ND	0% (17)	ND	0% (44)	ND	ND	2% (102)	1% (86)
Nutrients										
Nitrogen - Nitrite, dissolved (NO^2)	ND	0% (318)	ND	0% (12)	ND	0% (48)	ND	ND	0% (200)	0% (592)
Major Ions										
Chloride, dissolved	ND	ND	ND	0% (12)	ND	ND	ND	ND	0% (203)	0% (681)
Sulfate, dissolved	ND	ND	ND	0% (12)	ND	ND	ND	ND	0% (222)	0% (595)
Metals										
Aluminum, total	ND	ND	ND	0% (6)	ND	ND	ND	ND	19% (32)	20% (49)
Arsenic, total	ND	ND	ND	0% (15)	ND	ND	ND	ND	0% (1)	0% (58)
Cadmium, total	ND	ND	ND	47% (17)	ND	ND	ND	ND	9% (33)	24% (41)
Chromium, total	ND	ND	ND	33% (12)	ND	ND	ND	ND	100% (3)	35% (26)
Cobalt, total	ND	ND	ND	0% (17)	ND	ND	ND	ND	100% (1)	0% (61)
Copper, total	ND	ND	ND	0% (9)	ND	ND	ND	ND	2% (43)	0% (32)
Iron, total	ND	ND	ND	0% (17)	ND	ND	ND	ND	6% (89)	17% (59)
Lead, total	ND	ND	ND	6% (16)	ND	ND	ND	ND	0% (33)	5% (21)
Mercury, total	ND	ND	ND	ND	ND	ND	ND	ND	0% (47)	ND
Nickel, total	ND	ND	ND	0% (17)	ND	ND	ND	ND	0% (29)	0% (41)
Selenium, total	ND	ND	ND	0% (15)	ND	ND	ND	ND	ND	0% (24)
Silver, total	ND	ND	ND	0% (9)	ND	ND	ND	ND	ND	5% (22)
Other										
Phenols	ND	ND	ND	ND	ND	ND	ND	ND	0% (14)	ND

ND = no data; TSS = total suspended solids.

Table 5.15. Frequency of exceedance of the selected toxicity threshold for water in smolt outmigration routes in the Fraser River Basin.

Contaminant of Concern	Areas of Interest									
	Lower Fraser River		Upper Fraser River		Pitt River		Cultus Lake		Kakawa Lake	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)										
Residue: Non-filterable (TSS)	94% (35)	100% (7)	100% (31)	100% (24)	50% (2)	ND	ND	17% (12)	0% (4)	ND
Nutrients										
Nitrogen - Nitrite, dissolved (NO^2)	0% (2)	0% (34)	0% (11)	0% (32)	0% (2)	ND	ND	5% (21)	0% (6)	ND
Major Ions										
Chloride, dissolved	0% (35)	0% (86)	0% (42)	0% (89)	ND	ND	ND	0% (21)	0% (6)	ND
Sulfate, dissolved	0% (34)	0% (35)	0% (33)	0% (35)	ND	ND	ND	0% (19)	0% (5)	ND
Metals										
Aluminum, total	100% (3)	99% (72)	100% (21)	99% (72)	50% (2)	ND	ND	100% (5)	ND	ND
Arsenic, total	0% (16)	0% (44)	0% (23)	0% (47)	ND	ND	ND	0% (6)	ND	ND
Cadmium, total	19% (16)	3% (64)	4% (23)	3% (68)	ND	ND	ND	0% (5)	ND	ND
Chromium, total	80% (5)	99% (71)	100% (17)	99% (73)	ND	ND	ND	100% (6)	ND	ND
Cobalt, total	ND	0% (71)	0% (4)	0% (73)	ND	ND	ND	0% (6)	ND	ND
Copper, total	94% (16)	58% (64)	83% (23)	54% (68)	ND	ND	ND	0% (5)	0% (4)	ND
Iron, total	100% (17)	99% (71)	100% (39)	99% (73)	50% (2)	ND	ND	100% (6)	33% (3)	ND
Lead, total	6% (16)	0% (64)	0% (23)	3% (68)	ND	ND	ND	0% (5)	0% (4)	ND
Mercury, total	100% (14)	100% (5)	69% (16)	100% (9)	ND	ND	ND	ND	ND	ND
Nickel, total	0% (5)	0% (64)	0% (10)	1% (68)	ND	ND	ND	0% (5)	0% (4)	ND
Selenium, total	0% (16)	0% (40)	0% (23)	0% (45)	ND	ND	ND	0% (6)	ND	ND
Silver, total	ND	4% (51)	ND	0% (54)	ND	ND	ND	0% (6)	ND	ND
Other										
Phenols	ND	ND	13% (15)	ND	ND	ND	ND	ND	ND	ND

ND = no data; TSS = total suspended solids.

Table 5.15. Frequency of exceedance of the selected toxicity threshold for water in smolt outmigration routes in the Fraser River Basin.

Contaminant of Concern	Areas of Interest							
	Lower Thompson River		North Thompson River		South Thompson River		Chilko River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)								
Residue: Non-filterable (TSS)	60% (43)	80% (115)	46% (13)	20% (44)	0% (27)	9% (33)	ND	13% (8)
Nutrients								
Nitrogen - Nitrite, dissolved (NO^2)	0% (62)	0% (65)	0% (7)	0% (10)	2% (52)	0% (10)	ND	ND
Major Ions								
Chloride, dissolved	0% (29)	0% (102)	0% (25)	0% (44)	0% (37)	0% (33)	ND	ND
Sulfate, dissolved	0% (26)	0% (93)	0% (27)	0% (41)	0% (30)	0% (29)	0% (3)	0% (8)
Metals								
Aluminum, total	100% (4)	100% (7)	100% (3)	91% (23)	100% (8)	80% (25)	ND	100% (8)
Arsenic, total	0% (1)	0% (7)	0% (1)	0% (11)	ND	0% (12)	ND	0% (9)
Cadmium, total	ND	ND	ND	100% (13)	ND	100% (14)	0% (1)	0% (9)
Chromium, total	100% (1)	100% (6)	ND	100% (3)	ND	100% (6)	ND	0% (9)
Cobalt, total	ND	0% (7)	ND	0% (23)	ND	0% (25)	ND	0% (9)
Copper, total	25% (4)	ND	0% (1)	75% (4)	ND	80% (5)	100% (2)	0% (9)
Iron, total	86% (7)	100% (7)	60% (5)	74% (23)	38% (8)	36% (25)	ND	100% (1)
Lead, total	0% (4)	ND	0% (1)	100% (2)	ND	ND	0% (2)	0% (9)
Mercury, total	0% (6)	ND	ND	ND	0% (1)	ND	ND	ND
Nickel, total	ND	ND	ND	0% (13)	ND	7% (14)	ND	0% (9)
Selenium, total	0% (1)	ND	0% (1)	ND	ND	ND	ND	0% (9)
Silver, total	ND	ND	ND	ND	ND	ND	ND	0% (9)
Other								
Phenols	0% (5)	ND	ND	ND	0% (1)	ND	ND	ND

ND = no data; TSS = total suspended solids.

Table 5.15. Frequency of exceedance of the selected toxicity threshold for water in smolt outmigration routes in the Fraser River Basin.

Contaminant of Concern	Areas of Interest									
	Quesnel River		Nechako River		Bowron River		Reference		Fraser River Basin	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)										
Residue: Non-filterable (TSS)	0% (1)	53% (17)	23% (31)	36% (25)	ND	ND	0% (6)	0% (25)	54% (193)	50% (310)
Nutrients										
Nitrogen - Nitrite, dissolved (NO^2)	0% (1)	ND	0% (12)	0% (34)	ND	ND	ND	0% (28)	1% (155)	0% (234)
Major Ions										
Chloride, dissolved	ND	0% (17)	0% (43)	0% (91)	ND	ND	0% (17)	0% (79)	0% (234)	0% (562)
Sulfate, dissolved	ND	0% (17)	0% (39)	0% (34)	ND	ND	0% (17)	0% (48)	0% (214)	0% (359)
Metals										
Aluminum, total	ND	50% (10)	100% (18)	97% (77)	ND	ND	0% (1)	38% (60)	97% (60)	85% (359)
Arsenic, total	ND	0% (16)	0% (24)	0% (69)	ND	ND	0% (17)	0% (37)	0% (82)	0% (258)
Cadmium, total	ND	0% (11)	29% (24)	0% (71)	ND	ND	0% (17)	0% (58)	14% (81)	10% (313)
Chromium, total	ND	9% (11)	91% (11)	50% (76)	ND	ND	60% (5)	11% (62)	90% (39)	65% (323)
Cobalt, total	ND	0% (17)	0% (5)	0% (76)	ND	ND	0% (5)	0% (62)	0% (14)	0% (369)
Copper, total	ND	6% (17)	65% (23)	0% (71)	ND	ND	35% (17)	2% (58)	64% (90)	28% (301)
Iron, total	ND	18% (17)	97% (30)	93% (76)	ND	ND	6% (17)	0% (62)	78% (128)	71% (361)
Lead, total	ND	0% (11)	0% (23)	0% (71)	ND	ND	0% (17)	0% (58)	1% (90)	1% (288)
Mercury, total	ND	0% (6)	100% (17)	100% (7)	ND	ND	100% (4)	100% (8)	79% (58)	83% (35)
Nickel, total	ND	6% (17)	0% (11)	0% (71)	ND	ND	0% (5)	0% (58)	0% (35)	1% (319)
Selenium, total	ND	6% (17)	0% (23)	0% (67)	ND	ND	0% (17)	0% (37)	0% (81)	0% (221)
Silver, total	ND	0% (11)	ND	5% (57)	ND	ND	ND	0% (45)	ND	2% (233)
Other										
Phenols	ND	ND	0% (7)	0% (4)	ND	ND	ND	ND	7% (28)	0% (4)

ND = no data; TSS = total suspended solids.

Table 5.16. Frequency of exceedance of the selected toxicity threshold for surface water in adult upstream migration routes in the Fraser River Basin.

Contaminant of Concern	Areas of Interest: Lower Fraser River		Upper Fraser River		Pitt River		Cultus Lake		Kakawa Lake	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)										
Residue: Non-filterable (TSS)	75% (69)	100% (19)	89% (55)	84% (51)	40% (10)	70% (10)	ND	3% (36)	0% (8)	ND
Nutrients										
Nitrogen - Nitrite, dissolved (NO^2)	0% (10)	0% (73)	0% (17)	0% (61)	0% (10)	0% (20)	ND	3% (60)	0% (10)	ND
Major Ions										
Chloride, dissolved	0% (63)	0% (176)	0% (77)	1% (164)	ND	ND	ND	0% (42)	0% (11)	ND
Sulfate, dissolved	0% (61)	0% (73)	0% (60)	0% (68)	ND	ND	ND	0% (39)	0% (7)	ND
Metals										
Aluminum, total	100% (9)	94% (161)	100% (37)	99% (137)	80% (10)	ND	ND	38% (13)	ND	ND
Arsenic, total	0% (43)	0% (103)	0% (40)	0% (89)	ND	ND	ND	0% (25)	0% (1)	ND
Cadmium, total	23% (43)	1% (137)	8% (40)	1% (128)	ND	ND	ND	0% (8)	0% (1)	ND
Chromium, total	100% (17)	88% (162)	92% (26)	91% (140)	ND	ND	ND	39% (23)	ND	ND
Cobalt, total	ND	0% (165)	0% (8)	0% (140)	ND	ND	ND	0% (25)	ND	ND
Copper, total	42% (43)	28% (137)	53% (40)	21% (128)	ND	ND	ND	0% (8)	0% (7)	ND
Iron, total	98% (58)	95% (165)	99% (69)	98% (140)	60% (10)	ND	ND	100% (25)	33% (6)	ND
Lead, total	2% (43)	0% (137)	0% (40)	1% (128)	ND	ND	ND	0% (8)	0% (7)	ND
Mercury, total	100% (41)	100% (11)	58% (36)	100% (11)	ND	ND	ND	ND	ND	ND
Nickel, total	0% (12)	1% (137)	0% (20)	0% (128)	ND	ND	ND	0% (8)	0% (7)	ND
Selenium, total	0% (43)	0% (87)	0% (40)	0% (84)	ND	ND	ND	0% (20)	ND	ND
Silver, total	ND	4% (114)	ND	2% (102)	ND	ND	ND	0% (20)	ND	ND
Other										
Phenols	ND	ND	3% (29)	ND	ND	ND	ND	ND	ND	ND

ND = no data; TSS = total suspended solids.

Table 5.16. Frequency of exceedance of the selected toxicity threshold for surface water in adult upstream migration routes in the Fraser River Basin.

Contaminant of Concern	Areas of Interest							
	Lower Thompson River		North Thompson River		South Thompson River		Chilko River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)								
Residue: Non-filterable (TSS)	10% (59)	32% (93)	27% (22)	17% (59)	0% (40)	4% (46)	0% (2)	8% (12)
Nutrients								
Nitrogen - Nitrite, dissolved (NO^2)	0% (97)	0% (51)	0% (13)	0% (15)	0% (109)	0% (15)	0% (1)	0% (1)
Major Ions								
Chloride, dissolved	0% (97)	0% (134)	0% (50)	0% (59)	0% (68)	0% (46)	0% (1)	0% (1)
Sulfate, dissolved	0% (67)	0% (118)	0% (50)	0% (53)	0% (59)	0% (38)	0% (7)	0% (15)
Metals								
Aluminum, total	67% (6)	60% (10)	100% (2)	61% (33)	71% (14)	57% (35)	ND	92% (12)
Arsenic, total	0% (3)	0% (8)	0% (3)	0% (13)	0% (2)	0% (14)	ND	0% (15)
Cadmium, total	0% (4)	100% (2)	0% (3)	95% (21)	0% (1)	100% (22)	0% (1)	0% (14)
Chromium, total	80% (5)	100% (8)	67% (3)	100% (6)	100% (3)	100% (4)	ND	0% (15)
Cobalt, total	0% (2)	0% (10)	0% (2)	0% (33)	ND	0% (35)	ND	0% (15)
Copper, total	10% (10)	100% (1)	0% (5)	60% (5)	0% (1)	80% (5)	67% (3)	0% (14)
Iron, total	31% (16)	60% (10)	60% (10)	52% (33)	11% (19)	26% (35)	ND	100% (2)
Lead, total	0% (11)	ND	0% (5)	100% (2)	0% (1)	100% (1)	0% (3)	0% (14)
Mercury, total	0% (14)	ND	0% (5)	ND	0% (4)	ND	ND	ND
Nickel, total	0% (3)	0% (2)	0% (2)	0% (21)	0% (1)	5% (22)	ND	0% (14)
Selenium, total	0% (1)	ND	0% (1)	100% (1)	ND	100% (1)	ND	0% (15)
Silver, total	ND	ND	ND	ND	ND	ND	ND	0% (15)
Other								
Phenols	9% (11)	ND	ND	ND	0% (2)	ND	ND	ND

ND = no data; TSS = total suspended solids.

Table 5.16. Frequency of exceedance of the selected toxicity threshold for surface water in adult upstream migration routes in the Fraser River Basin.

Contaminant of Concern	Quesnel River		Nechako River		Bowron River		Reference		Fraser River Basin	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Conventionals (mg/L)										
Residue: Non-filterable (TSS)	0% (2)	59% (17)	0% (44)	7% (44)	ND	ND	0% (20)	0% (56)	35% (331)	28% (443)
Nutrients										
Nitrogen - Nitrite, dissolved (NO^2)	0% (5)	ND	0% (31)	0% (74)	ND	ND	ND	0% (57)	0% (303)	0% (427)
Major Ions										
Chloride, dissolved	0% (3)	0% (18)	0% (83)	0% (170)	ND	ND	0% (38)	0% (165)	0% (491)	0% (975)
Sulfate, dissolved	0% (5)	0% (18)	0% (70)	0% (62)	ND	ND	0% (38)	0% (104)	0% (424)	0% (588)
Metals										
Aluminum, total	0% (1)	62% (13)	68% (31)	73% (139)	ND	ND	100% (1)	84% (132)	83% (111)	83% (685)
Arsenic, total	ND	0% (17)	0% (42)	0% (139)	ND	ND	0% (37)	0% (82)	0% (171)	0% (505)
Cadmium, total	ND	0% (13)	35% (46)	0% (134)	ND	ND	3% (37)	0% (129)	17% (176)	8% (608)
Chromium, total	ND	31% (13)	73% (15)	15% (145)	ND	ND	67% (9)	8% (137)	86% (78)	51% (653)
Cobalt, total	ND	0% (18)	0% (7)	0% (145)	ND	ND	0% (9)	0% (137)	0% (28)	0% (723)
Copper, total	0% (2)	6% (18)	45% (44)	0% (134)	ND	ND	38% (37)	1% (129)	40% (192)	13% (579)
Iron, total	0% (1)	22% (18)	36% (55)	54% (145)	ND	ND	16% (37)	6% (137)	61% (281)	62% (710)
Lead, total	0% (2)	0% (13)	7% (44)	0% (134)	ND	ND	0% (37)	0% (129)	2% (193)	1% (566)
Mercury, total	ND	0% (8)	94% (31)	100% (7)	ND	ND	100% (11)	100% (17)	72% (142)	85% (54)
Nickel, total	ND	0% (18)	6% (17)	0% (134)	ND	ND	0% (9)	0% (129)	1% (71)	0% (613)
Selenium, total	ND	0% (16)	0% (42)	1% (133)	ND	ND	0% (37)	0% (82)	0% (164)	1% (439)
Silver, total	ND	0% (13)	ND	4% (114)	ND	ND	ND	2% (100)	ND	3% (478)
Other										
Phenols	ND	ND	9% (11)	0% (7)	ND	ND	ND	ND	6% (53)	0% (7)

Areas of Interest spans all river columns.

ND = no data; TSS = total suspended solids.

Table 5.17. Frequency of exceedance of toxicity thresholds for contaminants of concern in sediment for various Areas of Interest of the Fraser River Basin.

Contaminant of Concern	Frequency of Exceedance (Total Number of Samples)					
	Area of Interest					
	Lower Fraser River		Harrison River		South Thompson River	
	Pre-1990	Post-1990	Pre-1990	Post-1990	Pre-1990	Post-1990
Metals (mg/kg)						
Cadmium	0% (10)	0% (29)	0% (1)	ND	0% (1)	ND
Iron	0% (30)	14% (28)	0% (1)	ND	0% (1)	ND
Nickel	30% (30)	39% (28)	0% (1)	ND	100% (1)	ND
Plastics-Related Chemicals (mg/kg)						
Bis(2-ethylhexyl) phthalate	0% (10)	ND	ND	ND	ND	ND
Polycyclic Aromatic Hydrocarbons (mg/kg)						
Dibenz(a,h)anthracene	10% (10)	0% (27)	ND	ND	ND	ND

ND = no data.

Table 5.18. Fraser River Basin surface water hazard quotients calculated with a 95% percentile exposure point concentration for each key habitat use, and maximum 95% hazard quotient for all habitat uses in the Fraser River Basin.

Contaminant of Concern	Spawning & Incubation	Juvenile Rearing	Smolt Outmigration	Adult Upstream Migration	Maximum Hazard Quotient
Conventionals (mg/L)					
Residue: Non-filterable (TSS)	**3.22**	0.478	**9.56**	**5.03**	**9.560**
Nutrients					
Nitrogen - Nitrite, dissolved (NO_2)	0.0833	0.0500	0.283	0.392	0.392
Major Ions					
Chloride, dissolved	0.00835	0.00253	0.00528	0.00916	0.00916
Sulfate, dissolved	0.0957	0.0205	0.0340	0.0407	0.0957
Metals					
Aluminum, total	**19.4**	**12.1**	**57.1**	**38.2**	**57.1**
Arsenic, total	0.455	0.455	0.364	0.364	0.455
Cadmium, total	0.00110	0.00372	0.00294	0.00292	0.00372
Chromium, total	**6.18**	**25.6**	**12.0**	**10.0**	**25.6**
Cobalt, total	0.0532	0.0638	0.111	0.0904	0.111
Copper, total	**1.69**	0.536	**3.80**	**2.95**	**3.80**
Iron, total	**8.96**	**3.16**	**31.6**	**17.7**	**31.6**
Lead, total	0.290	0.424	0.822	0.501	0.822
Mercury, total	**69.5**	0.0904	**57.7**	**57.7**	**69.5**
Nickel, total	0.222	0.400	0.691	0.447	0.691
Selenium, total	0.900	0.500	0.300	0.250	0.900
Silver, total	**1.35**	0.500	1.00	1.00	**1.35**
Other					
Phenols	0.571	0.479	0.986	**1.02**	**1.02**

Bolded values indicate a hazard quotient > 1.0.

Table 5.19. Hazard quotients of contaminants of concern in sediments for various Areas of Interest of the Fraser River Basin.

Contaminant of Concern	Hazard Quotient for each Area of Interest		
	Lower Fraser River	Harrison River	South Thompson River
Metals (mg/kg)			
Cadmium	0.080	0.100	0.100
Iron	**1.02**	0.745	0.871
Nickel	**1.16**	0.473	**1.26**
Plastics-Related Chemicals (mg/kg)			
Bis(2-ethylhexyl) phthalate	0.506	ND	ND
Polycyclic Aromatic Hydrocarbons (mg/kg)			
Dibenz(a,h)anthracene	0.493	ND	ND

Bolded values indicate hazard quotients >1.0.

Table 5.20. Hazard quotients for contaminants of concern in Weaver and Adams sockeye and Thompson chinook salmon populations[1].

Contaminant of Concern	Toxicity Reference Value	Fraser River Mouth		Spawning Grounds	
		Muscle	Roe	Muscle	Roe
Metals (mg/g)					
Mercury	0.4 mg/g[3]	0.063	0.024	0.159	0.038
Selenium	1.58 mg/g[4]	0.095	**1.52**	0.487	**1.01**
Chemical Mixtures					
ΣTEQ[2]	3.0 pg/g lipid[5]	NB	**2.53**	NB	**1.48**

NB = No available benchmark; TEQ = toxic equivalent; PCB = polychlorinated biphenyl;
PCDD = polychlorinated dibenzo-*p*-dioxin; PCDF = polychlorinated dibenzofuran;
TCDD = tetraochlorodibenzo-*p*-dioxin.

[1]Data obtained from Siska Traditions Society 2009.
[2]ΣTEQ is calculated as the the sum of the PCB, PCDD, and PCDF TCDD-TEQ values.
[3]Toxicity reference value obtained from Dillon *et al.* (2010)
[4]Toxicity reference value obtained from USEPA (2010b); assuming 80% tissue moisture content.
[5]Toxicity reference value obtained from DeBruyn *et al.* (2004) and Giesy *et al.* (2002.)
Bolded values indicate hazard quotients > 1.0.

Table 5.21. Summary of muscle tissue data collected from Weaver and Adams sockeye and Thompson chinook salmon populations[1].

Contaminant of Concern	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Samples Collected at the Fraser River Mouth															
Metals (mg/g)															
Arsenic	11	11	0.0%	0.421	0.259	0.346	0.1	0.85	0.15	0.2	0.2	0.3	0.625	0.76	0.805
Cadmium	11	2	81.8%	0.026	0.019	0.023	< 0.03	0.08	0.015	0.015	0.02	0.02	0.02	0.04	0.06
Copper	11	11	0.0%	0.791	0.122	0.782	0.6	1	0.65	0.7	0.7	0.8	0.9	0.9	0.95
Lead	11	11	0.0%	0.251	0.108	0.233	0.135	0.522	0.136	0.136	0.1905	0.234	0.289	0.314	0.418
Mercury	11	11	0.0%	0.020	0.004	0.020	0.014	0.025	0.014	0.014	0.0155	0.021	0.0235	0.025	0.025
Selenium	11	0	100.0%	0.141	0.020	0.139	< 0.2	< 0.3	0.1	0.1	0.15	0.15	0.15	0.15	0.15
Thallium	11	0	100.0%	0.002	0.000	0.002	< 0.004	< 0.005	0.002	0.002	0.002	0.002	0.003	0.003	0.003
Vanadium	11	10	9.1%	0.232	0.425	0.067	< 0.02	1.23	0.015	0.02	0.03	0.05	0.08	0.93	1.08
Zinc	11	11	0.0%	8.51	4.13	7.95	5.9	20.5	5.94	5.98	6.34	7.32	8.39	9.18	14.8
Pesticides (pg/g)															
Aldrin	17	1	94.1%	0.944	0.687	0.813	< 0.72	3.43	0.360	0.459	0.665	0.810	1.01	1.13	1.67
a-HCH	16	15	6.3%	313	219	183	< 1.33	858	50.4	68.9	168	306	394	537	634
b-HCH	17	14	17.6%	360	268	123	< 1.12	782	0.860	1.02	116	445	609	640	700
Chlordane (total)	17	17	0.0%	985	268	940	378.11	1361	530	571	935	1046	1122	1251	1289
Dieldrin	17	17	0.0%	709	244	656	241.12	1050	278	353	536	781	851	940	995
g-HCH	17	10	41.2%	55.4	57.0	12.2	< 1.09	158	0.569	0.671	1.07	24.070	107	121	131
Heptachlor	16	3	81.3%	1.75	0.834	1.59	< 1.54	< 7.13	0.793	0.963	1.30	1.47	1.95	3.12	3.23
Moethoxychlor	17	0	100.0%	12.4	13.0	7.56	< 4.81	< 73.5	2.405	2.68	3.61	5.28	21.6	33.9	35.0
Mirex	17	17	0.0%	53.8	18.2	51.3	28.5	102.52	36.0	38.3	41.7	48.9	64.5	72.0	86.6
Sum DDD	17	17	0.0%	1047	348	989	366	2016	503	684	980	1055	1189	1273	1500
Sum DDE	17	17	0.0%	4756	1979	4309	1261	8197	1930	2468	3575	4116	6431	7134	7729
Sum DDT	17	17	0.0%	1362	1336	974	405	5757	429	436	440	978	1752	2251	3295

Table 5.21. Summary of muscle tissue data collected from Weaver and Adams sockeye and Thompson chinook salmon populations[1].

Contaminant of Concern	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Samples Collected in the Spawning Grounds															
Metals (mg/g)															
Arsenic	13	6	53.8%	0.155	0.181	0.070	< 0.040	0.56	0.020	0.020	0.020	0.025	0.300	0.380	0.464
Cadmium	13	3	76.9%	0.034	0.034	0.027	< 0.040	0.14	0.020	0.020	0.020	0.020	0.020	0.050	0.086
Copper	13	13	0.0%	6.131	19.2	1.13	0.7	70	0.700	0.700	0.800	0.800	0.800	1.000	28.6
Lead	13	13	0.0%	0.210	0.130	0.180	0.065	0.479	0.091	0.109	0.122	0.201	0.219	0.428	0.477
Mercury	13	13	0.0%	0.034	0.016	0.031	0.019	0.067	0.020	0.020	0.022	0.026	0.041	0.058	0.063
Selenium	13	1	92.3%	0.269	0.430	0.181	< 0.300	1.7	0.150	0.150	0.150	0.150	0.150	0.150	0.770
Thallium	13	0	100.0%	0.002	0.000	0.002	< 0.004	< 0.005	0.002	0.002	0.002	0.003	0.003	0.003	0.003
Vanadium	13	10	23.1%	0.034	0.020	0.028	< 0.020	0.070	0.010	0.010	0.020	0.030	0.050	0.058	0.064
Zinc	13	13	0.0%	9.41	9.76	7.68	5.50	41.8	5.63	5.85	6.39	6.80	7.02	8.10	21.68
Pesticides (pg/g)															
Aldrin	23	0	100.0%	0.822	0.357	0.759	< 0.69	< 3.95	0.397	0.434	0.648	0.760	0.893	1.25	1.33
a-HCH	22	10	54.5%	15.3	28.1	2.12	< 0.21	98.2	0.109	0.190	0.340	1.28	11.8	48.5	81.2
b-HCH	23	7	69.6%	5.68	22.0	0.823	< 0.24	106.6	0.130	0.218	0.348	0.570	1.81	3.60	3.87
Chlordane (total)	23	23	0.0%	866	404	769	148	1951	391	476	571	830	1077	1345	1406
Dieldrin	23	23	0.0%	356	241	294	71.0	1088	104	144	196	310	415	567	878
g-HCH	21	12	42.9%	6.74	11.1	1.85	< 0.46	40.7	0.275	0.280	0.595	0.930	7.33	21.3	26.3
Heptachlor	23	5	78.3%	1.91	1.16	1.62	< 0.99	< 8.83	0.852	0.868	1.04	1.39	2.16	3.93	4.01
Moethoxychlor	23	0	100.0%	5.31	3.95	4.50	< 5.17	< 36.7	2.66	2.80	3.50	3.67	4.71	8.76	14.018
Mirex	23	23	0.0%	44.8	10.5	43.6	20.2	69.7	29.9	34.9	39.2	44.5	49.3	58.4	59.0
Sum DDD	23	23	0.0%	955	436	842	113	2044	503	554	668	887	1287	1446	1629
Sum DDE	23	23	0.0%	3995	1678	3708	2241	7410	2367	2572	2735	3373	4898	6914	7101
Sum DDT	23	23	0.0%	983	477	870	298	2048	411	445	594	972	1230	1691	1700

[1]Data obtained from Siska Traditions Society 2009.
n = number, detect = detected, SD = standard deviation.

Table 5.22. Summary of roe tissue data collected from Weaver and Adams sockeye and Thompson chinook salmon populations[1].

Contaminant of Concern	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution 5th	10th	25th	50th	75th	90th	95th
Samples Collected at the Fraser River Mouth															
Metals (mg/g)															
Arsenic	5	2	60.0%	0.11	0.164	0.053	< 0.040	0.4	0.021	0.022	0.025	0.025	0.08	0.272	0.336
Cadmium	5	2	60.0%	0.036	0.022	0.031	< 0.040	0.060	0.020	0.020	0.020	0.020	0.060	0.060	0.060
Copper	5	5	0.0%	41.14	38.1	23.2	5.3	96.8	5.32	5.34	5.4	47.5	50.7	78.36	87.58
Lead	5	5	0.0%	0.192	0.065	0.183	0.127	0.290	0.130	0.133	0.141	0.187	0.214	0.260	0.275
Mercury	5	5	0.0%	0.008	0.002	0.008	0.006	0.010	0.006	0.006	0.007	0.009	0.009	0.010	0.010
Selenium	5	5	0.0%	1.68	0.554	1.61	1.10	2.60	1.18	1.26	1.50	1.60	1.60	2.20	2.40
Thallium	5	0	100.0%	0.002	0.000	0.002	< 0.004	< 0.005	0.002	0.002	0.003	0.003	0.003	0.003	0.003
Vanadium	5	5	0.0%	0.502	0.534	0.248	0.05	1.14	0.054	0.058	0.07	0.23	1.02	1.092	1.116
Zinc	5	5	0.0%	34.9	7.2	34.3	26.5	43.8	27.0	27.4	28.8	36.6	39.0	41.9	42.8
Pesticides (pg/g)															
Aldrin	6	0	100.0%	1.49	1.19	1.24	< 1.3	< 7.77	0.706	0.763	0.923	1.13	1.27	2.59	3.24
a-HCH	5	5	0.0%	965	100	961	848	1089	860	872	908	934	1048	1072	1081
b-HCH	6	4	33.3%	480	379	87.5	< 2.22	855	1.2	1.3	151	644	720	793	824
Chlordane (Total)	6	6	0.0%	1221	371	1175	873	1729	875	877	895	1166	1483	1621	1675
Dieldrin	6	6	0.0%	967	109	963	888	1153	892	896	904	905	1014	1102	1127
g-HCH	6	5	16.7%	229	127	106	< 2.07	383	54.4	107.9	220	242	280	337	360
Heptachlor	6	1	83.3%	2.08	1.11	1.84	< 2.1	< 6.87	1.08	1.10	1.20	1.68	3.08	3.45	3.45
Moethoxychlor	6	1	83.3%	25.4	13.6	21.9	< 15.82	< 85.05	9.49	11.1	16.3	24.2	35.8	40.8	41.7
Mirex	6	6	0.0%	34.5	14.1	32.1	17.3	56.8	18.5	19.7	24.9	35.1	39.9	48.8	52.8
Sum DDD	6	6	0.0%	1335	582	1246	895	2366	901	906	922	1094	1547	2005	2185
Sum DDE	6	6	0.0%	5509	1900	5275	3740	8943	3900	4059	4469	4790	6019	7679	8311
Sum DDT	6	6	0.0%	2220	2348	1213	373	6006	376	379	398	1268	3542	5014	5510

Table 5.22. Summary of roe tissue data collected from Weaver and Adams sockeye and Thompson chinook salmon populations[1].

Contaminant of Concern	n	n Detect	% Non-Detect	Mean	SD	Geometric Mean	Min	Max	Percentile Distribution						
									5th	10th	25th	50th	75th	90th	95th
Samples Collected in the Spawning Grounds															
Metals (mg/g)															
Arsenic	6	3	50.0%	0.107	0.118	0.058	< 0.040	0.300	0.020	0.020	0.020	0.050	0.170	0.250	0.275
Cadmium	6	1	83.3%	0.023	0.008	0.022	< 0.040	0.040	0.020	0.020	0.020	0.020	0.020	0.030	0.035
Copper	6	6	0.0%	34.4	24.9	19.7	2.5	58.8	2.875	3.25	12.8	43.7	52.1	56.1	57.5
Lead	6	6	0.0%	0.241	0.082	0.229	0.150	0.351	0.158	0.166	0.183	0.219	0.306	0.338	0.344
Mercury	6	6	0.0%	0.007	0.005	0.006	0.004	0.018	0.004	0.004	0.004	0.006	0.006	0.012	0.015
Selenium	6	4	33.3%	0.767	0.671	0.508	< 0.3	1.6	0.150	0.150	0.238	0.550	1.35	1.6	1.6
Thallium	6	0	100.0%	0.002	0.000	0.002	< 0.004	< 0.005	0.002	0.002	0.002	0.002	0.002	0.003	0.003
Vanadium	6	6	0.0%	0.070	0.032	0.061	0.020	0.090	0.025	0.030	0.053	0.090	0.090	0.090	0.090
Zinc	6	6	0.0%	21.3	4.0	20.9	17.3	27.4	17.4	17.5	18.0	20.7	23.4	25.6	26.5
Pesticides (pg/g)															
Aldrin	7	0	100.0%	2.76	1.55	2.38	< 2.18	< 8.86	1.23	1.36	1.57	1.89	4.39	4.43	4.43
a-HCH	5	3	40.0%	121	122	23.8	< 1.5	267.04	0.9	1.05	1.50	117	219	248	257
b-HCH	7	6	14.3%	184	83.9	99.1	< 2	239.79	55.3	110	188	202	235	240	240
Chlordane (Total)	7	7	0.0%	1384	309	1357	1095	1921	1101	1107	1170	1224	1554	1762	1842
Dieldrin	7	7	0.0%	914	162	902	702	1196	729	756	808	945	971	1077	1137
g-HCH	7	6	14.3%	98.0	43.0	64.1	< 4.12	130.9	33.2	64.4	108	111	113	120	126
Heptachlor	7	1	85.7%	2.95	1.80	2.43	< 1.66	< 11.28	0.941	1.05	1.67	2.32	4.27	4.82	5.23
Moethoxychlor	7	0	100.0%	19.0	9.02	17.2	< 13.25	< 72.69	9.38	12.1	15.8	17.2	20.7	27.9	32.1
Mirex	7	7	0.0%	40.8	8.34	40.1	32.7	54.9	33.3	33.8	35.9	37.2	44.6	52.0	53.4
Sum DDD	7	7	0.0%	1421	286	1398	1199	1866	1203	1207	1246	1291	1548	1829	1848
Sum DDE	7	7	0.0%	4644	1254	4514	3359	6882	3539	3720	3961	4172	5085	6274	6578
Sum DDT	7	7	0.0%	2039	681	1948	1255	3040	1350	1446	1659	1745	2458	2966	3003

[1]Data obtained from Siska Traditions Society 2009.
n = number, detect = detected, SD = standard deviation.

Table 5.23. Mean concentrations of ΣTEQs in roe collected along the adult upstream migration route for select sockeye salmon populations.

Sampling Location	ΣTEQ (pg/g lipid)	Hazard Quotient[1]
Early Stuart Stock[2]		
Port Renfrew	0.14	0.047
Yale	0.16	0.053
Gluskie Creek	0.42	0.140
Weaver Creek Stock[2]		
Harrison River	0.89	0.297
Weaver Creek	0.29	0.097
Predicted ∑TEQ[3]		
Adams Lake Stock	3.42	1.14
Chilko Lake Stock	4.39	1.46
Stuart Stock	6.94	2.31

NB = No available benchmark; TEQ = toxic equivalent; PCB = polychlorinated biphenyl;
PCDD = polychlorinated dibenzo-*p*-dioxin; PCDF = polychlorinated dibenzofuran;
TCDD = tetraochlorodibenzo-*p*-dioxin.

[1] Hazard quotients calculated using a toxicity threshold of 3.0 µg/g lipid (DeBruyn *et al.* 2004; Giesy *et al.* 2002)
[2] Data obtained from Kelly *et al.* (2007)
[3] Data obtained from DeBruyn *et al.* (2004.)
ΣTEQ is calculated as the the sum of the PCB, PCDD, and PCDF TCDD-TEQ values.

Table 6.1. Relative oestrogenic potencies of the active compounds (Jobling and Sumpter 1993).

Compound	N[a]	Mean ED_{50}	Standard Error	RP[b]
17ß-estradiol	8	1.81 nM	0.81	1
4-nonylphenol (4NP)	4	16.15 µM	0.79	0.0000090
4-tert-butylphenol (4-tBP)	3	2.06 µM	0.57	0.0001600
4-tert-octylphenol (4-tOP)	2	2.11 µM	0.22	0.0000370
nonylphenol diethoxylate (NP2EO)	2	17.27 µM	0.77	0.0000060
nonylphenol ethoxylate (NP9EO)	2	82.31 µM	7.79	0.0000002
nonylphenol ethoxyacetic acid (NP1EC)	2	15.25 µM	2.76	0.0000063

[a]Refers to the number of experiments conducted.

[b]Refers to the mean potency of each compound relative to 17ß-oestradiol.

Table 6.2. Effects of endocrine disrupting compounds on whole fish in the laboratory (Pait and Nelson 2002).

Fish/Species	Sex	Compound	Method of Exposure	Concentration	Duration	Vtg	T	E2	GSI	GD	I	Reference
Rainbow trout (*Oncorhynchus mykiss*)	male	4-Nonylphenol	whole fish (water)	30 μg/L	3 weeks	+			+			Jobling *et al.*, 1996
Killifish (*Fundulus heteroclitus*)	male	4-Nonylphenol	whole fish (intraperitoneal inj.)	50-150 mg/kg	8 days	+			+			Pait and Nelson, in prep.
Sheepshead minnow (*Cyprinodon variegatus*)	male	4-Nonylphenol	whole fish (water)	0.6-42.7 μg/L	42 days	+						Hemmer *et al.*, 2001
Japanese medaka (*Oryzias latipes*)	male	4-Nonylphenol	whole fish (water)	50 μg/L	3 months				+	–	+	Gray and Metcalfe, 1997
Japanese medaka (*Oryzias latipes*)	juvenile	4-Nonylphenol	whole fish (water)	17.7 - 51.5 μg/L	104 days						+	Yokota *et al.*, 2001
Summer flounder (*Paralichthys dentatus*)	male	Octylphenol	whole fish (intraperitoneal inj.)	2 - 200 mg/kg	8 weeks				–			Mills *et al.*, 2001
Fathead minnows (*Pimphales promelas*)	male	Bisphenol-A	whole fish (water)	1 - 1,280 μg/L	164 days	+			–	–		Sohoni *et al.*, 2001
Rainbow trout (*Oncorhynchus mykiss*)	juvenile	Bisphenol-A	whole fish (water)	10 - 500 μg/L	12 days	+						Lindholst *et al.*, 2000
Rainbow trout (*Oncorhynchus mykiss*)	juvenile	Bisphenol-A	whole fish (intraperitoneal inj.)	50 mg/kg	18 days	+						Christiansen *et al.*, 2000
Common carp (*Cyprinus carpio*)	male	4-*tert*-Pentylphenol	whole fish (water)	3-1,000 μg/L	3 months	+				–		Gimeno *et al.*, 1998a
Common carp (*Cyprinus carpio*)	male	4-*tert*-Pentylphenol	whole fish (water)	1,000 μg/L	140 days					–	+	Gimeno *et al.*, 1998b
Japanese medaka (*Oryzias latipes*)	male	17α–Ethinylestradiol	whole fish (water)	0.1 μg/L	2 months						+	Scholz and Gutzeit, 2000
Fathead minnows (*Pimphales promelas*)	male	17α–Ethinylestradiol	whole fish (water)	0.064 μg/L	305 days					–	+	Lange *et al*., 2001
Japanese medaka (*Oryzias latipes*)	juvenile	17α–Ethinylestradiol	whole fish (water)	0.1 μg/L	110 days						+	Metcalfe *et al.*, 2001
Rainbow trout (*Oncorhynchus mykiss*)	female	β-Napthoflavone and 17β-estradiol	whole fish (intraperitoneal inj.)	50 mg/kg β-NF and 0.5 mg/kg E_2	24 hours	–						Anderson *et al.*, 1996b
Atlantic croaker (*Micropogonias undulatus*)	female	Benzo[*a*]pyrene	whole fish (diet)	0.4 mg/70g	30 days			–	–	–		Thomas 1988

NE, no effect; Vtg, vitellogenin; T, testosterone; E2, β-estradiol; GSI, gonadosomatic index; GD, gonadal development; I, intersex condition

Table 6.2. Effects of endocrine disrupting compounds on whole fish in the laboratory (Pait and Nelson 2002).

Fish/Species	Sex	Compound	Method of Exposure	Concentration	Duration	Vtg	T	E2	GSI	GD	I	Reference
European flounder (*Platichthys flesus*)	female	Phenanthrene and chrysene	whole fish (diet)	0.4 - 12.5 nM/g food	12 weeks			–				Monteiro *et al.*, 2000b
Rock sole (*Lepidopsetta bilineata*)	female	Prudhoe Bay crude oil	whole fish (intraperitoneal inj.)	0.1 - 1.0 mg/kg	7 days			–				Johnson *et al*., 1993
Atlantic croaker (*Micropogonias undulatus*)	female	Aroclor 1254	whole fish (diet)	0.24 mg/70g	30 days				–			Thomas 1988
Atlantic croaker (*Micropogonias undulatus*)	female	Aroclor 1254	whole fish (diet)	0.24 mg/70g	30 days			–				Thomas 1989
White perch (*Morone americana*)	female	3,3',4,4'-Tetrachlorobiphenyl	whole fish (intraperitoneal inj.)	0.2-5.0 mg PCB/kg	9 weeks	NE	NE		–			Monosson *et al.*, 1994
Starry flounder (*Platichthys stellatus*)	female	Natural PCB exposure	whole fish (water/diet)	unknown	life					–		Spies and Rice, 1988
Japanese medaka (*Oryzias latipes*)	juvenile	*o'p*-DDT	whole fish (water)	7.5 µg/L	2-8 weeks	+					+	Cheek *et al.*, 2001
Atlantic croaker (*Micropogonias undulatus*)	female	*o'p*-DDT	whole fish (diet)	0.02 and 0.01 µg DDT/g	3-7 weeks				+			Khan and Thomas, 1998
Sheepshead minnow (*Cyprinodon variegatus*)	male	Endosulfan	whole fish (water)	0.28 - 0.79 µg /L	40 days	NE						Hemmer *et al.*, 2001
Walking catfish (*Clarias batrachus*)	female	Endosulfan	whole fish (water)	1.5 µg/L	16 days	–						Chakravorty *et al.*, 1992
Dwarf gourami (*Colisa lalia*)	female	Carbofuran	whole fish (water)	0.7 µg/L	20 days					–		Sukumar and Karpagaganapathy, 1992
Sheepshead minnow (*Cyprinodon variegatus*)	male	Methoxychlor	whole fish (water)	12.1 µg /L	35 days	+						Hemmer *et al.*, 2001
Rainbow trout (*Oncorhynchus mykiss*)	juvenile	Butylbenzyl phthalate	whole fish (water)	500 mg/kg	9 days	+						Christiansen *et al*., 1998
Rainbow trout (*Oncorhynchus mykiss*)	female	Lead	whole fish (water)	10 µg/L	12 days				–			Ruby *et al.*, 2000
Atlantic croaker (*Micropogonias undulatus*)	female	Lead	whole fish (diet)	1.34 mg/70g	30 days				–			Thomas, 1988
Atlantic croaker (*Micropogonias undulatus*)	female	Cadmium	whole fish (water)	1 mg/L	30 days			+	+			Thomas, 1989
Rainbow trout (*Oncorhynchus mykiss*)	juvenile	β-Sitosterol	whole fish (water)	75 - 100 µg/L	3 weeks	+	–					Tremblay and van Der Kraak, 1998
Goldfish	males/females	β-Sitosterol	whole fish (water)	75- 1,200 µg/L	12 days		–	–				MacLatchy *et al.*, 1997

NE, no effect; Vtg, vitellogenin; T, testosterone; E2, 17β-estradiol; GSI, gonadosomatic index; GD, gonadal development; I, intersex condition

Note: For references see Pait and Nelson (2002).

Table 6.3. Field studies of endocrine disruption in freshwater species of fish (Pait and Nelson 2002).

Fish/Species	Sex	Land Use	Location/ Study Site	Caged/wild fish	Vtg	I	T	E2	GSI	GD	EM	Possible Cause(s)	Reference
Roach *(Rutilus rutilus)*	M/F	Sewage treatment plants	15 sites in England	caged; 1-3 weeks	+							17α-ethinylestradiol	Purdom *et al.*, 1994
Rainbow trout *(Oncorhynchus mykiss)*	M	Sewage treatment plants	15 sites in England and Wales	caged; 3 weeks	+							17α-ethinylestradiol	Sumpter and Jobling, 1995
Rainbow trout *(Oncorhynchus mykiss)*	M	Sewage treatment plants	5 sites on River Lea in U.K.	caged; 3 weeks	+							17α-ethinylestradiol and alkylphenols	Harries *et al.*, 1996
Rainbow trout *(Oncorhynchus mykiss)*	M	Sewage treatment plants	5 sites on River Lea in U.K.	caged; 3 weeks	+				–			Estrogens and nonylphenol	Harries *et al.*, 1997
Rainbow trout *(Oncorhynchus mykiss)*	M	Sewage treatment plants	Berlin STP	6 months	+							Estrogens and nonylphenol	Hansen *et al.*, 1998
Roach *(Rutilus rutilus)*	M	Sewage treatment plants	8 rivers in the U.K.	wild	+	+			–			Estrogens and alkylphenols	Jobling *et al.*, 1998
Roach *(Rutilus rutilus)*	M	Sewage treatment plants	Chelmsford STP, U.K.	caged; 1 month	+	+						Estrogens and alkylphenols	Rodgers-Gray *et al.*, 2000
Rainbow trout *(Oncorhynchus mykiss)*	M	Sewage treatment plants	River Aire, U.K.	caged; 3 weeks	+							Alkylphenols from wool scouring plant	Sheahan *et al.*, 2002a
Gudgeon *(Gobio gobio)*	M	Sewage treatment plants	River Aire, U.K.	wild	+	+						Estrogens and alkylphenols	van Aerle *et al.*, 2001
Rainbow trout *(Oncorhynchus mykiss)*	M	Sewage treatment plant	Western Sweden	caged; 2 weeks	+							Estrogens and alkylphenols	Larsson *et al.*, 1999
Mosquitofish *(Gambusia a. holbrooki*	M	Sewage treatment plant	Hawkesbury River, Australia	wild							–	Estrogens and alkylphenols	Batty and Lim, 1999
Common carp *(Cyprinus carpio)*	M	Sewage treatment plants	St. Paul, Minnesota	wild	+		NE					Estrogens	Folmar *et al.*, 1996
Walleye *(Stizostedion vitreum)*	M	Sewage treatment plants	St. Paul, Minnesota	wild	+		–	+			–	Estrogens and alkylphenols	Folmar *et al.*, 2001
Walleye *(Stizostedion vitreum)*	F	Sewage treatment plants	St. Paul, Minnesota	wild	+			+		–		Estrogens and alkylphenols	Folmar *et al.*, 2001

M/F, male and female fish collected in study and effects same in both sexes; NE, no effect; Vtg, vitellogenin; I, intersex condition; T, testosterone; E2, 17β-estradiol; GSI, gonadosomatic index; GD, gonadal development; EM effect on external male/female morphology

Table 6.3. Field studies of endocrine disruption in freshwater species of fish (Pait and Nelson 2002).

Fish/Species	Sex	Land Use	Location/ Study Site	Caged/wild fish	Vtg	I	T	E2	GSI	GD	EM	Possible Cause(s)	Reference
Largemouth bass *(Micropterus salmoides floridanus)*	M	Pulp and paper mill	St. Johns River	wild			–					β-Sitosterol	Sepúlveda*et al.,* 2002
Largemouth bass *(Micropterus salmoides floridanus)*	F	Pulp and paper mill	St. Johns River	wild	–				–			β-Sitosterol	Sepúlveda*et al.,* 2002
Whitefish *(Coregonus lavaretus)*	M/F	Pulp and paper mill	Lake Saimaa, Finland	caged; 1 month	+							β-Sitosterol	Soimasuo*et al.,* 1998
Perch *(Perca fluviatilis L.)*	F	Pulp and paper mill	Lake Saimaa, Finland	wild					–			β-Sitosterol	Karels *et al.*, 2001
White sucker *(Catostomus commerson*	M/F	Pulp and paper mill	St. Maurice River, Quebec	wild			–	–				β-Sitosterol	Gagnon *et al.,* 1994
White sucker *(Catostomus commerson*	M/F	Pulp and paper mill	Lake Superior, Canada	wild			–	–	–			β-Sitosterol	McMaster *et al.,* 1991
Mosquitofish *(Gambusia holbrooki)*	F	Pulp and paper mill	St. John's River, Florida	wild							–	β-Sitosterol	Bortone and Cody, 1999
Mosquitofish *(Gambusia holbrooki)*	F	Pulp and paper mill	Perdido Bay, Florida	wild							–	β-Sitosterol	Cody and Bortone, 1997
Mosquitofish *(Gambusia holbrooki)*	F	Pulp and paper mill	Fenholloway River, Florida	wild							–	β-Sitosterol	Jenkins*et al.*, 2001
Channel catfish *(Ictalurus punctatus)*	F	Sugar beet processing plant	Red River, North Dakota	wild							–	β-Sitosterol	Hegrenes, 1999
Largemouth bass *(Micropterus salmoides)*	M/F	Power plant, chemical manufacture	Escambia/Blackwater River, Florida	wild	+		–					Contaminants	Orlando *et al.,* 1999
Common carp *(Cyprinus carpio)*	M	General survey	Various locations in U.S.	wild	+/NE		–/NE			–/NE		Contaminants	Goodbred *et al.*, 1997
Common carp *(Cyprinus carpio)*	F	General survey	Various locations in U.S.	wild				–/NE				Contaminants	Goodbred *et al.*, 1997
Fathead minnow *(Pimphales promelas)*	M/F	General survey	Mississippi River	wild	NE							None	Parks *et al.,* 1997

M/F, male and female fish collected in study and effects same in both sexes; NE, no effect; Vtg, vitellogenin; I, intersex condition; T, testosterone; E2, 17β-estradiol; GSI, gonadosomatic index; GD, gonadal development; EM effect on external male/female morphology

Note: For references see Pait and Nelson (2002).

Table 6.4. Compounds for National reconnaissance of emerging contaminants in US streams (USGS 2010).

Veterinary and Human Antibiotics	
Tetracyclines	**Sulfonamides**
Chlortetracycline	Sulfachlorpyridazine
Doxycycline	Sulfamerazine
Oxytetracycline	Sulfamethazine
Tetracycline	Sulfathiazole
Fluoroquinolones	Sulfadimethoxine
Ciprofloxacin	Sulfamethiazole
Enrofloxacin	Sulfamethoxazole
Norfloxacin	**Others**
Sarafloxacin	Lincomycin
Macrolides	Trimethoprim
Erythromycin-H2O (metabolite)	Carbadox
Tylosin	Virginiamycin
Roxithromycin	

Human Drugs	
Prescription	**Non-Prescription**
Metformin (antidiabetic agent)	Acetaminophen (analgesic)
Cimetidine (antacid)	Ibuprofen (anti-inflammatory, analgesic)
Ranitidine (antacid)	Codeine (analgesic)
Enalaprilat (antihypertensive)	Caffeine (stimulant)
Digoxin	1,7-Dimethylxanthine (caffeine metabolite)
Diltiazem (antihypertensive)	Cotinine (nicotine metabolite)
Fluoxetine (antidepressant)	
Paroxetine (antidepressant, antianxiety)	
Warfarin (anticoagulant)	
Salbutamol (antiasthmatic)	
Gemfibrozil (antihyperlipidemic)	
Dehydronifedipine (antianginal metabolite)	
Digoxigenin (digoxin metabolite)	

Table 6.4. Compounds for National reconnaissance of emerging contaminants in US streams (USGS 2010).

Industrial and Household Wastewater Products	
Insecticides	**Polycyclic aromatic hydrocarbons (fossil fuel and fuel combustion indicators)**
Diazinon	Naphthalene
Carbaryl	Phenanthrene
Chlorpyrifos	Anthracene
cis -Chlordane	Fluoranthene
N,N-diethyltoluamide (DEET)	Pyrene
Lindane	Benzo(*a*)pyrene
Methyl parathion	**Antioxidants**
Dieldrin	2,6-di-tert-Butylphenol
Plasticizers	5-Methyl-1H-benzotriazole
bis (2-Ethylhexyl)adipate	Butylatedhydroxyanisole (BHA)
Ethanol-2-butoxy-phosphate	Butylatedhydroxytoluene (BHT)
bis (2-Ethylhexyl)phthalate	2,6-di-tert-Butyl-p-benzoquinone
Diethylphthalate	**Others**
Triphenyl phosphate	Tetrachloroethylene (solvent)
Detergent metabolites	Phenol (disinfectant)
p -Nonylphenol	1,4-Dichlorobenzene (fumigant)
Nonylphenol monoethoxylate (NPEO1)	Acetophenone (fragrance)
Nonylphenol diethoxylate (NPEO2)	*p* -Cresol (wood preservative)
Octylphenol monoethoxylate (OPEO1)	Phthalic anhydride (used in plastics)
Octylphenol diethoxylate (OPEO2)	Bisphenol A (used in polymers)
Fire retardants	Triclosan (antimicrobial disinfectant)
Tri(2-chloroethyl)phosphate	
Tri(dichlorisopropyl)phosphate	

Sex and Steroidal Hormones	
Biogenics	**Pharmaceuticals**
17*b* -Estradiol	17*a* -Ethynylestradiol (ovulation inhibitor)
17*a* -Estradiol	Mestranol (ovulation inhibitor)
Estrone	19-Norethisterone (ovulation inhibitor)
Estriol	Equilenin (hormone replacement therapy)
Testosterone	Equilin (hormone replacement therapy)
Progesterone	**Sterols**
cis -Androsterone	Cholesterol (fecal indicator)
	3*b* -Coprostanol (carnivore fecal indicator)
	Stigmastanol (plant sterol)

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Conventional Variables																
Alkalinity	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Biological Oxygen Demand (BOD)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Chemical Oxygen Demand (COD)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Conductivity	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Hardness	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
pH	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Temperature	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Total Suspended Sediment	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Total Dissolved Solids	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Microbiological Variables																
Faecal Coliforms	√	√		√	√				√		√		√	√		√
Enterococci	√	√		√	√				√		√		√	√		√
Major Ions																
Anions																
Chlorides	√	√	√	√	√	√			√	√	√		√	√		√
Fluorides	√	√	√	√	√	√			√	√	√		√	√		√
Sulphates	√	√	√	√	√	√			√	√	√		√	√		√
Sulphides	√	√	√	√	√	√			√	√	√		√	√		√
Cations																
Calcium	√	√	√	√	√	√			√	√	√		√	√		√
Potassium	√	√	√	√	√	√			√	√	√		√	√		√
Sodium	√	√	√	√	√	√			√	√	√		√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Nutrients																
Nitrate	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Nitrite	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Ammonia	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Urea	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Phosphorus	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Metals																
Aluminum	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Barium	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Boron	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Chromium (III & VI)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Cobalt	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Copper	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Iron	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Mercury	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Manganese	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Molybdenum	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Nickel	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Selenium	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Strontium	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Silver	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Vanadium	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Zinc	√	√	√	√	√	√		√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Organometallics																
Organotins																
Monobutyltin	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Dibutyltin	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Tributyltin	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Tetrabutyltin	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Organomercury																
Methylmercury	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Cyanides																
Cyanide (SAD)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Cyanide (WAD)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Mono Aromatic Hydrocarbons (MAHs)																
Benzene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Toluene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Ethylbenzene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Xylene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Polycyclic Aromatic Hydrocarbons (PAHs)																
Parent PAHs																
Includes Low- and High-Molecular Weight PAHs	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Low-Molecular Weight PAHs																
Acenapthene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Acenaphthylene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Anthracene	√	√	√	√	√	√		√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Low-Molecular Weight PAHs (continued)																
Fluorene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Naphthalene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Phenanthrene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
2,6-dimethylnaphthalene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
1-methylnaphthalene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
2-methylnaphthalene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
1-methylphenanthrene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
2,3,5-trimethylnaphthalene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
High-Molecular Weight PAHs																
Chrysene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Fluoranthene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Pyrene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Benzo(k)fluoranthene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Benzo(b)fluoranthene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Benzo(a)pyrene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Benzo(a)anthracene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Benzo(e)pyrene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Benzo(g,h,i)perylene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Dibenz(a,h)anthracene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Indeno(1,2,3-c,d)pyrene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Perylene	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Alkylated PAHs																
C1-benzo(a)anthracenes/chrysenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C2-benzo(a)anthracenes/chrysenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C3-benzo(a)anthracenes/chrysenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Alkylated PAHs (continued)																
C4-benzo(a)anthracenes/chrysenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C1-fluoranthenes/pyrenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C1-fluorenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C2-fluorenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C3-fluorenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C1-naphthalenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C2-naphthalenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C3-naphthalenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C4-naphthalenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C1-phenanthrenes/anthracenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C2-phenanthrenes/anthracenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C3-phenanthrenes/anthracenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
C4-phenanthrenes/anthracenes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Total PAHs	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Phenolic Compounds																
Phenols																
Phenol	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Creosols																
Cresol	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Chlorinated Phenolic Compounds																
Chlorophenols																
Dichlorophenols	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Trichlorophenols	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Tetrachlorophenols	√	√	√	√	√	√		√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Pentachlorophenol	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Chloroguaiacols																
Trichloroguaiacols	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Tetrachloroguaiacols	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Chlorocatechols																
Trichlorocatechols	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Tetrachlorocatechols	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Polychlorinated Biphenyls (PCBs)																
PCB Congeners																
209 Congeners	√	√	√	√	√	√		√	√	√	√	√	√	√		√
PCB Homologs																
10 Homolog Groups	√	√	√	√	√	√		√	√	√	√	√	√	√		√
PCB Aroclors																
7+ Aroclor Mixtures	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Dioxin-like PCBs																
2,3,7,8-TCDD Toxic Equivalents	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Polychlorinated Dibenzo-*p*- Dioxins (PCDDs)																
PCDD Congeners																
75 Congeners	√	√	√	√	√	√		√	√	√	√	√	√	√		√
2,3,7,8-TCDD Toxic Equivalents	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Polychlorinated Dibenzofurans (PCDFs)																
PCDF Congners																
135 Congeners	√	√	√	√	√	√		√	√	√	√	√	√	√		√
2,3,7,8-TCDD Toxic Equivalents	√	√	√	√	√	√		√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															Fraser River Basin
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	
Resin Acids																
Abietic Acid	√	√							√	√	√		√	√		√
Neoabietic Acid	√	√							√	√	√		√	√		√
Dehydroabietic Acid	√	√							√	√	√		√	√		√
Palustric Acid	√	√							√	√	√		√	√		√
Levopimaric Acid	√	√							√	√	√		√	√		√
Pimaric Acid	√	√							√	√	√		√	√		√
Isopimaric Acid	√	√							√	√	√		√	√		√
Fatty Acids																
Palmitic Acid	√	√							√	√	√		√	√		√
Stearic Acid	√	√							√	√	√		√	√		√
Lignoceric Acid	√	√							√	√	√		√	√		√
Oleic Acid	√	√							√	√	√		√	√		√
Linoleic Acid	√	√							√	√	√		√	√		√
Linolenic Acid	√	√							√	√	√		√	√		√
Petroleum Hydrocarbons																
Oil and Grease	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Diesel Range Organics	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Alkanes	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Lube Oils	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Pesticides																
In-Use Herbicides																
Atrazine	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2,4-Dichlorophenoxyacetic acid (2,4-D)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															Fraser River Basin
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	
In-Use Herbicides (continued)																
2,4-D Amine	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Ethalfluralin	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Glyphosate	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Mineral Oil (Paraffin base)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Paraquat	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Pendimethalin	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Picloram	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Simazine	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Triallate	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Triclopyr	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Trifluralin	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
In-Use Insecticides																
Azinphosmethyl	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Bacillus thuringiensis	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Chlorpyrifos	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Diazinon	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Endosulfan	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Malathion	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Mineral Oil	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Parathion	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Legacy Organochlorine Pesticides																
Aldrin	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Chlordane	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
DDTs	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Dieldrin	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Endrin	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															Fraser River Basin
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	
Legacy Organochlorine Pesticides (continued)																
Endosulfan	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Heptachlor	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Heptachlor Epoxide	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Hexachlorobenzene	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Lindane	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Methoxychlor	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Nonachlor	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Toxaphene	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
In-Use Fungicides																
Captan	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Chlorothalonil	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Dazomet	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Mancozeb	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Metam	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Metiram	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Lime Sulphur	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Other Pesticides																
Formaldehyde	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Formalin	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Wood Preservation Chemicals																
Wood Preservatives																
Creosote	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Chromated Copper Arsenate (CCA)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Ammoniacal Copper Zinc Arsenate (ACZA)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Pentachlorophenol (PCP)	√	√	√	√	√	√		√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Anti-Sapstains																
Didecyldimethyl ammonium chloride (DDAC)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
3-iodo-2-propynyl butyl carbamate (IPBC)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Surfactants																
Alkylphenol Ethoxylates (APEOs)																
Nonylphenol Ethoxylates	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Octylphenol Ethoxylates	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Fluorosurfactants																
Amphoteric Fluorosurfactants	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Non-Ionic flurosurfactants	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Anionic flurosurfactants	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Pharmaceuticals																
Antibiotics																
Azithromycin	√	√		√	√			√	√	√	√	√	√	√		√
Ciprofloxacin	√	√		√	√			√	√	√	√	√	√	√		√
Doxycycline	√	√		√	√			√	√	√	√	√	√	√		√
4-Epitetracycline	√	√		√	√			√	√	√	√	√	√	√		√
Erythromycin	√	√		√	√			√	√	√	√	√	√	√		√
Oflocacin	√	√		√	√			√	√	√	√	√	√	√		√
Oxytetracycline	√	√		√	√			√	√	√	√	√	√	√		√
Tetracycline	√	√		√	√			√	√	√	√	√	√	√		√
Antihypertensives																
Atenolol	√	√		√	√			√	√	√	√	√	√	√		√
Anticonvulsants																
Carbamazepine	√	√		√	√			√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Antidepressants																
Fluoxetine	√	√		√	√			√	√	√	√	√	√	√		√
Sertaline	√	√		√	√			√	√	√	√	√	√	√		√
Anti-acid reflux compounds																
Cimetidine	√	√		√	√			√	√	√	√	√	√	√		√
Anti-inflamatory compounds																
Naproxen	√	√		√	√			√	√	√	√	√	√	√		√
Antifungal compounds																
Miconazole	√	√		√	√			√	√	√	√	√	√	√		√
Analgesic compounds																
Ibuprofen	√	√		√	√			√	√	√	√	√	√	√		√
Personal Care Products																
Fragrances																
Celestolide	√	√	√	√	√			√	√	√	√	√	√	√		√
Galaxolide	√	√	√	√	√			√	√	√	√	√	√	√		√
Tonalide	√	√	√	√	√			√	√	√	√	√	√	√		√
Insect Repellants																
Toluamide	√	√	√	√	√			√	√	√	√	√	√	√		√
Detergents																
Alkylphenols	√	√	√	√	√			√	√	√	√	√	√	√		√
Antimicrobial compounds																
Triclocarban	√	√	√	√	√			√	√	√	√	√	√	√		√
Triclosan	√	√	√	√	√			√	√	√	√	√	√	√		√
Fungicides																
Pentachloronitrobenzene	√	√	√	√	√			√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															Fraser River Basin
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	
Surfactants																
n-Nonylphenol	√	√	√	√	√			√	√	√	√	√	√	√		√
Stimulants																
Caffeine	√	√	√	√	√			√	√	√	√	√	√	√		√
Steroids, Hormones, and Hormone Mimickers																
Hormones																
Androstenedione	√	√		√	√			√	√	√	√	√	√	√		√
Beta-Stigmastanol	√	√		√	√			√	√	√	√	√	√	√		√
Campesterol	√	√		√	√			√	√	√	√	√	√	√		√
Cholestanol	√	√		√	√			√	√	√	√	√	√	√		√
Cholesterol	√	√		√	√			√	√	√	√	√	√	√		√
Hormones (continued)																
Coprostanol	√	√		√	√			√	√	√	√	√	√	√		√
17α-Ethinylestradiol	√	√		√	√			√	√	√	√	√	√	√		√
Epicporostanol	√	√		√	√			√	√	√	√	√	√	√		√
Estradiol	√	√		√	√			√	√	√	√	√	√	√		√
Estrone	√	√		√	√			√	√	√	√	√	√	√		√
Estriol	√	√		√	√			√	√	√	√	√	√	√		√
Stigmasterol	√	√		√	√			√	√	√	√	√	√	√		√
Testosterone	√	√		√	√			√	√	√	√	√	√	√		√
Natural Plant Hormones																
Phytosterols	√	√		√	√			√	√	√	√	√	√	√		√
Phytoestrogen Metabolites	√	√		√	√			√	√	√	√	√	√	√		√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Disinfectants	√	√	√	√	√			√	√	√	√	√	√	√		√
Disinfectants																
Bromine	√	√	√	√	√			√	√	√	√	√	√	√		√
Residual Chlorine	√	√	√	√	√			√	√	√	√	√	√	√		√
Iodine	√	√	√	√	√			√	√	√	√	√	√	√		√
Disinfection byproducts																
Trihalomethanes	√	√	√	√	√			√	√	√	√	√	√	√		√
Haloacetic Acids	√	√	√	√	√			√	√	√	√	√	√	√		√
Bromate	√	√	√	√	√			√	√	√	√	√	√	√		√
Chlorite	√	√	√	√	√			√	√	√	√	√	√	√		√
Fire Retardants																
Polybrominated diphenylethers (PBDEs)																
209 Congeners	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
10 Homolog Groups	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Fluorosurfactants																
Perfluorooctane Sulfonic Acid (PFOS)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Perfluorooctanoic acid (PFOA)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Other Fire Retardants																
Diammonium Sulphate	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Diammonium Phosphate	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Ammonium Sulphate	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Ammonium Phosphate	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Ammonium Polyphosphate	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Table 8.1. Inventory of aquatic contaminants within aquatic habitats in Areas of Interest in the Fraser River Basin.

Chemical Name	Area of Interest															
	Lower Fraser River	Upper Fraser River	Pitt River	Harrison River	Cultus Lake	Kakawa Lake	Nahatlatch River	Seton-Portage	Lower Thompson River	North Thompson River	South Thompson River	Chilko River	Quesnel River	Nechako River	Bowron River	Fraser River Basin
Plastics-Related Chemicals																
Phthalate Esters																
Diethyl Phthalate	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Dimethyl Phthalate	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Di-n-butyl Phthalate	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Bis(2)ethylhexyl Phthalate (BEHP)	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Other Plastic-related Chemicals																
Bisphenol A	√	√	√	√	√	√		√	√	√	√	√	√	√		√
Nanoparticles (NPs)																
Carbon Fullerenes	√	√		√					√		√			√		√
Carbon Nanotubes	√	√		√					√		√			√		√
Carbon Black	√	√		√					√		√			√		√
Metallic Nanoparticles (Copper or Silver)	√	√		√					√		√			√		√
Metal Oxide Nanoparticles	√	√		√					√		√			√		√
Quantum Dots	√	√		√					√		√			√		√
Other Nanoparticles	√	√		√					√		√			√		√

Figures

Figure 1.1. Productivity for the total Fraser sockeye from 1952 to 2009 (Lapointe 2010).

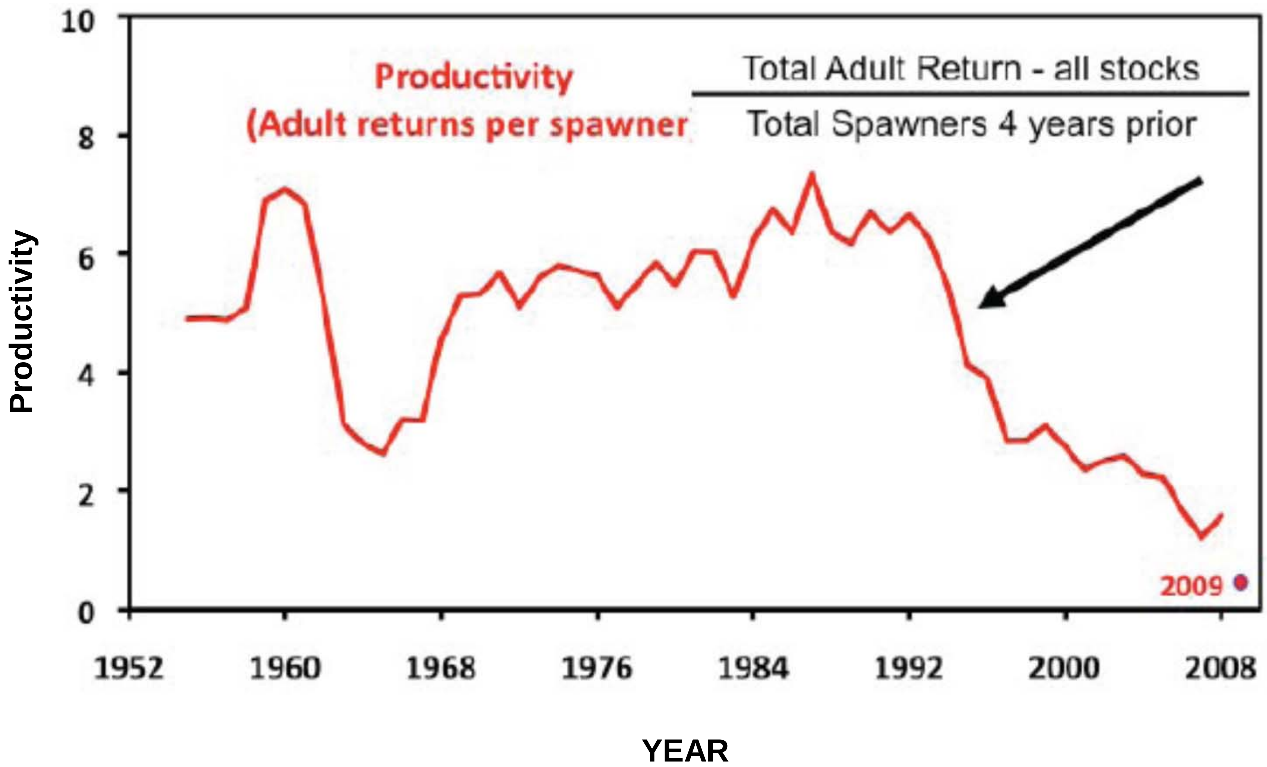


Figure 2.1. Map of the Fraser River Basin.

Figure 2.2. Map of the Fraser River Basin showing the locations of sockeye salmon presence.

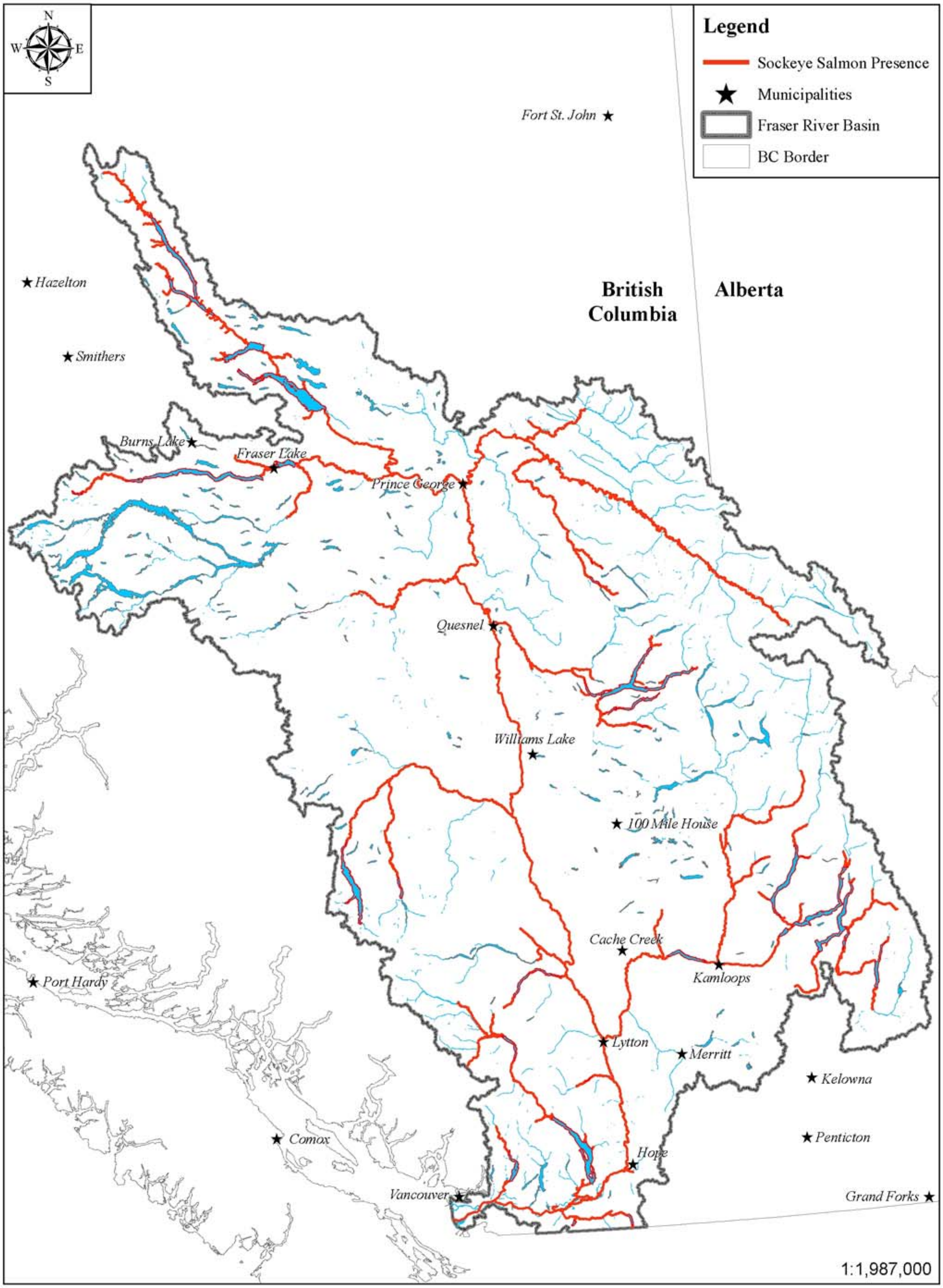


Figure 2.3. Map of the Fraser River Basin showing the locations of the 15 Areas of Interest (AoI).

Figure 2.4. Map of the Fraser River Basin showing the average annual escapement for each Area of Interest (1975 - 2007).

Figure 3.1. Map of the Fraser River Basin showing the locations of pulp and paper mills.

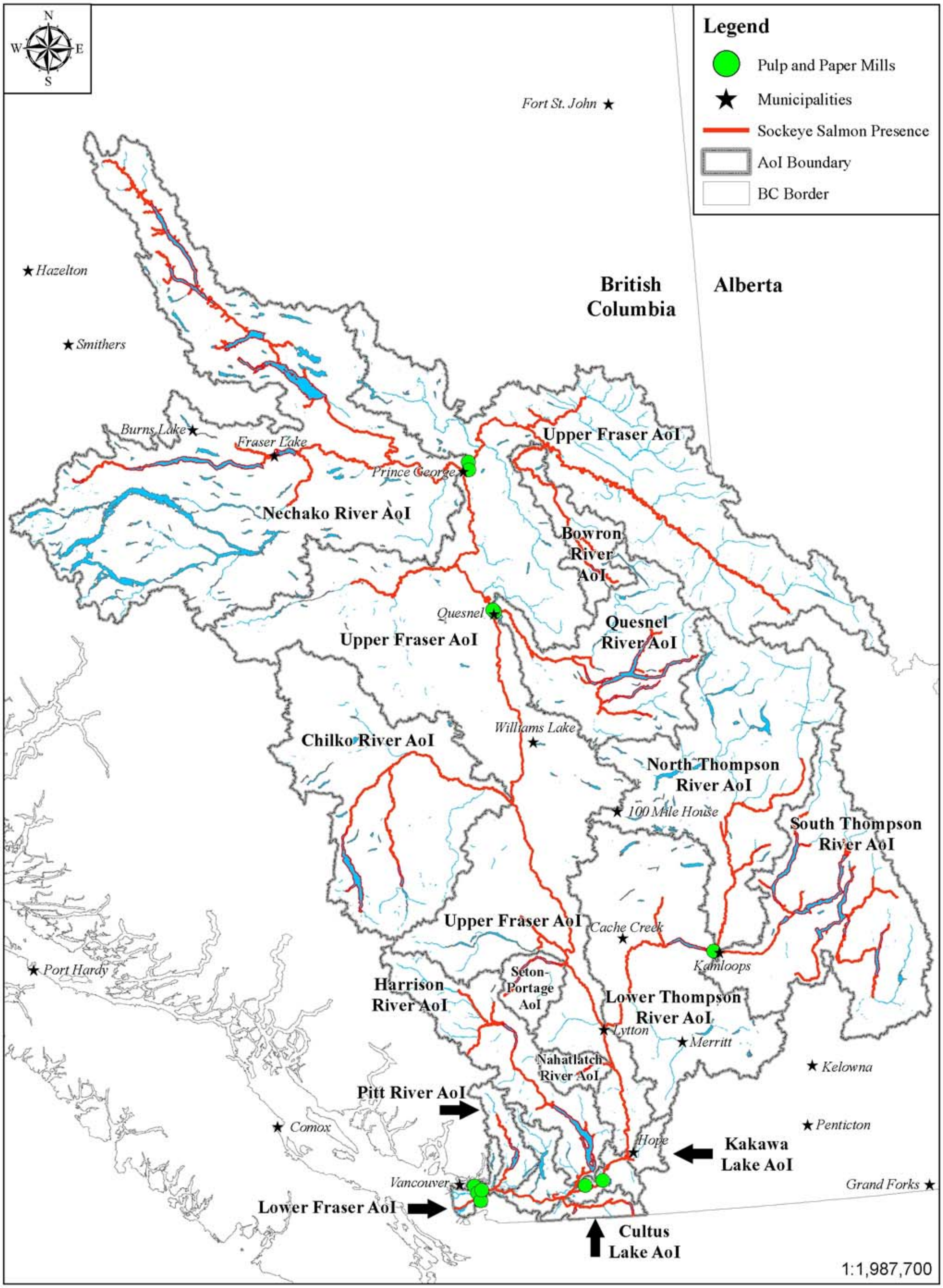


Figure 3.2. Map of the Fraser River Basin showing the locations of sawmills, plywood mills, shingle and shake mills, and waferboard, particleboard, and fibreboard mills.

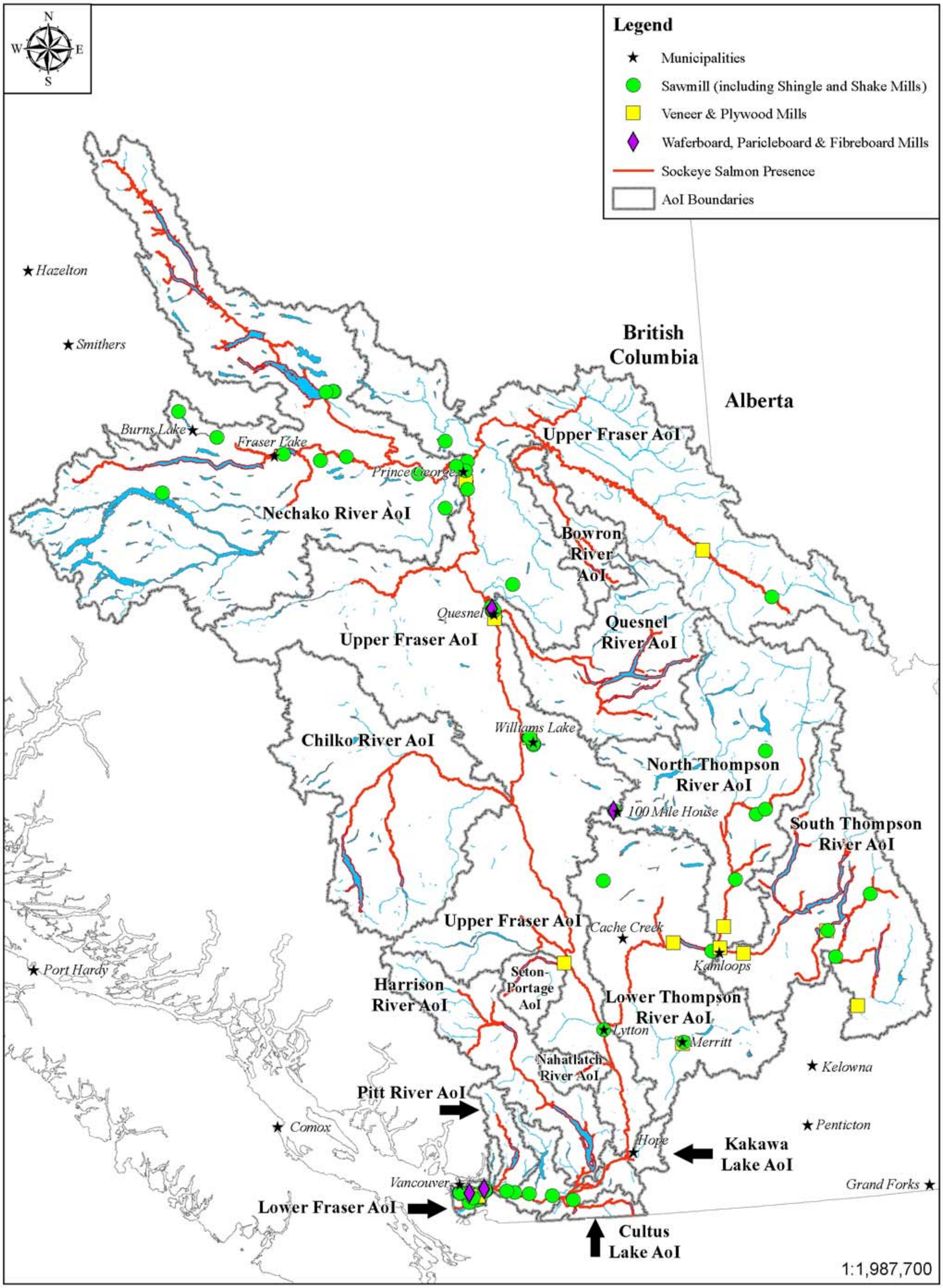


Figure 3.3. Map of the Fraser River Basin showing the locations of wood preservation facilities.

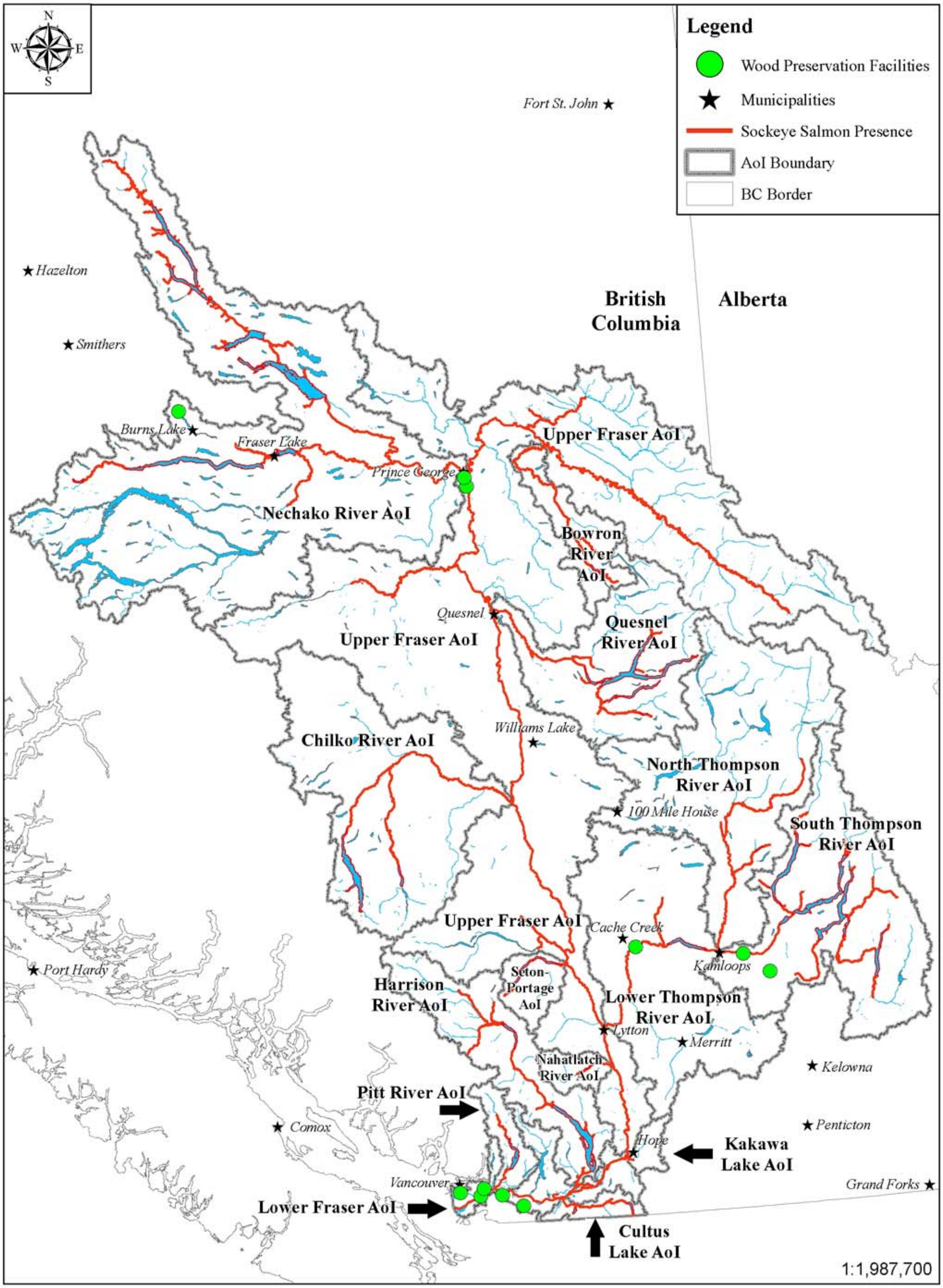


Figure 3.4. Map of the Fraser River Basin showing the locations of cement and concrete facilities.

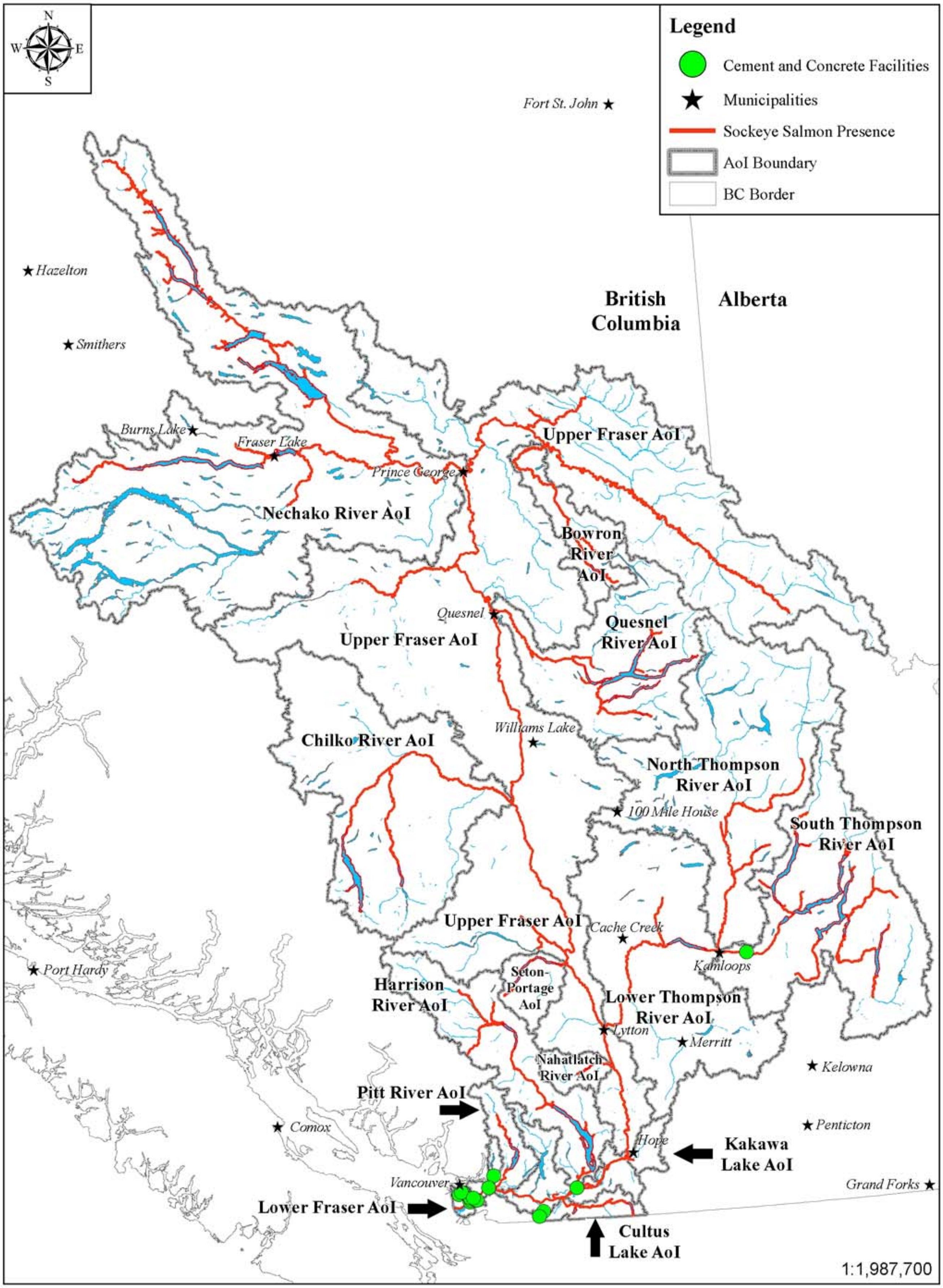


Figure 3.5. Map of the Fraser River Basin showing the locations of seafood processing facilities.

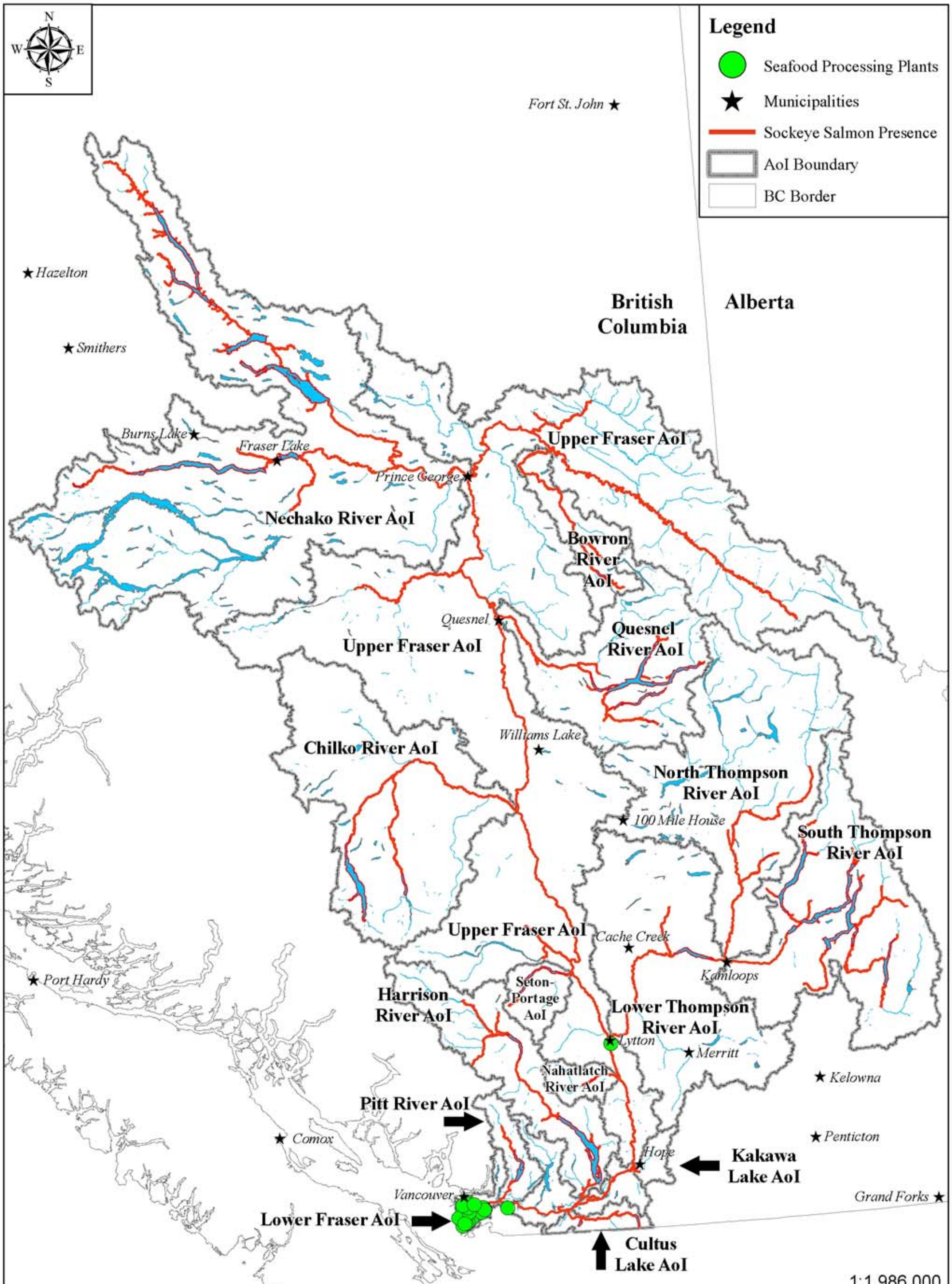


Figure 3.6. Map of the Fraser River Basin showing the locations of mines.

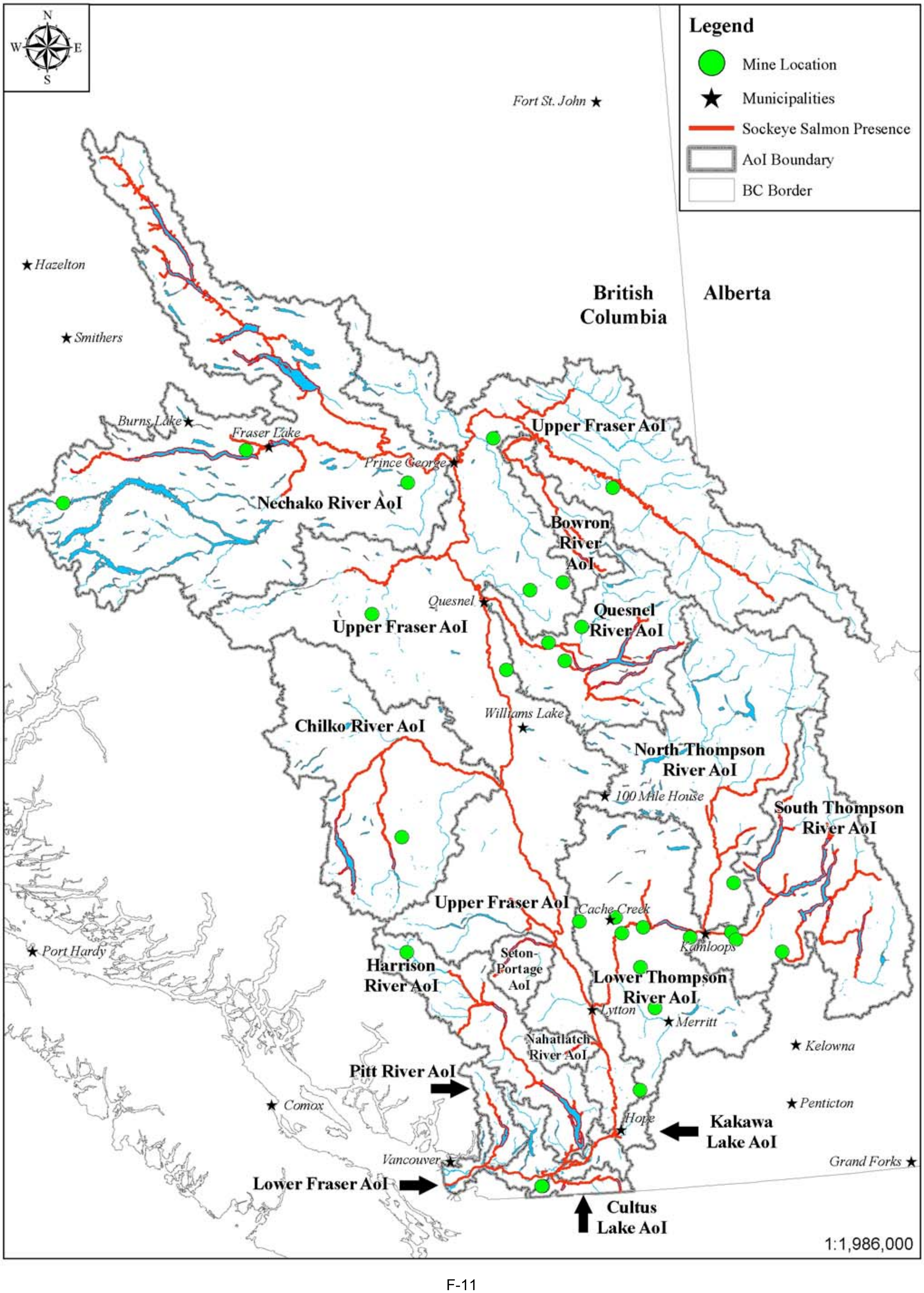


Figure 3.7. Map of the Fraser River Basin showing the locations of major gas plants, oil refineries, transmission facilities, delivery points and well heads.

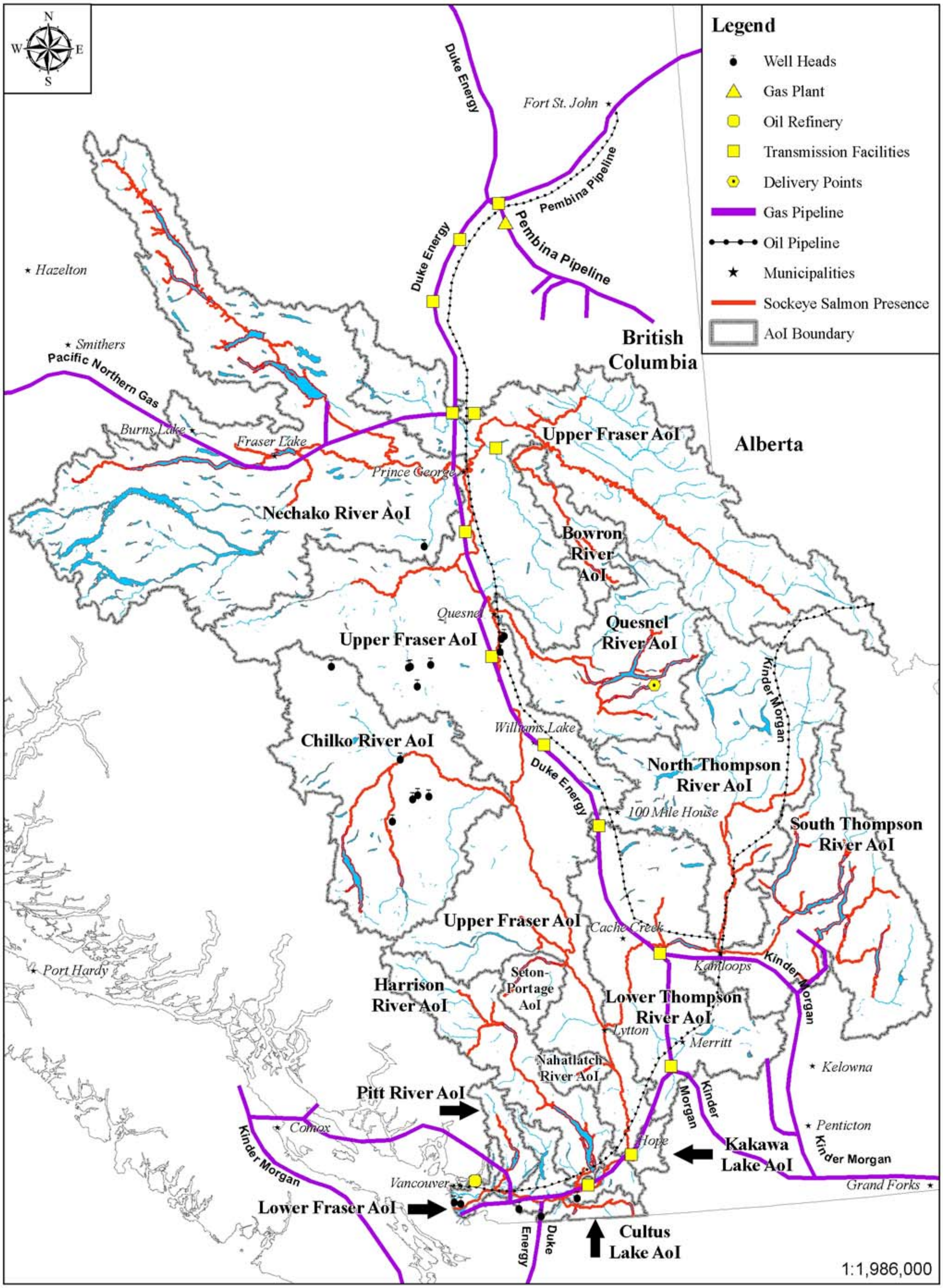


Figure 3.8. Map of the Fraser River Basin showing the locations of bulk storage and shipping facilities.

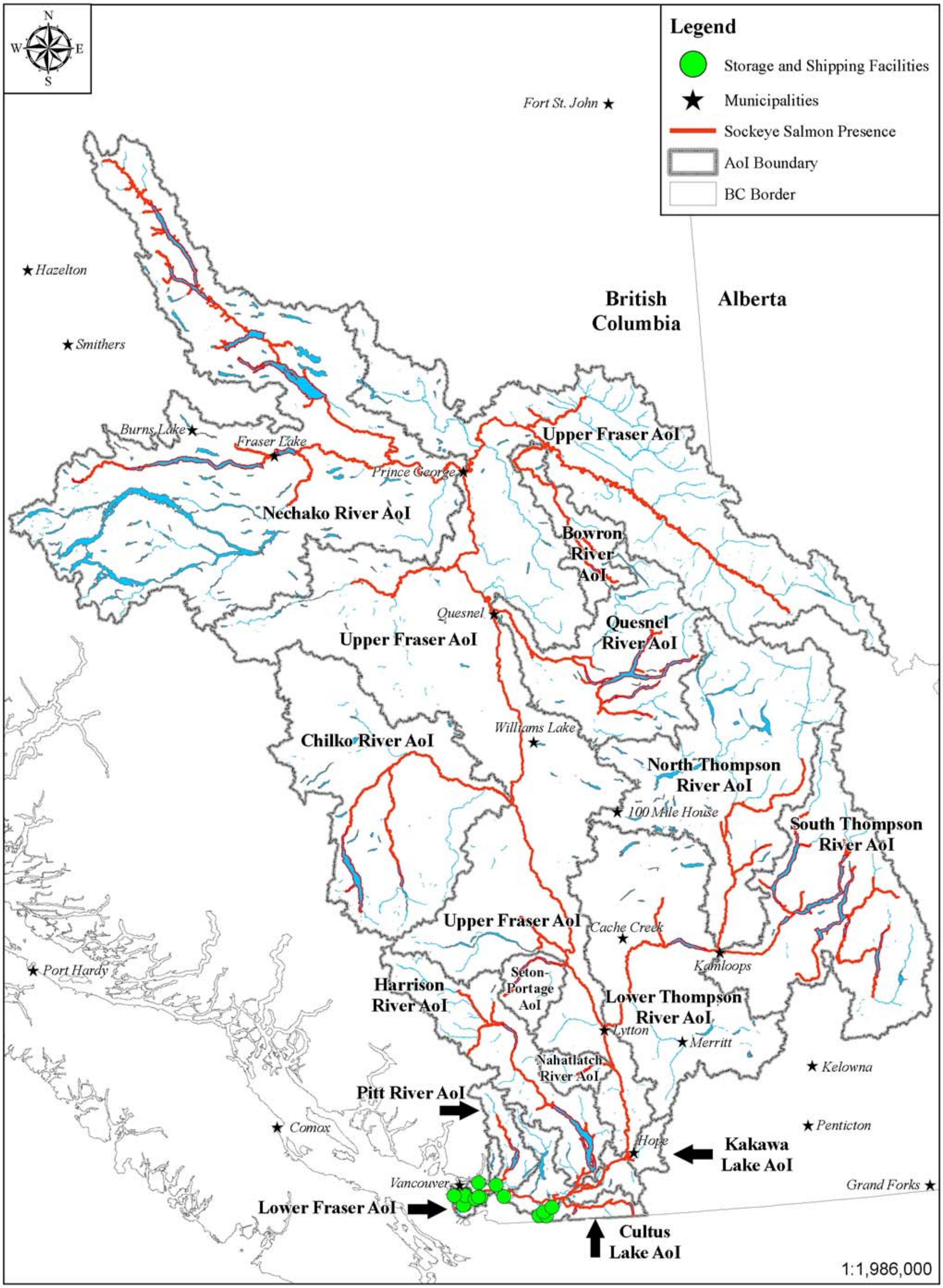


Figure 3.9. Map of the Fraser River Basin showing the locations of other manufacturing facilities.

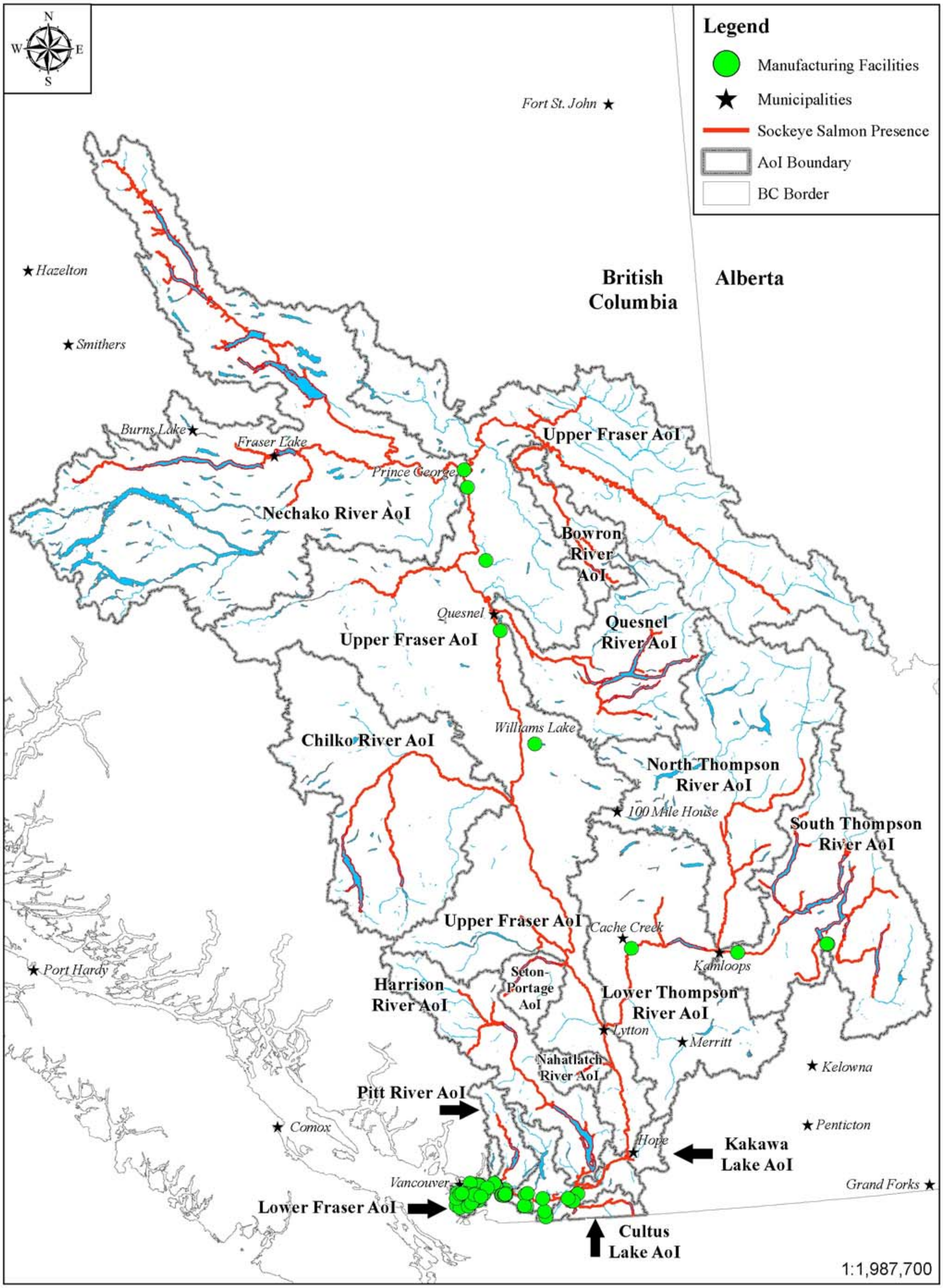


Figure 3.10. Map of the Fraser River Basin showing the locations of contaminated sites.

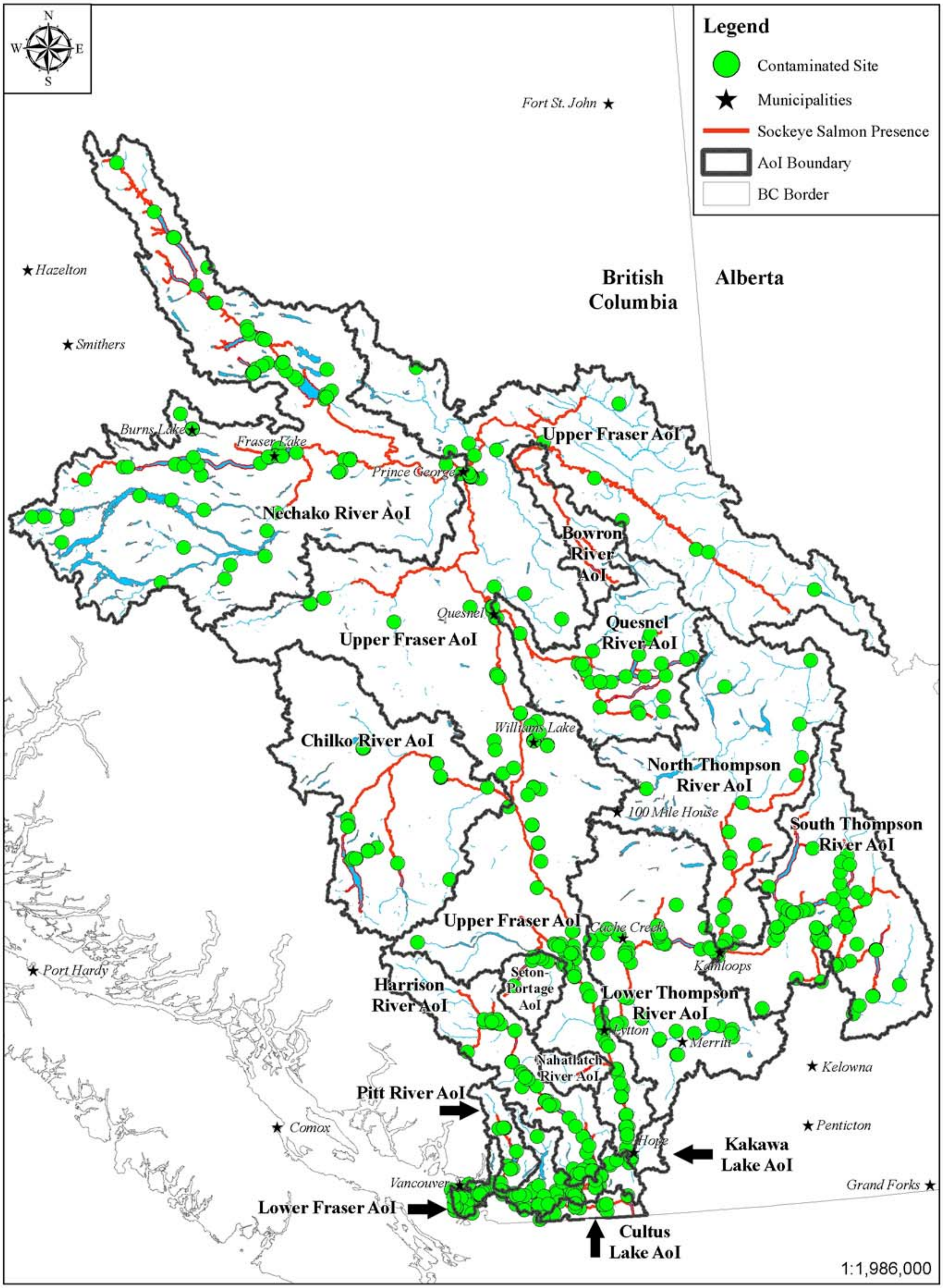


Figure 3.11. Map of the Fraser River Basin showing the locations of spills that were reported in 2007.

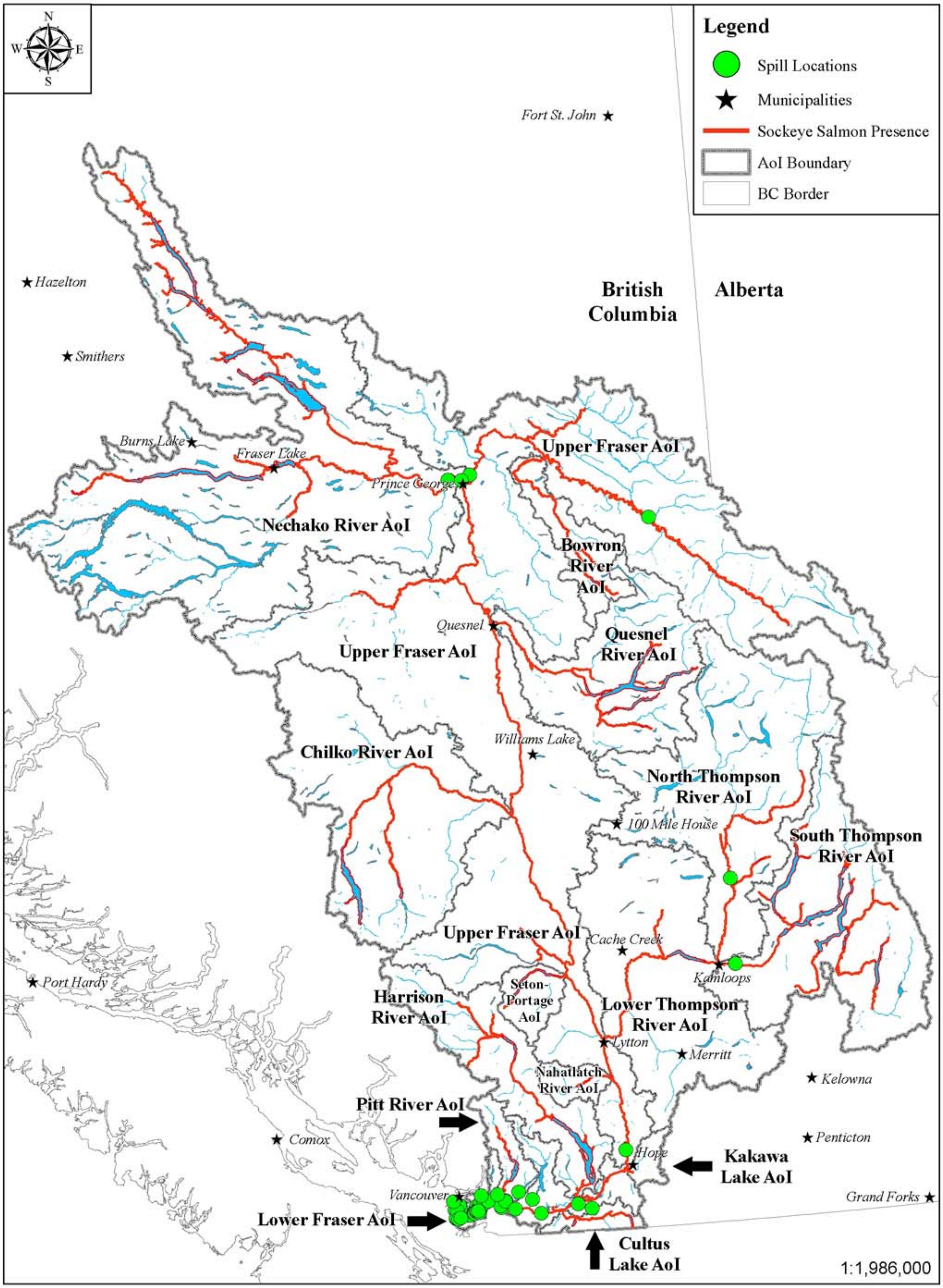


Figure 3.12. Map of the Fraser River Basin showing the locations of municipal wastewater treatment plants.

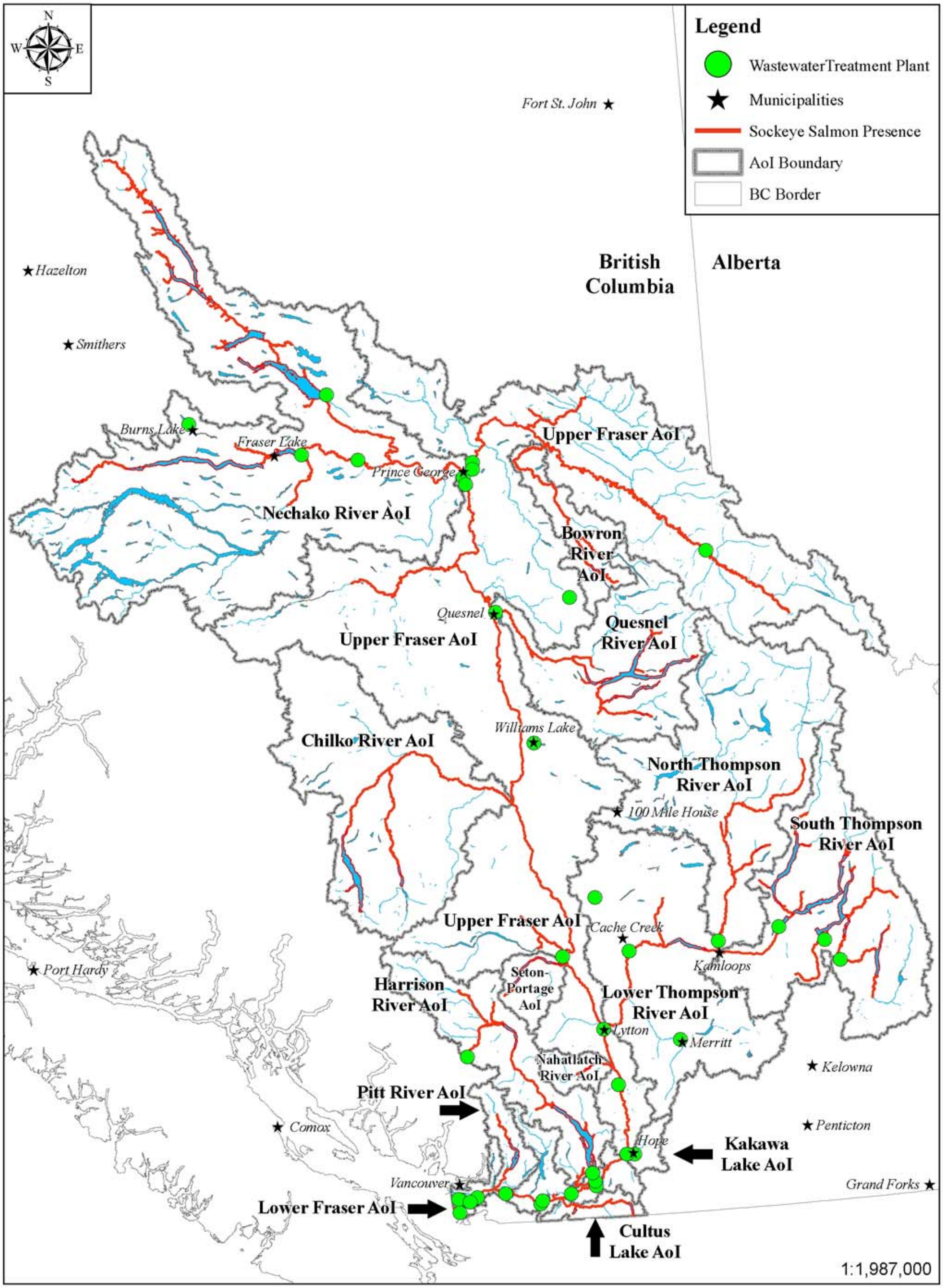


Figure 3.13. Map of the Fraser River Basin showing the locations of major industrial and muncipal landfills.

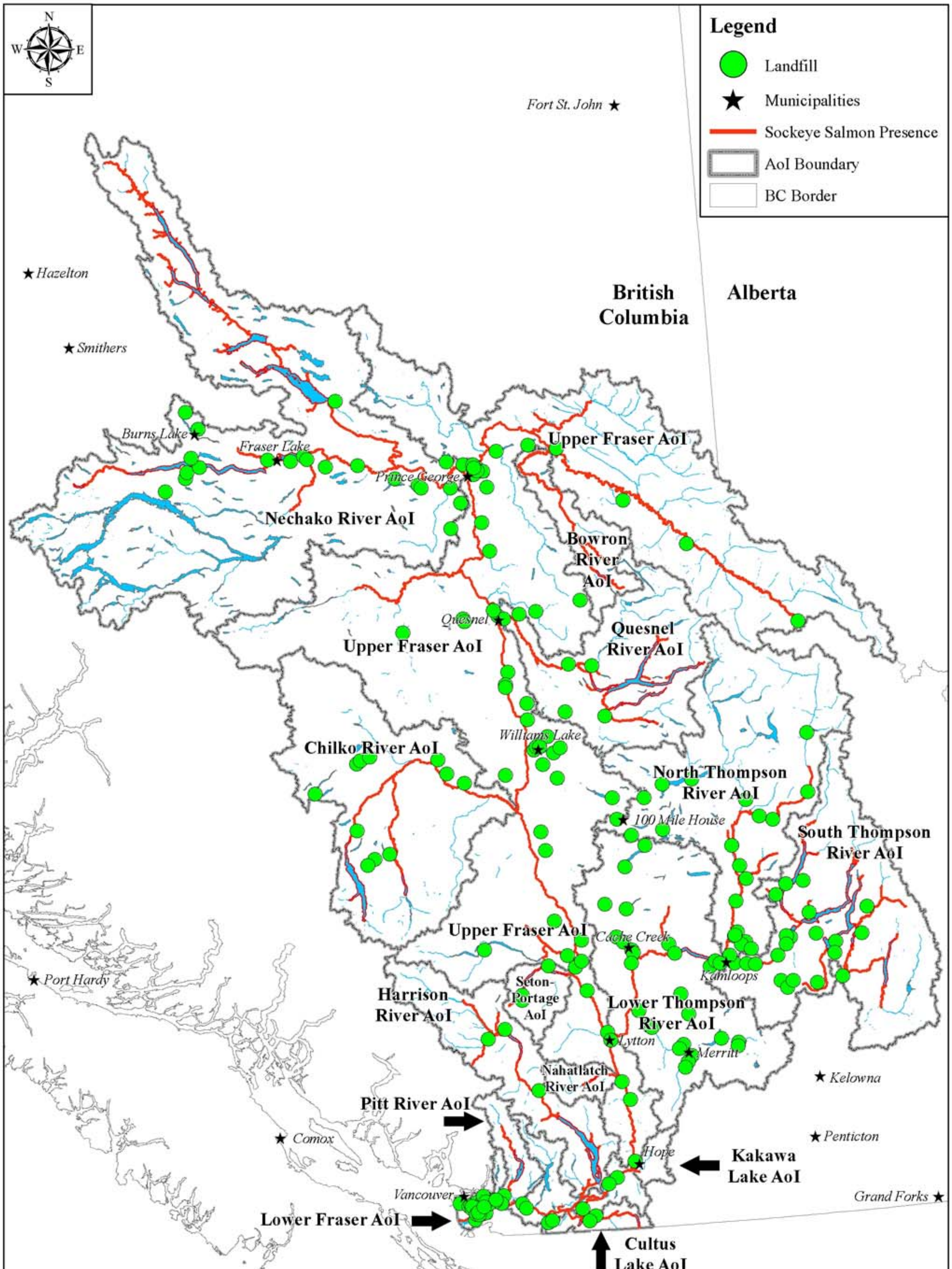


Figure 3.14. Map of the Fraser River Basin showing the locations of salmonid enhancement facilities.

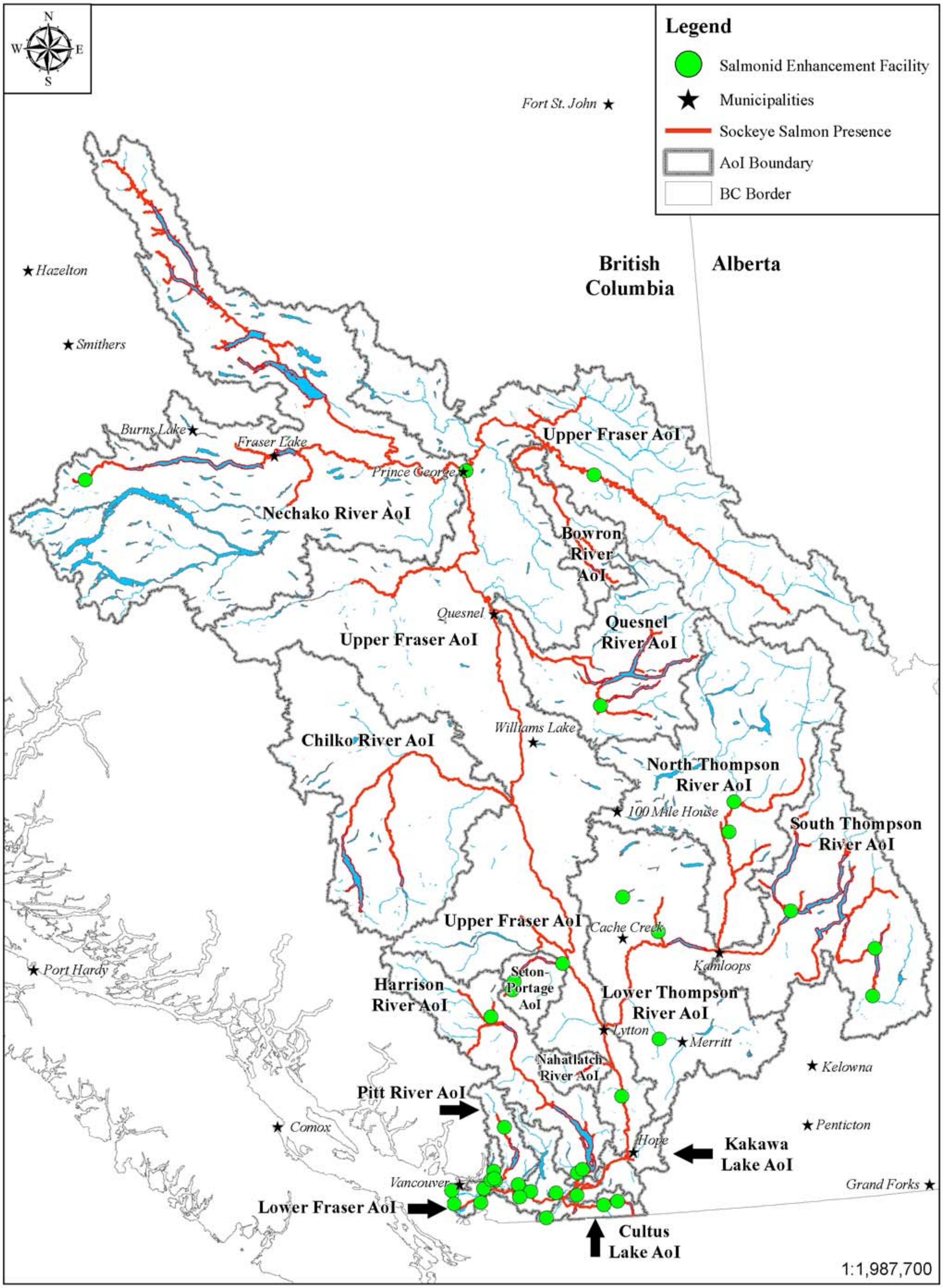


Figure 3.15. Map of the Fraser River Basin showing the locations of lake fertilization projects.

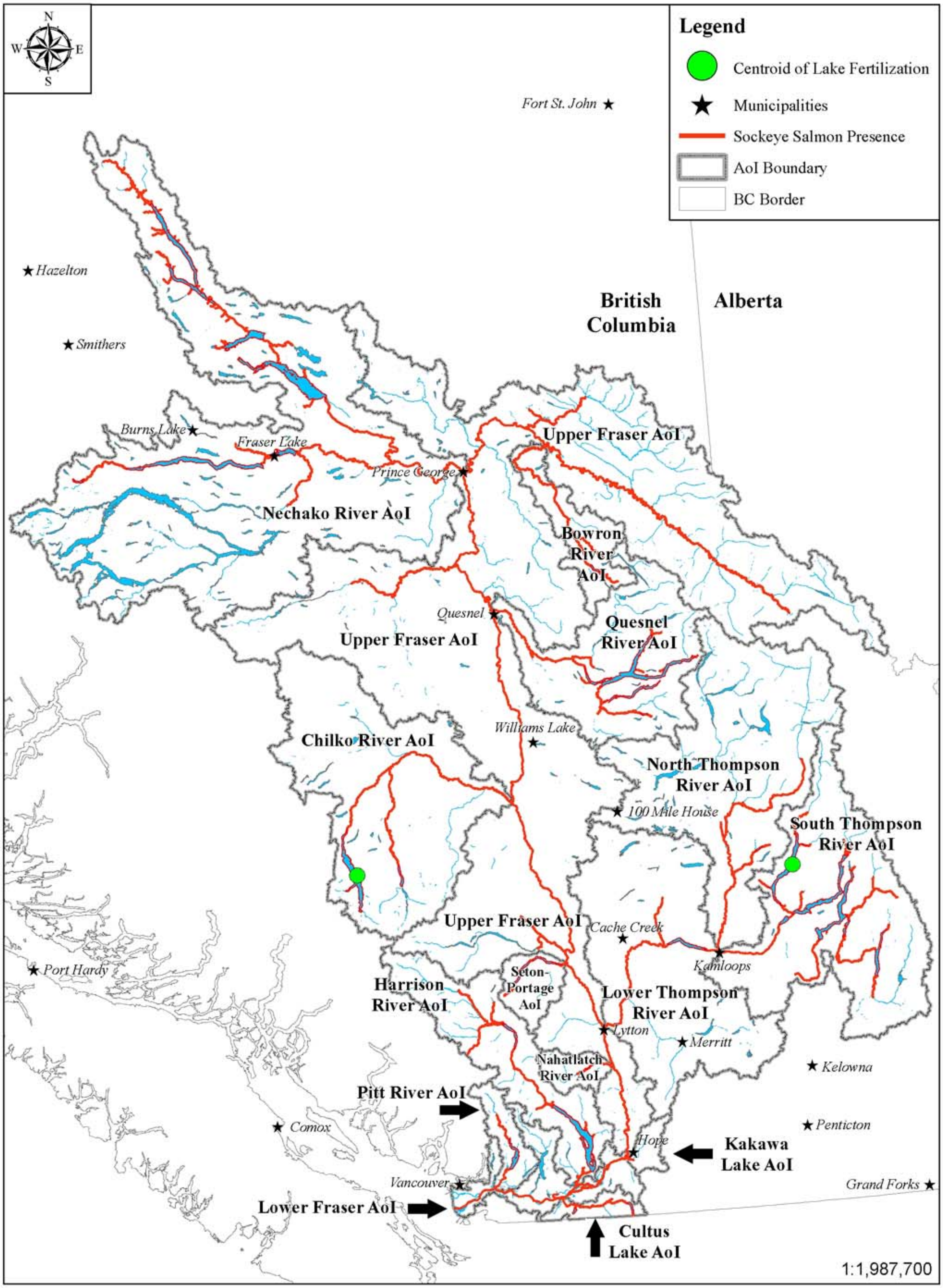


Figure 3.16. Map of the Fraser River Basin showing the locations of harvested areas and wildfires.

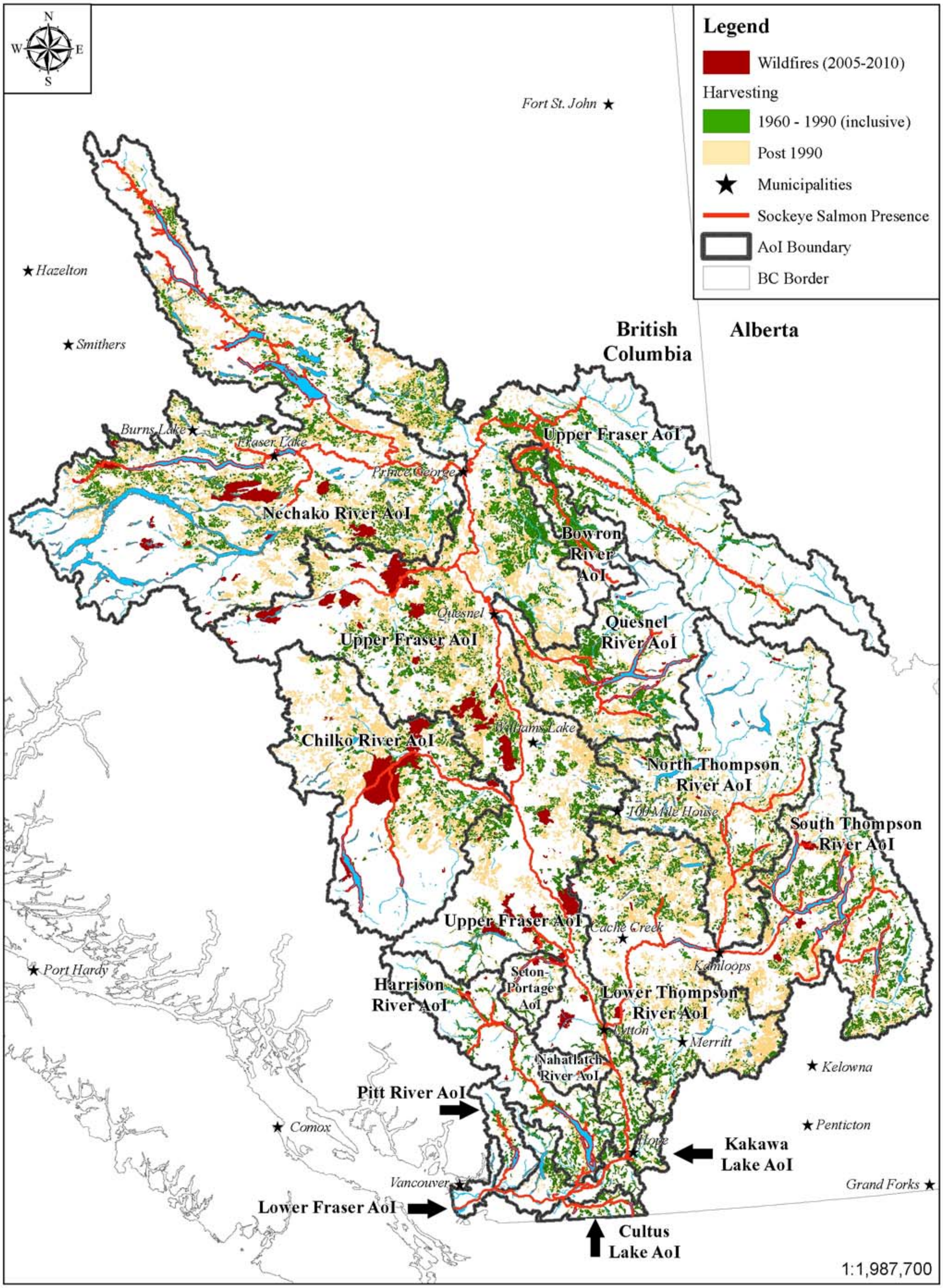


Figure 3.17. Map of the Fraser River Basin showing the locations of Pine Beetle infestation.

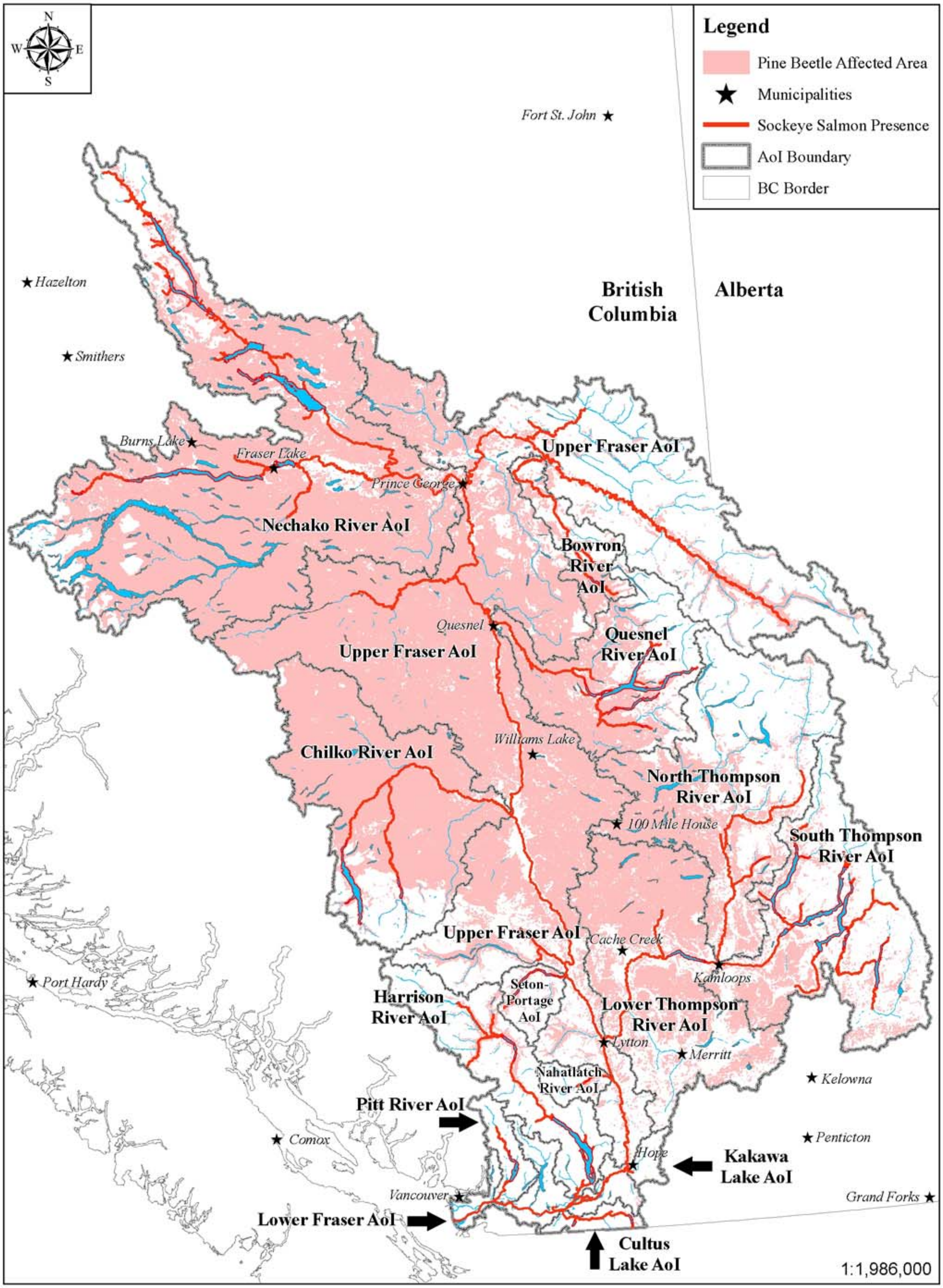


Figure 3.18. Map of the Fraser River Basin showing the locations of agricultural areas.

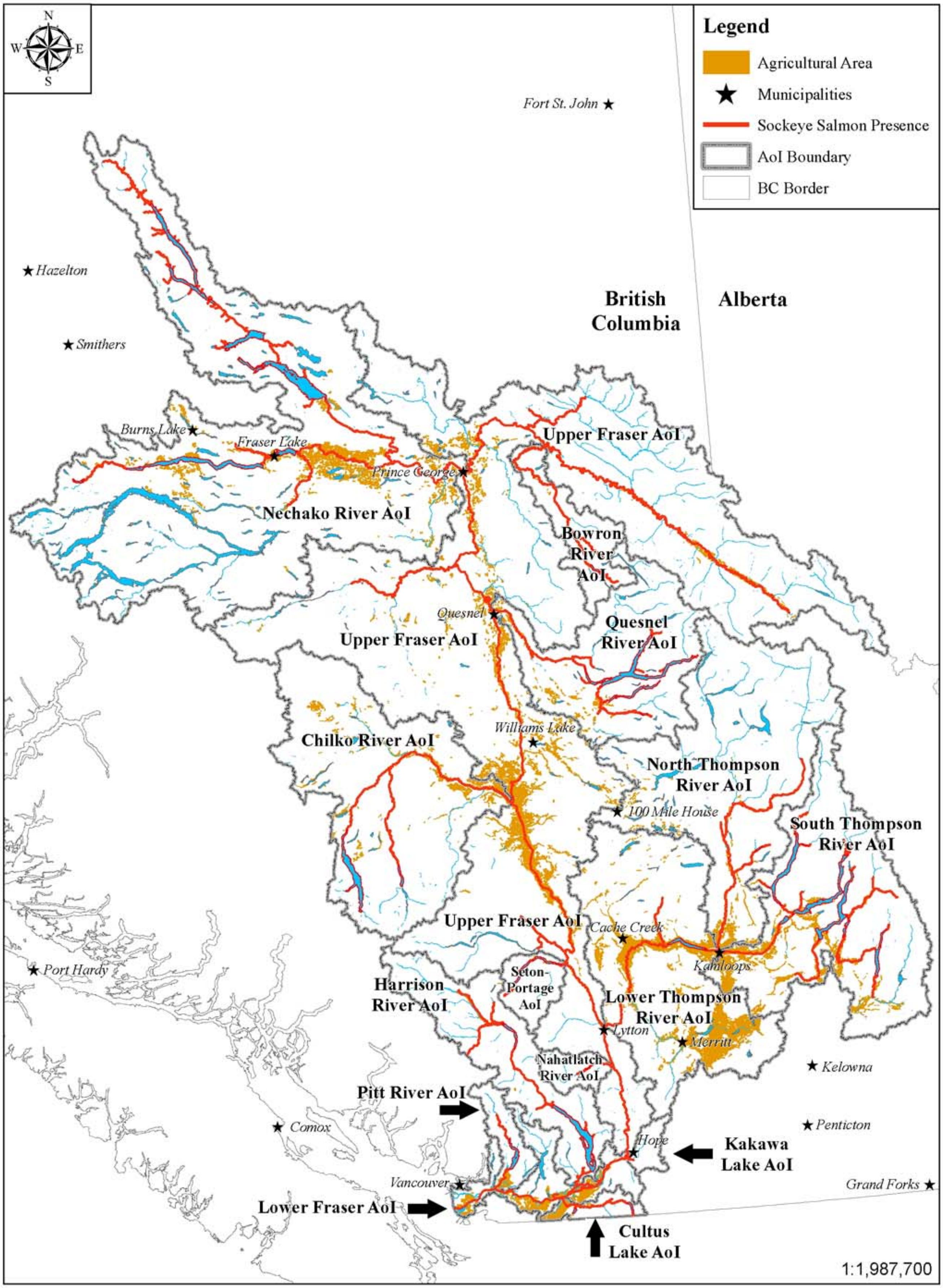


Figure 3.19. Map of the Fraser River Basin showing the locations of urban areas.

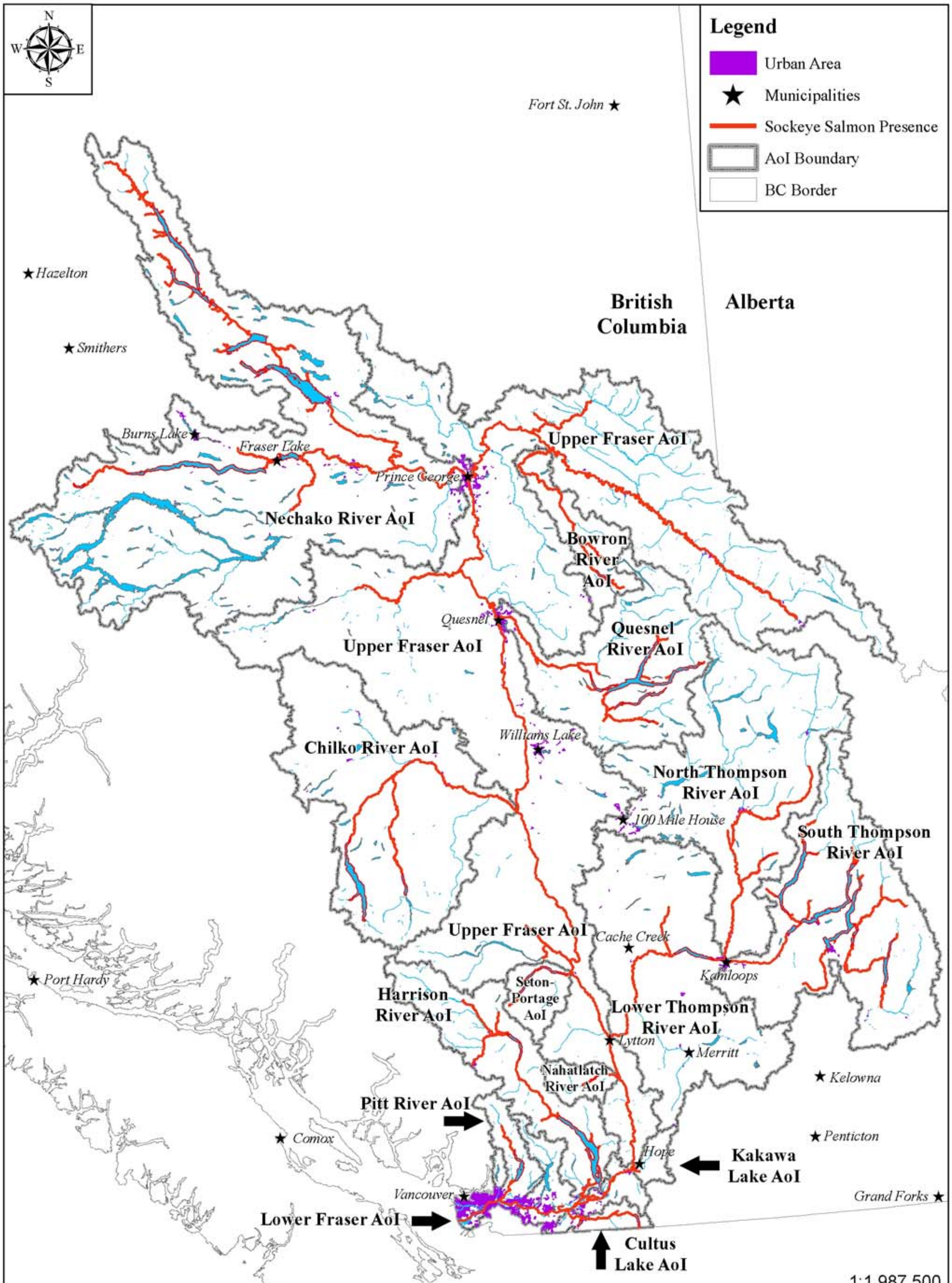


Figure 3.20. Map of the Fraser River Basin showing the locations of major linear developments.

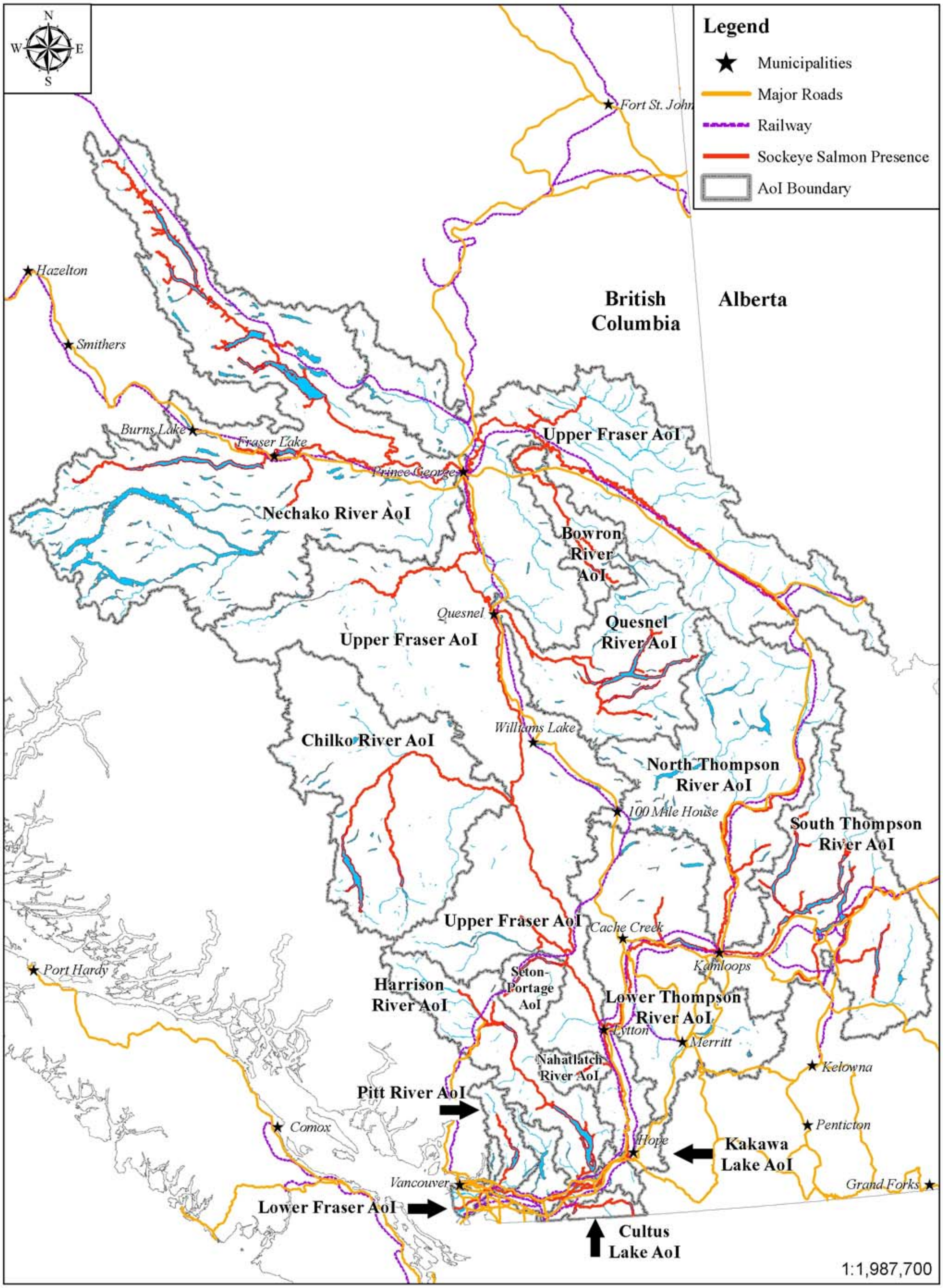


Figure 3.21. Map of the Fraser River Basin showing the locations of potentially active and inactive volcanoes.

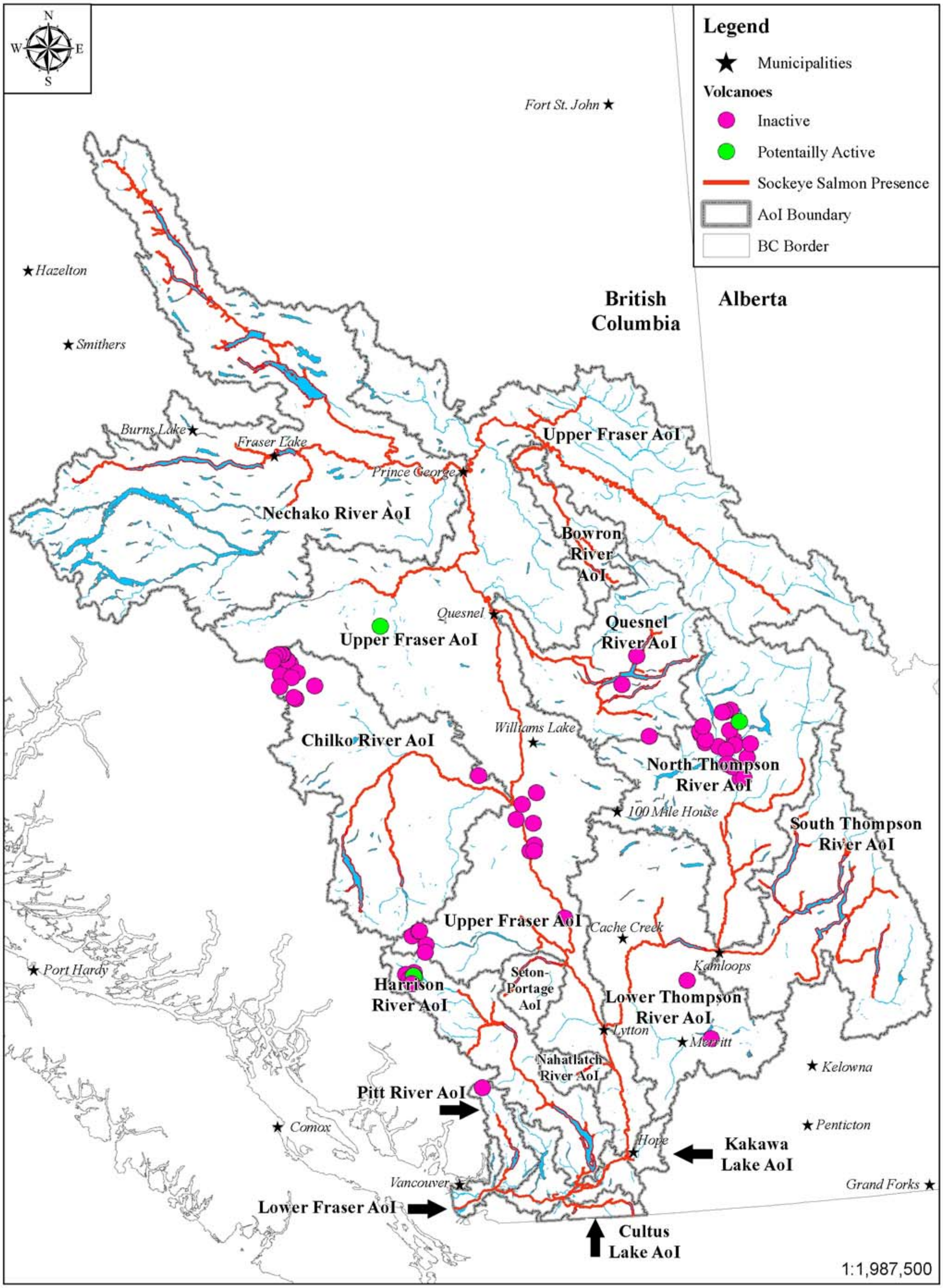


Figure 3.22. Map of the Lower Fraser AoI showing the locations of all land uses.

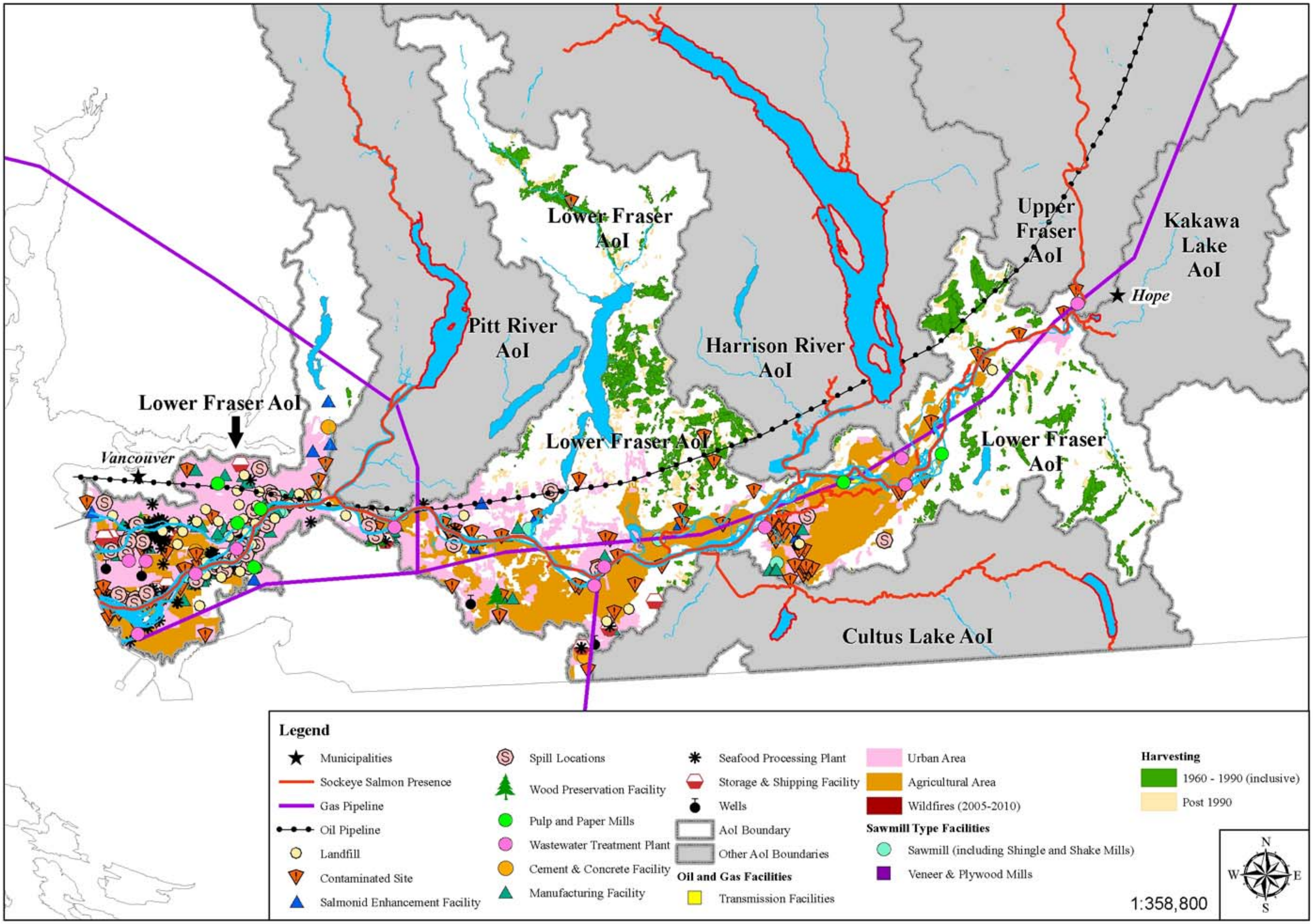


Figure 3.23. Map of the Upper Fraser AoI showing the locations of all land uses.

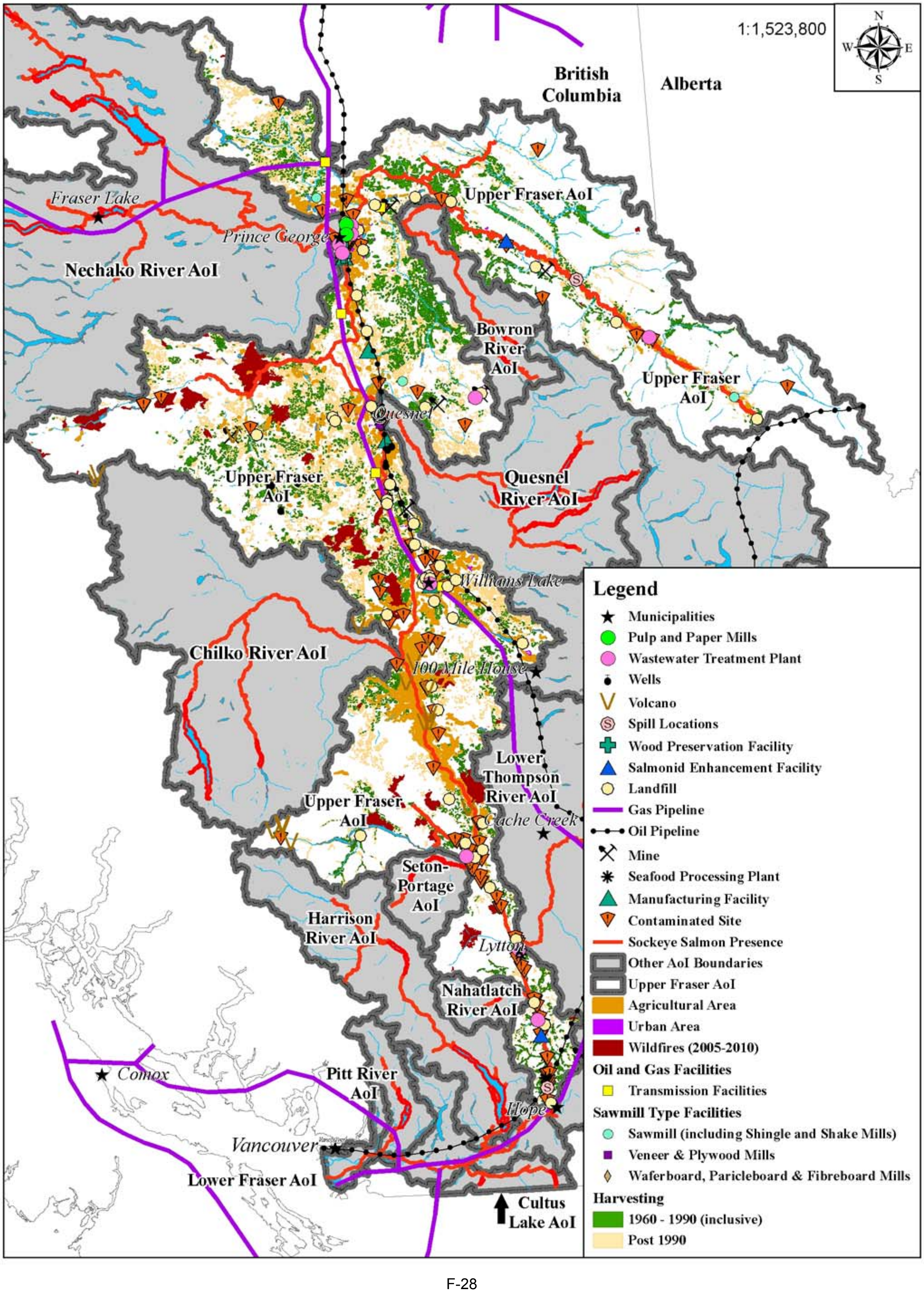


Figure 3.24. Map of the Pitt River AoI showing the locations of all land uses.

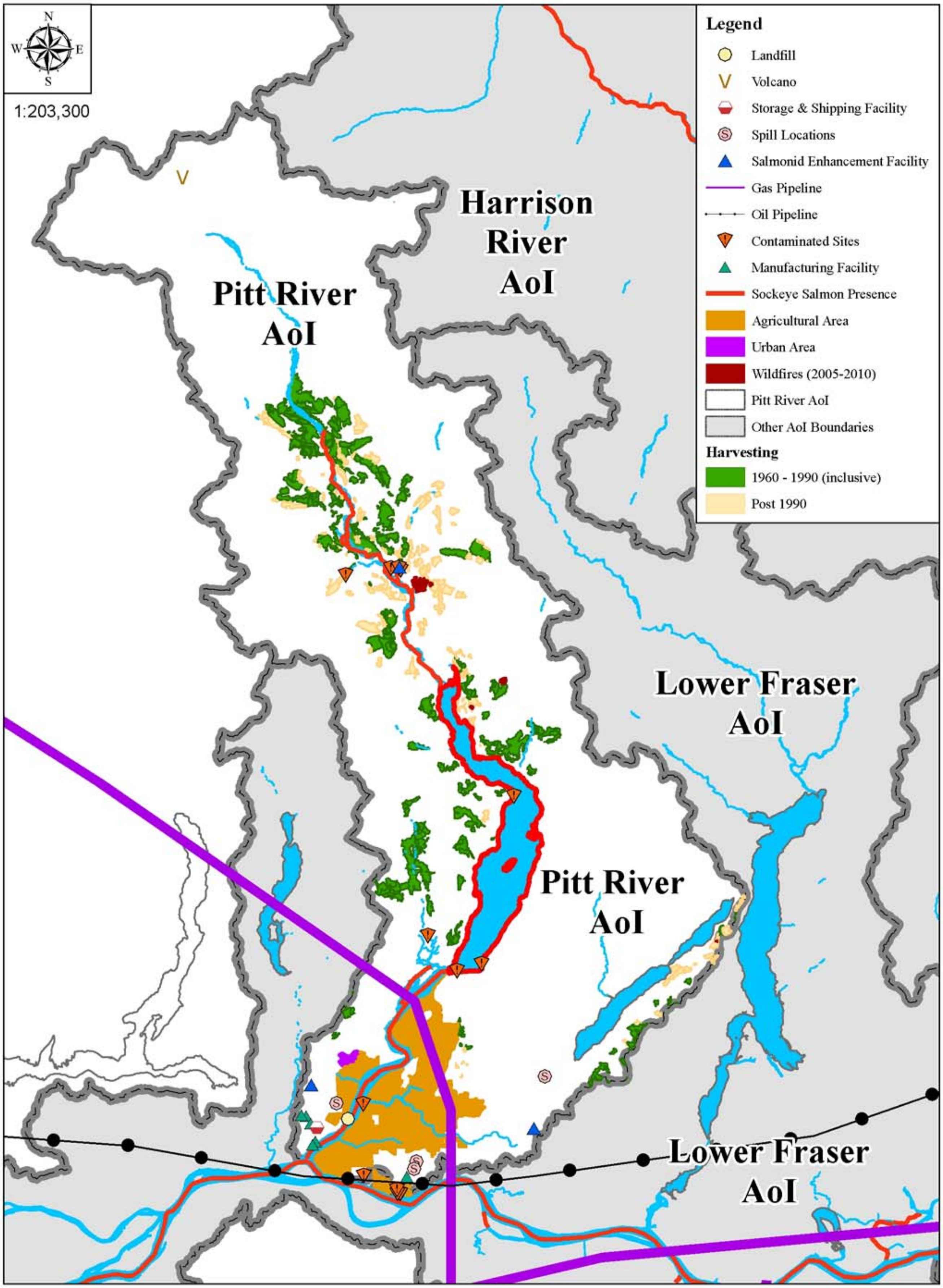


Figure 3.25. Map of the Harrison River AoI showing the locations of all land uses.

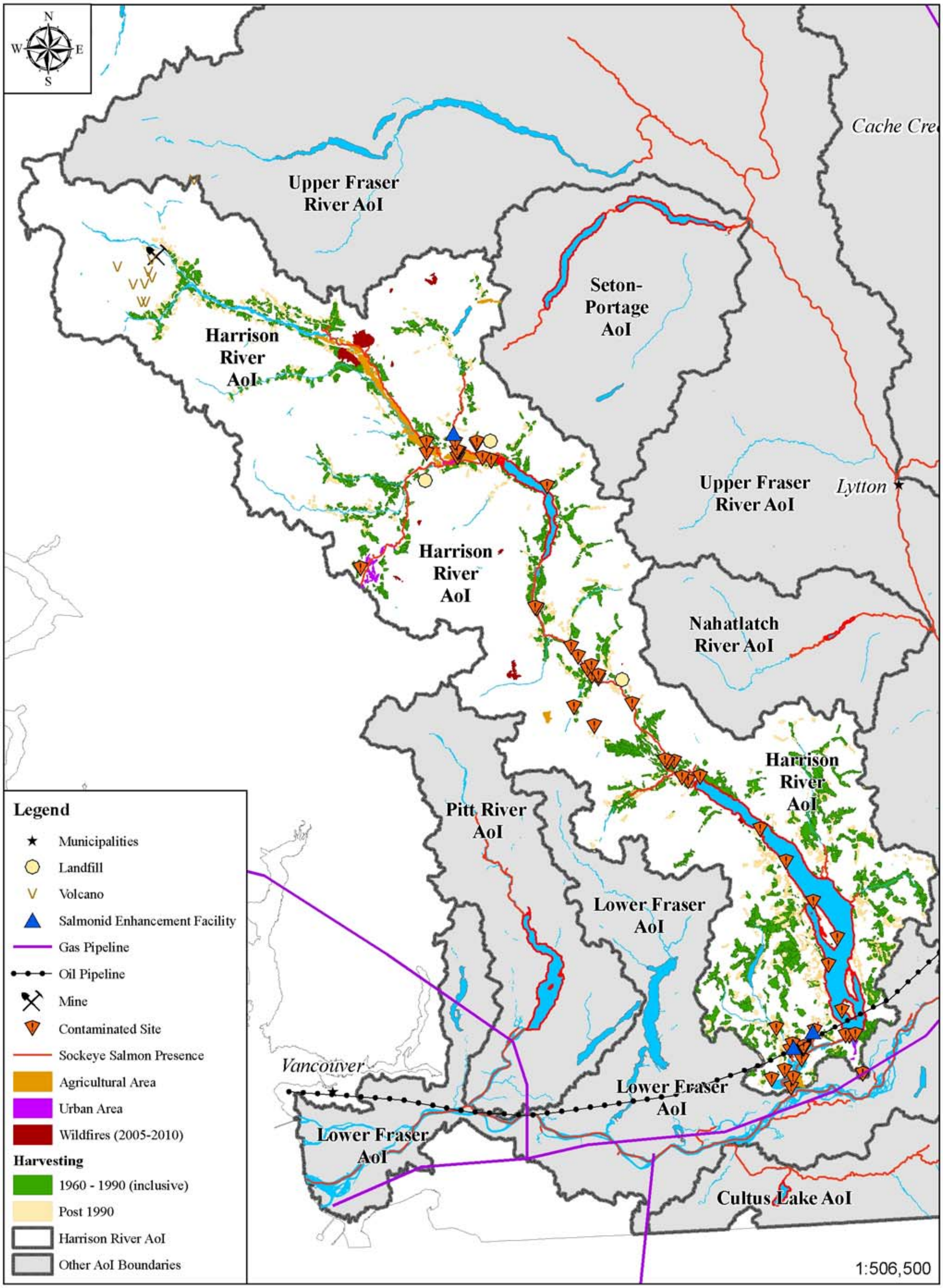


Figure 3.26. Map of the Cultus Lake AoI showing the locations of all land uses.

Figure 3.27. Map of the Kakawa Lake AoI showing the locations of all land uses.

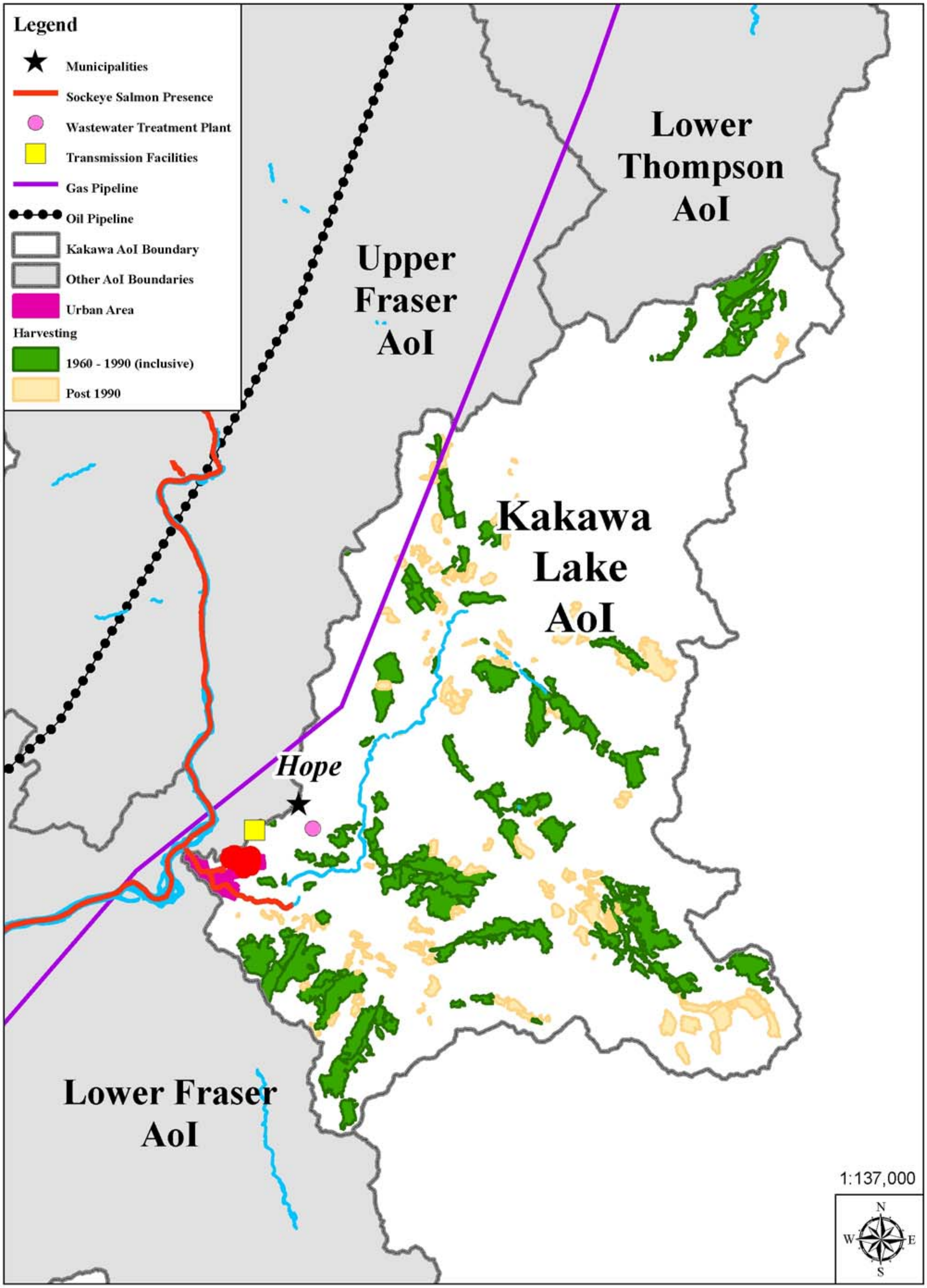


Figure 3.28. Map of the Nahatlatch River AoI showing the locations of all land uses.

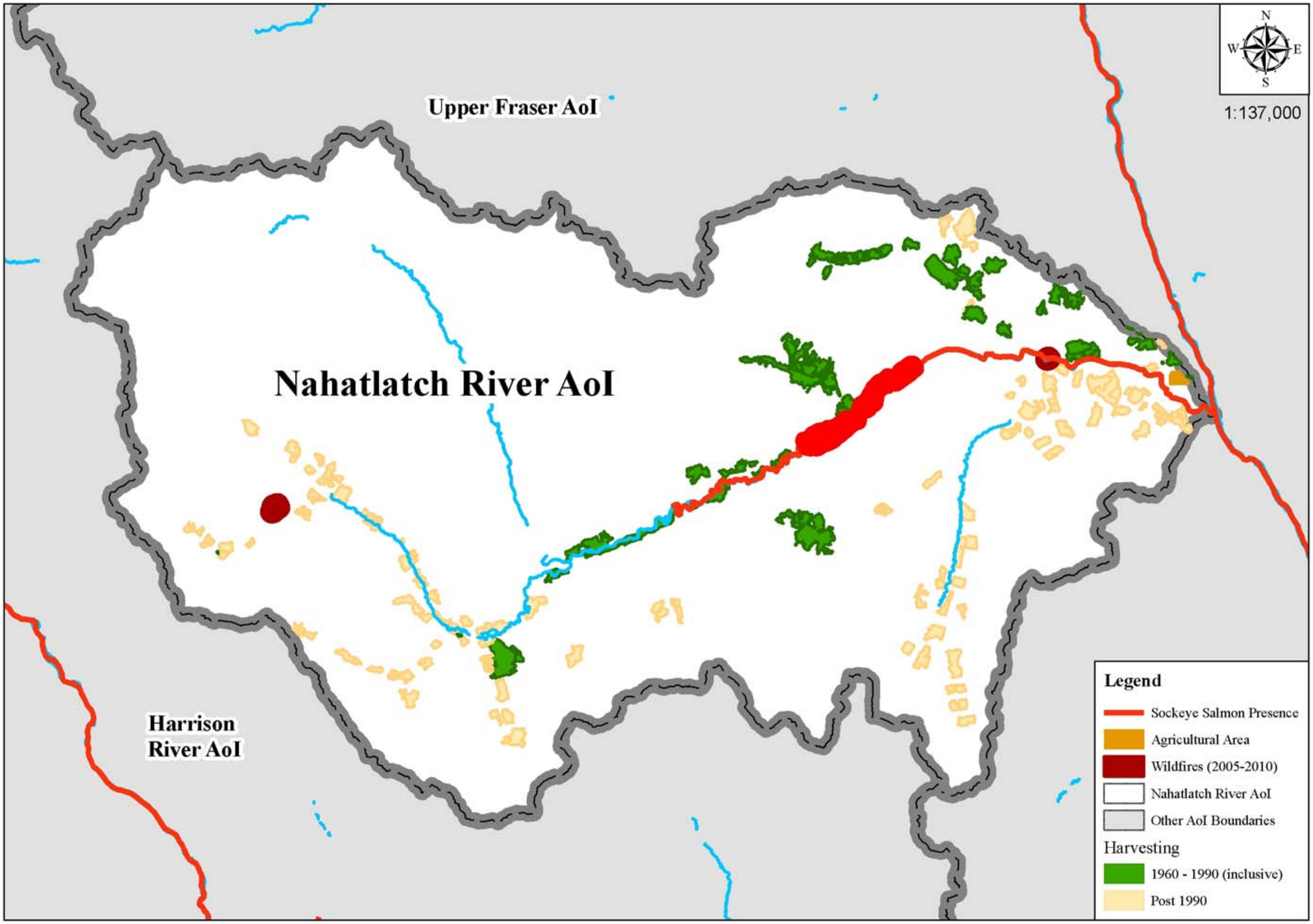


Figure 3.29. Map of the Seton-Portage AoI showing the locations of all land uses.

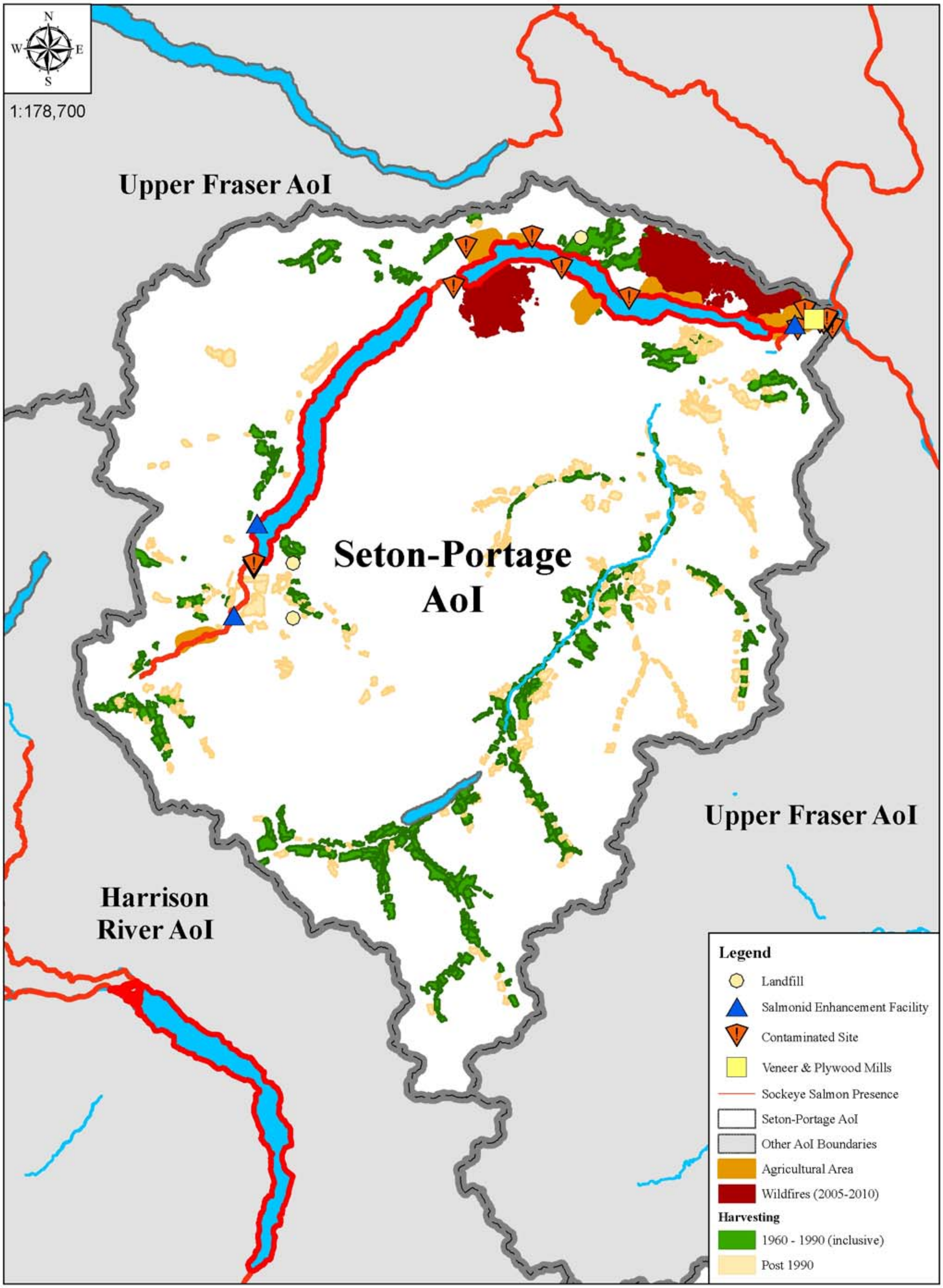


Figure 3.30. Map of the Lower Thompson River AoI showing the locations of all land uses.

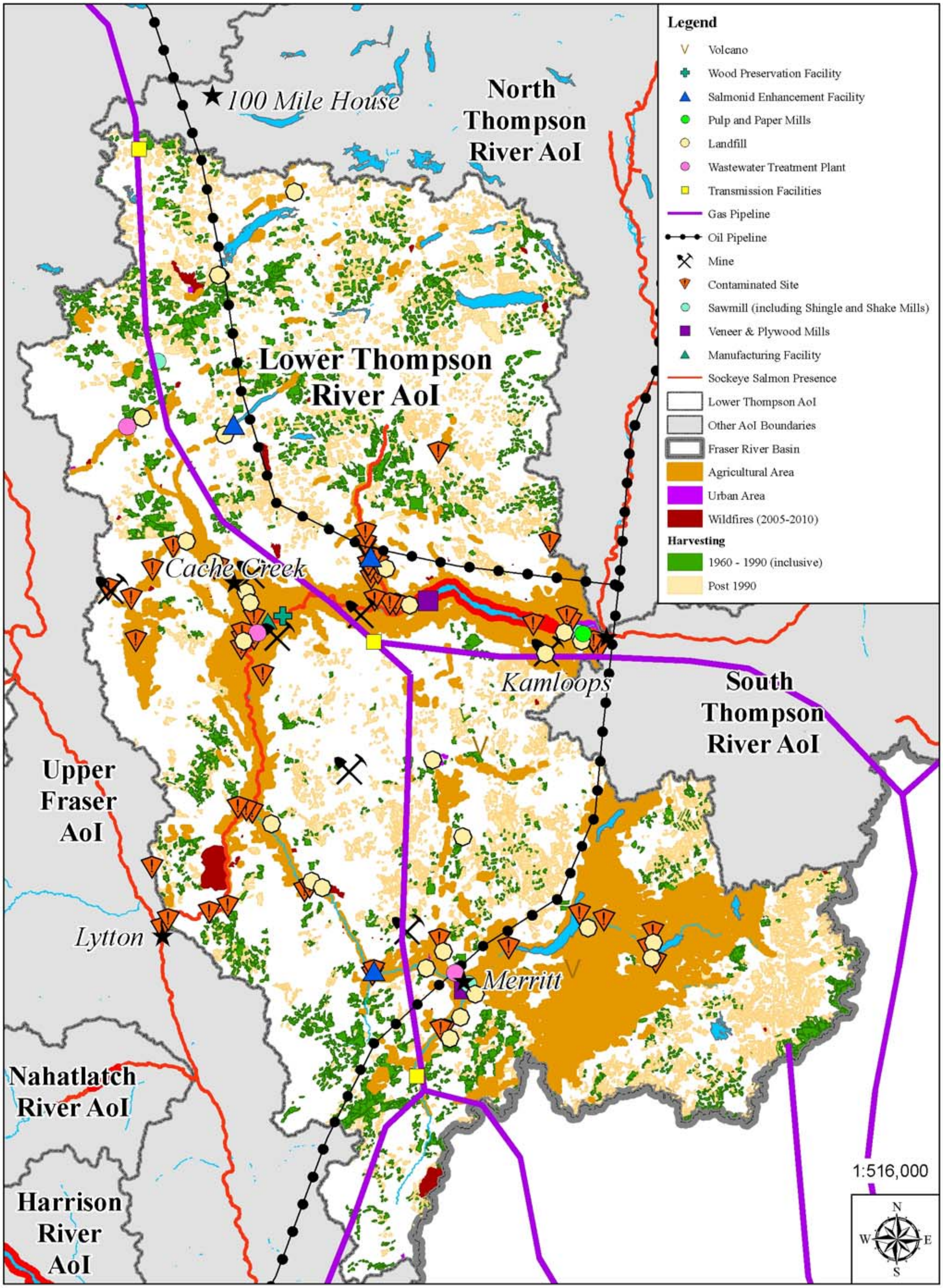


Figure 3.31. Map of the North Thompson River AoI showing the locations of all land uses.

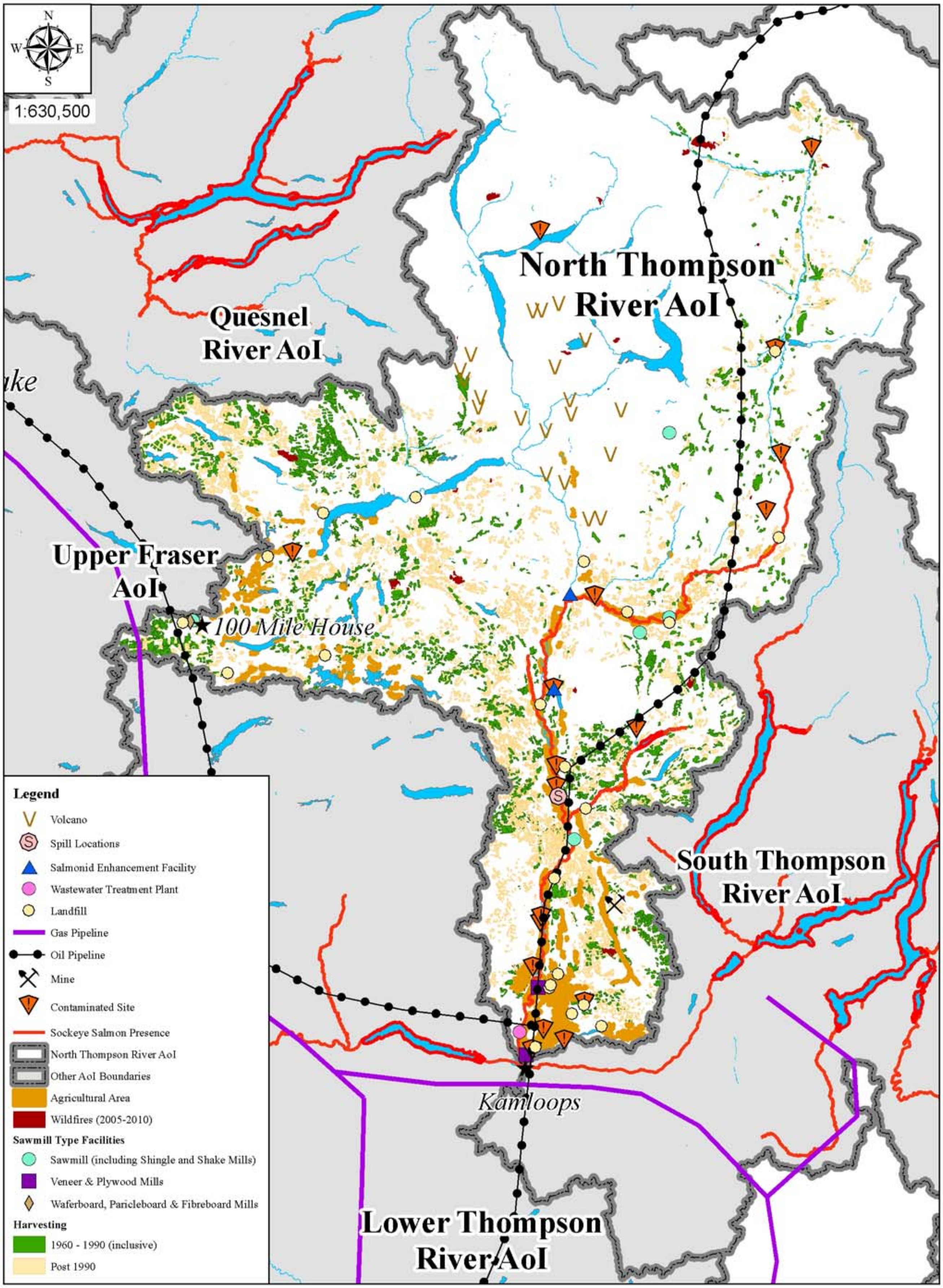


Figure 3.32. Map of the South Thompson River AoI showing the locations of all land uses.

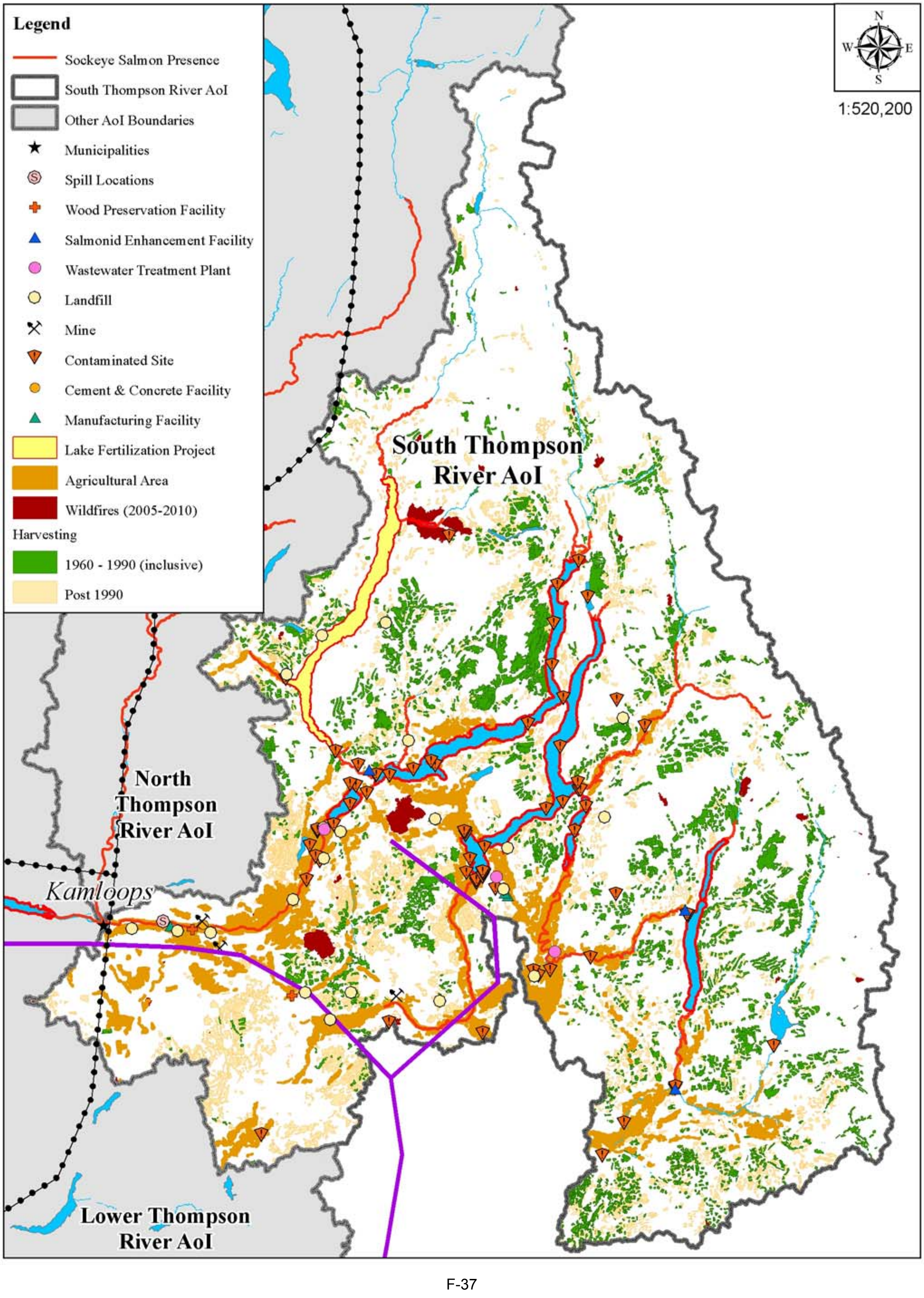


Figure 3.33. Map of the Chilko River AoI showing the locations of all land uses.

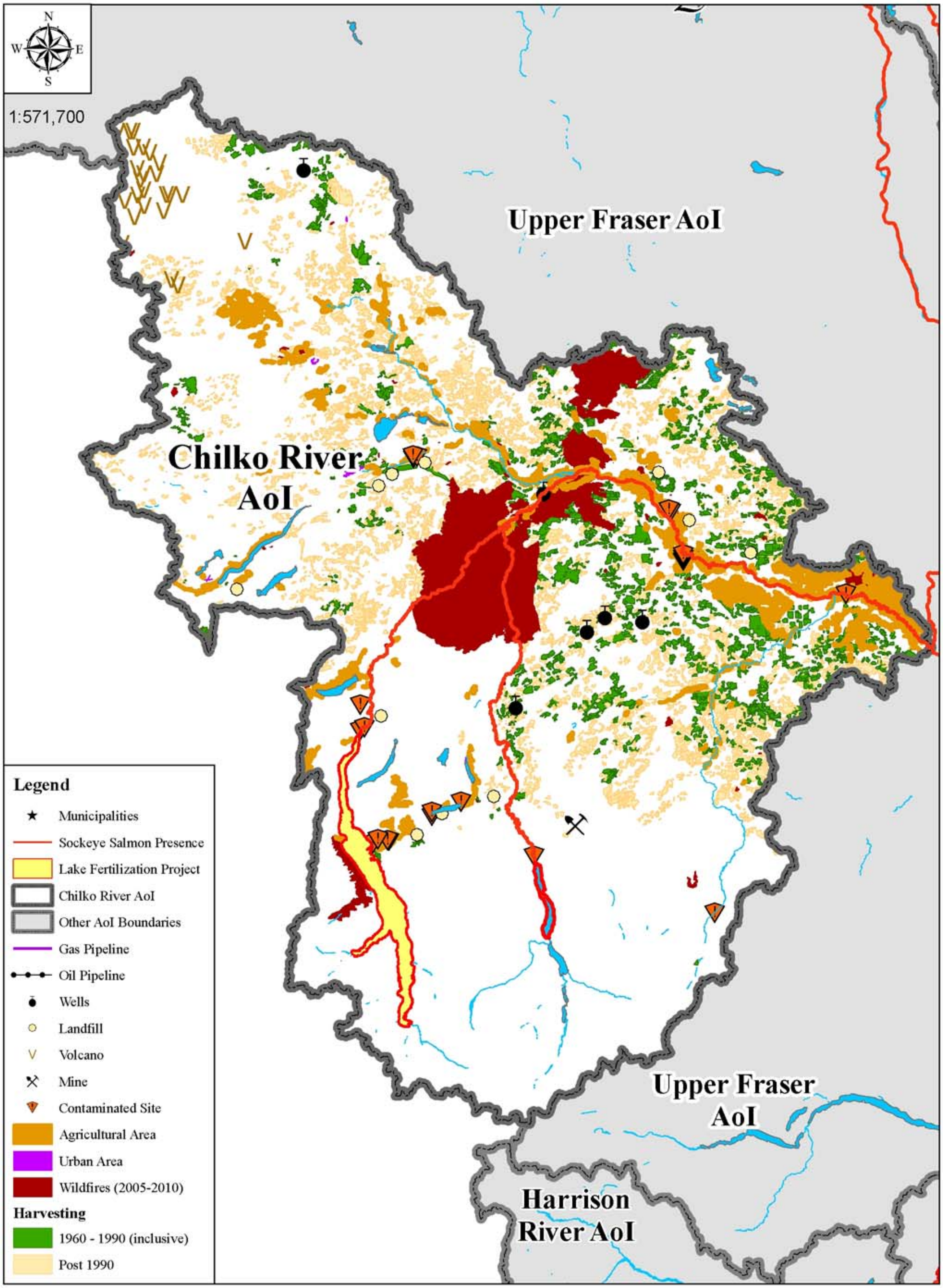


Figure 3.34. Map of the Quesnel River AoI showing the locations of all land uses.

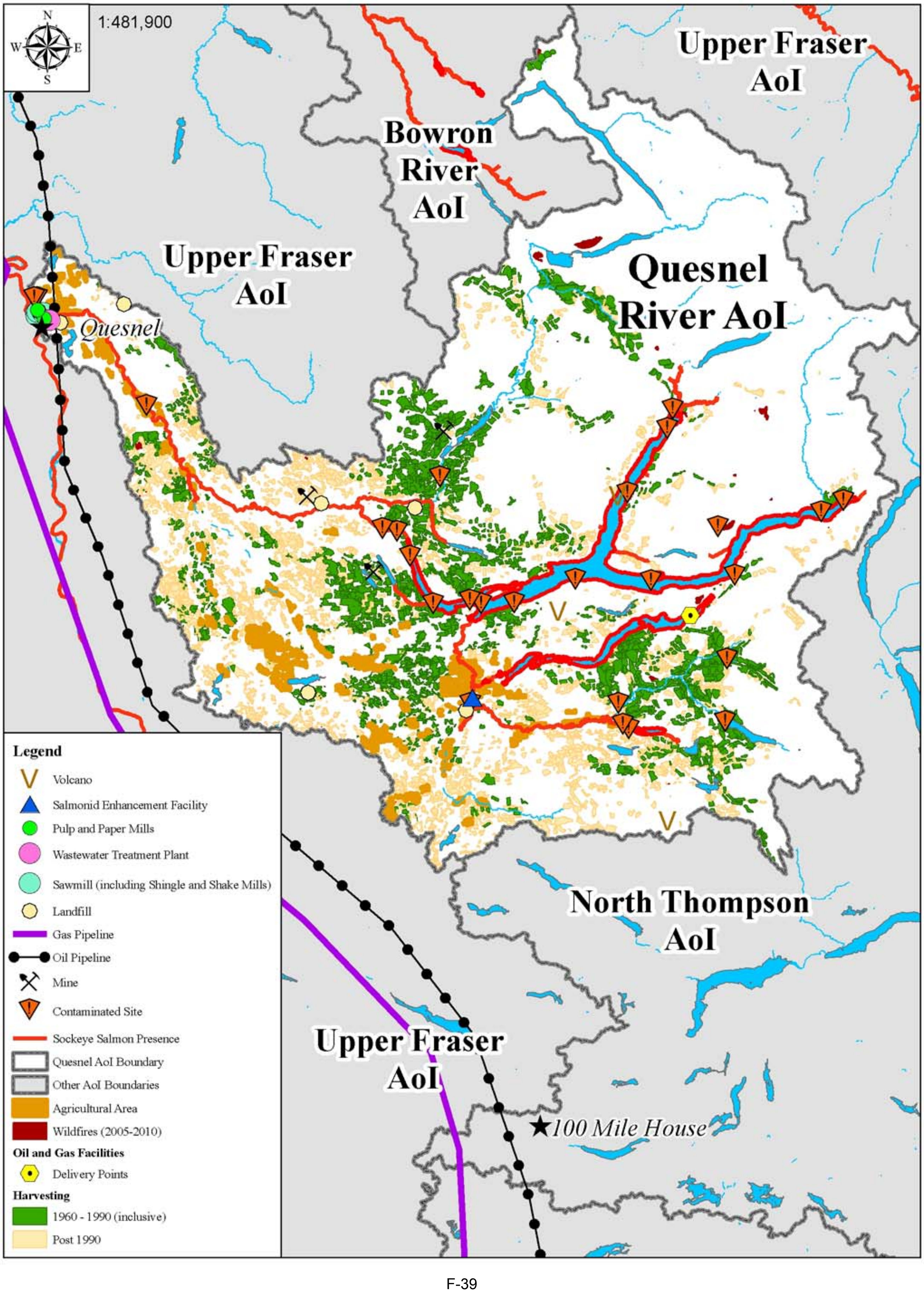


Figure 3.35. Map of the Nechako River AoI showing the locations of all land uses.

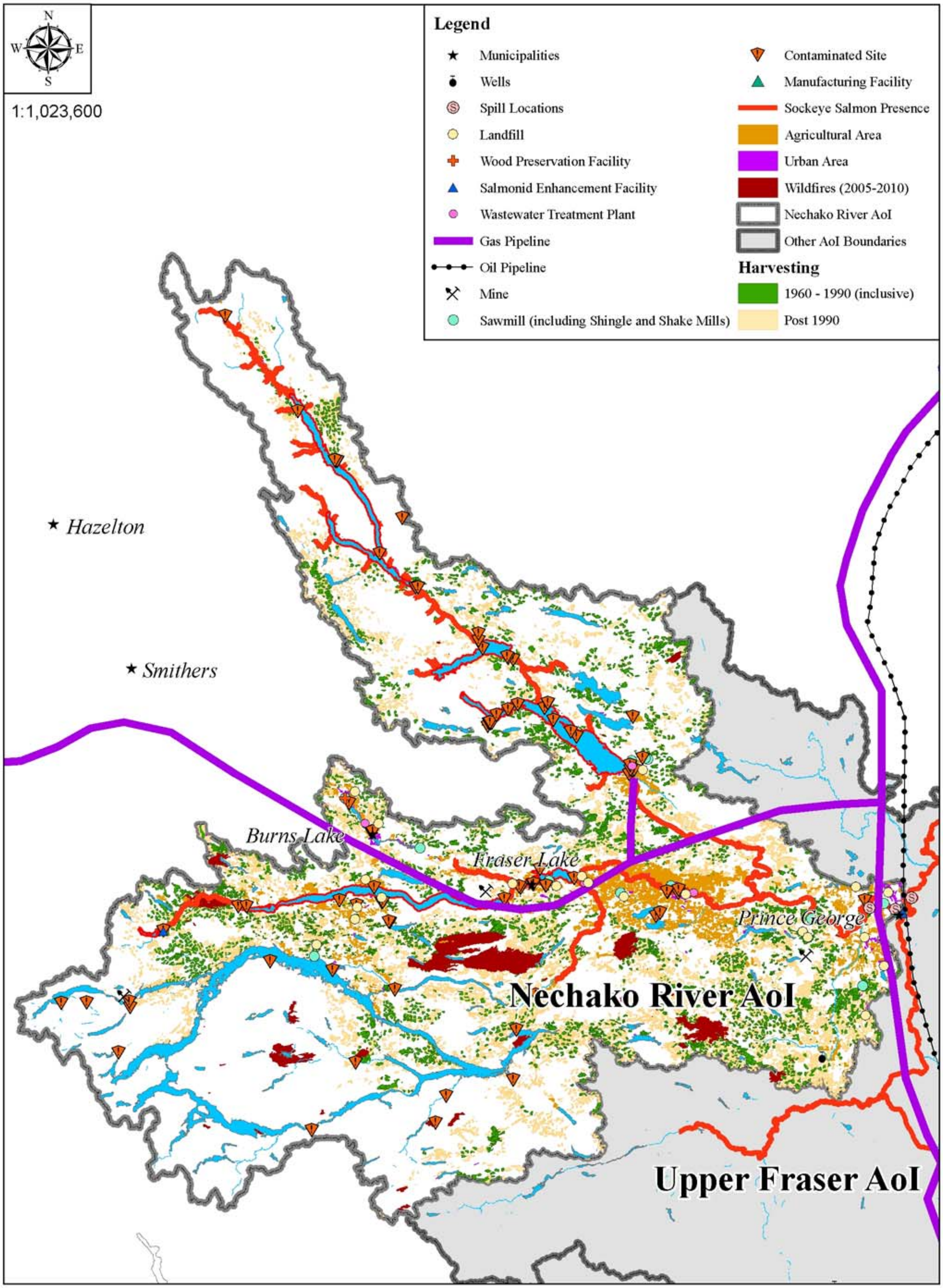


Figure 3.36. Map of the Bowron River AoI showing the locations of all land uses.

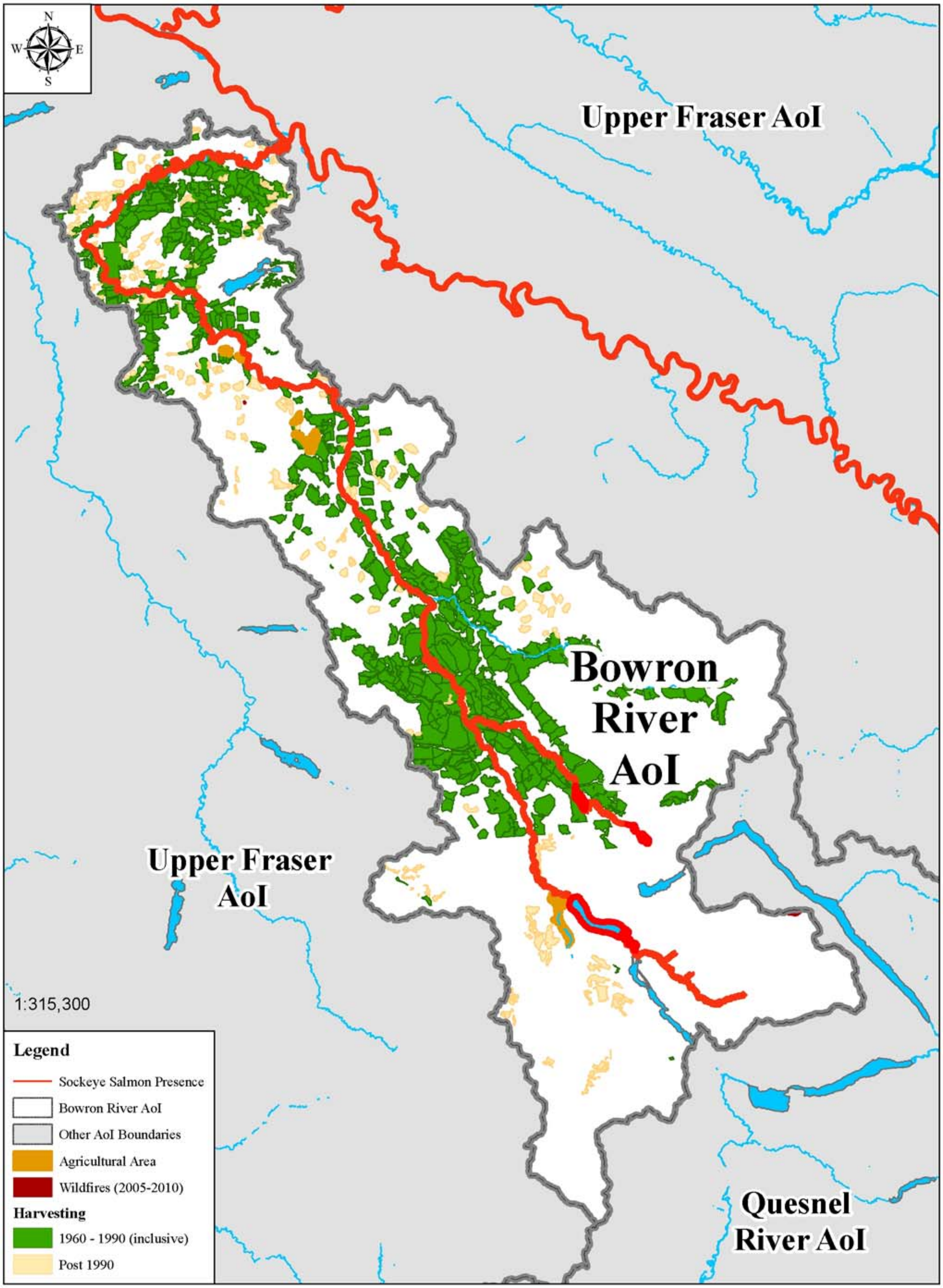


Figure 4.1. Map of the Fraser River Basin showing water quality stations used to characterize conditions in spawning and incubation locations.

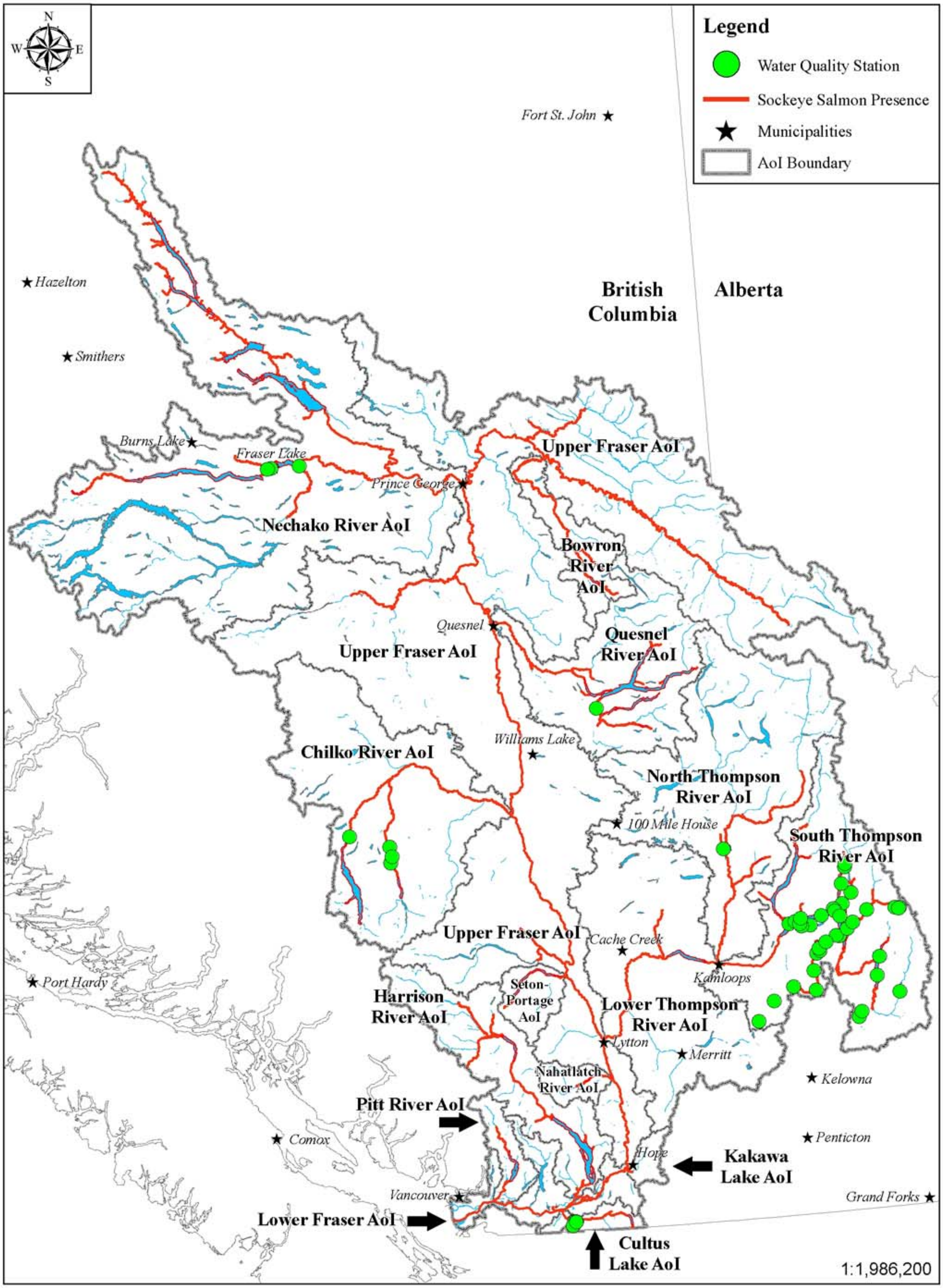


Figure 4.2. Map of the Fraser River Basin showing water quality stations used to characterize conditions in juvenile rearing locations.

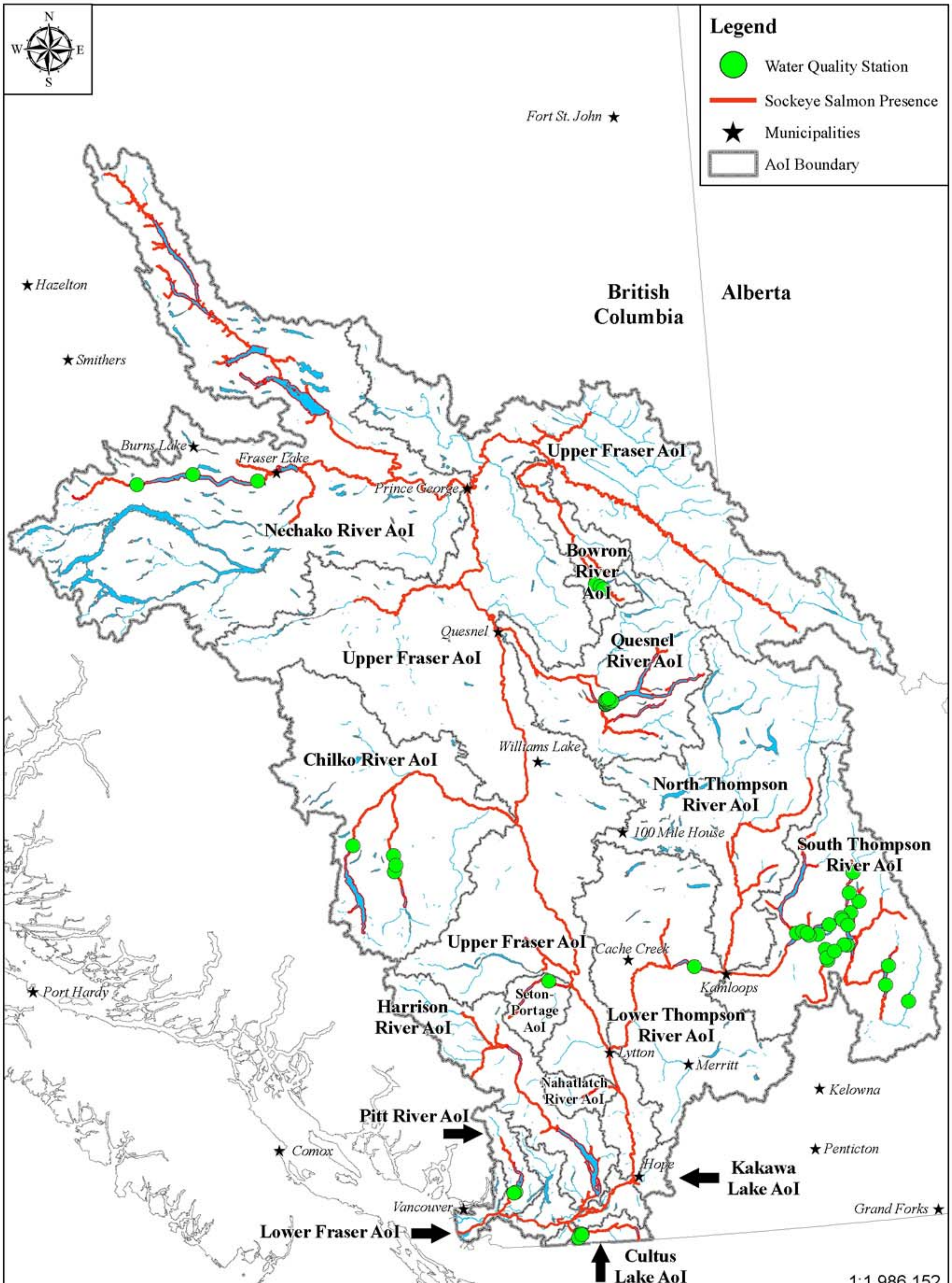


Figure 4.3. Map of the Fraser River Basin showing water quality stations used to characterize conditions in smolt outmigration locations.

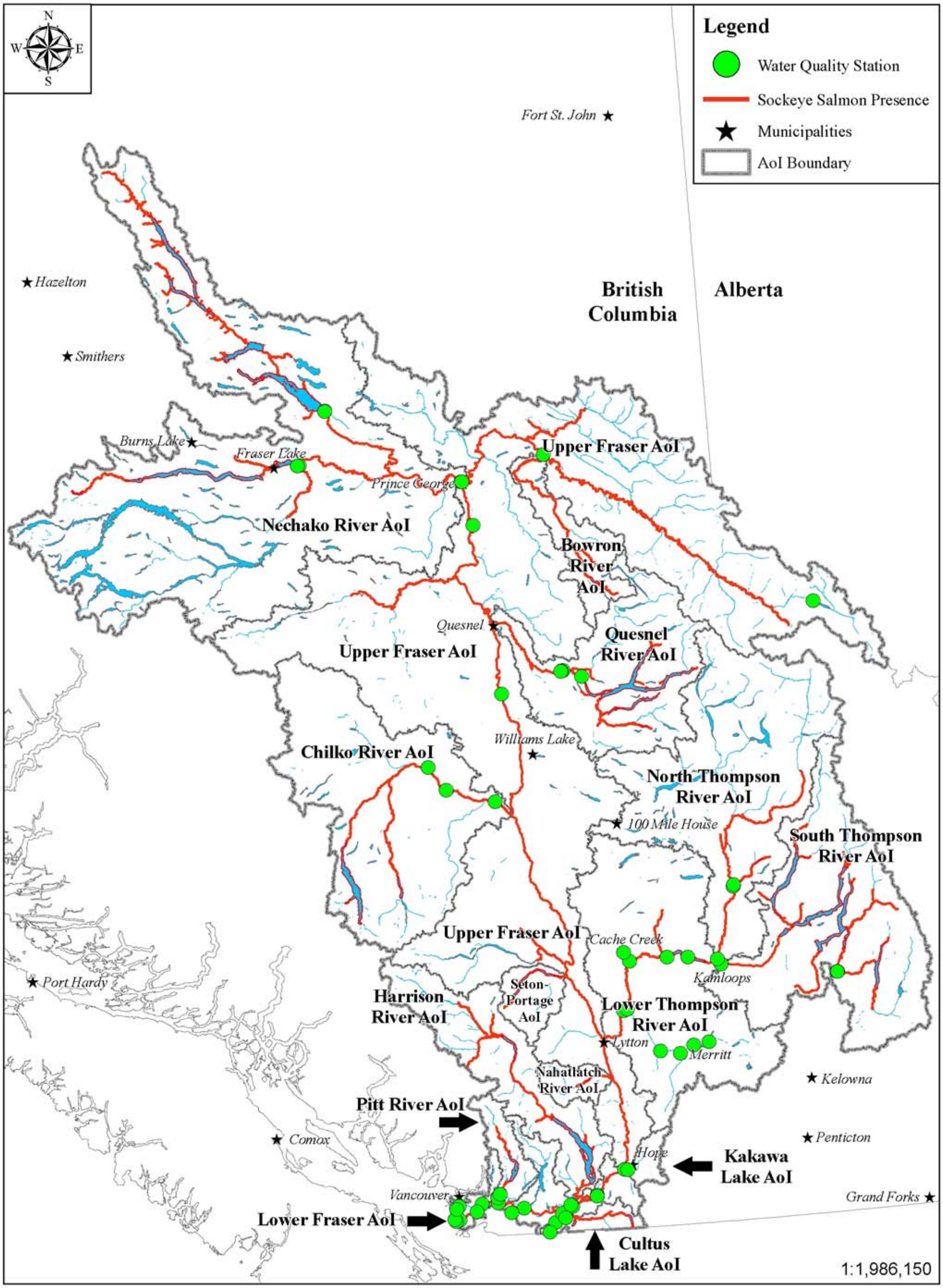


Figure 4.4. Map of the Fraser River Basin showing water quality stations used to characterize conditions in adult upstream migration locations.

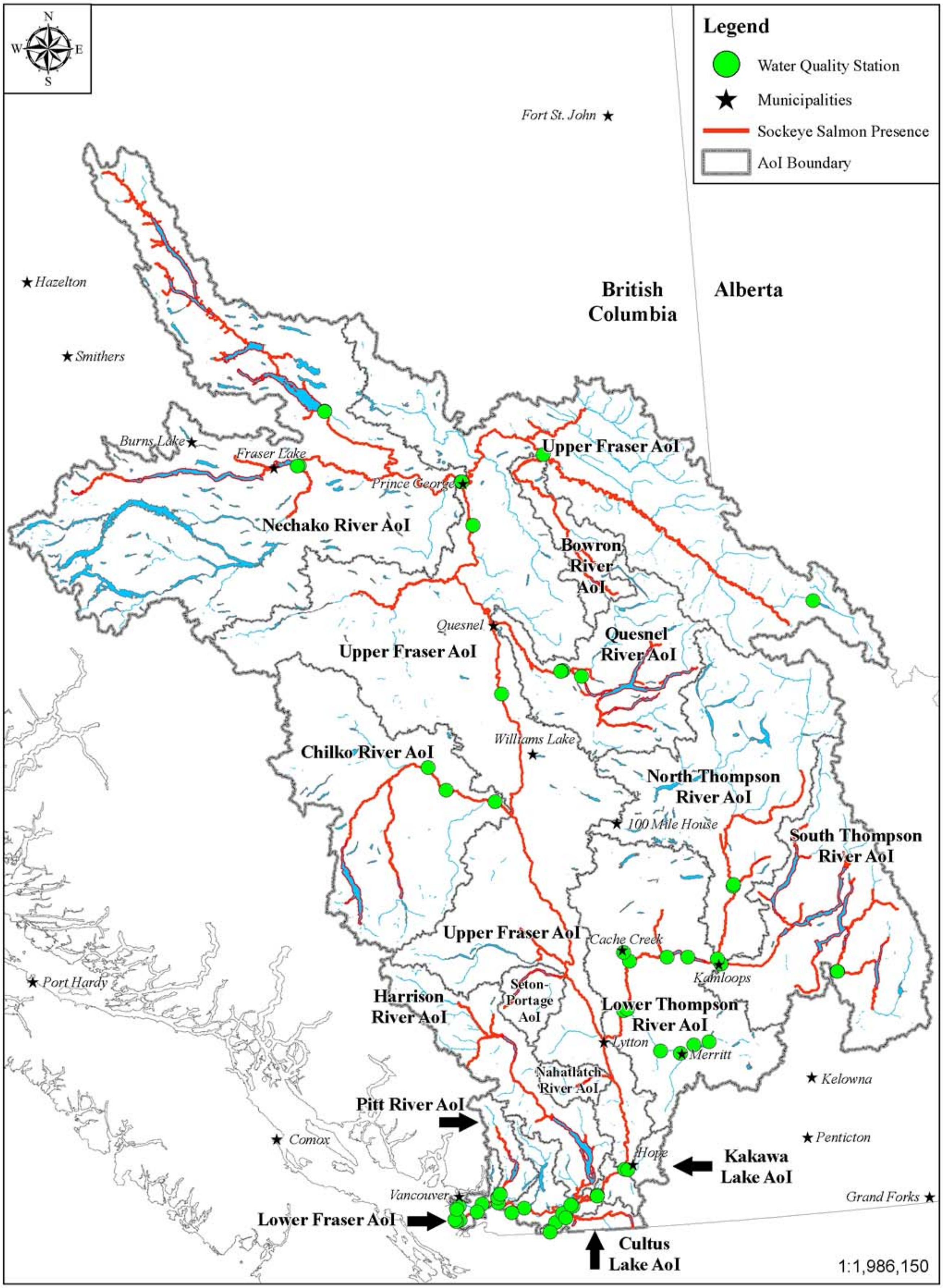


Figure 4.5. Map of the Lower Fraser AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

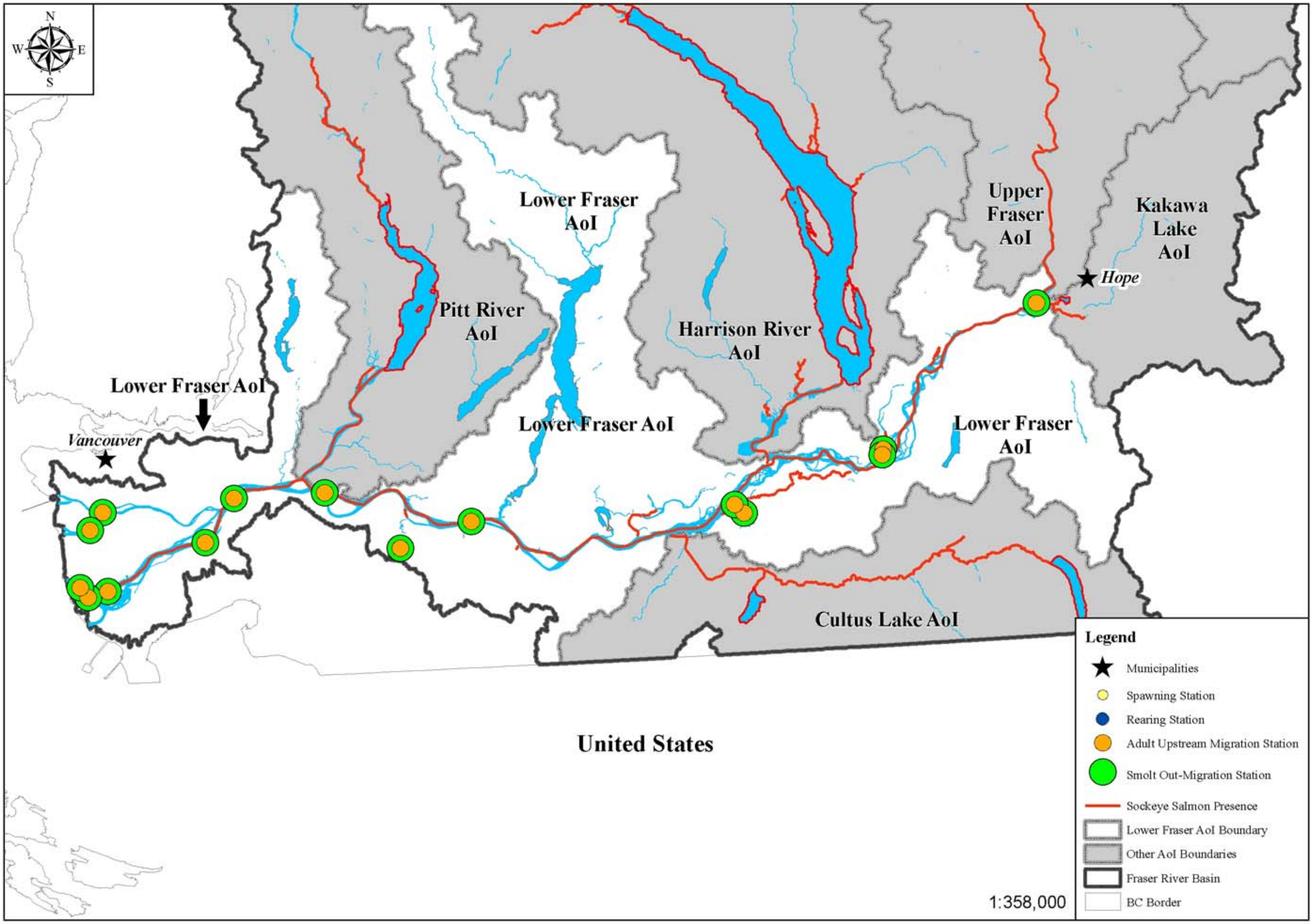


Figure 4.6. Map of the Upper Fraser River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

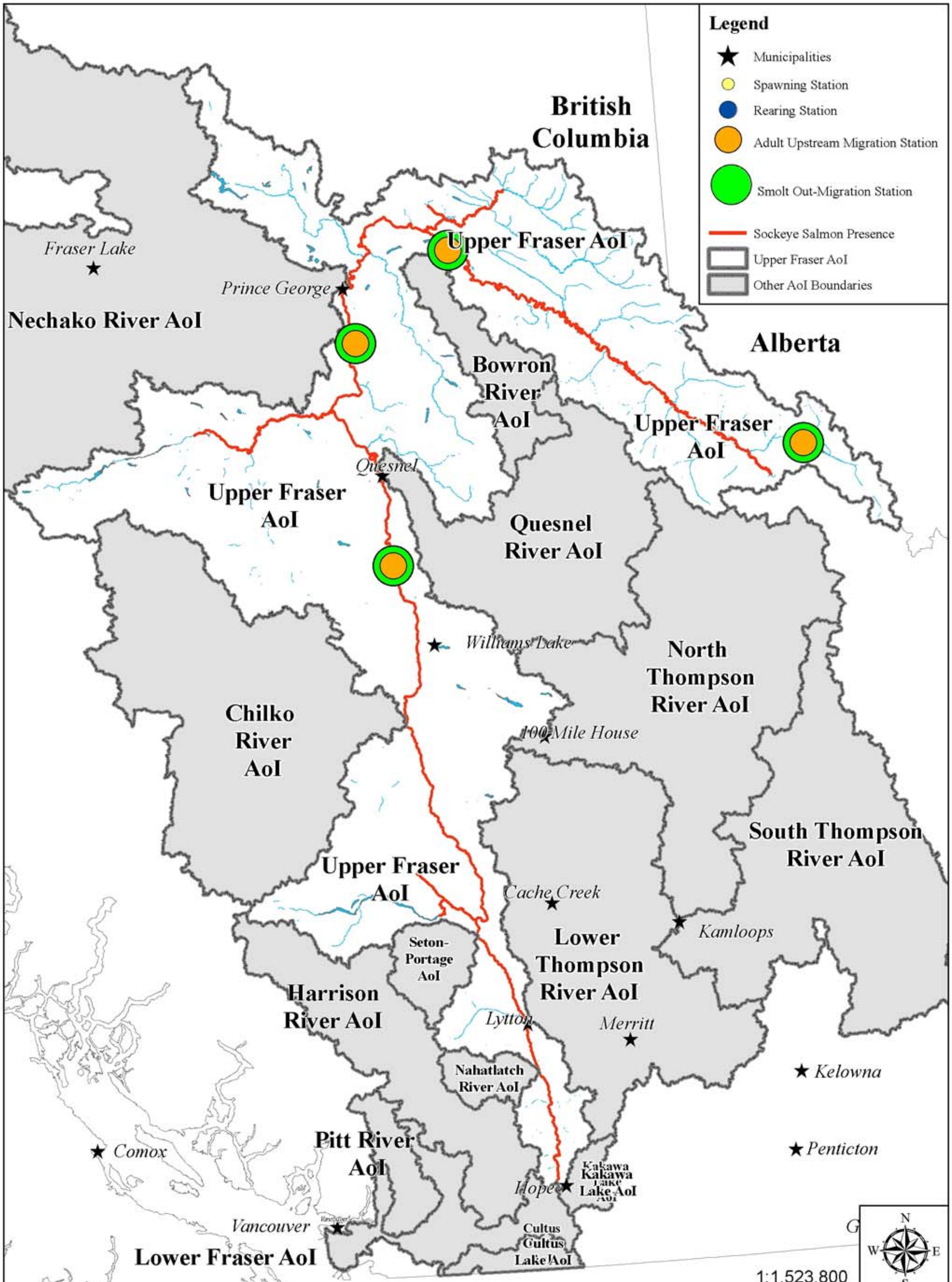


Figure 4.7. Map of the Pitt River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

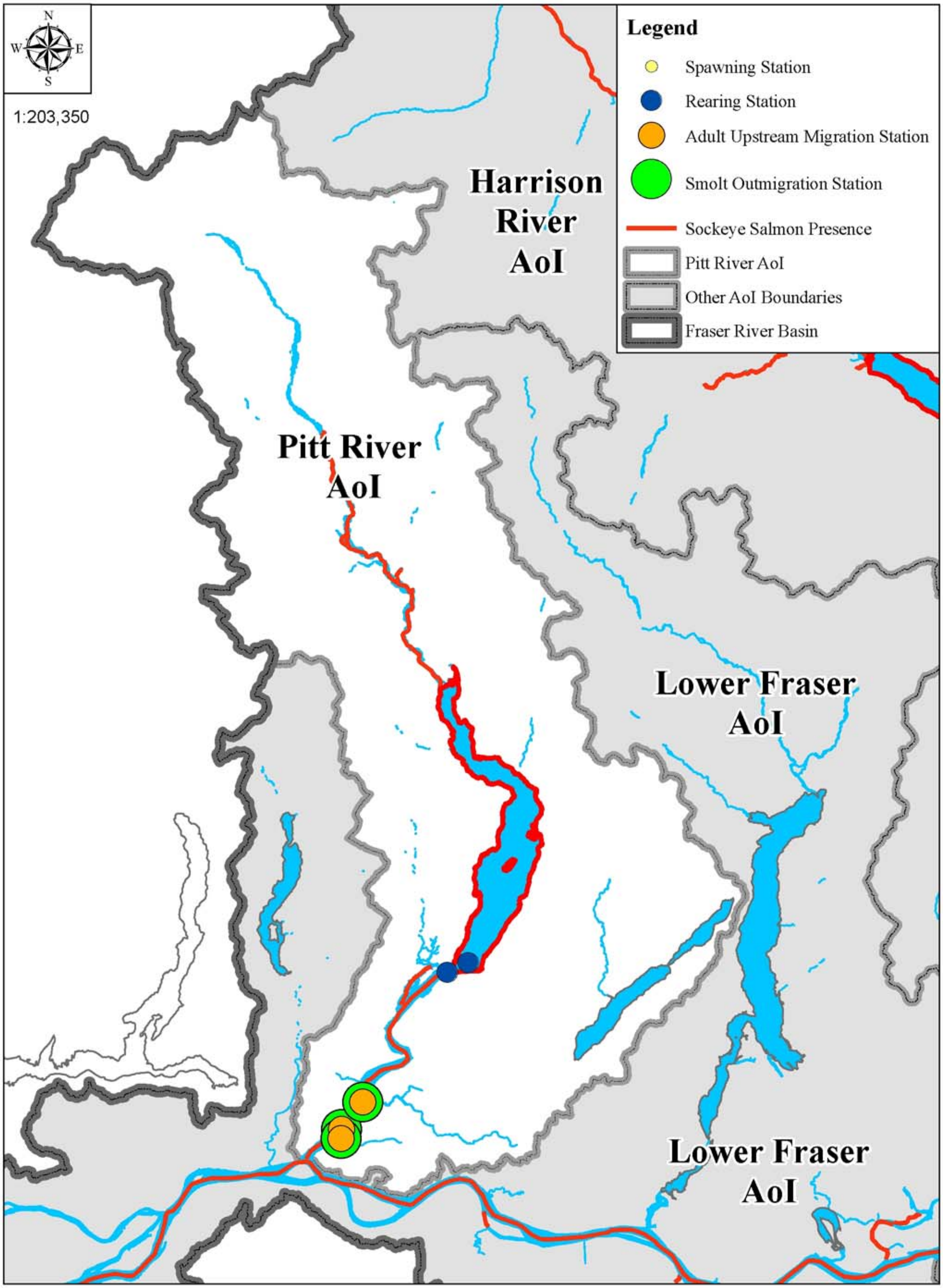


Figure 4.8. Map of the Harrison River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs (no stations).

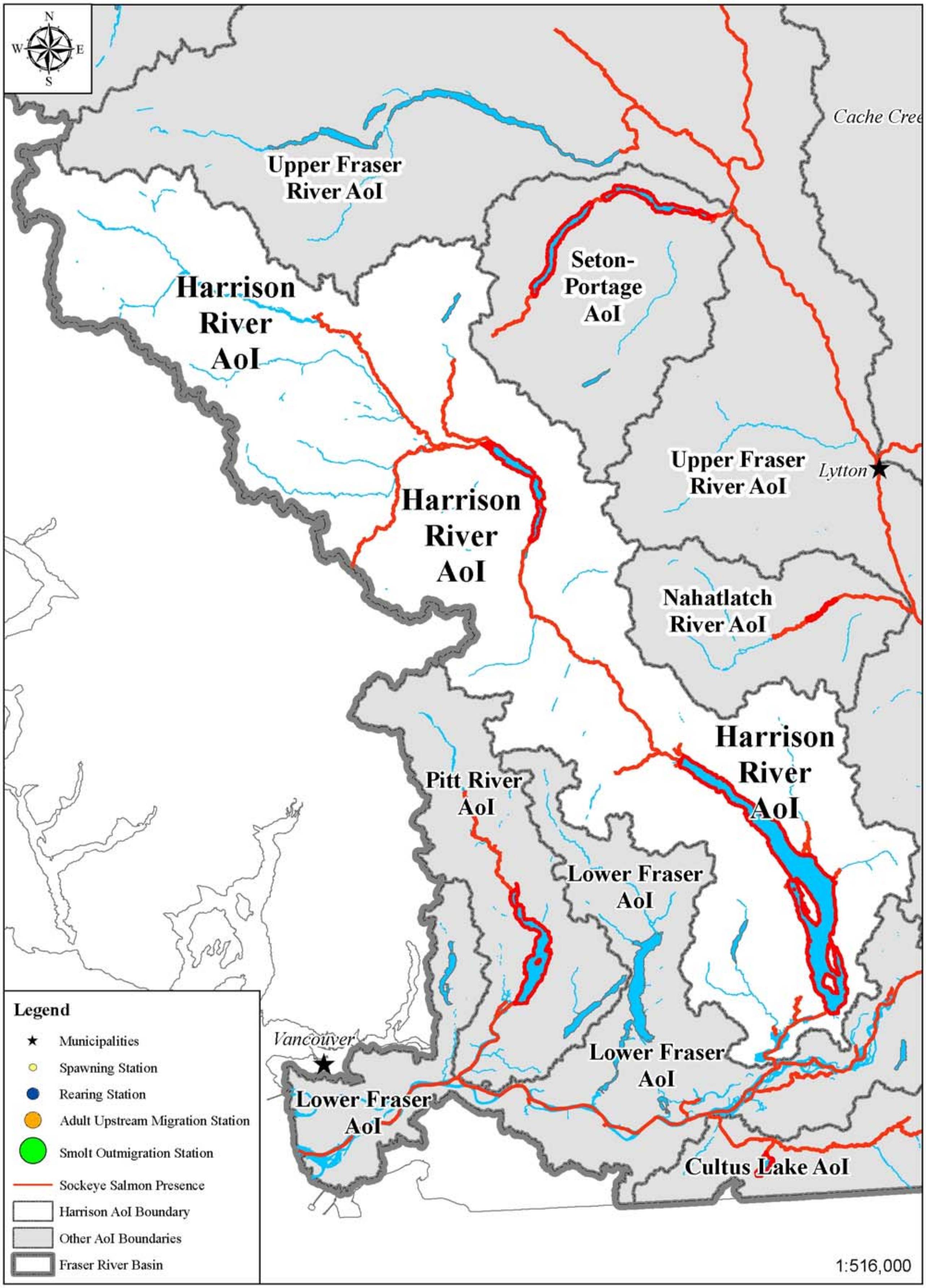


Figure 4.9. Map of the Cultus Lake AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

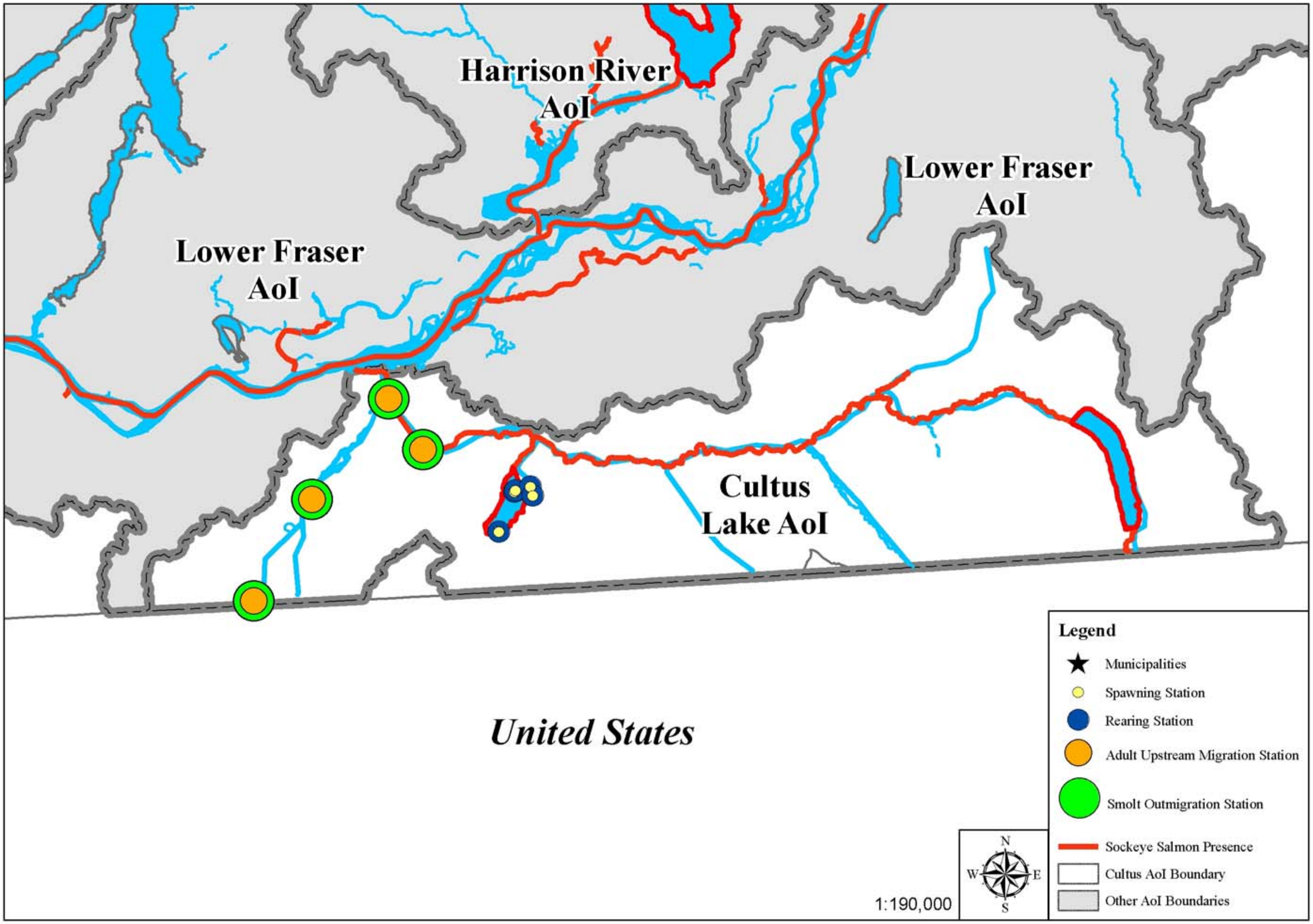


Figure 4.10. Map of the Kakawa Lake AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

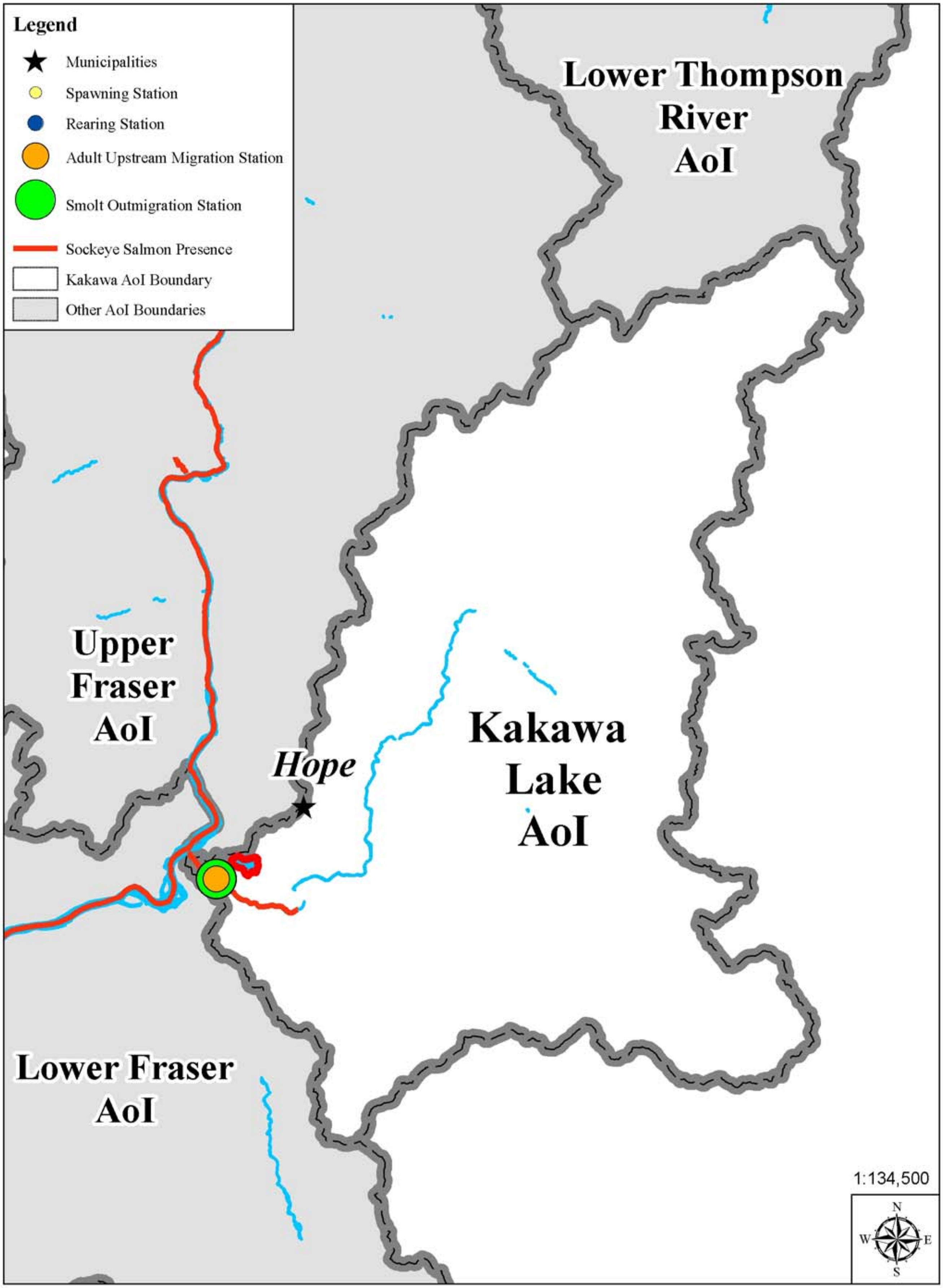


Figure 4.11. Map of the Nahatlatch River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs (no stations).

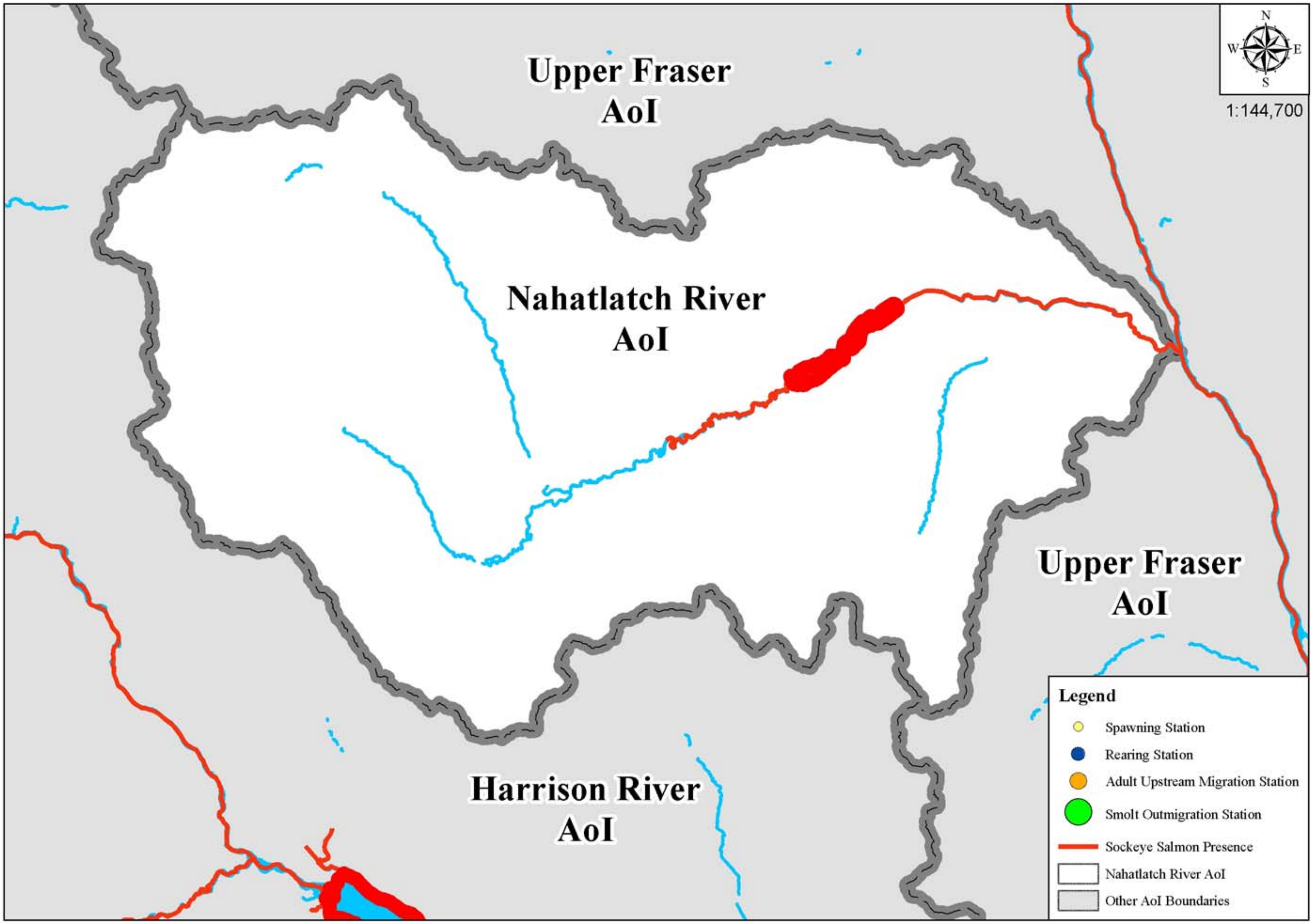


Figure 4.12. Map of the Seton-Portage AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

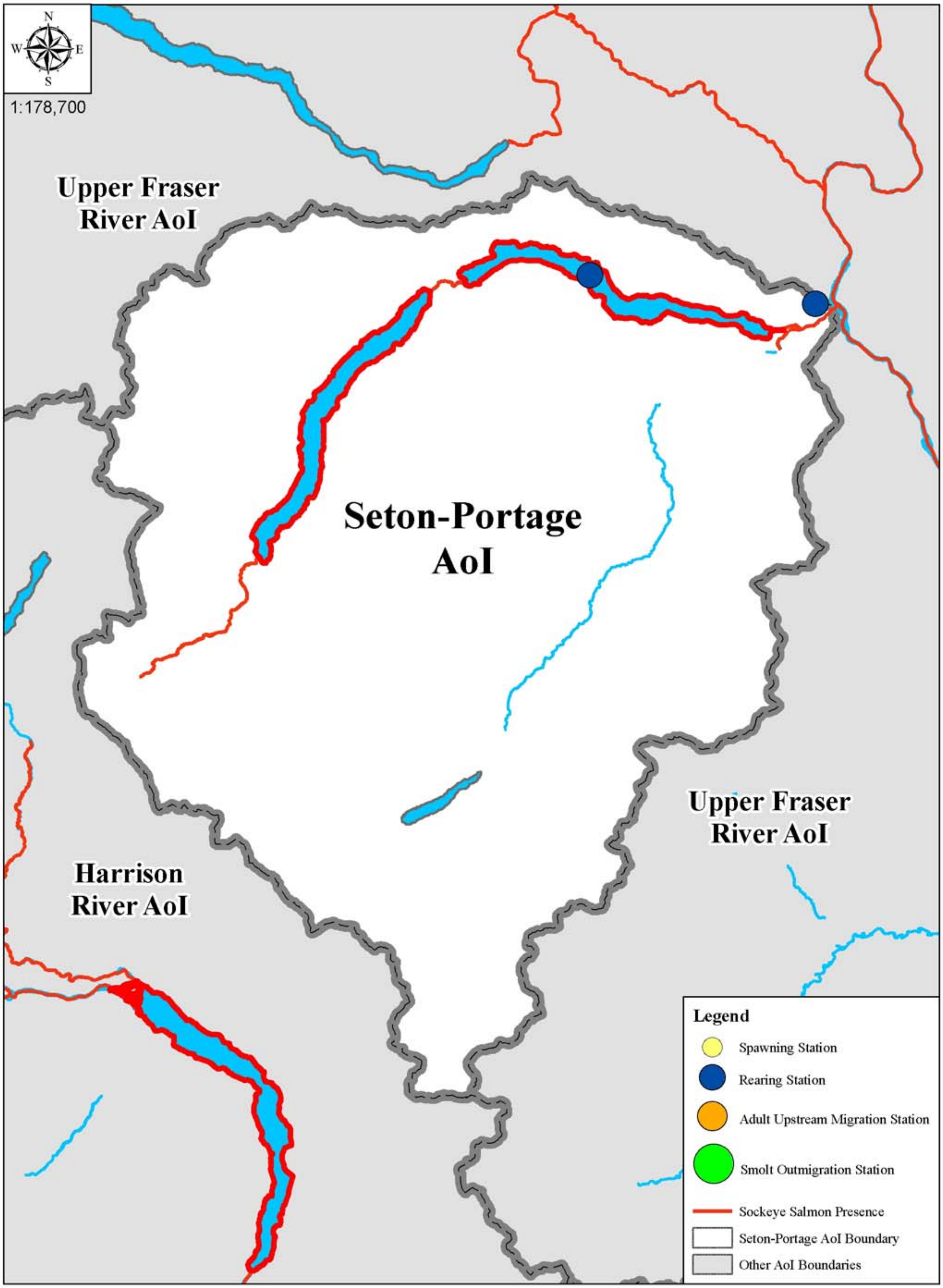


Figure 4.13. Map of the Lower Thompson River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

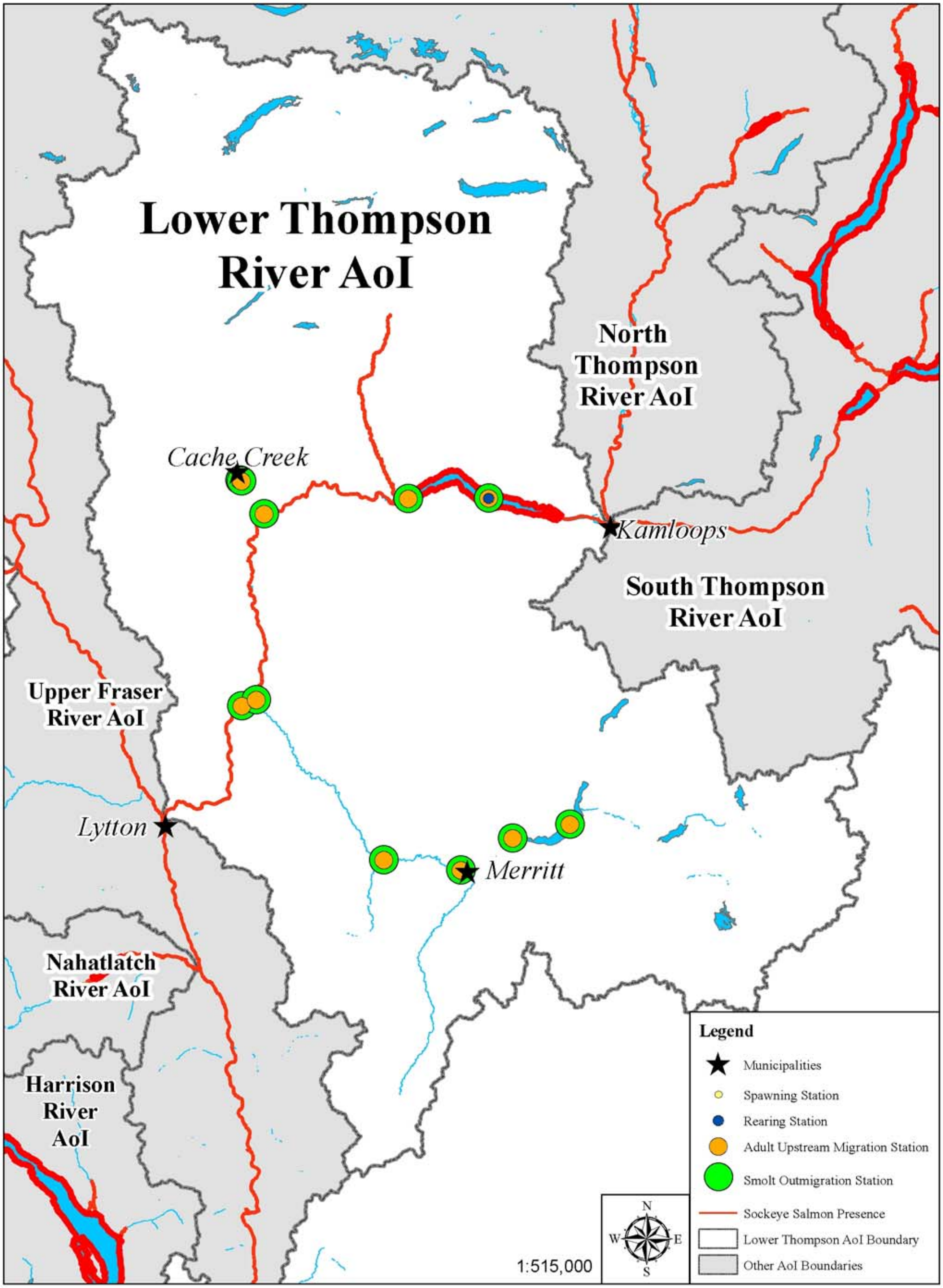


Figure 4.14. Map of the North Thompson River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

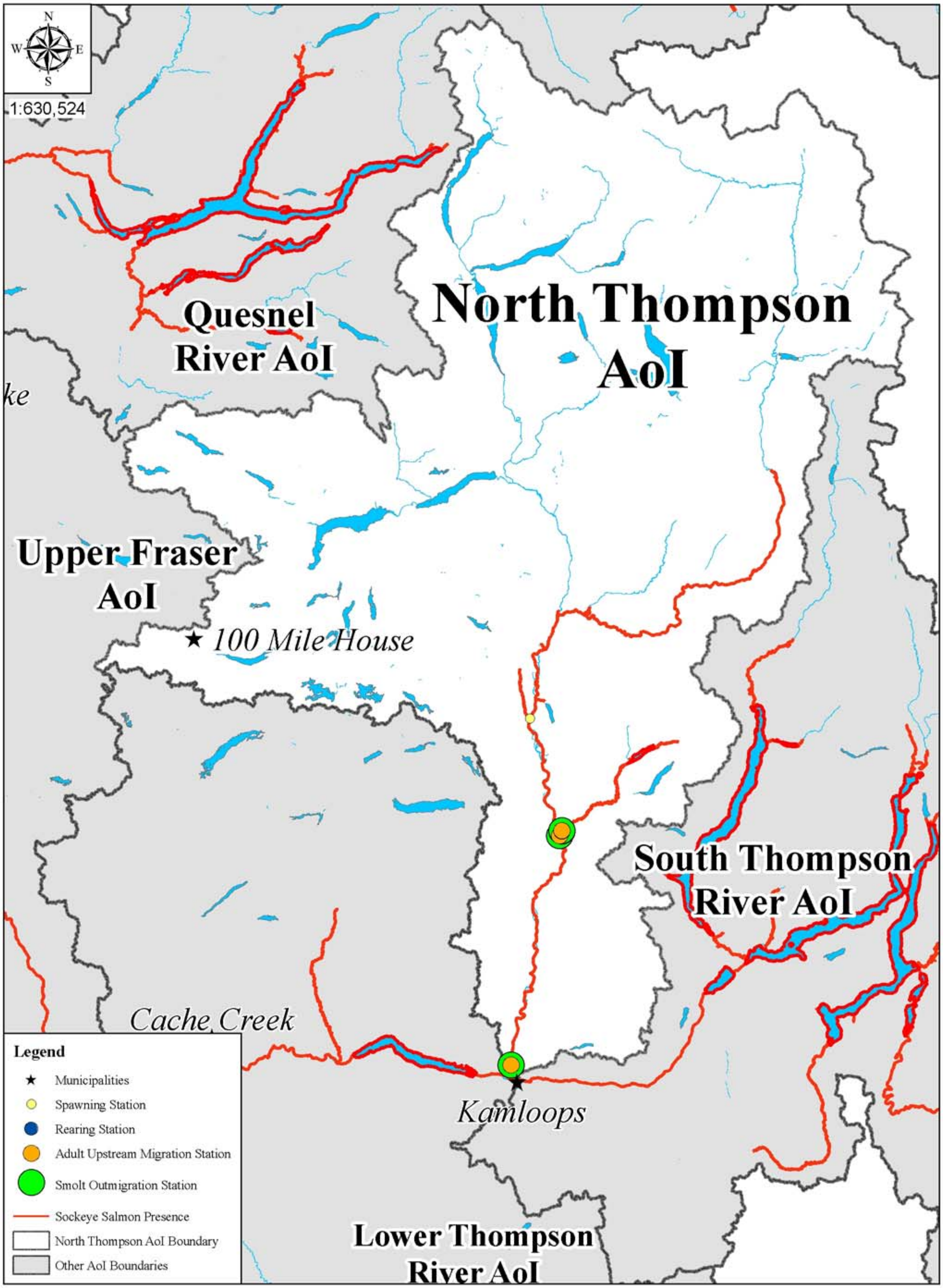


Figure 4.15. Map of the SouthThompson River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

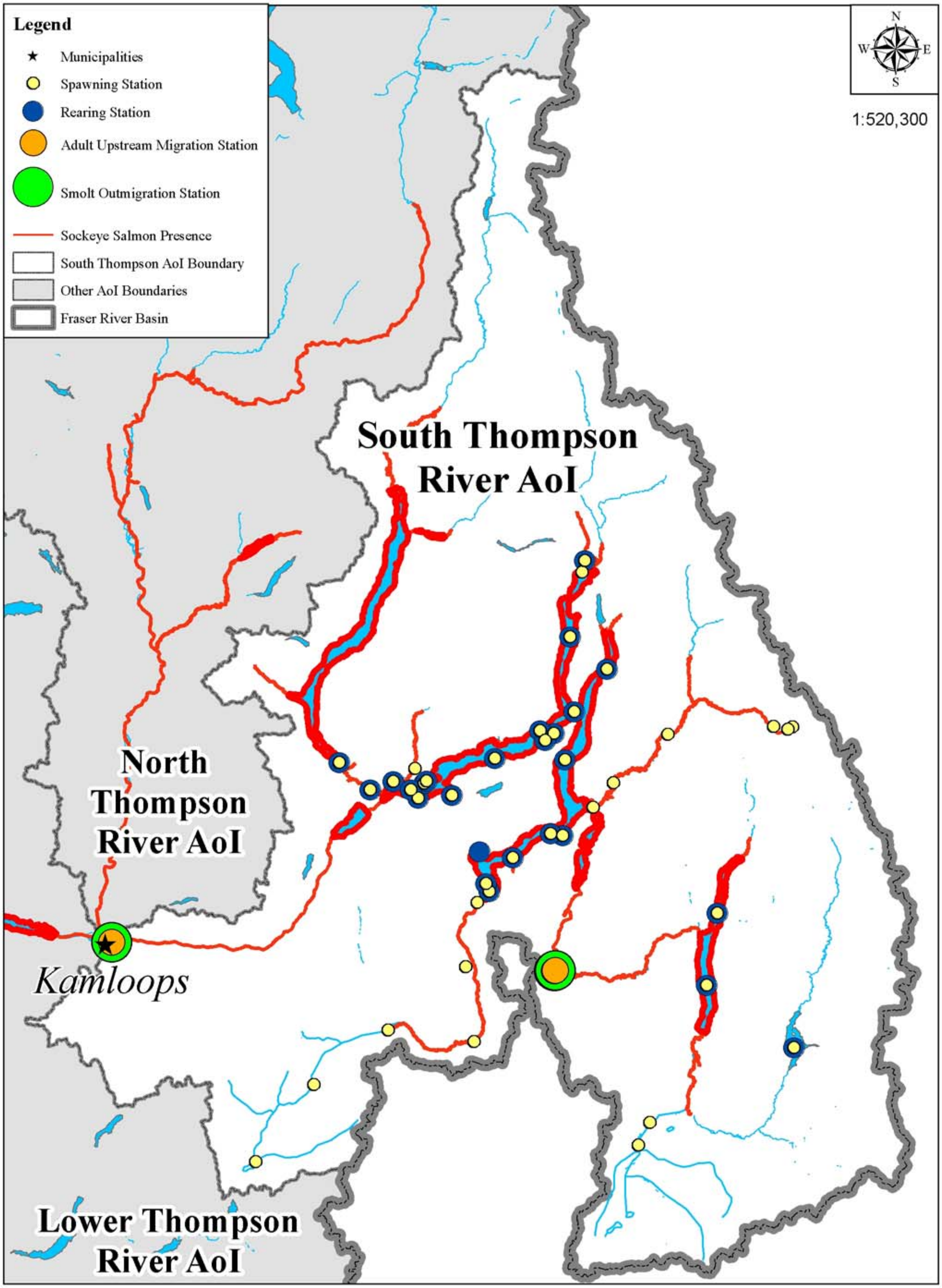


Figure 4.16. Map of the Chilko River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

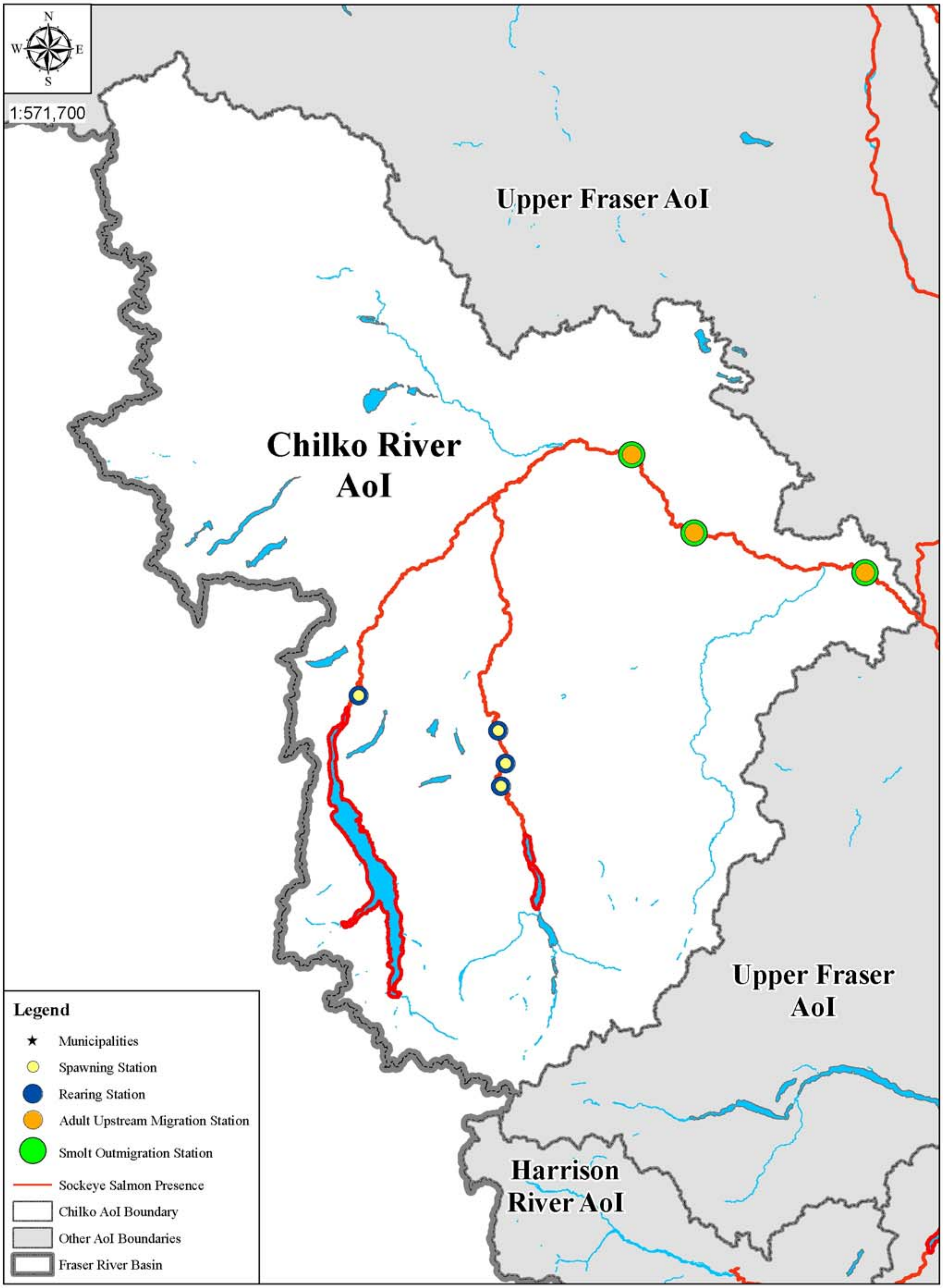


Figure 4.17. Map of the Quesnel River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

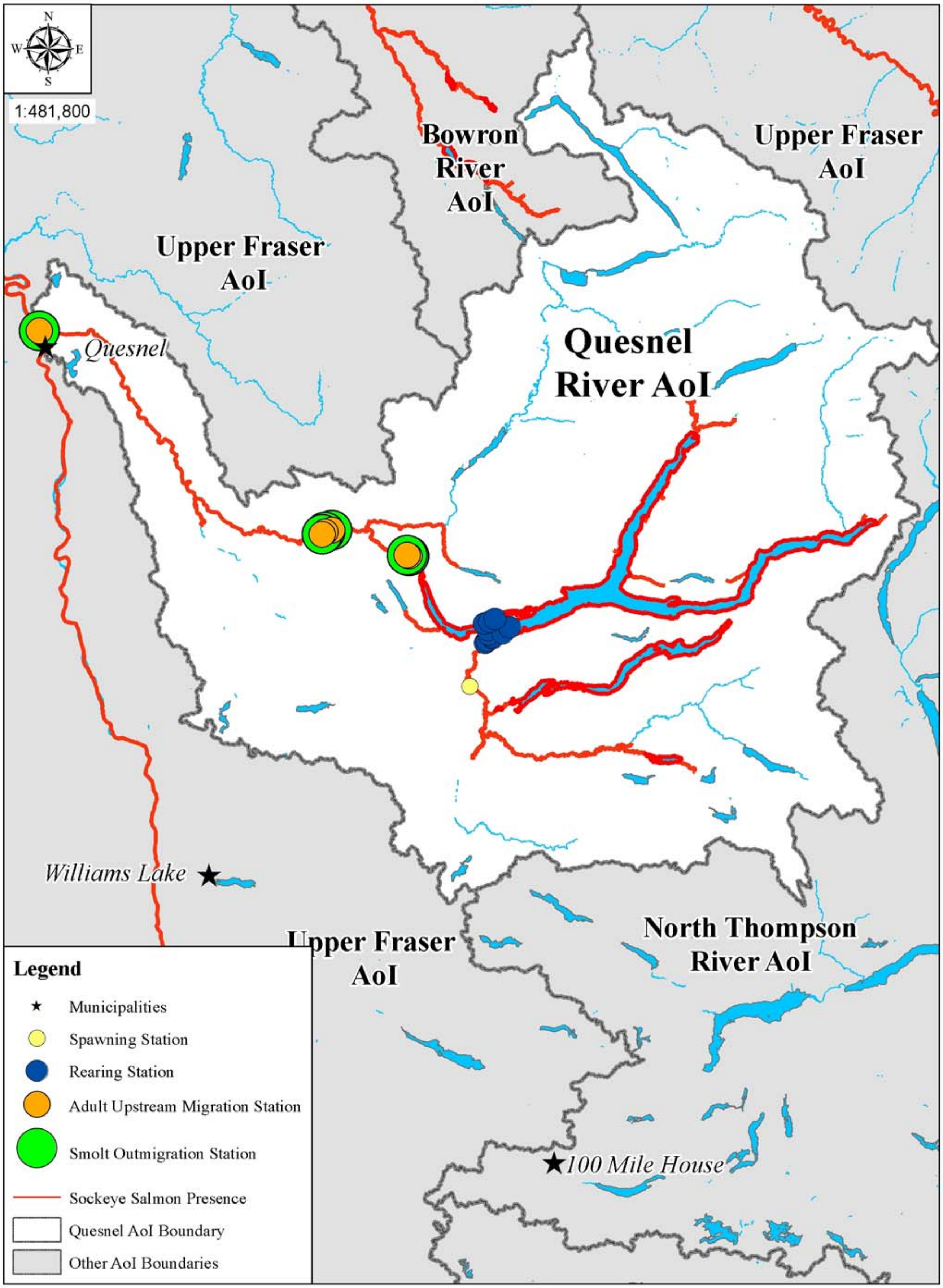


Figure 4.18. Map of the Nechako River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

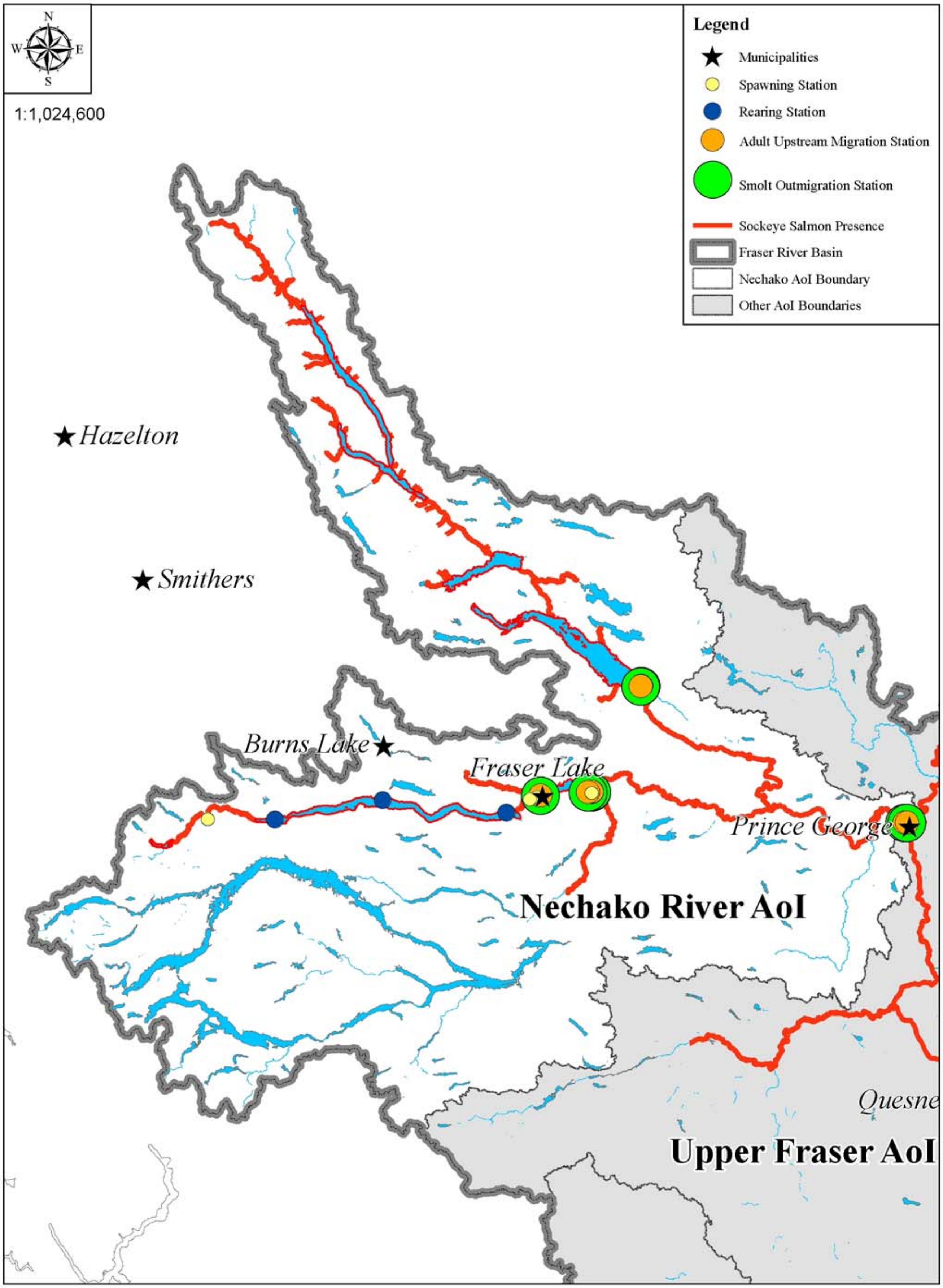


Figure 4.19. Map of the Bowron River AoI showing the locations of sampling stations used to evaluate exposure of each life stage of sockeye salmon to COPCs.

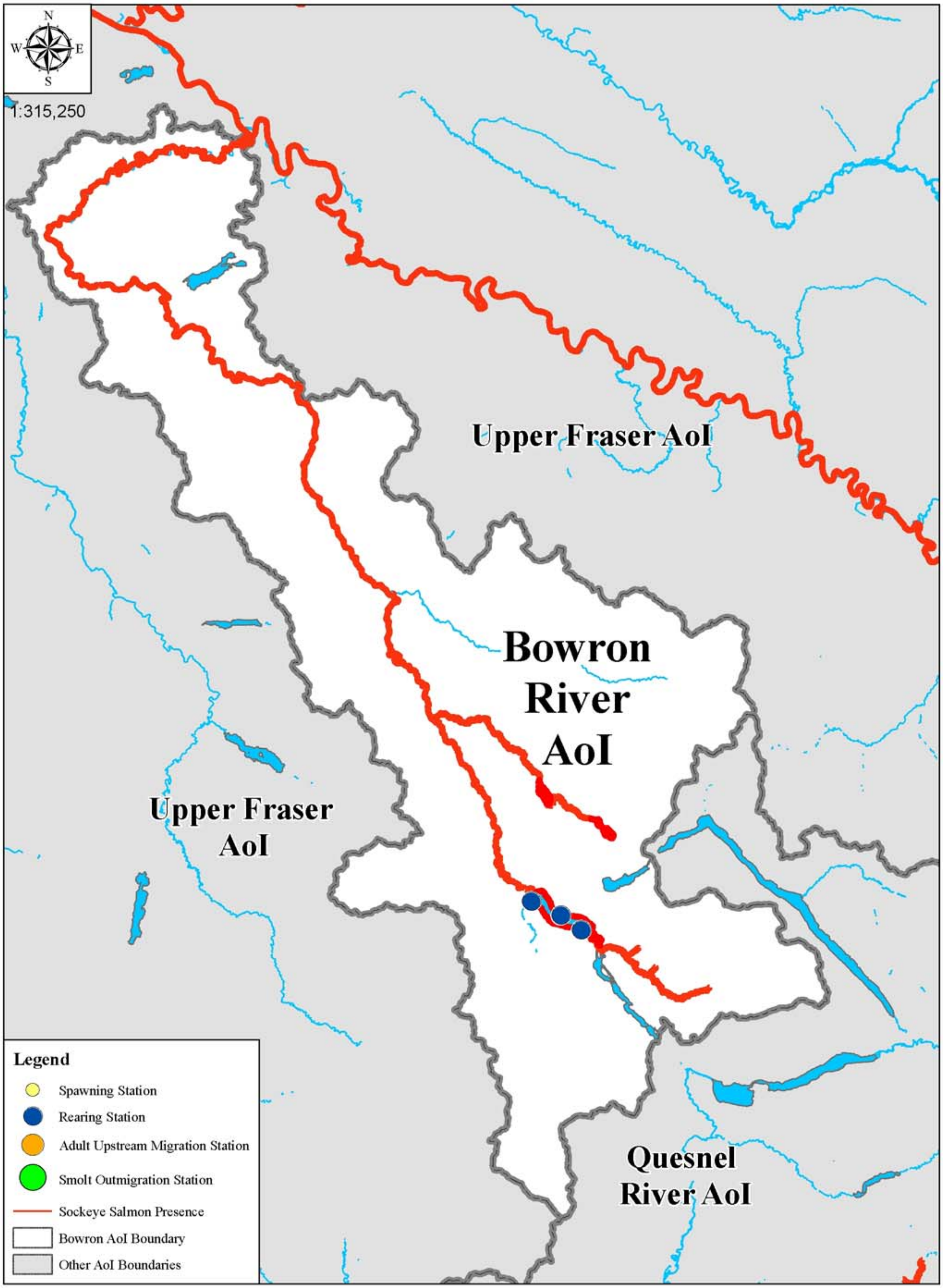


Figure 4.20. Mean Ricker Residuals for Fraser River Sockeye Salmon Stocks for Time Periods: 1948−1990 and 1991−2005. The 95% confidence interval and sample size are shown.

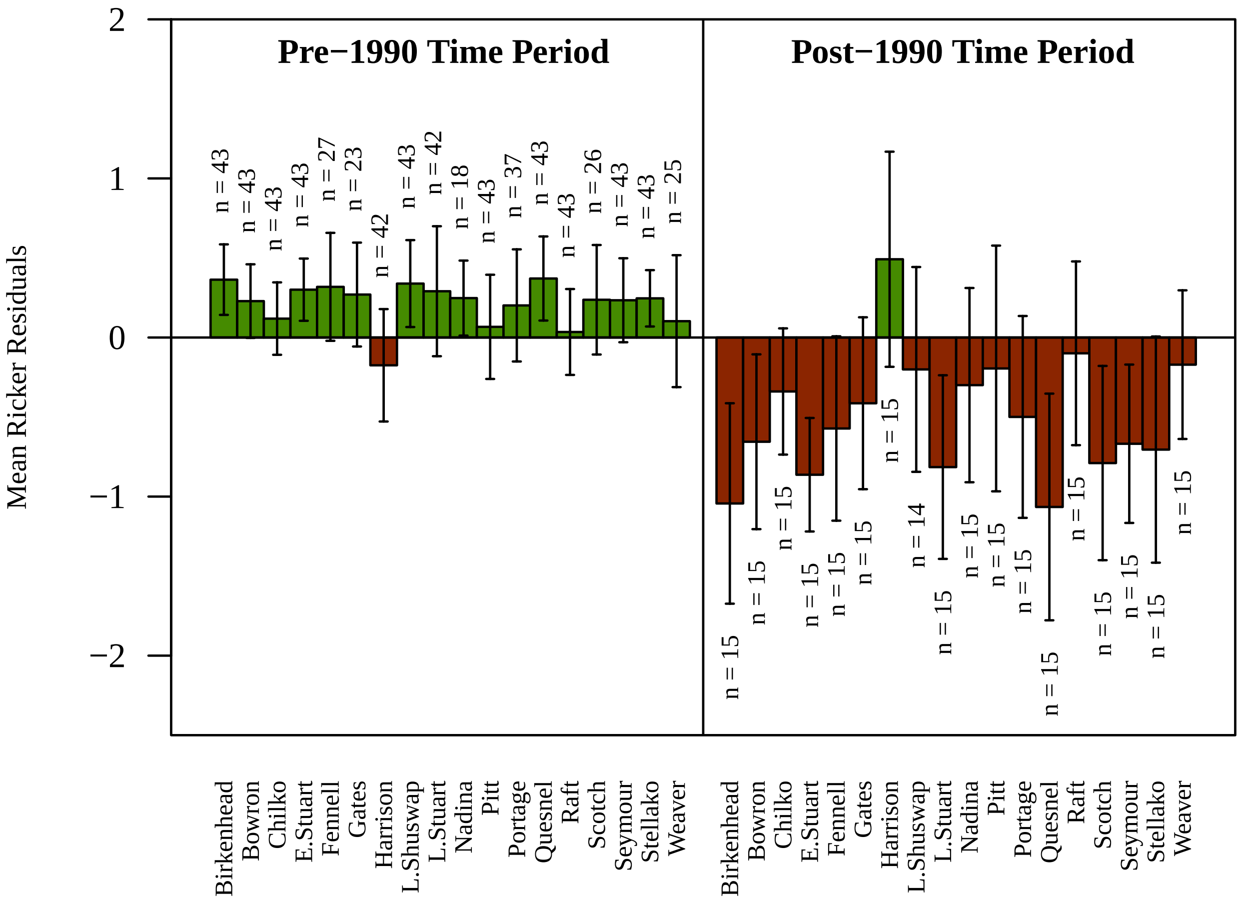


Figure 4.21. Map of the Fraser River Basin showing locations of all water quality stations used to characterize exposure of sockeye salmon to chemicals of potential concern in surface water.

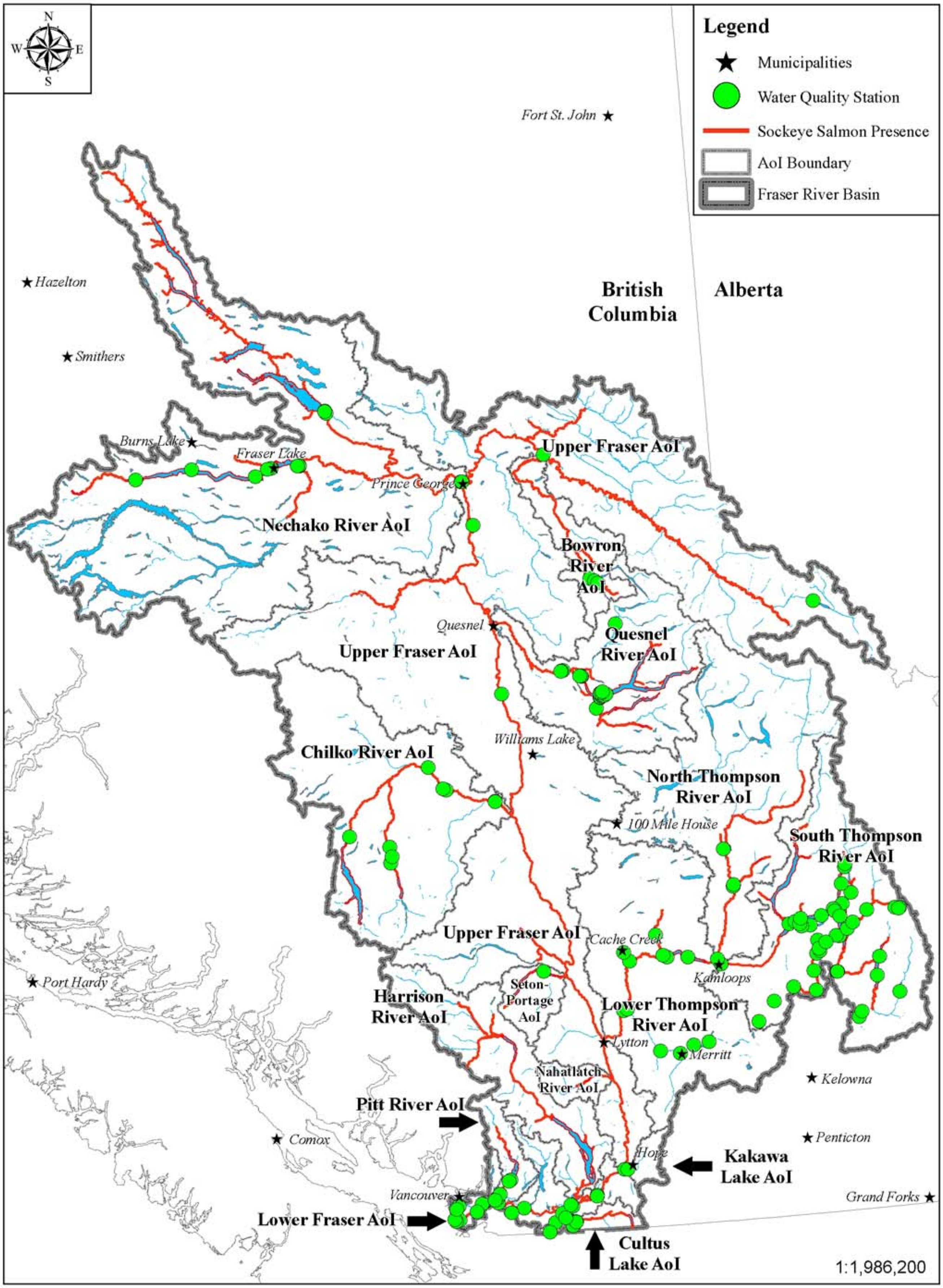


Figure 4.22. Map of the Fraser River Basin showing locations of sampling stations used to characterize exposure of sockeye salmon to chemicals of potential concern in sediment.

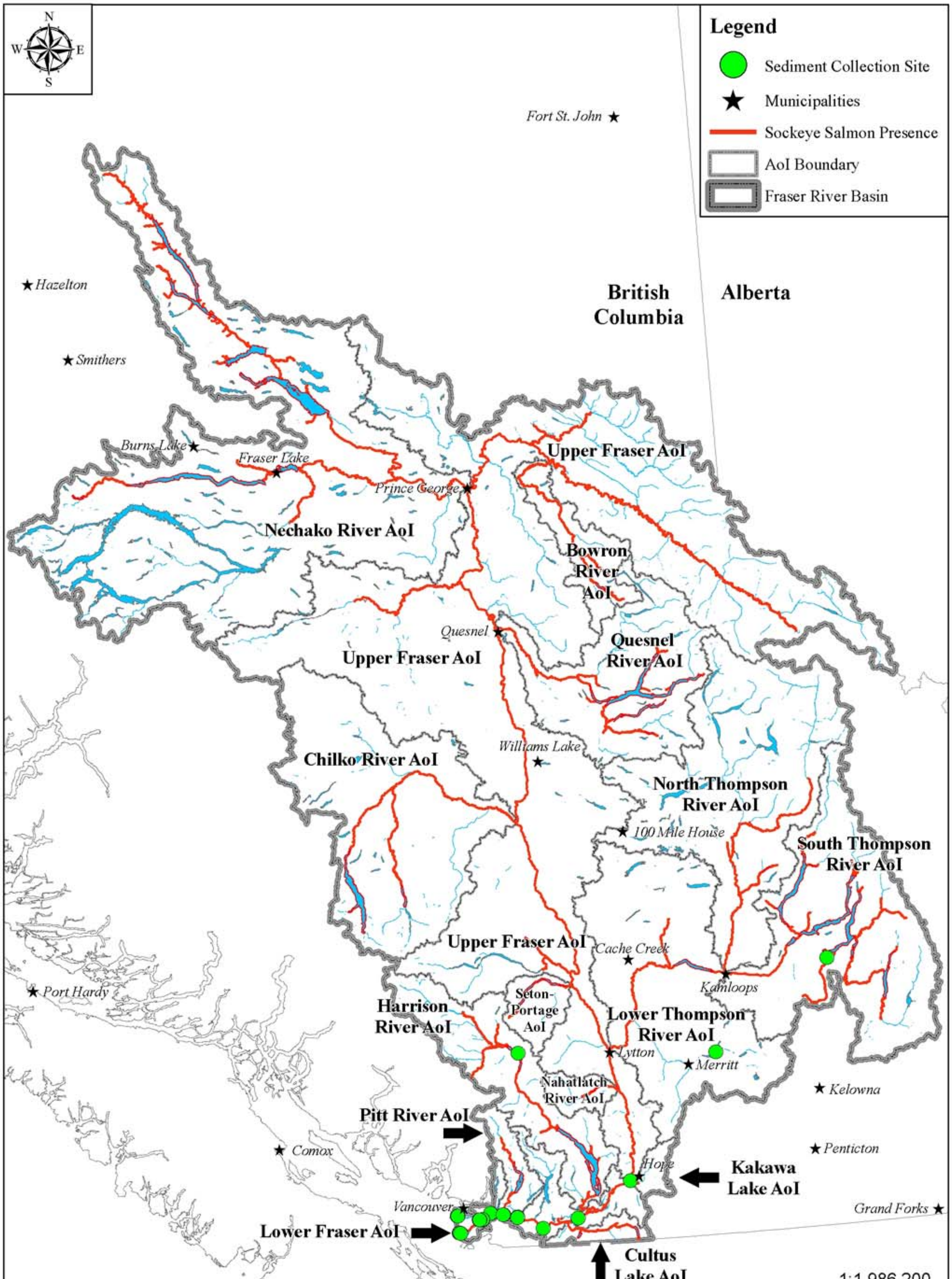


Figure 5.1. Water Quality Index scores vs time for the four habitat types in the Fraser River Basin for the period 1960−2010.

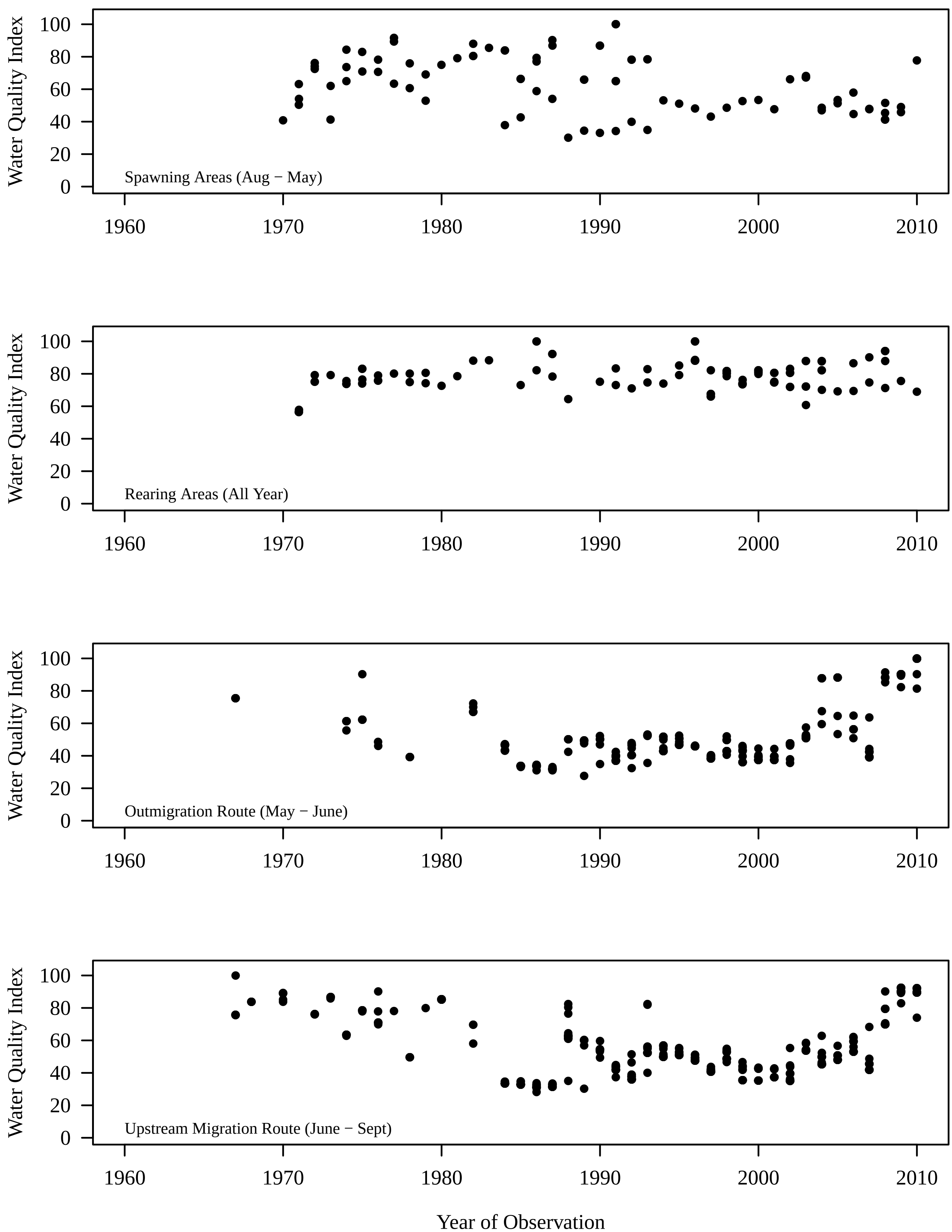


Figure 5.2. Expected relationship between sockeye salmon productivity (Ricker Residuals) and Water Quality Index.

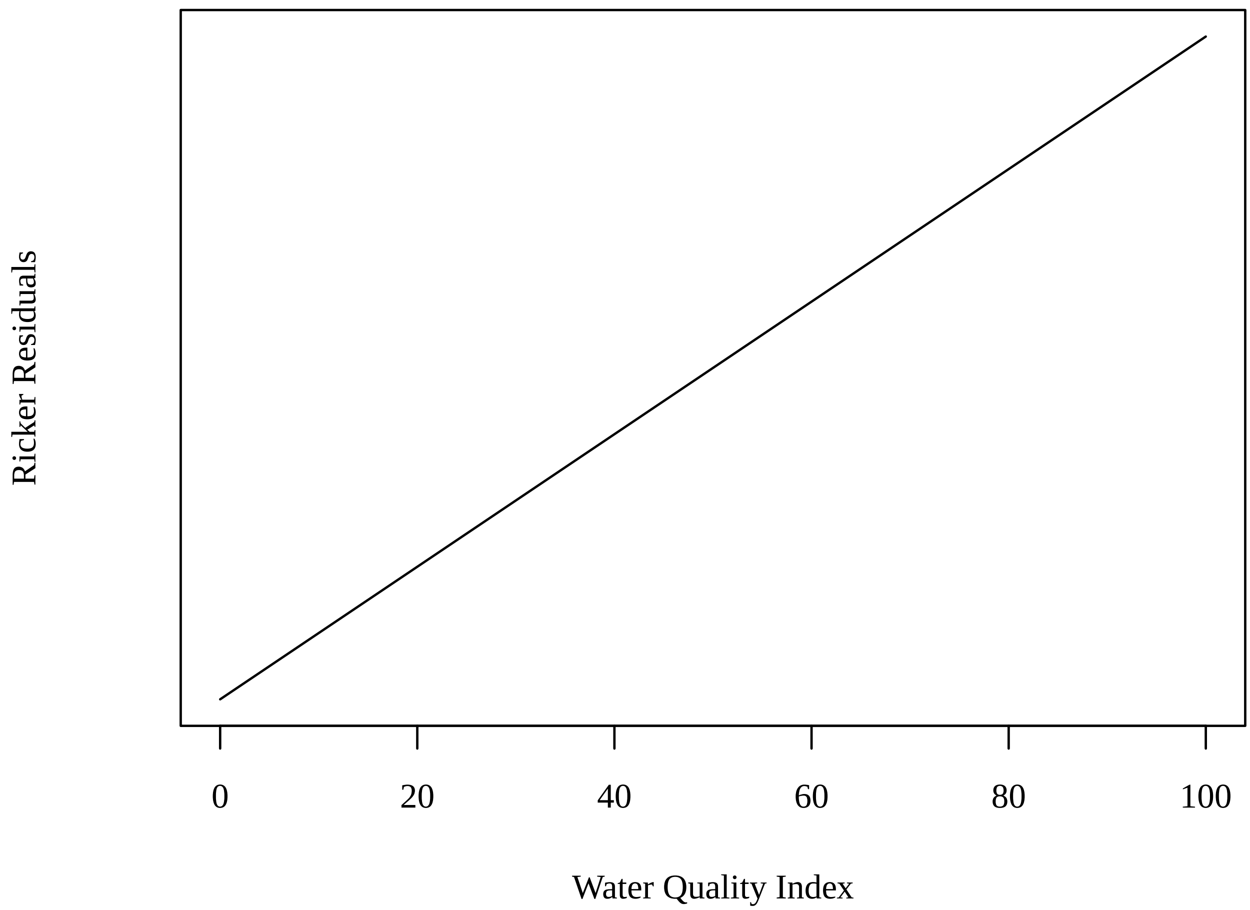


Figure 5.3. Fraser River Sockeye Salmon Productivity (Ricker Residuals) and Water Quality Index by Life History Stage.

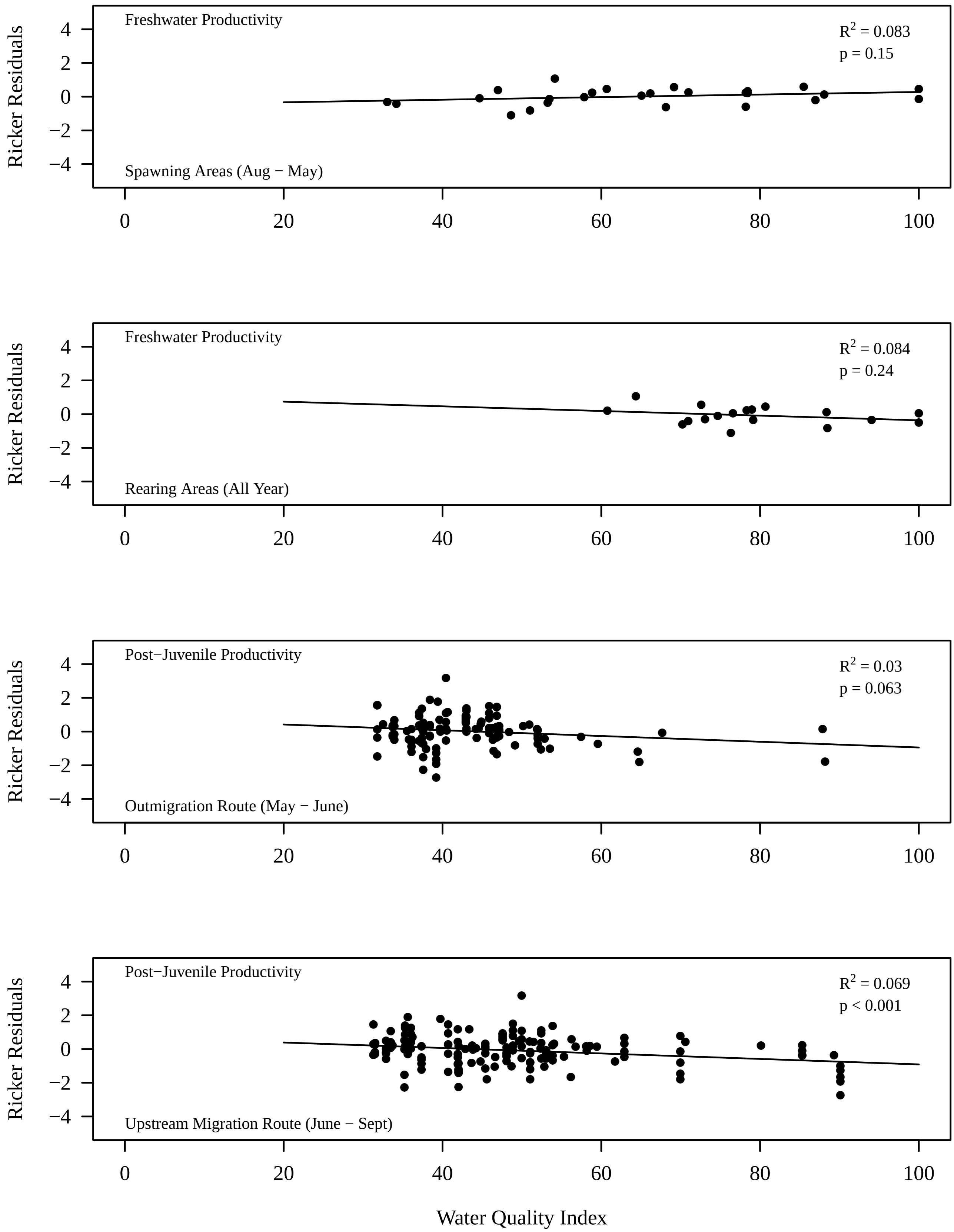


Figure 5.4. Fraser River Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

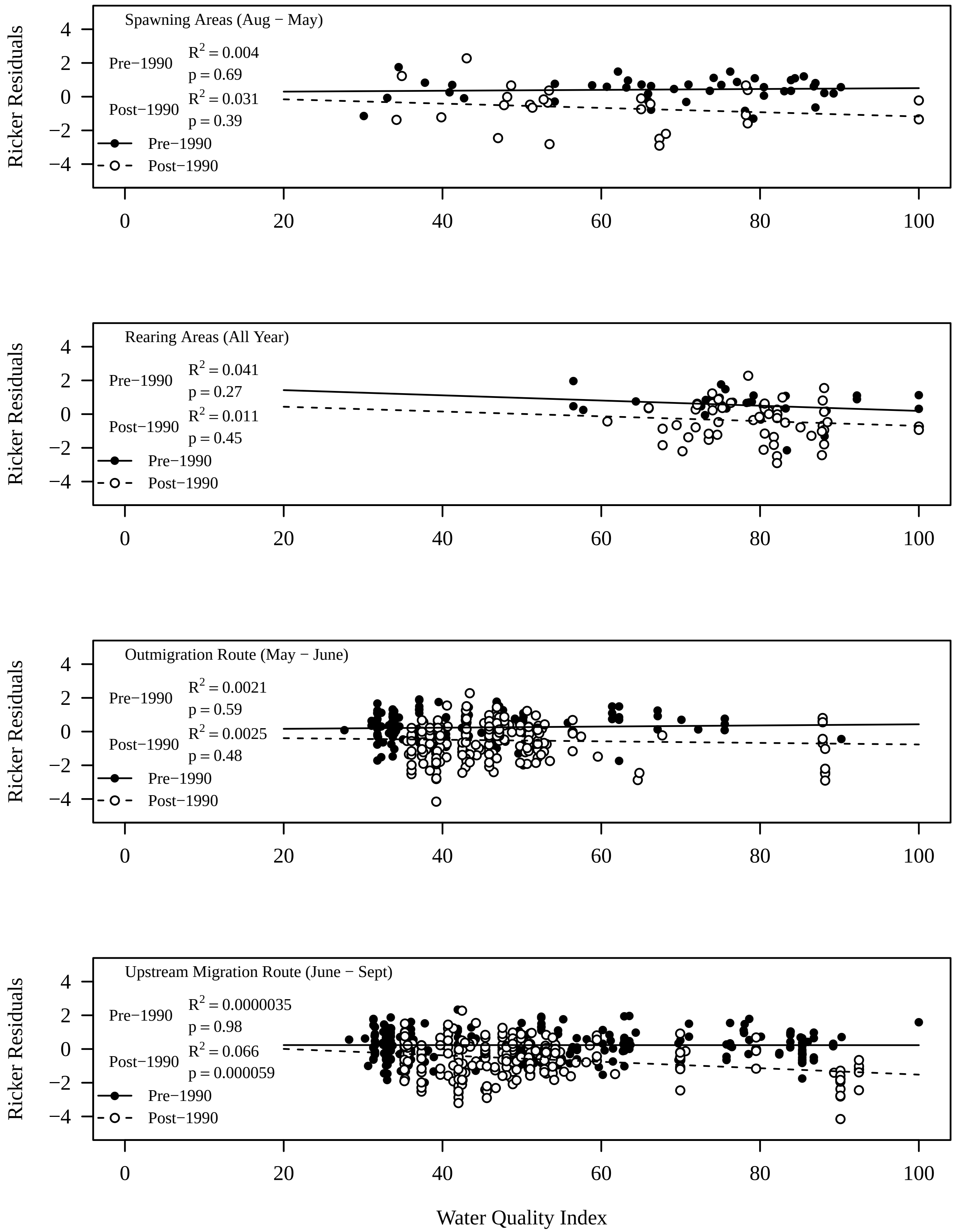


Figure 5.5. Pitt Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

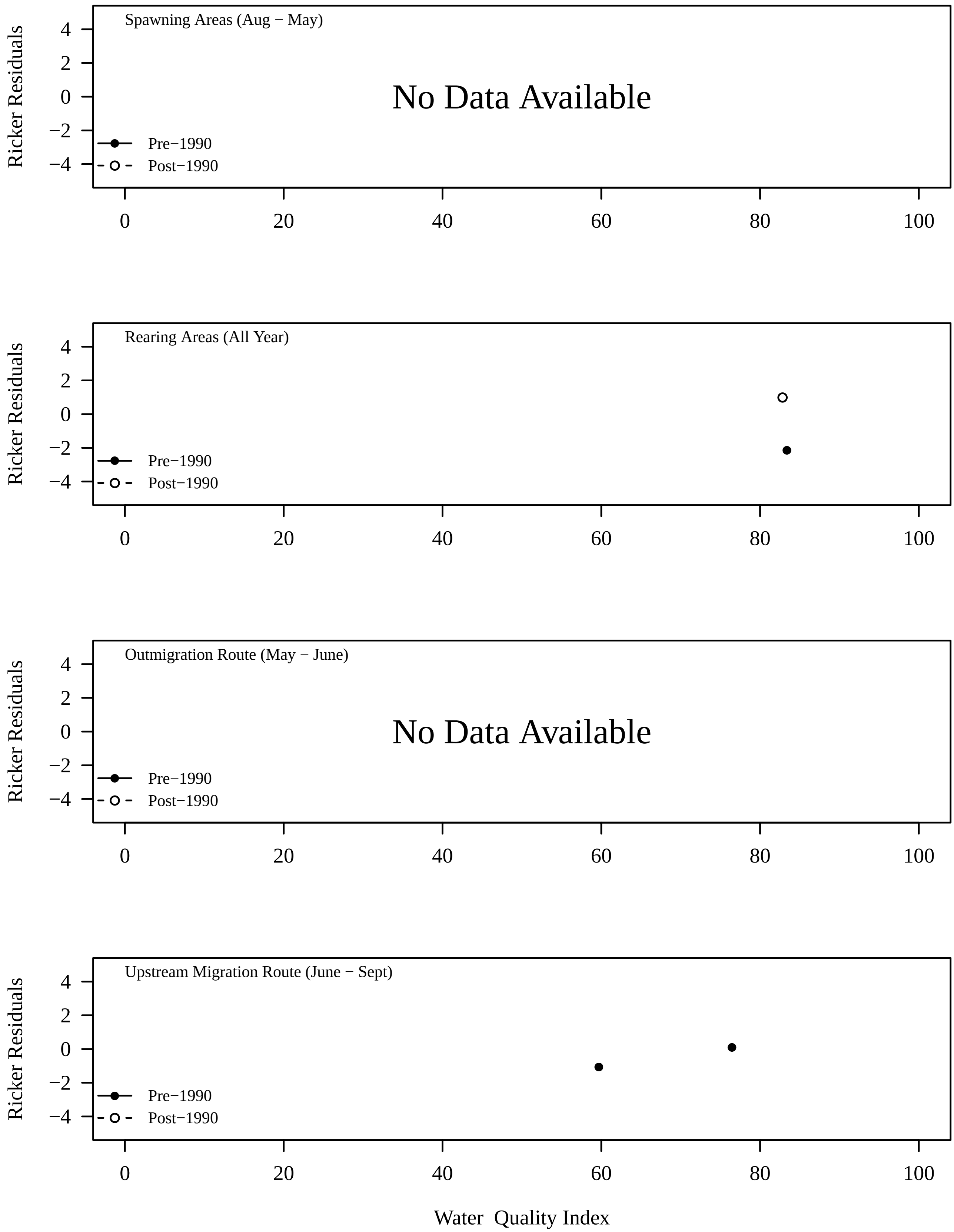


Figure 5.6. Harrison Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

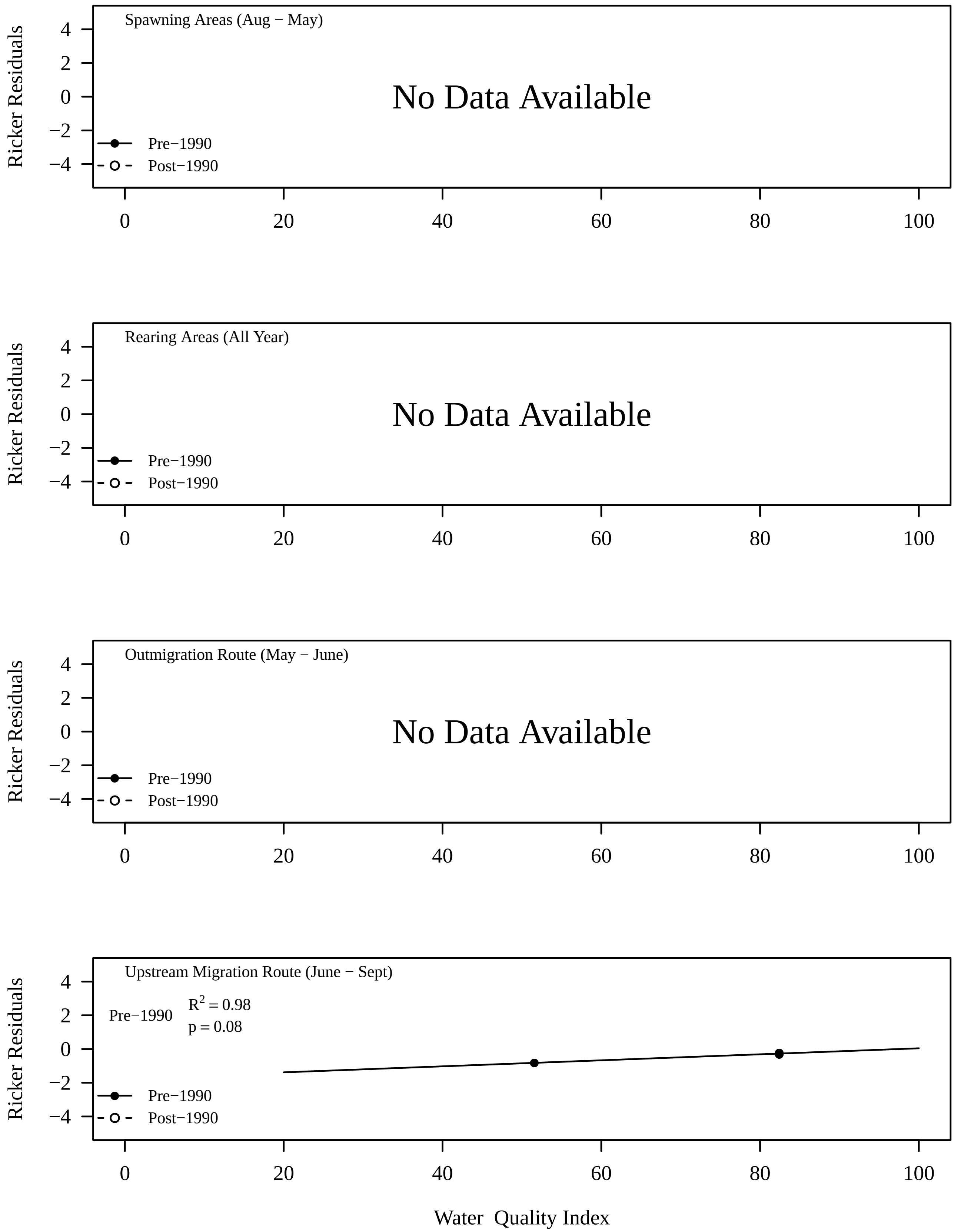


Figure 5.7. Weaver Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

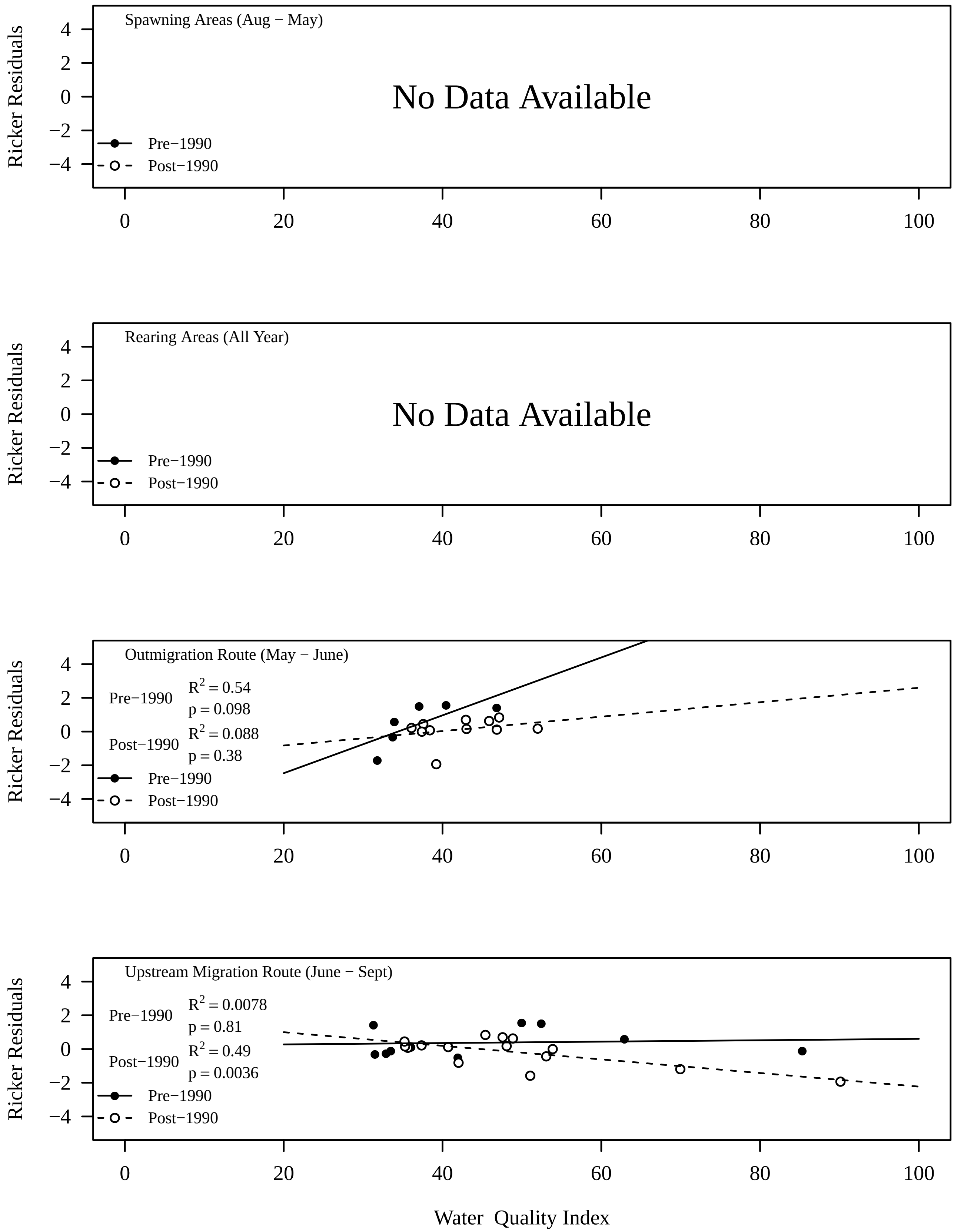


Figure 5.8. Birkenhead Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

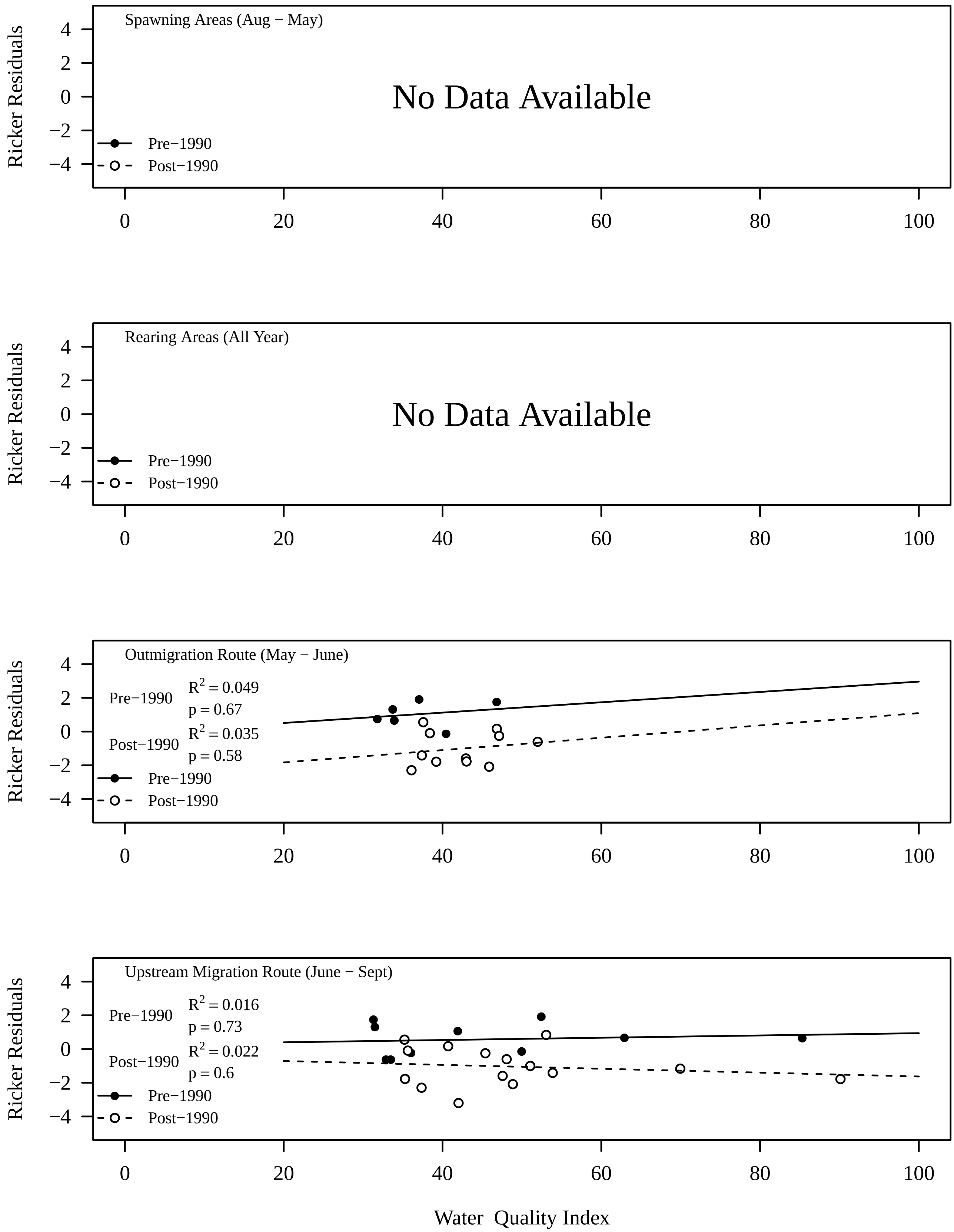


Figure 5.9. Cultus Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

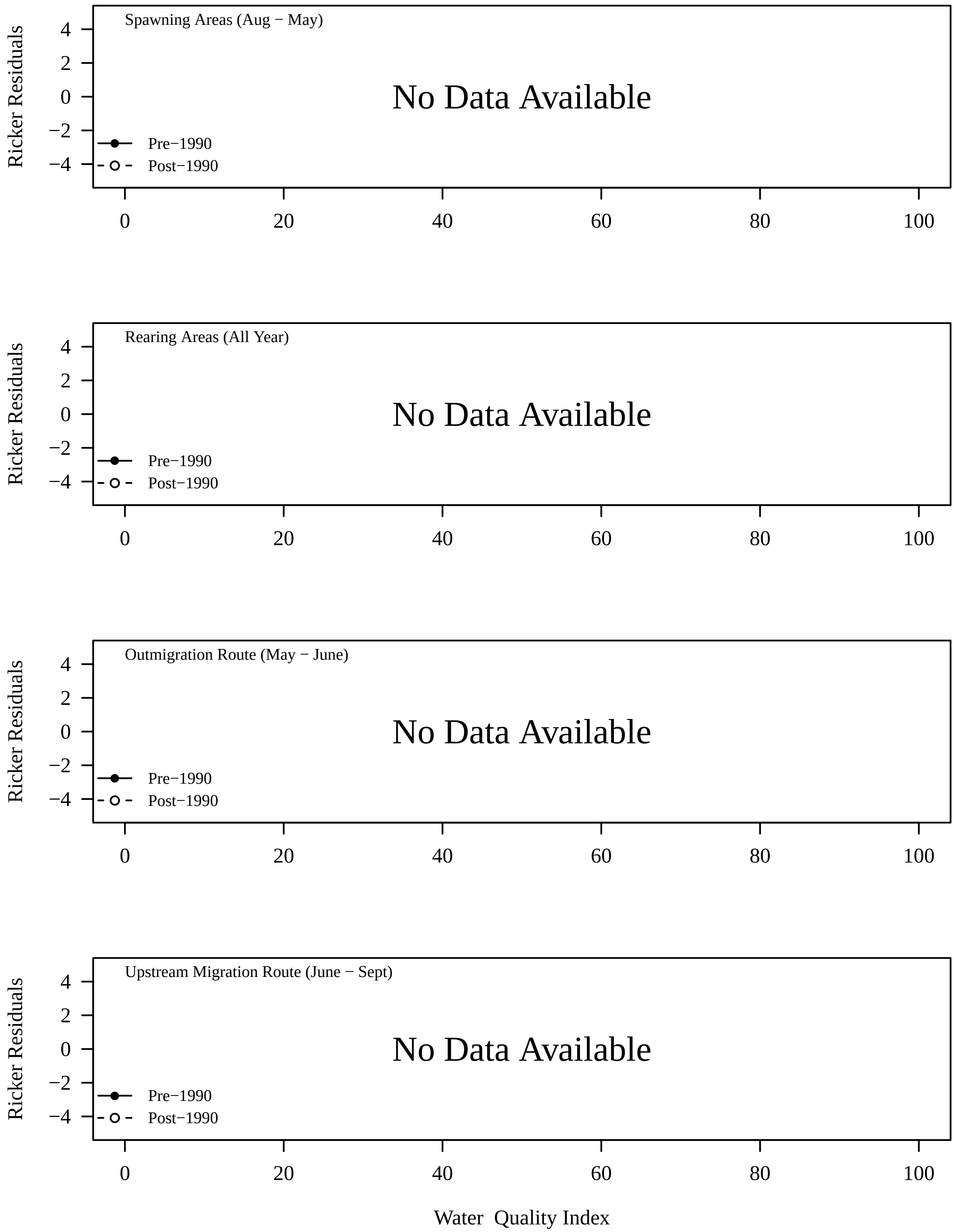


Figure 5.10. Gates Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

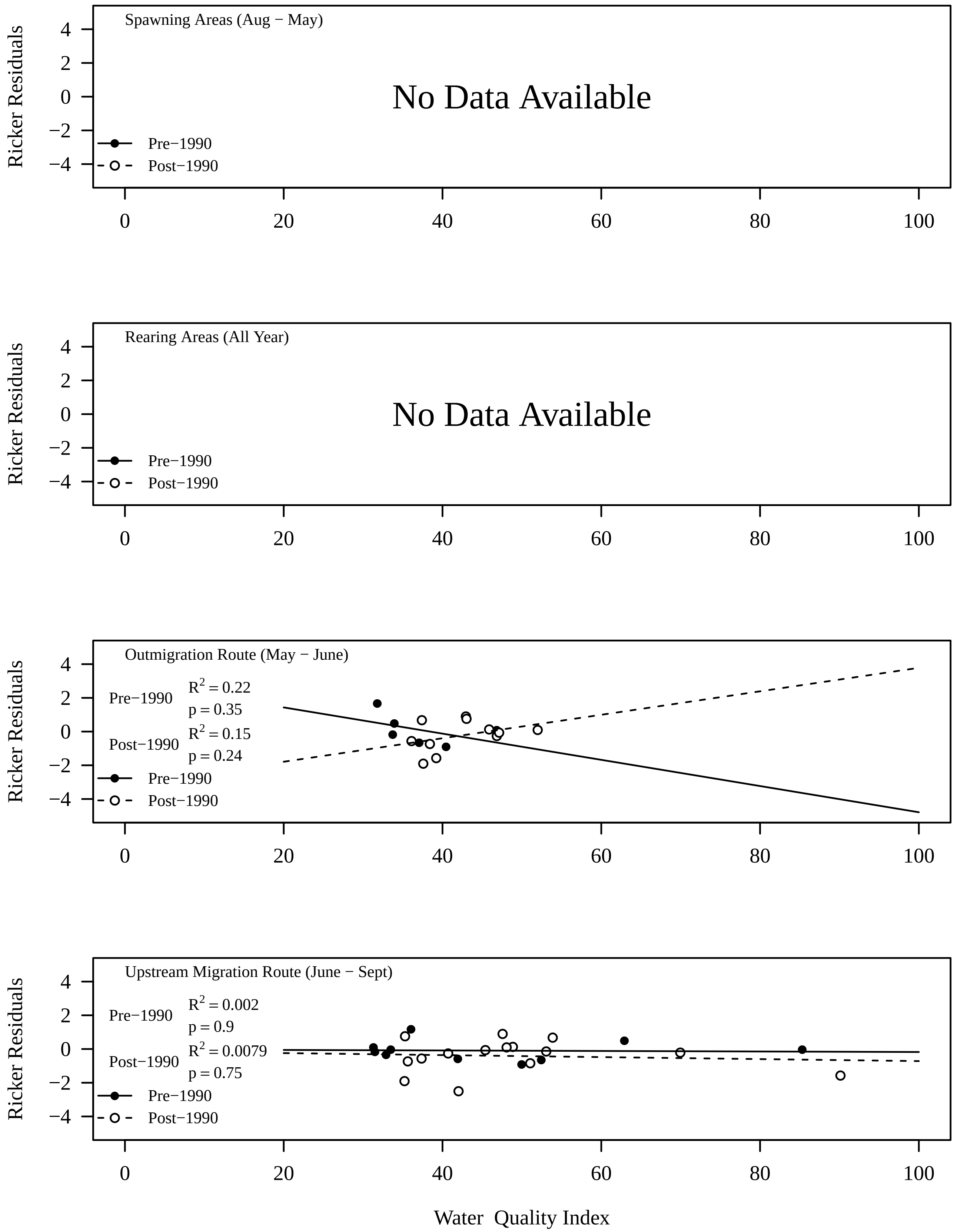


Figure 5.11. Portage Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

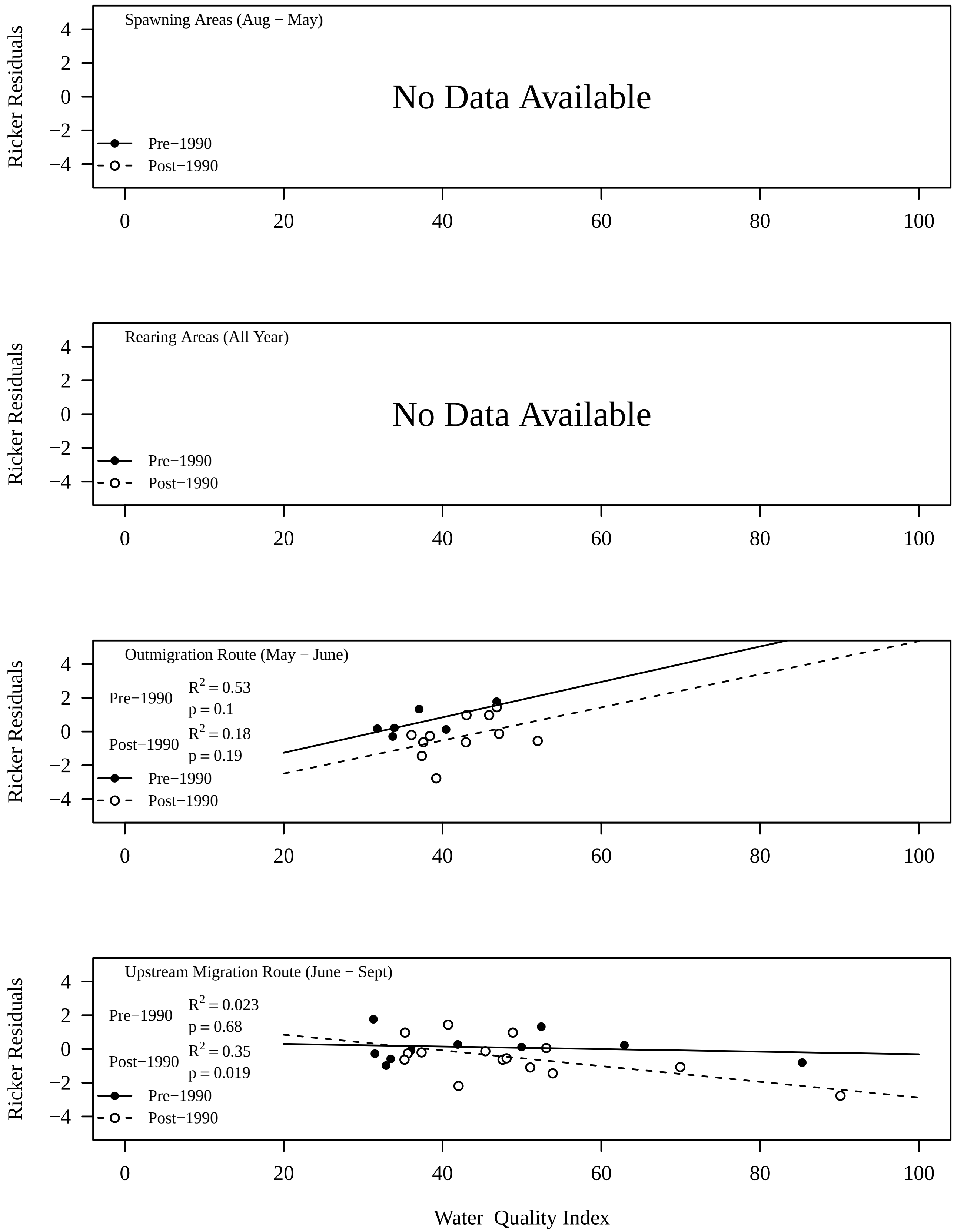


Figure 5.12. Raft Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

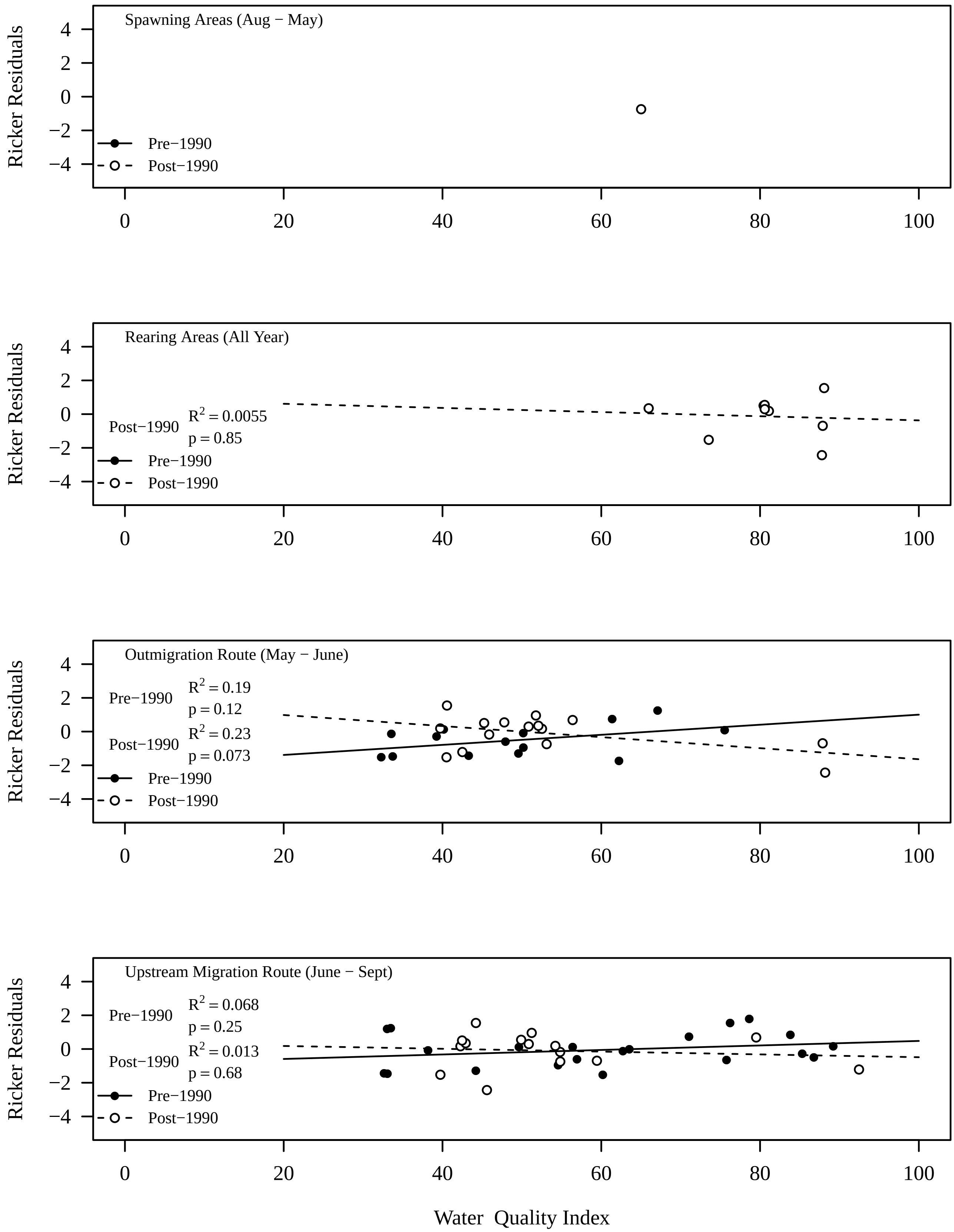


Figure 5.13. Fennell Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

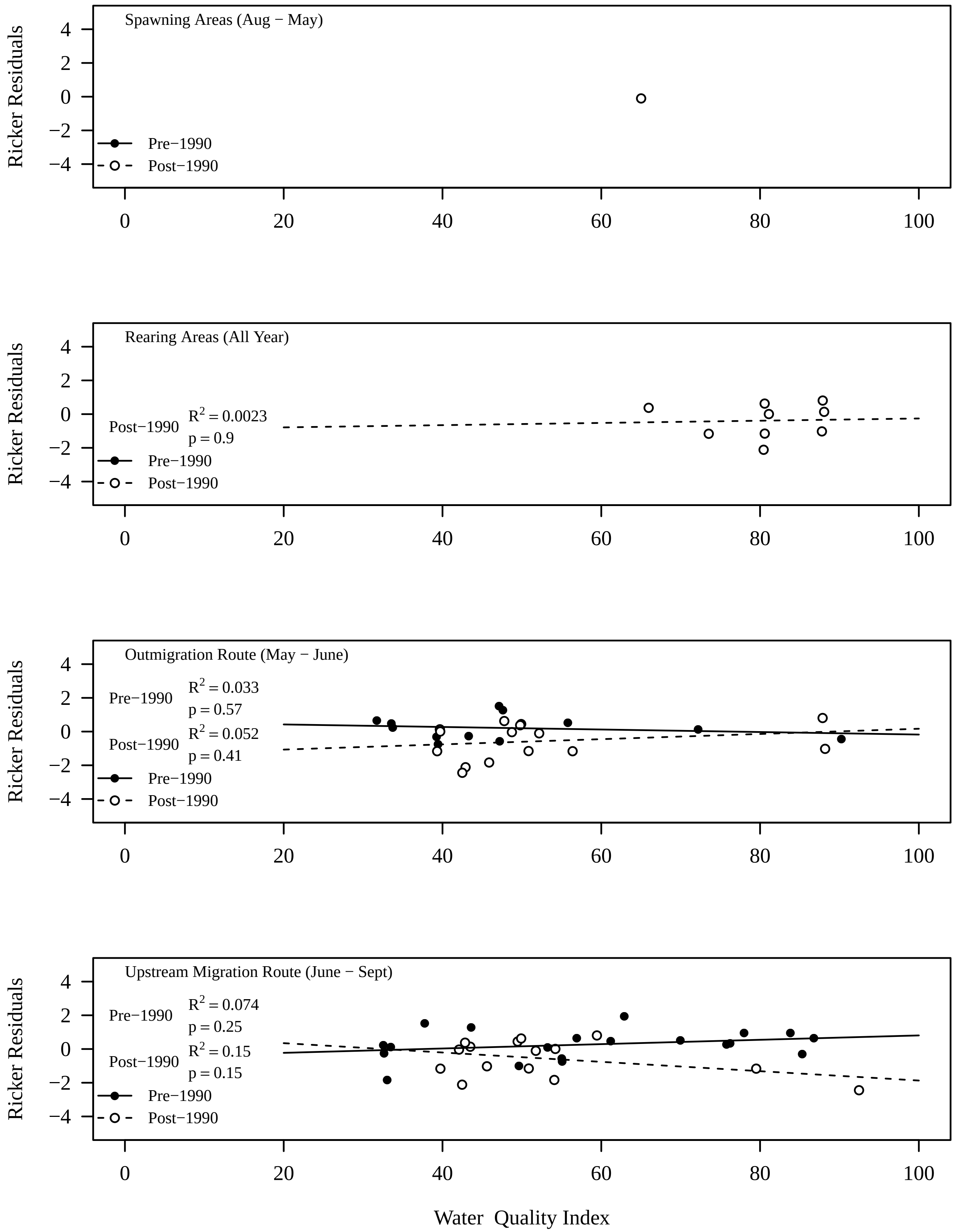


Figure 5.14. Seymour Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

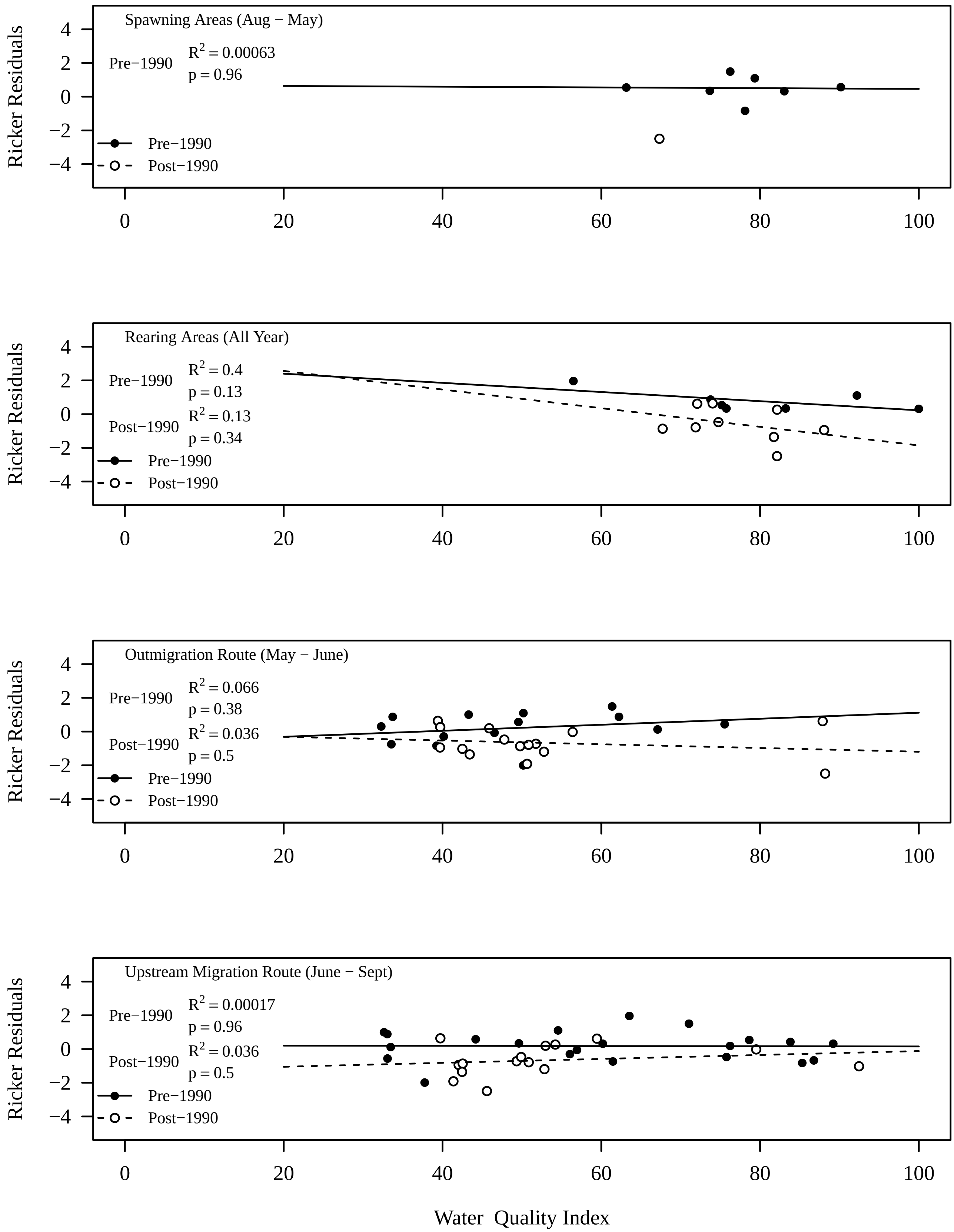


Figure 5.15. Late Shuswap Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

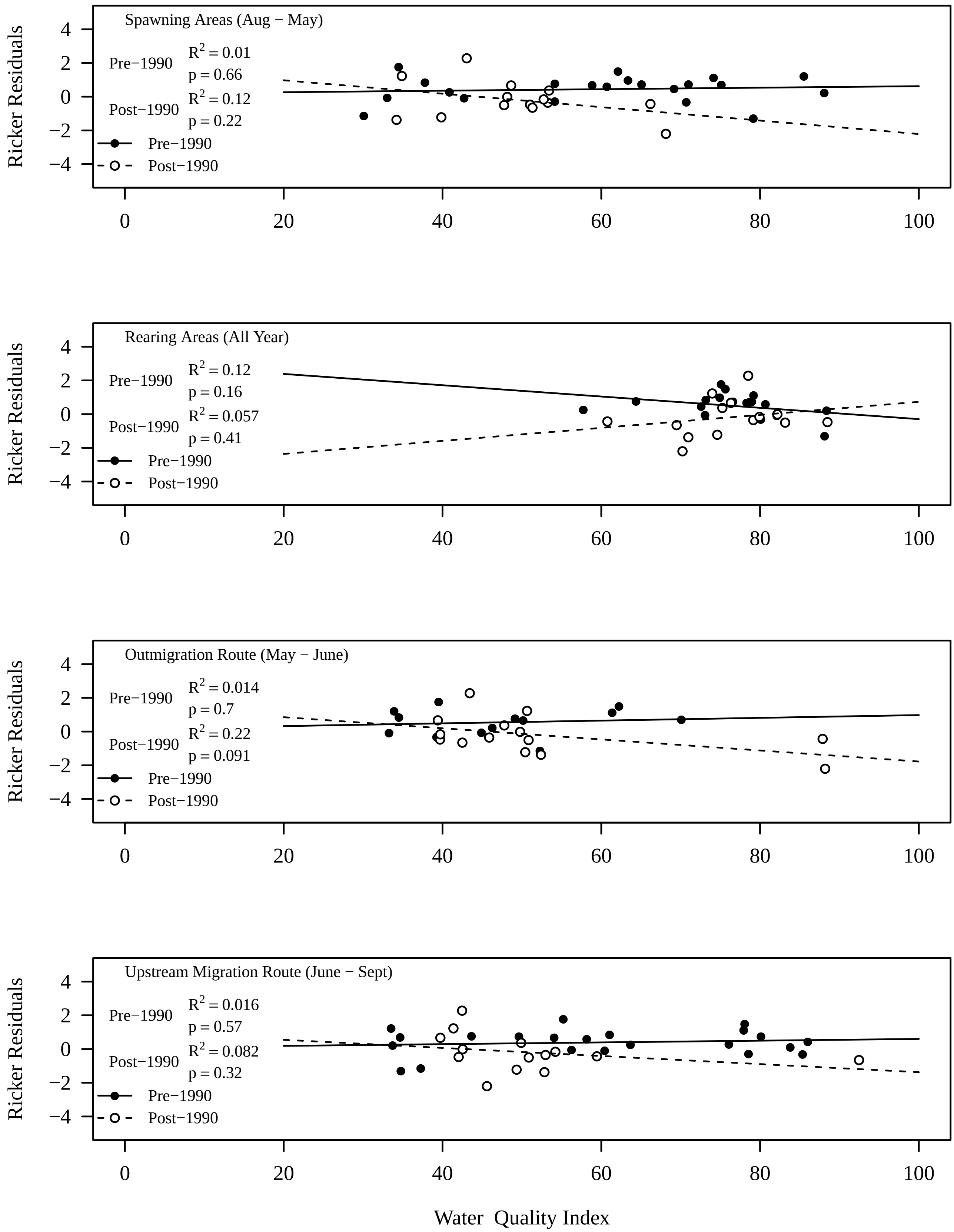


Figure 5.16. Scotch Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

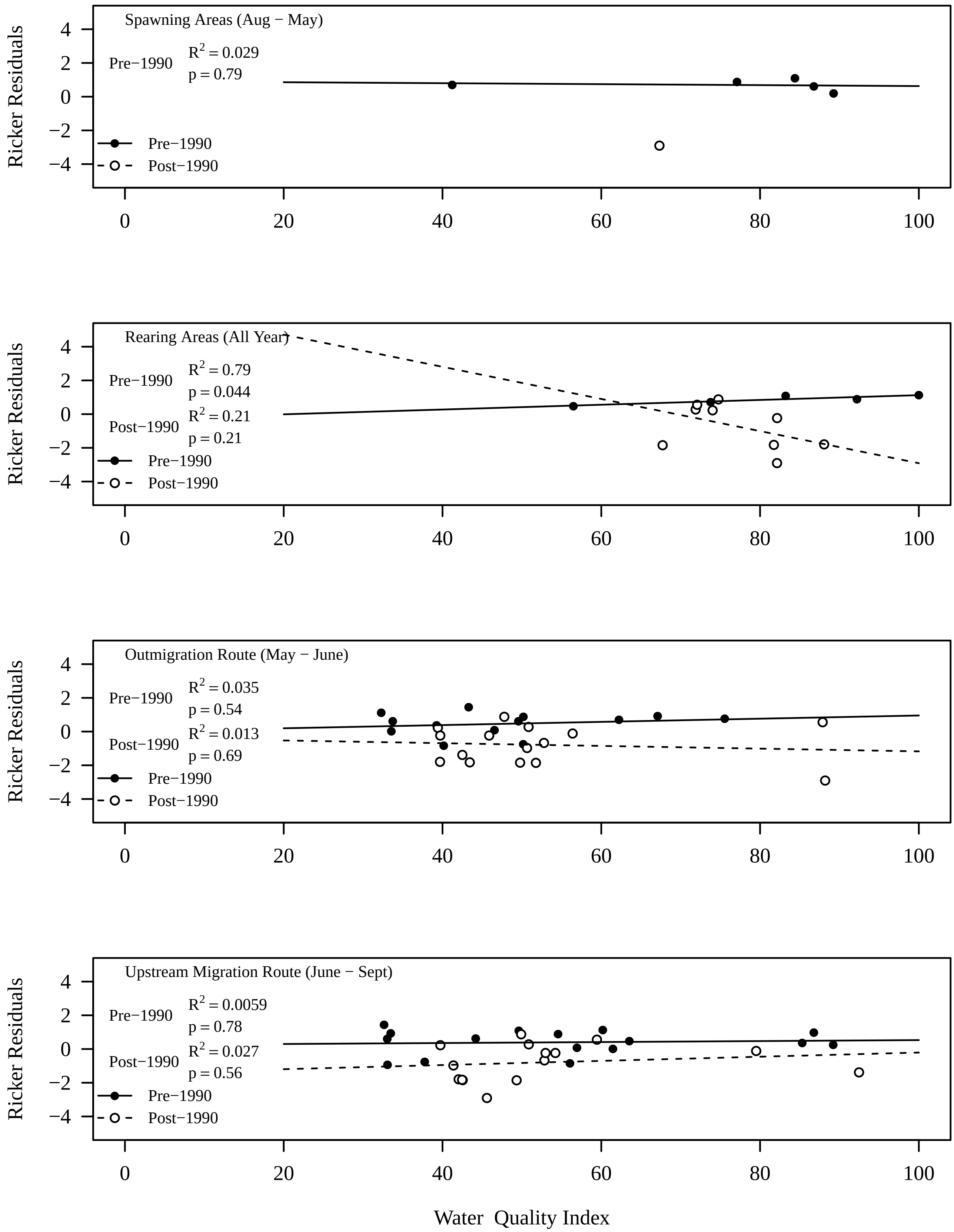


Figure 5.17. Chilko Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

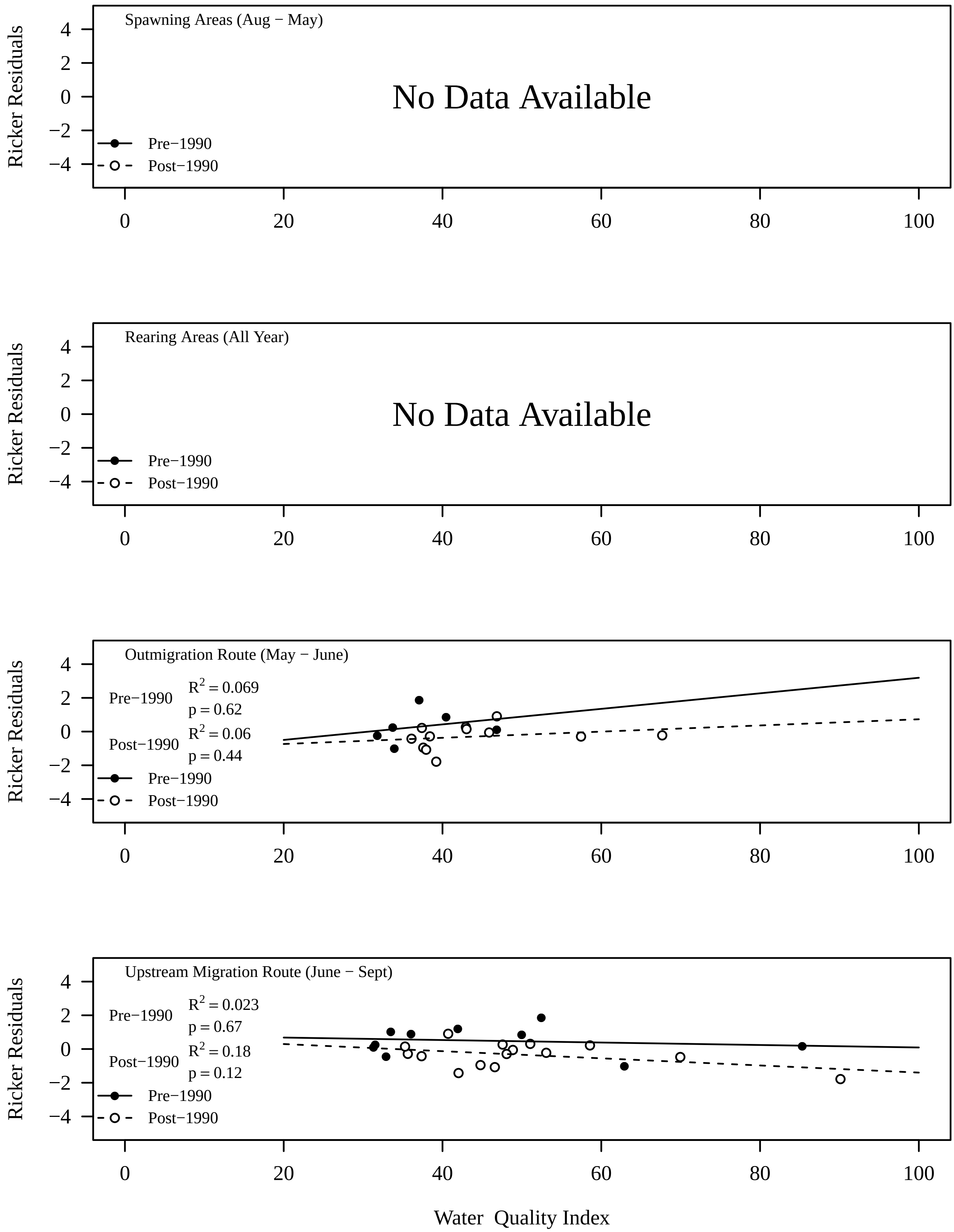


Figure 5.18. Quesnel Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

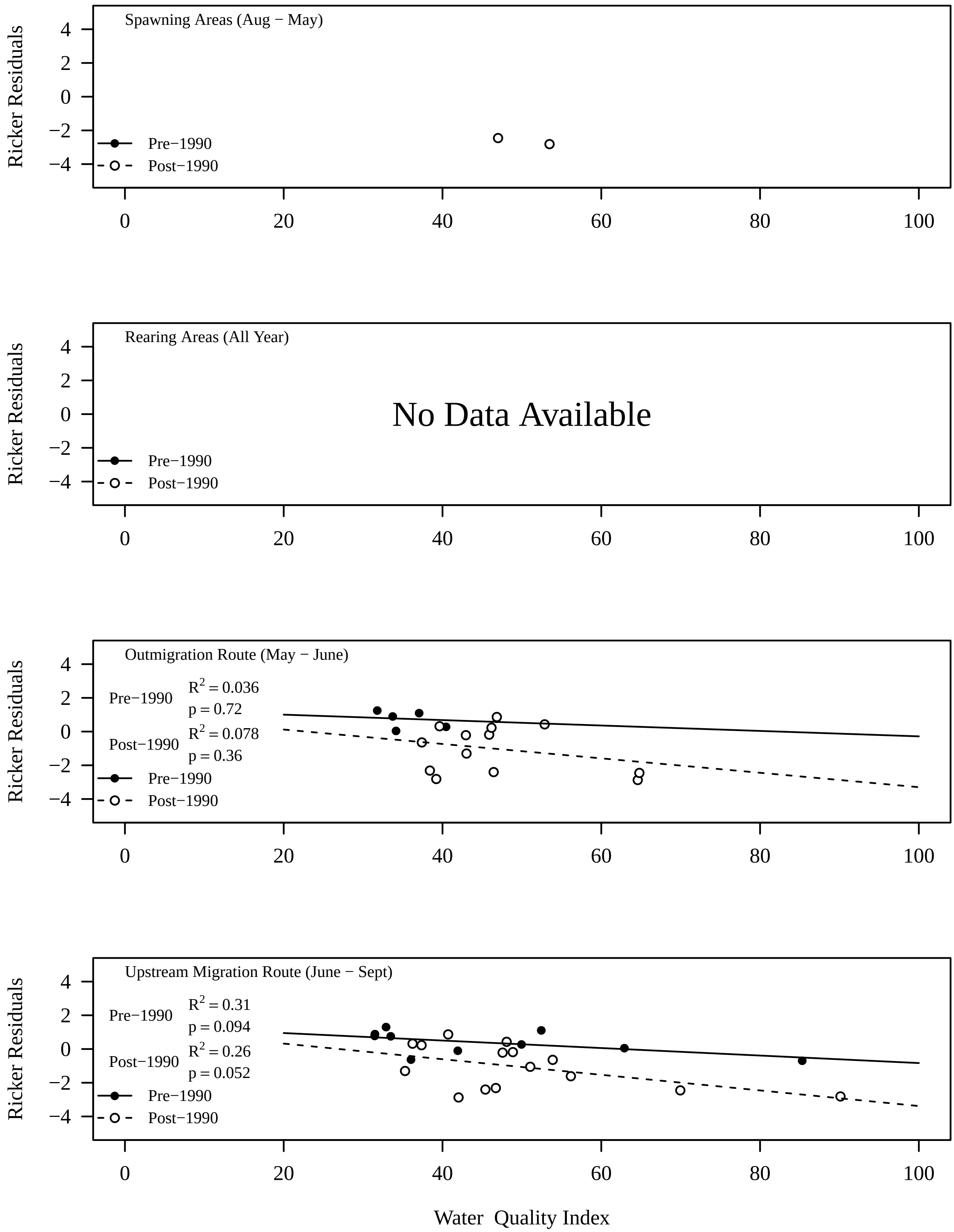


Figure 5.19. Early Stuart Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

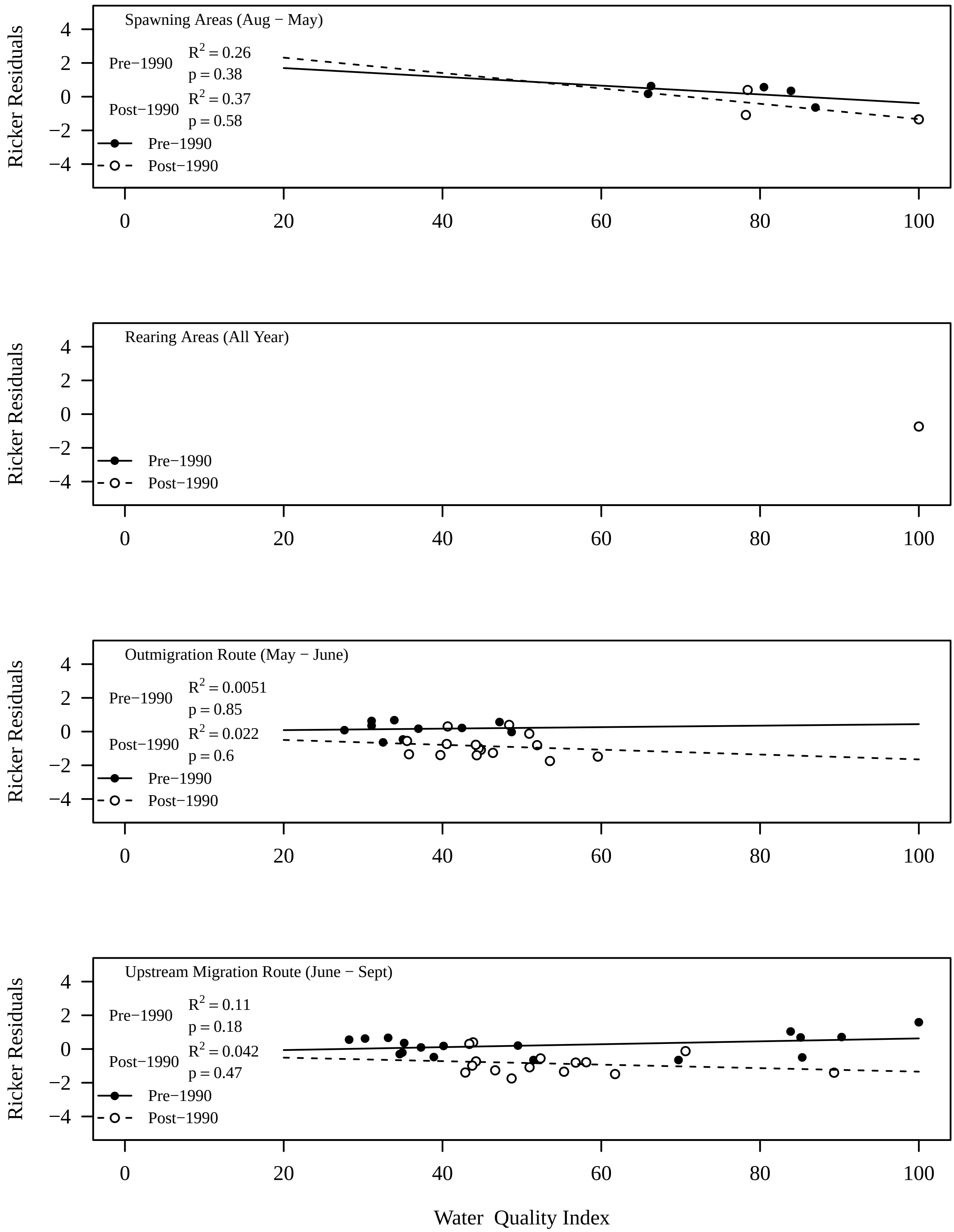


Figure 5.20. Late Stuart Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

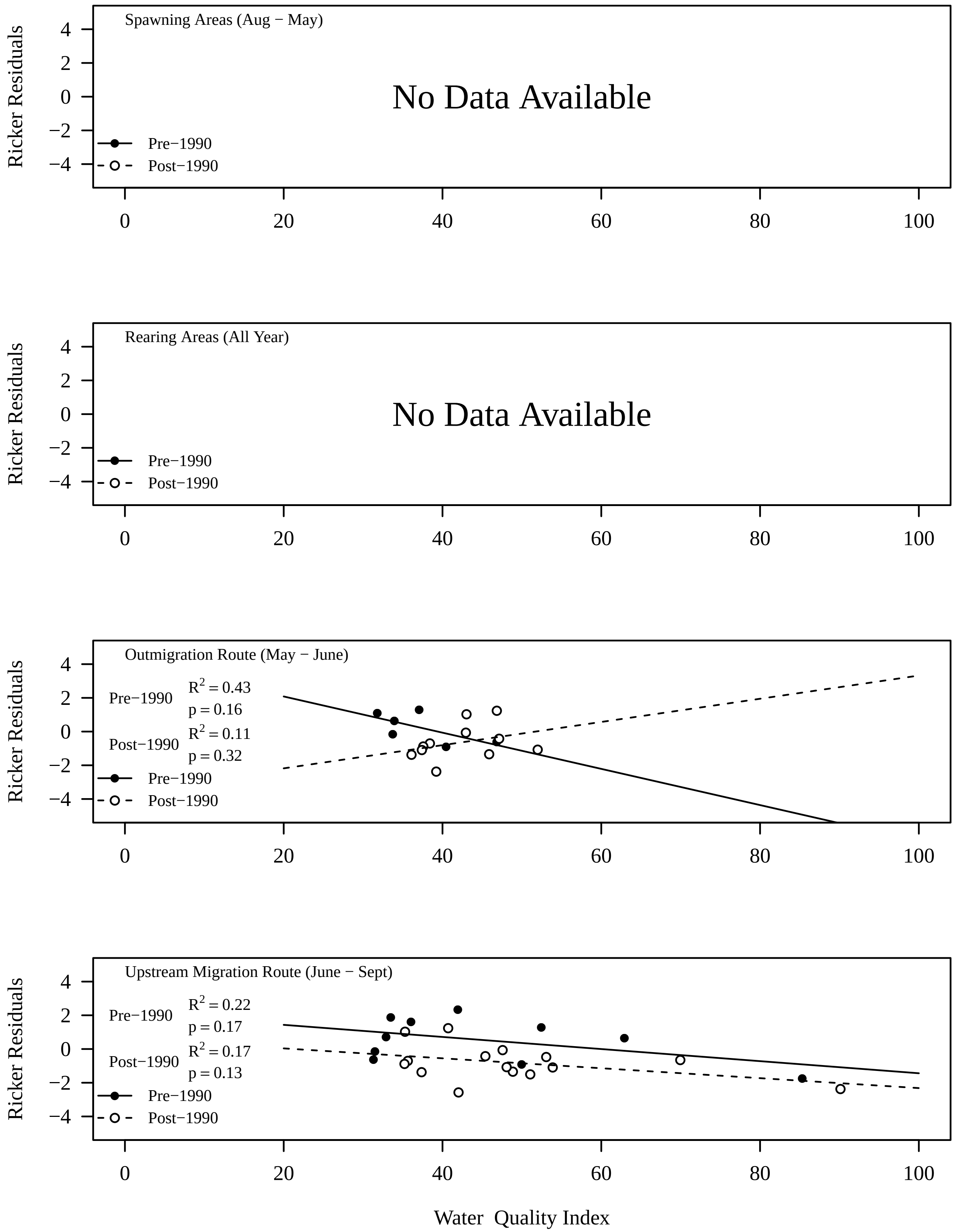


Figure 5.21. Stellako Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

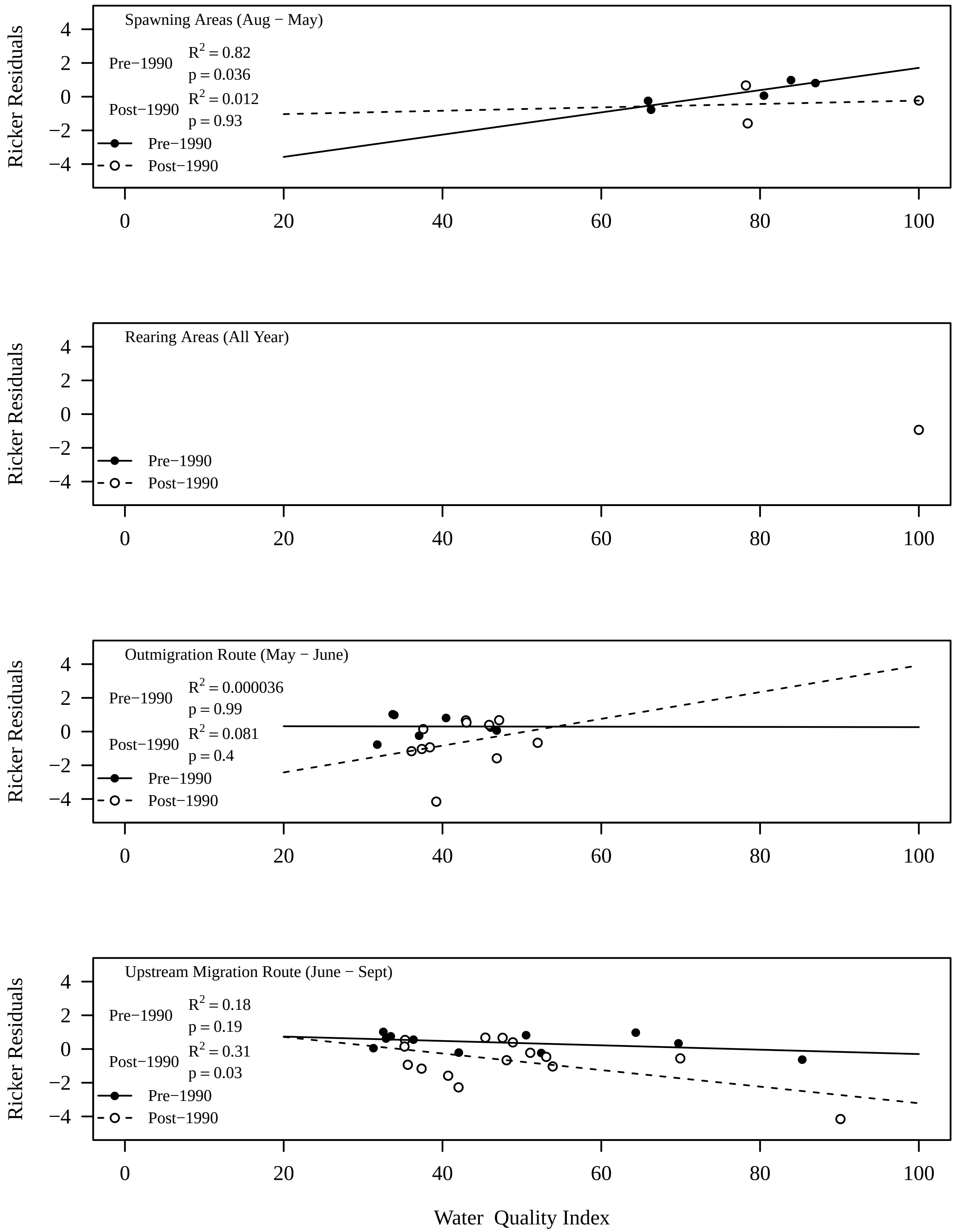


Figure 5.22. Nadina Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

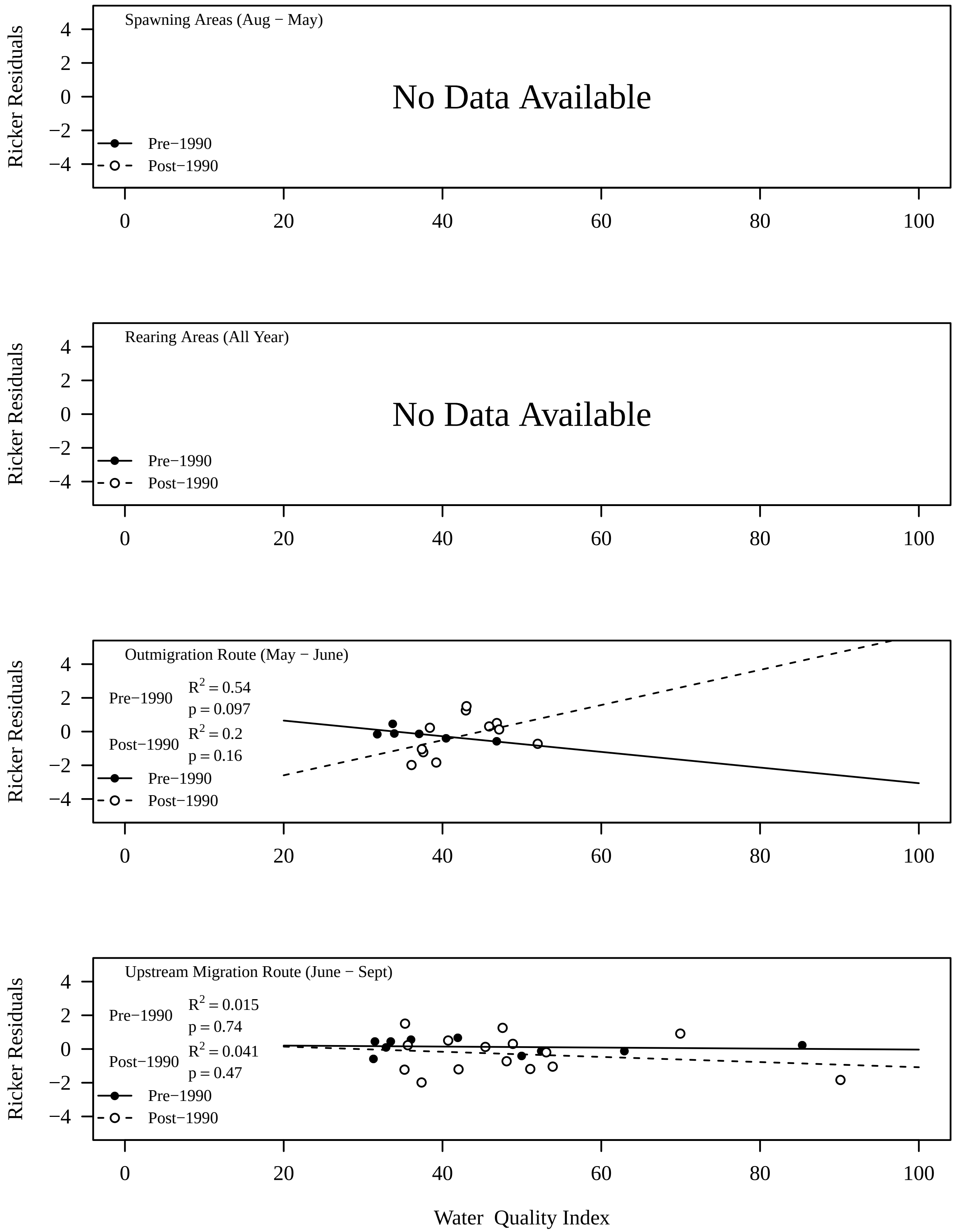


Figure 5.23. Bowron Sockeye Salmon Productivity (Ricker Residiuals − Entire Life Cycle) and Water Quality Index by Life History Stage.

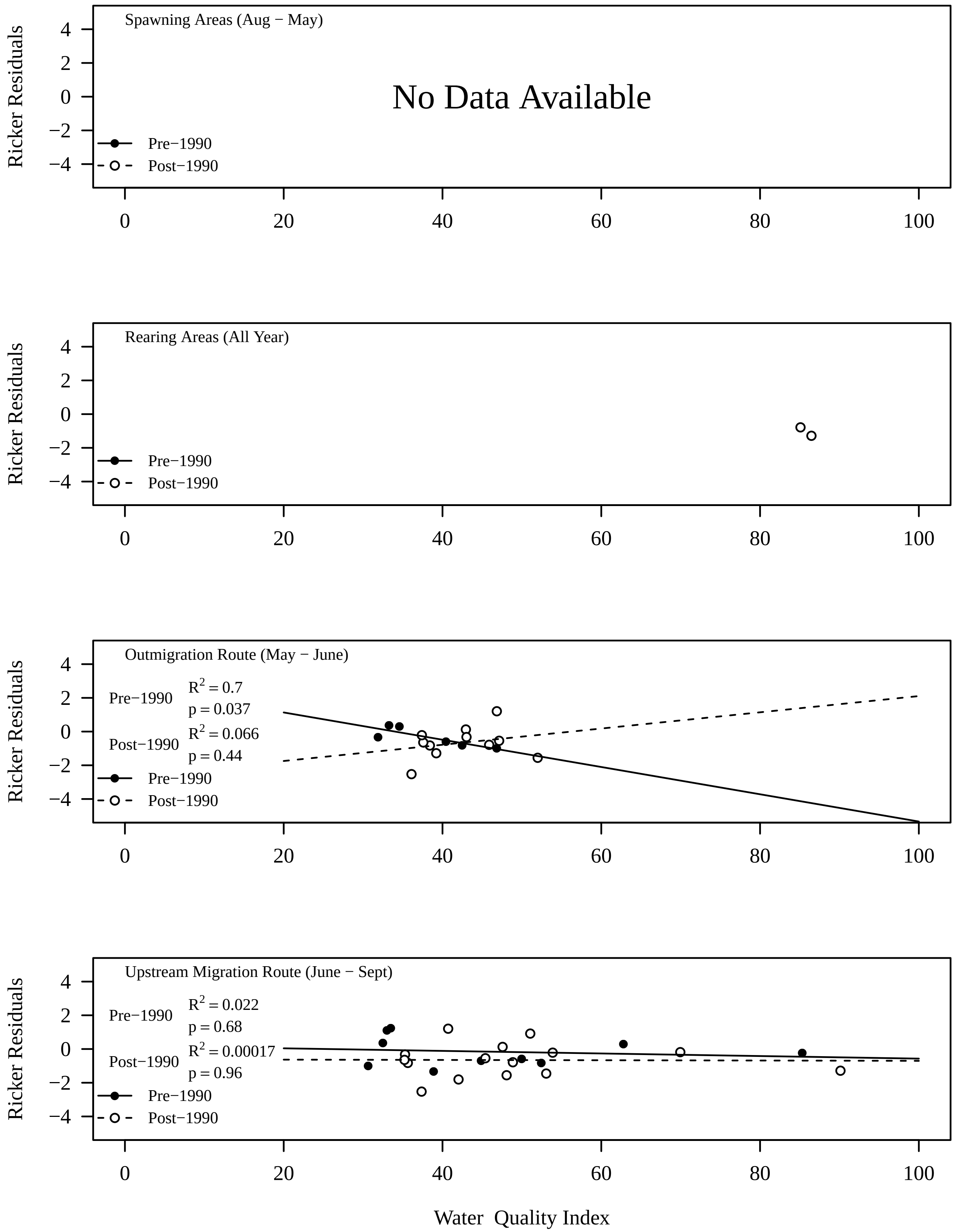
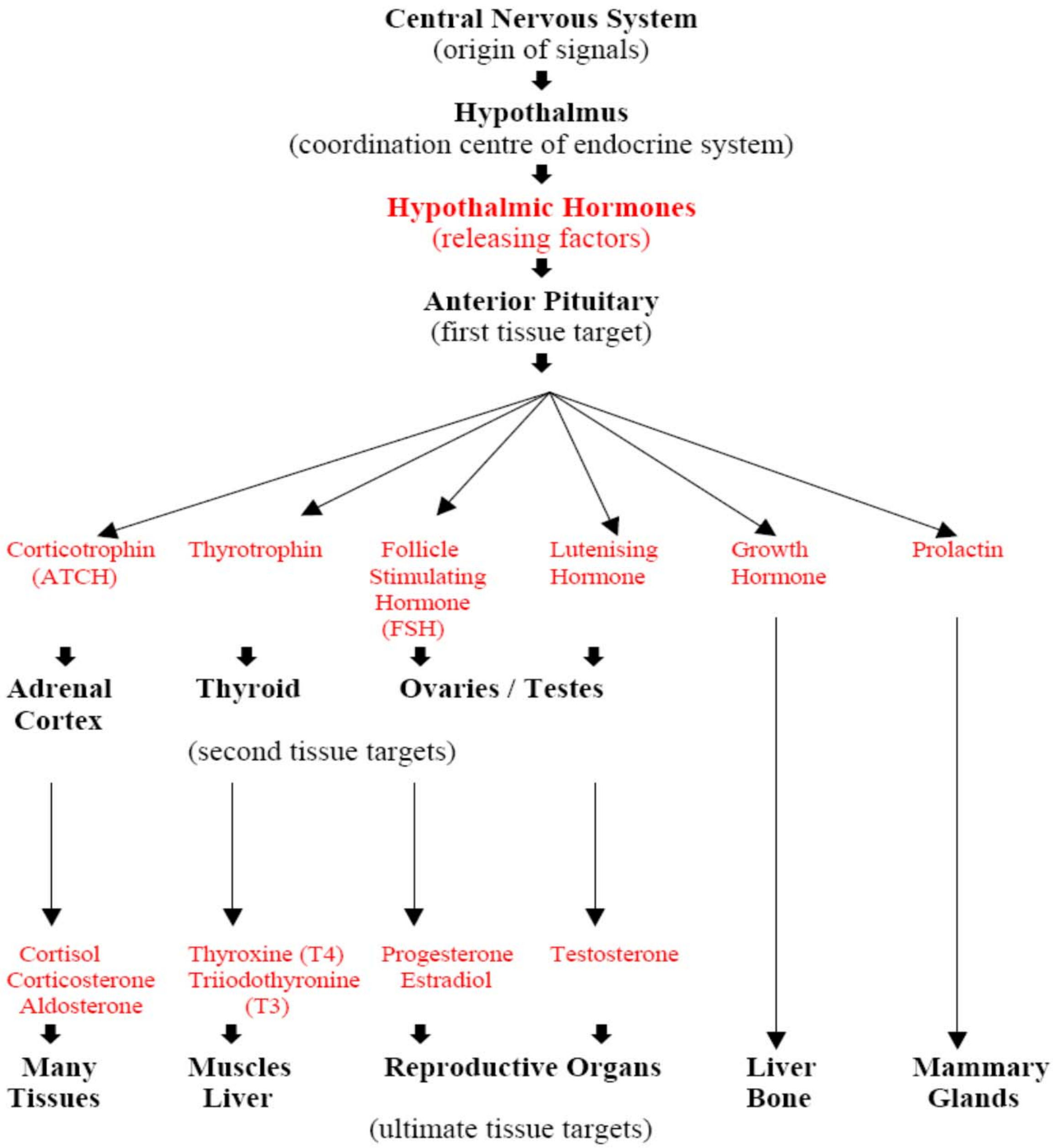


Figure 6.1. Selected major endocrine glands and their target tissues (Tarrant *et al.* 2005)



Appendices

Appendix 1. Statement of Work - MacDonald Environmental Sciences Ltd.

SW1 Background

1.1 The Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River (www.cohencommission.ca) was established to investigate and report on the reasons for the decline and the long term prospects for Fraser River sockeye salmon stocks and to determine whether changes need to be made to fisheries management policies, practices and procedures.

1.2 An inventory and evaluation of the effects of contaminants in the Fraser River is required to determine their importance on the ecology and survival of Fraser sockeye and to determine their role in the reductions in Fraser sockeye abundance.

SW2 Objective

2.1 To prepare a technical report containing a contaminant inventory and an evaluation of the effects of contaminants on Fraser River sockeye salmon.

SW3 Scope of Work

3.1 The Contractor shall provide the services of Don D. Macdonald, Jesse Sinclair, Meara Crawford, Heather Prencipe, Melissa Meneghetti, Mary Lou Haines and Debbie Pulak to perform the work.

3.2 The Contractor will prepare an inventory of aquatic contaminants in the Fraser River in relation to the distribution of sockeye Conservation Units. This will include an evaluation of pulp mill effluent contaminants, discharges from sewage treatment plants, non-point source contaminants endocrine disruptors and other contaminants. It will also include sewage discharges from the lower mainland and other urban centres in the Fraser Watershed.

3.3 The Contractor will compare toxicology data for sockeye to Fraser River water quality conditions to evaluate lethal and sub-lethal impacts of aquatic contaminants.

3.4 The Contractor will develop an overall assessment of for the suite of contaminants and natural substances (e.g. suspended sediments) that are encountered by juvenile and adult sockeye salmon.

3.5 The Contractor will evaluate the extent to which reductions in Fraser sockeye abundance are associated with contaminant conditions in the Fraser River.

3.6 The Contractor will reference reports prepared by Dr. Peter Ross, Inst. Of Ocean Sciences, and the Siska First Nation concerning contaminant concentrations in Fraser sockeye salmon.

SW4 Deliverables

4.1 The Contractor will organize a Project Inception meeting to be held within 2 weeks of the contract date in the Commission office. The meeting agenda will be set by the Contractor and will include a work plan for project implementation.

4.2 The main deliverables of the contract are 2 reports evaluating the effects of contaminants on Fraser River sockeye: 1) a progress report, and 2) a final report. The style for the Reports will be a hybrid between a scientific style and a policy document. An example of a document which follows this format is the BC Pacific Salmon Forum Final Report (www.pacificsalmonforum.ca).

4.3 A Progress Report (maximum 20 pages) will be provided to the Cohen Commission in pdf and Word formats by Nov. 1, 2010. Comments on the Progress Report will be returned to the contractor by Nov. 15, 2010.

4.4 A draft Final Report will be provided to the Cohen Commission in pdf and Word formats by Dec. 15, 2010. The draft Final Report should contain an expanded Executive Summary of 1-2 pages in length as well as a 1-page summary of the "State of the Science". Comments on the draft Final Report will be returned to the contractor by Jan. 15, 2011 with revisions due by Jan. 31, 2011.

4.5 The Contractor will make themselves available to Commission Counsel during hearing preparation and may be called as a witness.

4.6 The Contractor will participate in a 2-day scientific workshop on November 30 – December 1, 2010 with the Scientific Advisory Panel and other Contractors preparing Cohen Commission Technical Reports to address cumulative effects and to initiate discussions about the possible causes of the decline and of the 2009 run failure.

4.7 The Contractor will participate in a 2-day meeting presenting to and engaging with the Participants and the public on the results of the sockeye fisheries investigations on February 23-24, 2011.

SW5 Contractor's Proposal

5.1 The Contractor's proposal, designated as Annex 1, in so far as it is not at variance with the Terms and Conditions contained herein, shall apply to and form part of this agreement.

Appendix 2. Reviewer’s Comments and Response to Comments

Reviewer #1

Report Title: Potential Effects of Contaminants on Fraser River Sockeye Salmon
Reviewer Name: Rick Routledge
Date: January 3, 2011

1. Identify the strengths and weaknesses of this report.

Strengths:

1. Extensive screening for potential effects of contaminants;
2. Sensible use of standard methodology (as far as my limited expertise allows me to make such an assessment);
3. Balanced assessment of knowledge gaps;
4. Sensible concluding overview;
5. Reasonably well-justified recommendations.

Response: No response required.

Weaknesses:

1. Some apparent inconsistencies in the explanation of the methodology;
2. An overly lengthy Executive Summary.

Response: Agreed. The text was modified to provide a clearer explanation of the methodology used in the investigation. In addition, the Executive Summary was substantially edited to make it more focussed and concise.

Please see my comments to the authors for elaboration on these two latter points.

Response: Further details on the actions that were taken to address these comments are provided under Item 6 below.

2. Evaluate the interpretation of the available data, and the validity of any derived conclusions. Overall, does the report represent the best scientific interpretation of the available data?

Subject to my limited and peripheral expertise, I found the interpretation of the data to be sensible and the conclusions to be based on sound, balanced reasoning. Given my above-stated limits, I do not feel qualified to conclude that this was the best possible scientific interpretation of the data. In my understanding, the authors used standard methodology to perform a screening analysis of potentially harmful contaminants. They were careful to point out major uncertainties associated with such factors as (i) a lack of data on endocrine disrupting chemicals and emerging contaminants and (ii) the potential for cumulative effects through such factors as decreased disease resistance. I also felt that they conveyed an accurate perspective on the inherent limits of such screening analyses where it is, e.g., typically necessary to extrapolate observations obtained on one species, sometimes at substantially different doses, to another, often considerably different species.

Response: No response required.

Even in far more thoroughly studied problems, such as the potential effects of dioxins on human health, experts can disagree

Response: No response required.

3. Are there additional quantitative or qualitative ways to evaluate the subject area not considered in this report? How could the analysis be improved?

I do not have any suggestions for improving or extending the analysis. The most salient limiting factor from my perspective is the lack of data that could shed more light on the uncertainties described above.

Response: Agree. No changed to the text were made to address this comment.

4. Are the recommendations provided in this report supportable? Do you have any further recommendations to add?

I believe that the recommendations are well supported, and have no further ones to add. The issue of cost will inevitably arise though. Much as they are all desirable, someone will likely have to identify priority items. I would encourage the authors to provide further, focused commentary that would help in making such identifications. For example, I would presume that there would be a limited suite of contaminants worth looking for in spawning areas like the Horsefly River vs. the rearing habitat for Harrison sockeye. It might also be valuable for them to comment on potential benefits from international collaboration on research to investigate the impacts of PBDE's and other contaminants of emerging global concern.

Response: Agree. Table 8.1 was added to the document that identified the contaminants of concern in each area of interest. This table provides a basis for focussing monitoring activities on relevant contaminants in each area of interest. The concept of international collaboration on research on contaminants of emerging concern is a good one. Accordingly, the text of Chapter 8 was revised to highlight the need for international collaboration in research on the impacts of PBDE's and other emerging contaminants.

5. What information, if any, should be collected in the future to improve our understanding of this subject area?

Again, it seems important to me that more information be collected on such contaminants as PBDE's that are relatively recent additions to the environment and whose effects I gather have been inadequately assessed to date. I believe that such concerns are of global significance, and are certainly not restricted to Fraser sockeye salmon.

Response: See response to the comments provided under Item 4.

6. Please provide any specific comments for the authors.

I was a little concerned by the length and technical nature of the executive summary. I felt that this could benefit from more attention. I'd normally expect such a summary to contain less technical detail, and to focus on overarching summary statements and lay examples that could inform a non-expert of the main findings, their significance, and unavoidable uncertainties.

To this end, I would suggest that the lengthy discussion of background and methodology be omitted, and that the authors begin with a paragraph that provides a quick summary of their major findings, with subsequent paragraphs providing more details, caveats, and recommendations.

Response: Agree. The Executive Summary was substantially edited to remove the background and methods sections. In addition, major findings were highlighted at the beginning of this section of the report. The subsequent paragraphs provide more detailed, caveats, and recommendations.

I am also mildly concerned that, despite all the appropriate caveats that the authors have put forward, some readers may not fully appreciate the difficulties in making such assessments. Even in far more thoroughly studied problems, such as the potential effects of dioxins on human health, experts can disagree over what constitutes a relatively safe exposure level by several orders of magnitude. Since this sort of uncertainty has entered the public debate over the health of farmed fish, many readers might already be somewhat familiar with such debates. Perhaps it might be worth drawing attention to this sort of concern in the executive summary.

Response: Agree. The Executive Summary was revised to highlight uncertainty in the selection of toxicity screening values and toxicity reference values for chemicals of potential concern. In addition, uncertainty associated with the selection of toxicity thresholds for emerging contaminants was briefly discussed.

My concerns about the potential inconsistencies in the description of the methodology may simply arise from erroneous or misleading wording. Following is a passage from page 57, lines 2254-2260:

• For substances for which the selected TSV was based on toxicity data for non-salmonid species, toxicity thresholds were established using one of the following procedures:

1. Identify the lowest median lethal concentration (LC_{50}) obtained in a toxicity test conducted on sockeye salmon or another salmonid species that extended for more than 96 hours. The lowest LC_{50} was then multiplied by a safety factor of 0.1, in accordance with CCME (1999) procedures;
2. …

The opening bullet suggests that the following methods will not use toxicity data on salmonids, yet it looks as if the first (and subsequent) option calculates the selected value based on salmonid species data. It looks to me as if some passages got mislaid or lost when some components of the manuscript were shuffled around.

Response: It is agreed that the text in the report is difficult to follow for many readers. Accordingly, the introductory paragraph was revised to provide a better description of procedures that were used to identify the toxicity thresholds reported in the literature and the relevance of those toxicity thresholds to sockeye salmon. In addition, the subsequent descriptions of the procedures used to establish toxicity thresholds were reviewed and edited to ensure that they accurately reflected the methods that were actually used.

Appendix 2. Reviewer's Comments and Response to Comments

Reviewer #2

Report Title: Potential Effects of Contaminants on Fraser River Sockeye Salmon
Reviewer Name: Sonja Saksida
Date: Jan 4, 2011

1. Identify the strengths and weaknesses of this report.

My expertise is limited in the area of contaminants and hence the review is not as comprehensive as others.

Strengths

The report is very thorough. The authors have to be commended on having summarized a large amount of material they had to work with even though, as is apparent with the other reports, the datasets are incomplete and inconsistent.

Response: No response is necessary.

The authors do discuss the data gaps.

Response: No response is necessary.

The layout of the document is good.

Response: No response is necessary.

The study approach provided is good, and the authors provide good parameters used in their evaluations of potential impacts (pg 8 -Ln558-565)

Response: No response is necessary.

Good discussion on effects of contaminants - direct mortality vs endocrine disruption affecting the fishes ability to withstand other stessors (i.e. exposure to infectious disease).

Response: No response is necessary.

Good discussion on models and uncertainty, errors (Chapter 7).

Response: No response is necessary.

The conclusions and recommendations are appropriate.

Response: No response is necessary.

Weaknesses
There is a lot of repetition in the document (e.g. start of introduction and summary very similar as is the executive summary), removing some of this would make the document more concise.

Response: Agreed. The Executive Summary was revised as recommended. In addition, the rest of the document was reviewed to identify opportunities to make the text more concise.

Many abbreviations used - difficult to follow for somebody not an expert in the field.

Response: Agree. The text was edited to limit the use of abbreviations. While some abbreviations still exist in the Tables and Figures, abbreviations have largely been eliminated from the main text.

There is a lot of discussion on the sockeye decline over the last 20 years and the increase in many of the contaminants –it would be interesting to see how the high 2010 returns fit into this picture.

Response: A discussion of the implications of the high return of sockeye salmon in 2010 on the main findings of the evaluation was added to the text (See Chapter 8 for more information).

The authors focused primarily on contaminants in the FW phase; are there any concerns in the marine environments that should be considered?

Response: Yes, the potential effects of exposure to contaminants in the marine environment needs to be considered, particularly in the Strait of Georgia where there are discharges from various municipal wastewater treatment plants and industrial facilities. Such an evaluation was beyond the scope of this investigation, however.

2. Evaluate the interpretation of the available data, and the validity of any derived conclusions. Overall, does the report represent the best scientific interpretation of the available data?

The report does a very good job in interpreting the available data.

Response: No response is necessary.

3. Are there additional quantitative or qualitative ways to evaluate the subject area not considered in this report? How could the analysis be improved?

The authors focused primarily on contaminants in the FW phase; are there any concerns in the marine environments that should be considered?

Response: Yes. However, evaluation of the potential effects on sockeye

salmon associated with exposure to contaminants in the marine environment is beyond the scope of the current investigation.

4. Are the recommendations provided in this report supportable? Do you have any further recommendations to add?

Yes the recommendations do appear supportable

Response: No response is necessary.

5. What information, if any, should be collected in the future to improve our understanding of this subject area?

The authors discuss this in the recommendations.

Response: No response is necessary.

6. Please provide any specific comments for the authors.

Pg 36 Ln 1541 - do vineyards also contribute to agricultural pollution? - this has been on the rise in the last decade or so.

Response: Yes. The text was revised to identify the fungicides associated grape production (i.e., to discourage powdery mildew and grey mould) in the text (i.e., primarily sulphur). Other pesticides used in grape production were also identified.

Pg 47 Ln1909 - second bracket missing

Response: Bracket was added as noted.

Pg 49Ln1971 - Ricker not Richer.

Response: Spelling error was corrected.

Pg 44 - Figure 4.5 discussion. This figure could indicate the problem is in FW since all stocks with the exception of Harrison stay in FW for a year or problem is in the open ocean since all stocks beside Harrison leave Georgia Strait.

Response: Excellent observation! The text was revised to make this point explicitly.

Pg 97 Ln 3731 - comma not period

Response: Agreed. Text was changed accordingly.

Pg 109 Ln 4152 - 2007 not 1997?

Response: This typographical error was corrected in the text.

Pg 110 Ln 4189 - now called *Listenella anguillarum*

Response: Text was revised accordingly.

Appendix 2. Reviewer's Comments and Response to Comments

Reviewer #3

Report Title: Potential Effects of Contamination on Fraser River Sockeye Salmon
Reviewer Name: Ken Ashley
Date: January 14, 2011

1. Identify the strengths and weaknesses of this report.

The strength of this report is that it provides a detailed inventory of contaminants in the Fraser River watershed, and conducted a risk based analysis using available literature values to determine if various contaminants could have been responsible for the gradual decline in Fraser River sockeye stocks over the last 20 years, and the low return of sockeye to the Fraser River in 2009. The analysis which plotted Ricker life-cycle residuals against derived Water Quality Index (WQI) scores was innovative.

Response: No response required.

The weakness of the report is that it could only report on available data, and many of the potential contaminants in the Fraser river drainage have incomplete data, hence it was not possible to assess the magnitude of their potential effects on various life history stages of sockeye salmon. For example, no data was available on the volume of effluent discharges from wood preservative (Table 3.4), seafood processing (Table 3.6) and most major mining operations (Table 3.7).

Response: Agreed, these data limitations represent a weakness of the evaluation of potential contaminant effects on sockeye salmon.

In addition, the analysis relied on a variety of calculated toxicity indices, which were typically based on traditional bioassay toxicity tests e.g., 96 hr LC_{50} tests (i.e., the concentration of a contaminant which would kill 50% of the test organisms in a 96 hour period). While these types of laboratory tests were the scientific and legal standard for single contaminant testing of known toxic agents (e.g. pesticides) in the past, the emerging view is that newer and more sensitive tests are required to detect sub-lethal effects of various contaminants and endocrine disrupting substances, either individually, or in various combinations.

Response: Agreed. The text was revised to clarify how the toxicity thresholds were identified and to highlight the need for more sensitive indicators to evaluate effects on sockeye salmon and other aquatic organisms associated with exposure to emerging contaminants, such as endocrine disruptors.

2. Evaluate the interpretation of the available data, and the validity of any derived conclusions. Overall, does the report represent the best scientific interpretation of the available data?

The interpretation of the available data and the validity of the derived conclusions on the potential effects of contamination on Fraser River sockeye salmon are sound and scientifically defensible.

The two core conclusions, subject to the availability of existing data, is:

(1) that the exposure to various contaminants in surface water, sediments and fish tissues was not the primary factor responsible for the low returns of Fraser River sockeye in 2009, and
(2) that there is a possibility that exposure to various contaminants has contributed to the decline of sockeye abundance in the Fraser River over the past 20 years.

Overall, this report represents the best scientific interpretation on the effects of potential and known contaminants in the Fraser River basin on sockeye salmon, subject to the availability of existing data and conventional methodologies for deriving toxicity thresholds and indices.

Response: No response is required.

3. Are there additional quantitative or qualitative ways to evaluate the subject area not considered in this report? How could the analysis be improved?

Given the limitations on the available data, I do not believe there are any quantitative or qualitative ways to evaluate the potential effects of contamination on Fraser River sockeye salmon that have not been considered in this report. The idea to plot Ricker life-cycle residuals against derived Water Quality Index (WQI) scores was an innovative combination of fisheries science and ecotoxicology.

Response: No response is required.

Subject to the availability of existing data, and the large number of potential contaminants, I do not believe the analysis could be substantially improved.

Response: No response is required.

Substantial improvements in the report could only be achieved by conducting new sub-lethal and cumulative effects tests; however, this was outside the scope and terms of reference for this report.

Response: Agree. Such sub-lethal and cumulative effects tests would provide valuable information for evaluating the effects of contaminant exposures on sockeye salmon.

4. Are the recommendations provided in this report supportable? Do you have any further recommendations to add?

The recommendations provided in this report are supportable.

Response: No response is required.

It is unlikely that conventional bioassay-type of toxicity testing will be sufficiently sensitive to detect sub-lethal effects of individual contaminants of concern, combinations of contaminants of concern, emerging contaminants and endocrine disrupting substances. It will likely be necessary to adopt new toxicogenomic techniques to understand and evaluate the effects of sub-lethal contaminants.

Response: Agree. The report has be revised in several places to reflect this important perspective.

5. What information, if any, should be collected in the future to improve our understanding of this subject area?

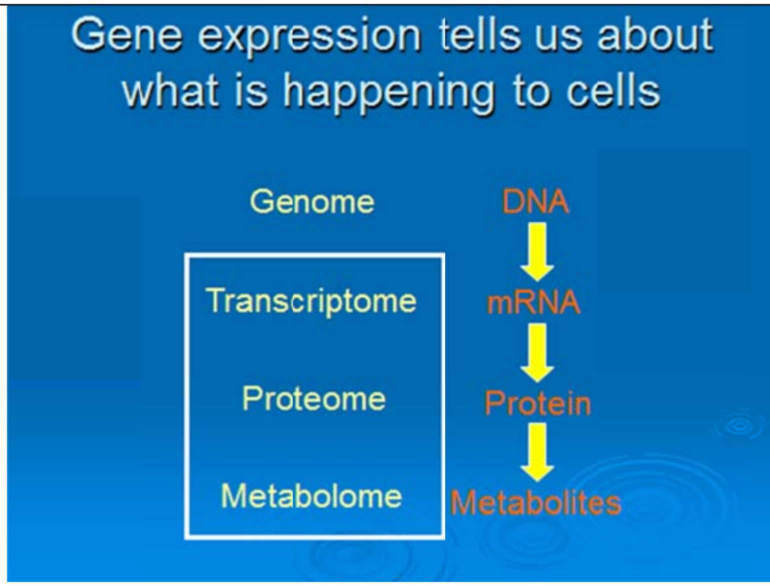
Information that should be collected in the future to improve our understanding on the potential effects of contaminants on Fraser River sockeye salmon is as follows:

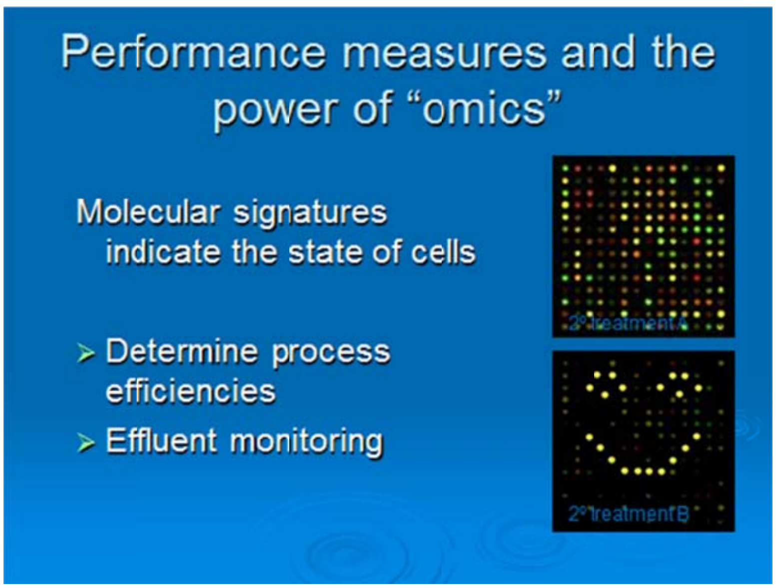
1. Obtain the information to fill in missing effluent discharge data gaps on industries that were not available for this report (e.g., wood preservative (Table 3.4), seafood processing (Table 3.6) and most major mining operations (Table 3.7)), and determine if the type and volume of effluents discharged could contribute to the 20 year decline in stock productivity of Fraser River sockeye;

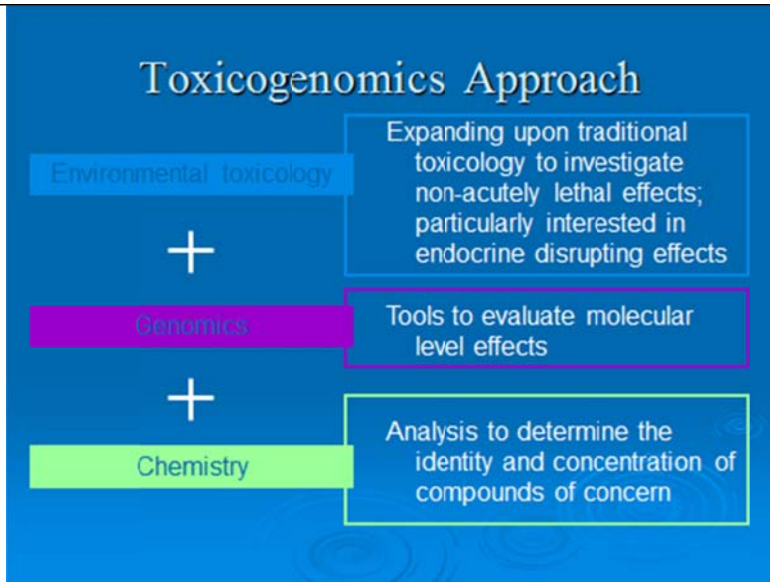
Response: Agree. This suggestion was added to the recommendations listed in Chapter 8 of the report.

2. As previously indicated, the emerging view is that newer and more sensitive tests are required to detect sub-lethal effects of various known and emerging contaminants and endocrine disrupting substances, either individually, or in various combinations. This is the new field of toxicogenomics.

   Effects happen at the molecular or genomic level and may not manifest themselves until adulthood or through some other subtle effects. Conventional aquatic toxicological testing endpoint measurements are not sensitive enough to measure effects of EDCs. The only way to do this is to look at the effect of various sub-lethal contaminants on the expression of genes:


Gene expression tells us about what is happening to cells
Genome
DNA
Transcriptome
mRNA
Proteome
Protein
Metabolome
Metabolites


Performance measures and the power of "omics"
Molecular signatures indicate the state of cells
➢ Determine process efficiencies
➢ Effluent monitoring
2° treatment A
2° treatment B



This new approach, which combines the field of environmental toxicology and genomics, is the most promising approach to determine the effects of various sub-lethal contaminants on Fraser River sockeye.

The first two industries which should be screened, using the toxicogenomics approach, are pulp and paper mills and municipal waste water plants, due to their high effluent volume and complex mixture of numerous known and suspected contaminants and endocrine disrupting substances. This toxicogenomic screening process can be semi-automated, and is relatively cost-effective relative to traditional 96 hr LC_{50} bioassay tests. Fortunately, the Environment Canada laboratory in North Vancouver, and the University of Victoria (Biology Department) are internationally recognized leaders in this emerging field;

Response: Agree. A discussion of the applications of this emerging approach to evaluating the potential effects of contaminants on ecological receptors was added to Chapter 8.

3. No information on the risk of nano-contaminants was included in this report. This is a new, but rapidly growing concern because of the potential for nanoparticles discharged from municipal wastewater treatment plants to negatively influence aquatic organisms. Nanosilver and nanocarbon particles in particular have been identified as being of potential concern, hence an inventory and toxicogenomic analysis of this emerging contaminant in the Fraser River is required;

Response: Agree. Nano-particles were added as chemicals of potential concern and uncertain contaminants of concern in the text.

4. Fish processing plants are fewer in number than in the past, hence sockeye and other salmonids caught in various areas of BC are centrally processed at fewer plants, many of which are on the Fraser River. Sockeye salmon are known to carry a wide range of native viral diseases, hence the possibility exists that fish processing plants are functioning as disease amplifiers due to the volume, and minimal level of treatment applied to their fish waste effluent.

   A screening survey of sockeye diseases in the ambient water above and below fish processing plants, before, during and after sockeye and other peak salmon processing periods should be conducted to determine if this is a factor in the long term decline in Fraser River sockeye salmon.

Response: This is an excellent suggestion. Accordingly, it was added to the recommendations listed in Chapter 8.

6. Please provide any specific comments for the authors.

Page 8, line 569 – change to "…each stock of sockeye…"

Response: Text revised as suggested.

Page 14, line 736 – change to "…Cariboo Pulp…"

Response: Text revised as suggested.

Page 19, following line 92, consider adding another bullet stating that fish diseases should be tested in the effluent from fish processing plants;

Response: Text revised as suggested.

Page 30, line 1327 – add a space between "…theeffluents…"

Response: Text revised as suggested.

Page 32, line 1415 – state the years when Adams Lake and Chilco Lake were fertilized, as neither lake is currently being fertilized and this gives the impression that these are ongoing fertilization programs;

Response: Text revised as suggested.

Page 70, following line 2728, consider adding nanoparticles to the list of emerging contaminants;

Response: Text revised as suggested.

Page 131, line 4958 – incomplete citation for Asplund et al. 1999;

Response: Text revised to provide a complete reference for Aspluld et al. (1999).

Table T-51 – correct spelling of “tertiary” for Salmon Arm Water Pollution Control Center;

Response: Table 3.15 (on page T-51) was revised as suggested.

Tables 6.1, 6.2, 6.3 and 6.4 were mentioned in the text but not included in the tables.

Response: The missing tables were added to the text, as suggested.

Appendix 3. Environmental Data Sources

A3.1 Department of Fisheries and Oceans (Spatial Data) - Sockeye Salmon Conservation Units

Conservation Units have been developed by the Department of Fisheries and Oceans (DFO) in order to assess the status of salmonid species in British Columbia. The sockeye salmon conservation units are comprised of lakes and rivers which serve as important spawning and rearing areas for the sockeye salmon. The conservation units were created by grouping sockeye salmon stocks based on ecology, life history (i.e., lake, ocean, or river-type), molecular genetics, and run timing. To support the assessment of sockeye exposure to contaminants in the Fraser River Basin, the conservation units are grouped together to form areas of interest, defined by the drainage area for the waterbody grouping. The ESRI shapefiles for the sockeye salmon lake and river conservation units were obtained from DFO (Dwight McCullough - GIS Co-ordinator and Martin Huang - GIS Analyst). Using the sockeye conservation units, areas of interest were developed based on the GeoBC Assessment Watersheds (described below).

A3.2 GeoBC (Land and Resource Data Warehouse)

GeoBC operates the Land and Resource Data Warehouse for the B.C Government. The warehouse stores integrated geographic data on the resources and land-uses of British Columbia. Geographic data on the Fraser River watersheds were obtained from GeoBC to form the base for building the areas of interest. The Assessment Watersheds are built using GIS rules, which follow upstream/downstream networks, making manageable watersheds (between 2,000 and 10,000 Ha in size) for use in environmental assessments. The Assessment Watersheds are pieced together to form larger areas of interest defined by the drainage into each group of sockeye salmon conservation units. The Assessment Watersheds, obtained from GeoBC were built into areas of interest using the logical stream network to form complete watersheds for each of the sockeye salmon lake conservation units. Fifteen areas of interest have been created: Lower Fraser River, Upper Fraser River, Pitt River, Harrison River, Cultus Lake, Kakawa Lake, Nahatlatch River, Seton-Portage, Lower Thompson River, North Thompson River, South Thompson River, Chilko River, Quesnel River, Nechako River, and the Bowron River.

Additional spatial and attribute data, including: seafood processing facilities, forestry runoff, forest fires, gas and oil well heads, and hydrology were also retrieved for the assessment through GeoBC. In addition, one of the main databases that was acquired from the GeoBC Data Discovery Service was the Baseline Thematic Mapping (BTM) Database. The BTM database supplies polygons containing the following categories of polygons:

- Sub Alpine Avalanche Chutes,
- Alpine,
- Residential Agriculture Mixtures,
- Agriculture,
- Barren Surfaces,
- Estuaries,
- Freshwater,
- Glaciers and Snow,
- Mining,
- Old Forest,
- Outside of BC,
- Range Lands,
- Recently Burned Forest,
- Recently Logged Forest,
- Recreation Activities,
- Salt Water,
- Selectively Logged Forest,
- Shrubs,
- Urban,
- Wetlands; and,
- Young Forest.

Four of these categories were used for analysis within this report: Residential Agriculture Mixtures, Agriculture, Mining and Urban. The BTM data were derived from satellite images that were captured from 1990 to 1997.

A3.3 British Columbia Environmental Monitoring System (EMS)

The EMS database houses environmental data collected by the B.C. Ministry of Environment. The database was accessed to compile information on water quality stations that are applicable to the assessment of sockeye salmon exposure to contaminants. The water quality stations in each area of interest and in the Fraser River mainstem and its major tributaries were identified using multiple sources:

1. Keyword (i.e., area of interest names) searches for water quality stations using the EMS Web Reporting application;
2. Water quality stations identified as part of the Federal-Provincial Water Quality Monitoring Program;
3. BCMOE Water Quality Objectives Reports developed between 1985 and 2009;

4. Keyword searches for water quality stations using the names of lakes and tributaries identified in Pestal and Cass (2009) for each area of interest using the EMS Web Reporting application; and,
5. Water quality stations identified in research projects and assessment reports in the Fraser River Basin.

Water quality data in the EMS database include samples that were collected to support environmental impact assessments, water quality objectives monitoring, trend analysis, and background characterization. Additionally, samples have been collected for compliance monitoring at sites with permitted discharges such as wastewater treatment plants and industrial discharges (e.g., pulp and paper mills, manufacturing plants). As the objectives at each of the EMS stations vary, the monitoring requirements and measured parameters also vary between each station. Generally, parameters of interest include conventional parameters (e.g., water temperature, pH, turbidity, and dissolved oxygen concentration), and nutrients (e.g., nitrogen and phosphorus). Depending upon the land-use activities in the watersheds, contaminants associated with wastewater treatment plants (e.g., fecal coliforms), pulp mills [e.g, resin acids, adsorbable organic halids (AOXs)], agriculture (e.g., fecal coliforms, major ions), and mining (e.g., metals) may additionally be measured for different assessments. Furthermore, the duration of the monitoring record and the seasonal timing of sample collection vary with the monitoring objectives. EMS stations used for trend analysis for example, may have a long-term dataset spanning 10 years or more, whereas stations monitored for background characterization may consist of a dataset with few measurements gathered over a season.

The analysis of exposure of sockeye salmon to contaminants in the Fraser River Basin included the compilation of existing water quality data at relevant EMS water quality stations. Data were compiled for all stations that could be used for characterizing water quality in each of the areas of interest. However, due to the variability in measured parameters, length of monitoring period and, timing of water quality data collection, water quality stations were selected based on the following priorities:

- Water quality stations that characterize conditions within the spawning, rearing and migration areas of the areas of interest;
- Water quality stations that characterize conditions within the main migration route (i.e., Lower Fraser River and Upper Fraser River);
- Water quality stations where collected data include the parameters of interest needed to assess exposure of salmon to contaminants in the Fraser River Basin (e.g., water temperature, pH, turbidity/TSS, dissolved oxygen concentration, metals and other contaminants identified in the Inventory of Aquatic Contaminants, based on land-use activities in the watershed);
- Water quality data collected over a long period of time at a high frequency (i.e., stations used for trend analysis);

- Water quality stations used for compliance of permitted discharges (e.g., waste-water treatment plants, pulp and paper mills, industrial discharges); and,
- Water quality stations that span key temporal periods (i.e., pre-1990 and post-1990; 2006 and 2007).

Data from a total of 142 water quality stations used in environmental impact assessments, water quality objectives development and attainment studies, trend monitoring, discharge compliance and background characterization were compiled using the methods listed above (Table A3.1). Spatial information (i.e., latitude and longitude), number of samples, and length of monitoring period for each of these stations were collated in a GIS. Of these water quality stations, a majority of the stations (identified by meeting the listed priority criteria above) were used to develop an integrative index (CCME Water Quality Index; WQI) to characterize water quality conditions in each of the areas of interest. The Water Quality Index (see Appendix 4) was calculated using the available water quality data and toxicity screening values (TSVs) selected from BCMOE, CCME, USEPA, or other water quality guideline sources that are protective of any life stage of any aquatic species exposed for extended time periods.

A3.4 National Pollutant Release Inventory

The National Pollutant Release Inventory (NPRI), maintained by Environment Canada, contains spatial and tabular data on the release of contaminants to air, water, and land (e.g., landfills, reclamation sites) by various industrial discharges. Industrial discharges relevant to the assessment of sockeye salmon exposure to contamination in the Fraser River Basin were identified in the NPRI database, including point discharges from the following industrial classifications:

- Agricultural industries;
- Chemical and chemical product industries;
- Crude petroleum and natural gas industries;
- Fabricated metal products industries;
- Industrial and heavy (engineering) construction industries;
- Mining industries;
- Other manufacturing industries;
- Paper and allied products industries;
- Pipeline transport industries;
- Plastic products industries;
- Refined petroleum and coal products industries;
- Transportation industries; and,
- Wood industries.

A3.5 Contaminant Spill Reports

Data on contaminant spills reported between March and June of 2007 in the Fraser River Basin were compiled from Dangerous Goods Incident Reports (DGIR) provided by the B.C. Ministry of Environment. Spill type, date of spill, description and location of spill were all compiled from the Dangerous Goods Incident Reports. In addition, oil spills reported in the Fraser River were compiled from data collected by the Canadian Coast Guard.

These compiled data were used to assess the potential for co-location of contaminants and sockeye salmon during the smolt outmigration, which could affect sockeye salmon health and productivity of the 2009 return.

A3.6 Contaminated Sites

Data on the location of contaminated sites in the Fraser River Basin were compiled from the Treasury Board of Canada's Federal Contaminated Sites Inventory. In addition to geographical location, this database contains information on environmental media affected (i.e., groundwater, sediment, soil, surface soil, surface water), volume or area of contamination, the identity or types of contaminants present, last step completed (e.g., initial or detailed testing program, site classification process), and class of site (e.g., action required, action not likely required).

A3.7 Metro Vancouver Sediment Assessment

In 2006, ENKON Environmental Limited conducted a sediment monitoring program in the Lower Fraser River for the Metro Vancouver Regional District (ENKON Environmental Ltd. 2007). The monitoring program was designed to meet a commitment to the District's Liquid Waste Management Plan.

Sediment data were collected at seven sites in the Lower Fraser River (downstream of McMillan Island, downstream of Barnston Island, Sapperton Channel, Annacis Channel, Ewen Slough, Tree Island Slough, and McDonald Slough) in 2006. Parameters measured in the sediments included: conventional parameters, fecal coliforms, total metals, PAHs (including alkylated PAHs), PCBs, organochlorine pesticides, various surfactants and plasticisers, dioxins and furans, PBDEs, and estradiols and sterols.

Data were compiled from the monitoring program report and incorporated into the project database for use in the assessment of potential effects of contaminants on Fraser River sockeye salmon.

A3.8 Siska Salmon and Indigenous Peoples Life Work

In 2007, Siska Traditions Society (2009) initiated a study to assess the potential contamination of Fraser River sockeye and chinook salmon in the Adams/Thompson and Weaver Stocks. The concentration of metals, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins/furans (PCDD/Fs), and organochlorine pesticides were measured in both sockeye and chinook salmon tissue and roe collected from sampling sites in the Lower Fraser River, mid-river locations, and in the spawning grounds of the Weaver and Adams River stocks. Classification of stocks was completed by DNA analysis of the captured individuals.

The Siska Traditions Society and study investigators were contacted to obtain information on the study. Nancy MacPherson (University of British Columbia) provided the data and reports with permission from Chief Fred Sampson and Terry Raymond of the Siska First Nation for use of the data. These data were used to assess the exposure of sockeye salmon to contaminants of potential concern, including metals, PCBs, PCDD/Fs, and organochlorine pesticides, and to evaluate the potential for this exposure to have adverse effects on reproduction and survival of sockeye salmon.

A3.9 Effluent Quality Data for Wastewater Treatment Plants

Information on the major wastewater treatment plants discharging into water bodies in each of the areas of interest was collected from effluent permits, personal communication with the facilities, and municipal websites outlining their wastewater treatment facilities. These data include the treatment type (i.e., primary, secondary, tertiary), permitted effluent volume, and identification of variables (e.g., pH, total suspended solids) listed under permit requirements. These data have been collected for 36 of the major wastewater treatment plants in the 15 areas of interest. Additionally, stream-flow data have also been collected where available. EMS water quality stations associated with each of the wastewater treatment plants (i.e., in effluent receiving environments, where available) have been identified in the GIS files. Additionally, data on environmental concentrations of chemicals of potential concern were compiled for those wastewater treatment plant-associated EMS stations, where available.

A3.10 Effluent Quality Data for Pulp and Paper Mills

Information on the pulp and paper mills that discharge into waterbodies situated in each of the 15 areas of interest have been collected. Data include location and effluent discharge points and the identification of EMS water quality stations associated with (i.e., downstream of) each pulp and paper mill. Ten pulp and paper mills in the Fraser River Basin have been identified including: Northwood Pulp Mill, Prince George Pulp and Paper Mills, Cariboo Pulp and Paper Company, Quesnel

River Pulp, Kamloops Cellulose Fibres, Buckeye Canada-Delta Division, and Norampac Burnaby (previously Crown Paper), three facilities under Kruger Products L.P. [Carey Island Paper Mill, Herrling Island Paper Mill, and Kruger Produces (Previously Scott Paper)]. Data collected on releases of pulp and paper effluent are from the National Pollutant Registry Inventory database, personal communication with companies, effluent permits, and company and summary reports. These sources have been used to assess contaminant levels and exposure of sockeye salmon to these contaminants.

A3.11 Environmental Trends in British Columbia: 2007 – State of the Environment

The 2007 Environmental Trends in British Columbia report is a review of the state of the environment. Trends are assessed using 44 indicators of environmental health. Indicators which are of use to assess the exposure of sockeye salmon to contaminants in the Fraser River Basin include water quality indices and contaminant releases associated with industrial discharges. The 2007 Environmental Trends report served as a reference to identify potential data sources that would provide relevant information on the assessment of sockeye salmon exposure to contaminants in the Fraser River Basin. Additionally, indicators of environmental health were identified for use in this assessment.

A3.12 Internet

Website searches were completed as part of research on a variety of land-uses. Company websites, provincial summary sites, reports posted on websites, federal summary sites, industry summary sites and land use websites all aided in compiling both spatial information on facilities within the Fraser River Basin, as well as information regarding details of the facilities that were included in the land use tables.

A3.13 Personal Communication

Personal communication via email was also used in order to receive the most up to date and accurate information for individual companies and organizations.

A3.14 References Cited

ENKON Environmental Limited. 2007. Fraser River Ambient Monitoring Program 2006 Sediment Monitoring. Prepared for the Greater Vancouver Regional District. Burnaby, British Columbia.

Pestal, G. and A. Cass. 2009. Using qualitative risk evaluations to prioritize resources assessment activities for Fraser River sockeye. Canadian Scientific Advisory Secretariat Research Document 2009/071. Fisheries and Oceans Canada. 81 pp.

Siska Traditions Society. 2009. Sísqeʔ Sqyéytn eɬ ƛ̓’uʔsqáyʷs Suméx Scúws (Siska Salmon and Indigenous Peoples’ Life Work). Effects of Environmental Contaminants in Up-river Migration: Toxicity and Exposure Levels. Assessment Report. 127 pp. Nɬeʔkepmx First Nation Territory: Siska Traditions Society.

Table A3.1. Water quality stations used in the assessment of potential effects of contaminants on sockeye salmon.

Environmental Monitoring System Station	Sampling Start Date	Sampling End Date	Sockeye Salmon Habitat Use	Latitude	Longitude
Bowron River Area of Interest					
E221759	01-May-95	04-May-06	Rearing	53.25	-121.4167
E262699	04-May-06	21-Jul-08	Rearing	53.2334	-121.3669
E262704	04-May-06	21-Jul-08	Rearing	53.2167	-121.3334
Chilko River Area of Interest					
0600024	19-Jul-72	19-Jun-78	Upstream and Outmigration	51.8314	-122.5661
0600148	03-Jul-75	30-Nov-77	Spawning; Rearing	51.5625	-123.6975
E206763	03-Mar-87	15-Apr-87	Spawning; Rearing	51.6361	-124.1164
E207214	18-Aug-87	25-Oct-88	Upstream and Outmigration	51.9208	-123.0808
E207303	05-Nov-87	24-Nov-87	Upstream and Outmigration	51.9292	-123.1156
E207655	09-May-89	09-May-89	Upstream and Outmigration	51.8328	-122.5658
E216941	13-May-92	03-Mar-93	Spawning; Rearing	51.4586	-123.6953
E216942	13-May-92	03-Mar-93	Spawning; Rearing	51.5008	-123.6789
E248626	24-Jun-02	03-Jun-04	Upstream and Outmigration	52.0723	-123.2609
Cultus Lake Area of Interest					
0300037	26-Jul-72	28-Mar-94	Spawning; Rearing	49.0608	-121.9814
E207095	02-Jul-87	02-Aug-93	Spawning; Rearing	49.0617	-121.9806
E207096	02-Jul-87	02-Aug-93	Spawning; Rearing	49.0636	-121.9664
E207098	02-Jul-87	02-Aug-93	Spawning; Rearing	49.0367	-121.9981
E207041	11-Aug-87	10-Sep-87	Upstream and Outmigration	49.09	-122.0647
0300033	24-Aug-88	28-Mar-00	Upstream and Outmigration	49.1225	-122.0944
0300030	07-Jul-92	13-Nov-08	Upstream and Outmigration	49.0633	-122.1711
E246447	30-Oct-01	30-Nov-01	Spawning; Rearing	49.0579	-121.9645
0300038	30-Jul-02	29-Sep-10	Upstream and Outmigration	49.0025	-122.2306
Kakawa Lake Area of Interest					
0300050	23-May-72	28-Apr-86	Upstream and Outmigration	49.3817	-121.4217
Lower Fraser River Area of Interest					
0301507	19-Oct-78	02-Aug-93	Upstream and Outmigration	49.1731	-122.0078
E206581	08-Feb-80	09-Aug-10	Upstream and Outmigration	49.3854	-121.4529
0300040	15-May-86	13-Nov-08	Upstream and Outmigration	49.1622	-121.9917
E206970	12-Jan-87	02-Mar-09	Upstream and Outmigration	49.1013	-123.1554
E206965	13-Jan-87	02-Mar-09	Upstream and Outmigration	49.2108	-122.73
0301311	20-Aug-87	13-Mar-03	Upstream and Outmigration	49.1594	-122.9447
E105892	20-Aug-87	30-Mar-95	Upstream and Outmigration	49.1072	-123.1197
E207393	03-Feb-88	02-Aug-93	Upstream and Outmigration	49.2272	-121.74
E207407	18-Feb-88	13-Mar-03	Upstream and Outmigration	49.1131	-123.1683
0300005	22-Aug-88	13-Mar-03	Upstream and Outmigration	49.2089	-122.8908
E207600	22-Aug-88	13-Mar-03	Upstream and Outmigration	49.1789	-123.1469
0301550	23-Aug-88	02-Aug-93	Upstream and Outmigration	49.1694	-122.4739

Table A3.1. Water quality stations used in the assessment of potential effects of contaminants on sockeye salmon.

Environmental Monitoring System Station	Sampling Start Date	Sampling End Date	Sockeye Salmon Habitat Use	Latitude	Longitude
Lower Fraser River Area of Interest (continued)					
E207603	31-Aug-88	14-Mar-03	Upstream and Outmigration	49.2208	-121.7422
E207612	31-Aug-88	30-Nov-01	Upstream and Outmigration	49.1422	-122.6011
0300002	07-Sep-88	24-Feb-04	Upstream and Outmigration	49.1994	-123.1231
Lower Thompson River Area of Interest					
0600005	01-Aug-66	16-Mar-10	Upstream and Outmigration	50.4189	-121.3556
0600004	18-Nov-71	27-Feb-08	Upstream and Outmigration	50.75	-120.8742
0600506	16-Apr-74	20-Sep-06	Upstream and Outmigration	50.8011	-121.3197
0600508	16-Apr-74	20-Sep-06	Upstream and Outmigration	50.7992	-121.3172
0600329	07-Feb-78	16-Mar-10	Upstream and Outmigration	50.7408	-121.2622
0600534	08-Aug-85	04-Oct-89	Upstream and Outmigration	50.1156	-120.8067
0600190	29-Aug-85	29-Aug-85	Upstream and Outmigration	50.1419	-121.0081
0603006	17-May-89	05-Oct-99	Upstream and Outmigration	50.1792	-120.5103
E216848	13-Apr-92	29-Sep-10	Upstream and Outmigration	50.4275	-121.3161
E218768	19-Jul-93	02-Mar-10	Rearing; Upstream and Outmigration	50.7403	-120.6594
0600116	03-May-95	05-Oct-98	Upstream and Outmigration	50.1631	-120.6636
0600030	08-Oct-01	08-Oct-01	Upstream and Outmigration	50.9006	-120.9739
0600117	19-Oct-04	16-Mar-10	Upstream and Outmigration	50.7644	-120.9128
Nechako River Area of Interest					
0920101	01-Aug-66	30-Mar-10	Upstream and Outmigration	54.4158	-124.2697
0920066	18-Jul-74	20-Aug-86	Upstream and Outmigration	53.9272	-122.7778
0400629	27-May-76	05-Mar-09	Spawning	54.0628	-124.5678
0400630	27-May-76	29-Oct-97	Upstream and Outmigration	54.065	-124.5669
0400631	27-May-76	05-Mar-09	Upstream and Outmigration	54.0658	-124.5672
0400405	19-May-82	14-Aug-84	Spawning	54.0522	-124.8839
0400488	19-Apr-83	30-Mar-10	Upstream and Outmigration	54.4175	-124.2686
0400487	14-Dec-83	11-Apr-84	Upstream and Outmigration	54.4039	-124.2536
E206583	24-Jul-84	05-Aug-10	Upstream and Outmigration	53.9272	-122.765
E206563	01-May-85	25-Aug-86	Spawning	54.0444	-124.9236
E208562	21-Sep-87	08-Feb-88	Upstream and Outmigration	54.0642	-124.5881
E224945	14-Feb-97	28-May-08	Rearing	53.98	-126.39
E224946	16-Feb-97	29-May-08	Rearing	54	-125.06
E271703	28-May-08	28-May-08	Rearing	54.0467	-125.7716
North Thompson River Area of Interest					
0600164	07-Jan-65	01-Mar-10	Upstream and Outmigration	50.7125	-120.3547
E207161	22-Jul-87	22-Jul-87	Upstream and Outmigration	51.1881	-120.1261
0600023	31-Mar-92	07-Oct-01	Upstream and Outmigration	51.1878	-120.1253
0600162	31-Mar-92	24-Nov-94	Spawning	51.425	-120.2006
E221805	10-May-95	02-Oct-00	Upstream and Outmigration	51.1783	-120.1339

Table A3.1. Water quality stations used in the assessment of potential effects of contaminants on sockeye salmon.

Environmental Monitoring System Station	Sampling Start Date	Sampling End Date	Sockeye Salmon Habitat Use	Latitude	Longitude
Pitt River Area of Interest River					
0300012	26-Jun-90	16-Nov-93	Upstream and Outmigration	49.2478	-122.7311
E208803	26-Jun-90	01-Aug-90	Upstream and Outmigration	49.2417	-122.7317
0300013	05-Jul-90	02-Nov-93	Rearing	49.3556	-122.5936
E216028	30-Jul-91	16-Nov-93	Upstream and Outmigration	49.2656	-122.7078
E246448	01-Nov-01	27-Nov-01	Upstream and Outmigration	49.2299	-122.7618
E246450	01-Nov-01	27-Nov-01	Rearing	49.3497	-122.6151
Quesnel River Area of Interest					
0600034	12-Jul-72	24-Nov-88	Upstream and Outmigration	52.6156	-121.5714
E207681	24-Nov-88	24-Nov-88	Upstream and Outmigration	52.6181	-121.5797
E207682	16-Mar-95	16-Mar-95	Upstream and Outmigration	52.6196	-121.5926
E240061	23-Apr-99	30-May-00	Upstream and Outmigration	52.6633	-121.7683
E240062	23-Apr-99	07-Nov-06	Upstream and Outmigration	52.6611	-121.7869
E240063	23-Apr-99	30-May-00	Upstream and Outmigration	52.6583	-121.7944
E245982	03-Oct-01	04-Oct-01	Upstream and Outmigration	52.9456	-121.1733
E256574	09-Aug-04	25-Sep-06	Rearing	52.4706	-121.3875
E256575	09-Aug-04	25-Sep-06	Rearing	52.4733	-121.3825
E256576	09-Aug-04	25-Sep-06	Rearing	52.4772	-121.3675
E256577	09-Aug-04	25-Sep-06	Rearing	52.4794	-121.3689
E256578	09-Aug-04	25-Sep-06	Rearing	52.4833	-121.3767
E256582	09-Aug-04	26-Sep-06	Rearing	52.4839	-121.3408
E256584	09-Aug-04	09-Aug-04	Rearing	52.4928	-121.3211
E256579	10-Aug-04	26-Sep-06	Rearing	52.4908	-121.3775
E256580	10-Aug-04	26-Sep-06	Rearing	52.5014	-121.3861
E256585	10-Aug-04	10-Aug-04	Rearing	52.5033	-121.3731
E256586	10-Aug-04	26-Sep-06	Rearing	52.5072	-121.3583
E256314	23-Nov-04	26-Jul-10	Spawning	52.4033	-121.4342
Seton-Portage Area of Interest					
1131023	03-Jun-03	03-Jun-03	Rearing	50.7075	-122.1533
South Thompson River Area of Interest					
0500070	25-May-70	30-Nov-93	Spawning	50.8359	-118.9924
0500001	26-May-70	07-Oct-01	Spawning; Rearing	50.9022	-119.5897
0500064	26-May-70	09-Dec-97	Spawning	50.9314	-119.4631
0500025	11-Mar-71	28-Feb-95	Spawning	50.8744	-118.9306
0500123	17-May-71	24-Mar-09	Spawning; Rearing	50.8953	-119.4808
0500124	17-Jun-71	23-Sep-10	Spawning; Rearing	50.9214	-119.0558
0500065	28-Jun-71	07-May-87	Spawning	51.2383	-118.9583
0500118	15-May-73	22-Sep-10	Spawning; Rearing	50.5127	-118.7346
0500117	15-May-73	22-Sep-10	Spawning; Rearing	50.6337	-118.6873
0500119	16-May-73	26-Aug-10	Spawning; Rearing	50.3915	-118.5197

Table A3.1. Water quality stations used in the assessment of potential effects of contaminants on sockeye salmon.

Environmental Monitoring System Station	Sampling Start Date	Sampling End Date	Sockeye Salmon Habitat Use	Latitude	Longitude
South Thompson River Area of Interest (continued)					
0600135	18-Oct-73	01-Mar-10	Upstream and Outmigration	50.6794	-120.3233
0500293	23-Oct-73	10-Aug-10	Spawning	50.2525	-118.9603
0500462	29-Jul-75	25-Aug-98	Spawning	50.9379	-118.4315
0500463	29-Jul-75	05-Oct-94	Spawning	50.9417	-118.4822
0500498	08-Jan-76	29-Nov-90	Upstream and Outmigration	50.5634	-119.1394
0500497	08-Jan-76	27-Feb-91	Upstream and Outmigration	50.5639	-119.1367
0500697	01-Mar-79	15-Apr-09	Spawning	50.2886	-118.9242
0500686	15-Mar-79	04-Aug-94	Spawning	50.9342	-118.4447
E206092	23-Jan-85	03-Aug-10	Spawning	50.6929	-119.3298
E206084	23-Jan-85	18-Mar-10	Spawning	50.2844	-119.985
E206087	23-Jan-85	18-Mar-10	Spawning	50.4892	-119.6
E206086	23-Jan-85	18-Mar-10	Spawning	50.4078	-119.8119
E206089	26-Feb-85	22-Sep-10	Spawning	50.4561	-119.3728
E206246	11-Apr-85	22-Sep-10	Spawning	50.9475	-118.7708
E206771	03-Sep-86	21-Jul-10	Spawning; Rearing	50.7239	-119.3014
E206964	21-May-87	15-Dec-87	Spawning; Rearing	51.2578	-118.9483
E207579	27-Jul-88	18-Mar-08	Spawning; Rearing	50.7634	-119.2223
E208719	30-May-90	28-Sep-04	Spawning; Rearing	51.0022	-119.0177
E208721	30-May-90	23-Sep-10	Spawning; Rearing	51.0686	-118.917
E208722	31-May-90	17-Aug-10	Spawning; Rearing	51.1301	-119.0089
E208734	19-Jul-90	17-Mar-10	Spawning; Rearing	50.8805	-119.4623
E222131	13-Sep-95	17-Mar-10	Spawning; Rearing	50.9582	-119.1044
E227530	06-Aug-97	22-Aug-07	Spawning; Rearing	50.9756	-119.1149
E233390	16-Aug-98	07-Oct-02	Spawning	50.5848	-119.3764
E263504	18-May-10	21-Jul-10	Spawning; Rearing	50.7094	-119.2941
E263503	18-May-10	21-Jul-10	Spawning; Rearing	50.7094	-119.2941
E282475	06-Jul-10	06-Jul-10	Spawning; Rearing	50.9124	-119.5254
E282479	06-Jul-10	06-Jul-10	Spawning; Rearing	50.8794	-119.3709
E282484	06-Jul-10	06-Jul-10	Spawning; Rearing	50.9686	-119.0791
E282477	06-Jul-10	06-Jul-10	Spawning; Rearing	50.7982	-119.1136
E282485	06-Jul-10	06-Jul-10	Spawning; Rearing	50.936	-119.245
E282481	07-Jul-10	07-Jul-10	Spawning; Rearing	50.7928	-119.0815
E282480	07-Jul-10	07-Jul-10	Rearing	50.7794	-119.3104
Upper Fraser River Area of Interest River					
0600011	01-May-72	16-Aug-10	Upstream and Outmigration	52.53	-122.4425
0400023	17-May-72	18-Mar-97	Upstream and Outmigration	54.0761	-121.8458
E206182	05-Mar-85	03-May-05	Upstream and Outmigration	53.6383	-122.6644
Reference					
E236796	28-Jul-84	19-Jul-10	N/A	52.9881	-119.0092

Appendix 4. Data Treatment and Methodology

A4.1 Treatment of Spatial Data

Spatial data were obtained from multiple sources in various formats. To standardize the spatial data into a consistent format, data were converted into ESRI® shapefiles and projected using the North American Datum (NAD) 1983 BC Environment Albers coordinate system. Due to the lack of data availability and, in some cases, difficulty acquiring spatial data, a variety of data mining and data creation techniques were implemented. This included, but was not limited to, using Google Earth to generate geographic representations, geo-referencing figures from existing reports, and plotting facilities and land-use activities from coordinates presented in tabular data. In some circumstances, only the mailing address of the facility was available. In this situation, Google Earth was utilized to obtain the spatial coordinates of the facility and subsequently plotted in ESRI® ArcMap™.

Many of the spatial datasets required formatting and conversion in order to accurately and efficiently use the data, information, and maps. Sources of spatial data included scientific and grey-literature, published reports, Microsoft Access databases, Microsoft Excel spreadsheets, ESRI® ArcMap™ shapefiles, online mapping tools, and text descriptions. Spatial datasets, which required unique handling, are described below.

RESULTS-Openings Spatial Database

The RESULTS-Openings spatial database was acquired through GeoBC's Data Discovery Service and was used to identify predominant tree species and to summarize and display harvesting activities within the Fraser River Basin in the following time periods: "Pre-1990" (1960-1990 inclusive) and "Post-1990".

To achieve these results, the polygons provided in the RESULTS-Openings database were overlaid and intersected with the area of interest boundaries to extract the relevant information. Microsoft Access was then used to classify the data into the "Pre-1990" and "Post-1990" time periods. In order to do this, the DN1_CompDate (the first disturbance completion date) and DN2_CompDate (the second disturbance completion date) fields were used in several queries. To achieve the desired results, the following rules were used:

- All DN1_CompDate years falling between 1960 and 1990 (inclusive) were classified as "Pre-1990".
- All DN1_CompDate years occurring after 1990 were classified as "Post-1990".
- All DN2_CompDate years falling between 1960 and 1990 (inclusive) where DN1_CompDate field was blank were classified as "Pre-1990".

- All DN2_CompDate years occurring after 1990 where the DN1_CompDate field was blank were calculated to “Post-1990".
- Records where both DN1_CompDate and DN2_CompDate were blank were left out of the analysis.

The *Dissolve* tool in ArcGIS was used to generalize the RESULTS-Openings spatial polygons for each area of interest and the PREV_SPP1 (primary species description) field. The geoprocessing results were exported into a geodatabase, grouped by area of interest and summarized in order to determine the predominant tree species.

Fraser Basin Landfill Inventory

The Fraser Basin Landfill Inventory listed in the *Fraser River Action Plan: Fraser Basin Landfill Inventory* (Gartner Lee Ltd. 1997; Appendix 5) lists solid waste landfills in the Fraser River Basin and their associated geographic coordinates. The Microsoft Access database developed for the 1997 report was not available. To obtain the location of the landfills in the Fraser River Basin, a map [Figure 2.1 of the Gartner Lee Ltd. (1997) report] showing the spatial location of each landfill was scanned and imported into ESRI® ArcMap™. The map image was rubber-sheeted and geo-referenced using a comparable provincial dataset (i.e., the provincial border and the Fraser River basin). All locations were manually digitized to create the spatial representation of landfill locations. Associated attribute data listed in Appendix B of the Gartner Lee Ltd. (1997) report, was imported into a Microsoft Excel spreadsheet to accompany the spatial data. Due to differences in the delineation of regions in the Gartner Lee Ltd. (1997) report and areas of interest used in this contaminant assessment, a direct link between the created spatial layer and the supplemental attribute data was not available. All landfill locations were confirmed and cross-referenced to the supplementary data and each of the landfills was assigned to an area of interest. Lastly, the landfill categories [Table 2.1 of the Gartner Lee Ltd. (1997) report] were used to assist in evaluating landfill characteristics.

A4.2 Treatment of Environmental Data

To support the assessment of potential effects of contaminants on Fraser River sockeye salmon, environmental data (including surface water quality, sediment quality, and fish tissue chemistry) were obtained and compiled into multiple project databases. As data were collected from multiple government agencies, reports, and scientific literature, data were screened to ensure they were comparable and that adequate quality assurance was performed.

Surface water data were additionally screened for erroneous values and values which were unlikely (i.e., data were screened based on the accompanying metadata). Examples of this procedure include the screening of pH values to exclude those that fall outside of the range of 0 to 14, and the screening of water temperature to exclude values below 0 °C. Furthermore, an exposure point concentration was determined when multiple samples were reported in surface water at the same station on the same sampling date and time; the maximum value for each contaminant of potential concern was used as the exposure point concentration in all cases except for dissolved oxygen, when the minimum value was used. Total metals concentrations in surface water data were used in the assessment rather than dissolved metals to achieve greater spatial and temporal coverage of the surface water quality data; implications of this procedure are discussed in Chapter 7.

The treatment of environmental data has the potential to influence the results of the assessment. In particular, the treatment of less than detection limit data can affect the results of the exposure assessment, the hazard evaluation, and the calculation of the Water Quality Index. A number of investigators have evaluated the implications of applying various procedures for estimating the concentrations of contaminants of potential concern from less than detection limit data (Gaskin *et al.* 1990; Porter and Ward 1991; El-Shaawari and Esterby 1992; Clarke and Brandon 1994). While there is no consensus on which data censoring methods should be used in various applications, the simplest methods tend to be used most frequently, including deletion of non-detect values or substitution of a constant, such as zero, the detection limit, or one-half the detection limit (USACE 1995).

To address the need for guidelines for statistical treatment of less than detection limit data, the USACE (1995) conducted a simulation study to assess the performance of ten methods for censoring data. The results of that investigation indicated that no single data censoring methods works best in all situations. Accordingly, USACE (1995) recommended a variety of methods depending on the proportion of the data that requires censoring, the distribution and variance of the data, and the type of data transformation. For data sets for which a low to moderate proportion of the data require censoring, substitution of the detection limit is generally the preferred methods (i.e., to optimize statistical power and control type I error rates). However, as the proportion of the data that requires censoring and the coefficient of variation of the data increases, statistical power is better maintained by substituting one-half the detection limit for the less than detection limit data, particularly for log-normally distributed and transformed data. Substitution of zero or other constants was also recommended for a variety of circumstances. Overall, it was concluded that simple substitution methods work best to maintain power and control error rates in statistical comparisons of chemical concentration data (USACE 1995).

In this analysis, decisions regarding the treatment of less than detection limit data were taken by considering the recommendations that have emerged from previous investigations in the context of their potential effects on the results of this assessment. Including all of the surface water, sediment, and fish-tissue chemistry data that were compiled in the project databases, more than 30% of the data required censoring prior to data analysis. To minimize the potential effects of the less than detection limit data on the results of the analysis, none of the less than detection limit data for which the detection limits were greater than the corresponding toxicity screening value or toxicity thresholds for surface-water, sediment, or fish- tissue chemistry were used in the effects and exposure assessment. That is, non-detect values that exceeded the toxicity screening values in the preliminary evaluation of chemicals of potential concern, and non-detect values that exceeded the toxicity thresholds in the evaluation of contaminants of concern were excluded from the respective analysis. Consistent with the guidance developed by USACE (1995), one-half of the detection limit was substituted for all of the other less than detection limit data. This procedure facilitated the estimation of distributions of the concentrations of chemicals of potential concern and eliminated the potential for identifying significant risks based on less than detection limit data.

Selection of an alternate procedure for treating the less than detection limit data has the potential for influencing the results of the analysis. For example, substitution of zero for less than detection limit data would have skewed the distributions of the chemicals of potential concern concentration data for the 15 areas of interest, and for the study area as a whole (i.e., the estimated 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 95^{th} percentile concentrations would likely have been lower than the estimates developed for the assessments). Likewise, substitution of the detection limit for the less than detection limit data would have also skewed the distributions of the chemicals of potential concern concentration data (i.e., the estimated 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 95^{th} percentile concentrations would likely have been higher than the estimates developed for the assessments). Although the influence of these alternate methods on the estimate of the 75^{th} or 95^{th} percentile concentration would likely have been relatively minor, their selection could have influenced the identification of contaminants of concern. Nevertheless, it is unlikely that the nature, magnitude, or spatial distribution of risks to sockeye salmon was affected by the selection of data treatment methods. As such, the potential impact of the methods that were selected for treating less than detection limit data on the results of the assessment are considered to be minor.

A4.3 Methodologies used in the Assessment of Contaminant Exposure of Fraser River Sockeye Salmon

A4.3.1 Classification of Environmental Data

Adverse effects on ecological receptors can occur when stressors and receptors are present in the same place and at the same time. As such, determination of exposure of sockeye salmon to contaminants in the Fraser River Basin requires an understanding of the life history of this species. Based on a review of the literature on life history characteristics, four key time periods when sockeye salmon could be exposed to contaminants in freshwater habitats were identified, including:

- Spawning and incubation of sockeye salmon eggs and alevins in stream and lakeshore habitats (August 1 to May 31);

- Early rearing of sockeye salmon fry in nursery lakes (April 1 to March 31);
- Downstream migration of sockeye salmon smolts through riverine (i.e., Fraser River and tributaries) and estuarine habitats (May 1 to June 30); and,
- Upstream migration of sockeye salmon adults through estuarine and riverine (i.e., Fraser River and tributaries) habitats (June 1 to September 30).

Surface water chemistry data, which were collected during the listed exposure periods, were extracted from the project database and used in all further analyses. The preliminary evaluation of chemicals of potential concern and the evaluation of contaminants of concern were performed using the surface water quality data for each area of interest. Due to limitations in the available sediment quality data, these data were not further categorized according to exposure periods.

In addition, the assessment of the environmental data was conducted for two distinct historical time periods: prior to and including 1990 (i.e., pre-1990); and, 1991 up to and including 2010 (i.e., post-1990), where data were available. The separation of the environmental data into these two time periods facilitated the evaluation of environmental quality conditions during two distinct trend periods in sockeye salmon productivity observed over the last 50 years.

A4.3.2 Calculation of the Water Quality Index

The CCME Water Quality Index provides a consistent basis for evaluating the proportion of toxicity screening values exceeded, the frequency of exceedance of the toxicity screening values and the magnitude of exceedance. Accordingly, the Water Quality Index provides a convenient tool for comparing water quality conditions across geographic areas and time periods (CCME 2001; Saffran *et al.* 2001).

Water quality data for the index calculation were grouped by three factors: year, exposure period (e.g., rearing), and salmon stock (e.g., Birkenhead stock). In addition, the index period was adjusted to reflect the actual exposure period for each brood year as follows:

- Water quality data collected during the brood year were used to calculate the index during the spawning exposure period;
- Water quality data collected one year after the brood year were used to calculate the index during the rearing exposure period;
- Water quality data collected two years after the brood year were used to calculate the index during the outmigration exposure period; and,

- Water quality data collected four years after the brood year were used to calculate the index during the upstream migration exposure period.

For example, water quality data collected between April 1, 2007 and March 31, 2008 from all water quality stations in the rearing habitats for the Birkenhead stock were grouped together to calculate one index for the rearing period for the 2006 Birkenhead stock. In the case of smolt outmigration the index was inclusive of all applicable water quality stations in the migration corridor between the rearing area and the mouth of the Fraser River. Similarly, in the case of the adult upstream migration, applicable water quality stations in the migration corridor between the mouth of the Fraser River and the spawning grounds were included.

The calculation of the Water Quality Index (Saffran *et al*. 2001) requires at least four independent measurements of at least four water quality variables for each period of time (i.e., index period). As data on water quality variables were not consistent spatially or temporally for all stocks, the variables and samples used in the index calculations had the potential to be inconsistent within and between stocks from year-to-year.

A description of the calculation is provided below [from the CCME Water Quality Index 1.0 User's Manual (Saffran *et al.* 2001)]:

Calculation of the Index

After the body of water [or group of water quality stations], the period of time, and the variables and objectives have been defined, each of the three factors that make up the index must be calculated. The calculation of *F1* and *F2* is relatively straightforward; *F3* requires some additional steps.

F1 (**Scope**) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration ("failed variables"), relative to the total number of variables measured:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100$$

F2 (**Frequency**) represents the percentage of individual tests that do not meet objectives ("failed tests"):

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100$$

F3 (**Amplitude**) represents the amount by which failed test values do not meet their objectives. *F3* is calculated in three steps.

i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an “excursion” and is expressed as follows. When the test value must not exceed the objective:

$$Excursion_i = \left(\frac{\text{Failed test value}}{\text{Objective}_j} \right) - 1$$

For the cases in which the test value must not fall below the objective:

$$Excursion_i = \left(\frac{\text{Objective}_j}{\text{Failed test value}} \right) - 1$$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{Number\ of\ tests}$$

iii) *F3* is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01 nse + 0.01} \right) \times 100$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

The CCME Water Quality Index (CCME WQI):

$$CCME\ WQI = \left(\frac{\sqrt{F_1^{\ 2} + F_2^{\ 2} + F_3^{\ 2}}}{1.732} \right)$$

The divisor 1.732 normalizes the resultant values to a range between 0 and 100, where 0 represents the“worst” water quality and 100 represents the “best”water quality.

The CCME Water Quality Index calculation produces an index that ranges between 0 and 100. In addition, the Water Quality Index can be classified categorically:

- Excellent water quality (WQI: 95 - 100);
- Good water quality (WQI: 80 - 94);
- Fair water quality (65 - 79);
- Marginal water quality (45 - 64); and,
- Poor water quality (0 - 44).

A4.3.3 Compilation of Toxicity Screening Values for the Preliminary Evaluation of Contaminants of Potential Concern

Toxicity Screening Values for Surface Water - A tiered approach was used to select toxicity screening values for surface-water chemistry data for the Fraser River Basin. Using this procedure, the lower of the Canadian water quality guidelines (CCME 1999) or the British Columbia approved and working water quality criteria (BCMOE 2010) was selected as the toxicity screening value for a chemical of potential concern. Both types of benchmarks define the concentrations of these chemicals in water that would not adversely affect any life stage of any aquatic species that are exposed for extended time periods. If such guidelines or criteria were not available for a substance, then the criterion continuous concentration promulgated by USEPA (2009) or a similar value (i.e., JWQB 1998) was selected as the toxicity screening value. For toxicity screening values that are hardness, pH, or temperature dependent, data on the characteristics of each water sample were used to calculate a sample-specific toxicity screening value for that chemical of potential concern in water.

Toxicity Screening Values for Sediment - Exposure to contaminated sediments has the potential to adversely affect sockeye salmon during incubation of eggs and alevins.

In addition, some sockeye salmon (e.g., Harrison River fish) can be exposed to sediment-associated contaminants through the consumption of benthic invertebrates during early rearing in areas that are dominated by benthic production (e.g., sloughs in the Lower Fraser River Area of Interest). Numerical sediment quality guidelines provide a basis for assessing the effects on benthic invertebrates and other aquatic organisms associated with exposure to sediment-associated chemicals of potential concern. A hierarchical approach was employed to compile toxicity screening values for use in this assessment. Consensus-based threshold effect concentrations (MacDonald *et al.* 2000a, MacDonald *et al.* 2000b) were chosen as toxicity screening values for some metals, PAHs, sum PCBs, and organochlorine pesticides. Interim sediment quality guidelines promulgated by CCME (1999) were selected for the contaminants for which consensus-based threshold effect concentration values have not been developed. The BCMOE Compendium of Working Water Quality Guidelines for sediments (Nagpal *et al.* 2006) and the peer-reviewed literature (e.g., MacDonald 1994) was used to further identify threshold effect concentration-type values for use in the screening-level assessment.

A4.3.4 Compilation of Water Quality, Sediment Quality, and Tissue Toxicity Thresholds for the Evaluation of Contaminants of Concern

Toxicity Thresholds for Water - A total of 17 substances were identified as contaminants of concern in water, based on the results of the preliminary evaluation of contaminants of potential concern and subsequent refinement of the contaminants of concern list. For each of these substances, toxicity thresholds for sockeye salmon or other salmonid fishes were estimated using data and information contained in the published literature. More specifically, compilations of the available toxicity data (such is contained within substance-specific water quality guidelines and water quality criteria documents) were reviewed to support identification of the toxicity thresholds for each contaminant of concern in water. The sockeye salmon-specific or salmonid-specific toxicity thresholds were established using the following procedures:

- For substances for which the toxicity screening value used in the preliminary evaluation was based on toxicity data for non-salmonid species (i.e., data on the toxicity of the substance to aquatic plants, invertebrates, non-salmonid fishes, or amphibians), toxicity thresholds for evaluating the contaminants of concern in sockeye salmon were established using one of the following procedures:
    1. Identify the lowest median lethal concentration (LC_{50}) obtained in a toxicity test conducted on sockeye salmon or another salmonid species that extended for at least 96 hours. The lowest LC_{50} was then multiplied by a safety factor of 0.1, in accordance with CCME (1999) procedures;
    2. Identify the lowest effective concentration (i.e., EC_{25}-type value) for a non-lethal endpoint obtained in a toxicity test conducted on

sockeye salmon or another salmonid species that extended for more than 96 hours. The lowest EC_{25} was then multiplied by a safety factor of 0.5;

3. For hardness-dependent water quality guidelines, substitute the intercept value for sockeye salmon or the most sensitive salmonid species for the intercept value for the non-salmonid species used to derive the toxicity screening value (the slope was not adjusted, however);
4. Calculate the ratio of the final acute value for sockeye salmon or the most sensitive salmonid species to the final acute value for the species that was used to derive the water quality guideline. Multiply the toxicity screening value by the ratio of final acute values derived in this manner to estimate the toxicity threshold for sockeye salmon; or,
5. Identify the toxicity threshold directly from the maximum acceptable toxicant concentration reported for a sub-lethal endpoint obtained based on the results of an acceptable long-term study on sockeye salmon or another salmonid species.

- For substances for which the selected toxicity screening value was based on toxicity data for salmonid species, toxicity thresholds for sockeye salmon were established using the following procedures:
    1. Calculate the ratio of the final acute value for sockeye salmon to the final acute value for the salmonid species that was used to derive the water quality guideline. Multiply the toxicity screening value by the ratio of final acute values derived in this manner to estimate the toxicity threshold for sockeye salmon.

In some cases, the toxicity screening values used in the preliminary evaluation were adopted directly as the toxicity thresholds for sockeye salmon. In these cases, the toxicity screening value was already based on salmonid toxicity data and/or no sockeye-salmon specific toxicity data were available.

Toxicity Thresholds for Sediment - A total of five substances were identified as contaminants of concern in sediment, based on the results of the preliminary evaluation of contaminants of potential concern and subsequent refinement of the contaminants of concern list. Sockeye salmon-specific, salmonid-specific, or fish-specific sediment quality guidelines were not located in the literature to support the detailed evaluation of sediment chemistry data for the Fraser River Basin. For this reason, effects-based sediment quality guidelines for the protection of benthic invertebrates were obtained from multiple jurisdictions and reviewed to identify toxicity thresholds that could be used to assess sediment quality conditions in the study area. A tiered-approach was used to select toxicity thresholds for use in the evaluation which involved:

- Selecting probable effect concentrations or median effect concentrations from MacDonald *et al.* (2000a; 2000b) when such values were available;
- Selecting probable effect levels from CCME (1999) or MacDonald (1994) when probable effect or median effect concentrations were not available; and,
- Selecting the lowest effect levels from Nagpal *et al.* (2006) for those substances for which none of the other sediment quality guidelines were available.

Such toxicity thresholds represent the concentrations of contaminants of concern above which adverse effects on the benthic invertebrate community are likely to be observed when the contaminants of concern occur in complex mixtures with other contaminants.

Toxicity Thresholds for Fish Tissues - Accumulation of certain contaminants in tissues has the potential to adversely affect the survival, growth, or reproduction of sockeye salmon. In this study, toxicity thresholds for fish tissues were identified from selected reviews of the scientific literature that evaluate adverse effects on fish associated with accumulation of chemicals of potential concern in their tissues (deBruyn *et al.* 2004; Dillon *et al.* 2010; Giesy *et al.* 2002; USEPA 2010).

A4.3.4 Exposure Assessment and Hazard Evaluation

In the preliminary evaluation, potential risks posed to sockeye salmon associated with exposure to contaminants of potential concern were estimated by calculating frequency of exceedances (i.e., the comparison of environmental data to toxicity screening values and/or toxicity thresholds) and hazard quotients. More specifically, the exposure estimates were used in conjunction with toxicity screening values to identify contaminants of concern associated with exposure to surface water or sediment within the Fraser River Basin, using the following equation:

$$HQ = EPC / TSV$$

Where:
HQ = Hazard Quotient;
EPC = Exposure Point Concentration (maximum concentration of an individual chemical of potential concern); and,
TSV = Toxicity Screening Value.

A hazard quotient of less than 1.0 was considered to indicate that exposure to the measured concentrations of the chemicals of potential concern would not pose risks to sockeye salmon. These results were used to eliminate negligible-risk chemicals of potential concern from further consideration. The chemicals of potential concern with hazard quotients > 1.0 were considered to pose potential risks to sockeye salmon and were retained as contaminants of concern, while chemicals of potential concern with insufficient data to support calculation of an exposure point concentration were retained as uncertain contaminants of concern and were brought forward to the *Evaluation of the Potential Effects of Endocrine Disrupting Chemicals and Emerging Contaminants on Fraser River Sockeye Salmon* (Chapter 6).

The contaminants of concern identified in the preliminary evaluation (described above) were brought forward for further refinement. Specifically, those contaminants of concern with hazard quotients greater than or equal to 2.0 were retained as contaminants of concern for further evaluation. All other contaminants of concern were eliminated from further analysis. Contaminants of concern were then evaluated in conjunction with salmonid-specific toxicity thresholds to more accurately evaluate the potential risks of contaminant exposure to sockeye salmon, using the following equation:

$$HQ = EPC / TT$$

Where: HQ = Hazard Quotient;
EPC = Exposure Point Concentration (95th Percentile for each individual contaminant of concern); and,
TT = Toxicity Threshold.

The contaminants of concern with hazard quotients greater than or equal to 1.0 in this subsequent evaluation were considered to be at concentrations sufficient to adversely affect the survival, growth, or reproduction of Fraser River sockeye salmon.

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Appendix 5. Data description and sources for all maps.

Map	Source
Agriculture	
Baseline Thematic Mapping, from this file was pulled polygons related to Agriculture, Rangelands, and Res_agro_Mixture	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?from=advancedsearch&edit=true&showall=showall&recordSet=ISO19115&recordUID=33711
NPRI Database 1994 - 2008, Utilized Agriculture class	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
Used to determine principal agricultural activities	http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/423101/tr041.pdf
Used to determine principal agricultural activities	http://www.for.gov.bc.ca/dch/range.htm
Used to determine principal agricultural activities	http://en.wikipedia.org/wiki/Seton_Portage,_British_Columbia
The spatial representation for agricultural reserve land, which is a parcel of land, based on soil and climate, deemed necessary to be maintained for agricultural use. The ALR digital data is not considered the official representation of the ALR.	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=3553&recordSet=ISO19115
Bulk Storage and Shipping Facilities	
NPRI Database 1994 - 2008. Selected records where NA12Code_N = Manufacturing,Warehousing & Storage.	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
Permitted Effluent Permit Information	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)
Cement and Concrete Plants	
NPRI Database 1994 - 2008. Selected records where NA12Code_NAICS_E = Cement & Concrete Product Mfg.	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)
Website accessed to determine the principal products manufactured at Lehigh Northwest Cement Ltd. (Delta Cement Plant)	http://www.lehighcement.com/AboutLehigh/About_Lehigh_Delta.htm
Website accessed to determine the principal products manufactured at Con-Force Structures Limited	http://investing.businessweek.com/research/stocks/private/snapshot.asp?privcapId=6536279
Website accessed to determine the principal products manufactured at Re-Con Building Products Inc.	http://www.thiessenteam.com/materialhandling/completedprojects/other.htm#recon

Appendix 5. Data description and sources for all maps.

Map	Source
Cement and Concrete Plants (continued)	
Website accessed to determine the principal products manufactured at Rempel Bros. Concrete.	http://www.rempelbros.com/Products/index.htm
Website accessed to determine the principal products manufactured at Ocean Construction Supplies Ltd.	http://www.oceanconcrete.com/
Website accessed to determine the principal products manufactured at Coquitlam Concrete (1993) Ltd.	http://www.coquitlamconcrete.com/home
Website accessed to determine the principal products manufactured at Lafarge (Kamloops cement plant).	http://www.lafarge-na.com/wps/wcm/resources/file/ebb47644d164835/KamloopsBrochure.pdf
Spatial and facility information regarding Lafarge Canada Inc.	Personal communication with Ian Paine, Marketing Director, Ready Mix Western Canada Region, Lafarge Canada Inc.
Contaminated Sites	
Database highlighting Contaminated Sites	Personal Communication with Jason Smith, Senior Systems Analyst, Ledbetter Associates Inc. Treasury Board of Canada, Contaminated Sites Database.
Fish Processing Plants	
Techinal report that identifies the locations and analyzes chemistry data for seven key fish processing facilities.	NovaTec Consultants Inc. and EVS Consultants. 1994. Fraser River Action Plan: Wastewater characterization of fish processing plant effluents. Technical Report Series. FREMP. WQWM 93-10. DOE FRAP 1993-39. Document available at http://research.rem.sfu.ca/fr
Fish Processor Tenures - Coastal Resource Information Management System (CRIMS). This dataset contains information regarding processor facilities in British Columbia including location, company name and license tag information.	GeoBC Geographic Data Discovery Service. 2010. Dataset download available at https://geobc.gov.bc.ca/.
Website accessed to identify additional fish processing facilities in the Fraser River Basin that were not identified in above data.	BCSeafood.ca. Search BC Seafood Companies. 2010. http://www.bcseafood.ca/.
Permitted Effluent Permit Information	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)
Metro Vancouver Waste Permit List	http://www.metrovancouver.org/services/permits/Permits%20%20Regulations

Appendix 5. Data description and sources for all maps.

Map	Source
Forestry Runoff	
RESULTS - Openings. This dataset conatins the spatial polygon representation of the administrative boundary that has been harvested with silviculture obligations or natural distrubance with intended forest management activities on Crown Land. (12/15/1888 to 11/26/2010).	GeoBC Geographic Data Discovery Service. 2010. Dataset download available at https://geobc.gov.bc.ca/. Associated metadata can be viewed at https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=52583&recordSet=ISO19115.
Fire Incident Locations - Historical, Fire Locations - Current, Fire Perimeters - Currents, Fire Perimeters - Historical. These layers include the spatial polygon data which represents the perimeter area of historical and current/active fire incidents as well as the point coordinates where current and past fire activities have occurred.	GeoBC Geographic Data Discovery Service. 2010. Dataset download available at https://geobc.gov.bc.ca/.
Provided a link as to where to retrieve wildfire spatial GIS files per year.	Personal Contact with Sunjit Mark, Fuel Geomatics Analyst, Wildfire Management Branch, Ministry of Natural Resource Operations
Forest Vegetation Composite Polygons: A composite table comprising the polygon table attributes joined to the attributes from the non veg, non tree, land cover component, tree layer, tree species and tree volume tables. This SDE layer coverage contains vegetation cover from the Ministry of Forests. Attribute information is also maintained in this table. It will supersede F_FC. Vegetation Cover is comprised of spatial layers for the collection, manipulation and production of forest inventory data, which has a accompanying textual attributes. This joined table was created to support the Data Distribution Services on the LRDW.	GeoBC Geographic Data Discovery Service. 2010.VRI - Forest Vegetation Composite Polygons and Rank 1 Layer - Dataset can be viewed at file:///G:/MESL%20Data/Projects/Cohen%20Commission/GIS/Data/Databases/veg_comp_lyr_r1_poly.gdb.zip.metadata.html
Gas and Oil Development	
NPRI Database 1994 - 2008, Selected records where NA12Code_NAICS_E = Mining & Oil & Gas Extraction. Organized data into 4 types: Transmission Facilities, Delivery Points, Oil Refinery, Gas Plant.	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
Well Surface Hole Status. This dataset contains the spatial surface location of a well and provides information on the current status of the surface hole.	GeoBC Geographic Data Discovery Service. 2010. Dataset download available at https://geobc.gov.bc.ca/.

Appendix 5. Data description and sources for all maps.

Map	Source
Gas and Oil Development (continued)	
Figure displaying pipelines and facilities in B.C. Figure was georeferenced and used to capture spatial locations of oil and gas pipeline rights-of-way.	Hannigan P., P.J. Lee, K. Osadetz et al. 1993-1998. Offshore oil and gas potential in British Columbia. Geological Survey of Canada.unpublished. Map accessed online at http://www.empr.gov.bc.ca/OG/oilandgas/publications/pamphlets/Documents/OilandGasStats-
Lake Fertilization	
Lake Fertilization for Juvenile Sockeye	Factors limiting juvenile sockeye production and enhancement potential for selected B.C> Nursery Lakes, Fisheries and Oceans Canada, Research Document 2001/098 Available at http://www.dfo-mpo.gc.ca/CSAS/Csas/DocREC/2001/RES2001_098e.pdf
Linear Developments	
GIS Files, (municipality, major roads, railways and BC border)	ArcGis 9, ESRI Data & Maps CD, World, Europe, Canada, and Mexico
Major Industrial and Municipal Landfills	
Figure 2.1 displaying Fraser River basin landfill locations. Figure was georeferenced and used to capture spatial locations of landfills in Fraser River Basin.	Gartner Lee Ltd. 1997. Fraser River Action Plan: Fraser Basin Landfill Inventory. Prepared for Environment Canada, Environmental Protection Fraser Pollution Abatement. North Vancouver, B.C.
Mines	
Baseline Thematic Mapping, from this file was pulled polygons related to Mining.	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?from=advancedsearch&edit=true&showall=showall&recordSet=ISO19115&recordUID=33711
NPRI Database 1994 - 2008, Utilized Mining	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
Website accessed to determine the commodities produced at Criagmont Mines.	http://www.craigmontmines.com/
Website accessed to determine the commodities produced at Highland Valley Copper Mine.	http://www.teck.com/Generic.aspx?PAGE=Operations+Pages%2fCopper+Pages%2fHighland+Valley+Copper&portalName=tc,

Appendix 5. Data description and sources for all maps.

Map	Source
Mines (continued)	
Website accessed to determine the commodities produced at Highland Valley Copper Mine.	http://www.infomine.com/minesite/minesite.asp?site=hvc
Website accessed to determine the commodities produced at Highland Valley Copper Mine.	http://www.mining-technology.com/projects/highland/
Website accessed to determine the commodities produced at New Afton Mine.	http://www.infomine.com/suppliers/minedevelopments/newafton/welcome.asp
Website accessed to determine the commodities produced at New Afton Mine.	http://www.newgoldinc.com/
Website accessed to determine the commodities produced at Huckleberry Mine.	http://www.imperialmetals.com/i/pdf/2010_AIF.pdf
Website accessed to determine the commodities produced at Endako Mine.	www.thompsoncreekmetals.com
Website accessed to determine the commodities produced at Keithley Creek Mine.	http://minfile.gov.bc.ca/Summary.aspx?minfilno=093A++004
Website accessed to determine the commodities produced at Mount Polley Mines.	www.imperialmetals.com
Permitted Effluent Permit Information	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)
Website accessed to determine the commodities produced at QR Mine & Mill.	http://www.barkervillegold.com/s/Home.asp
Website accessed to determine the commodities produced at Gribraltar and Prosperity Mines.	www.tasekomines.com
Provided an excel sheet summarizing Tailing and Water Permit for Tech High land Valley Copper.	Personal communication with Peter Martell, Sr. Environmental Coordinator, Teck Highland Valley Partnership
Provided a copy of the premit effluent for New Afton Mine.	Personal communication with Julie Taylor Pantziris Director, Corporate Communications and Investor Relations New Gold Inc.
Provided information regarding Cragmont mines.	Personal communication with Dick Hermann Craigmont mines representative.
Provided the Permit Effluent number for Highland Valley Copper	Personal communication with Mark Freberg, Supt Envir & Community Affairs Highland Valley Copper
Provided a GIS layer of the locations of mines.	Personal communication with Emilia Saarinen, Ministry of Healthy Living and Sport.

Appendix 5. Data description and sources for all maps.

Map	Source
Mines (continued)	
Provided information regarding Mount Polley's effluent permit.	Personal communication with Tim Fisch, General Manager, Mount Polley Mining Corporation
2006 Mines Directory. Website lists information on various mining operations as well as contact information and website links. Information available includes owner/operator, mine and commodities.	http://www.empr.gov.bc.ca/Mining/Geoscience/ExplorationandMines/Pages/2006DirectoryandMap.aspx
Provided Permit information on the Endako mine.	Personal communication with Barb Riordan, Environmental Superintendent, regarding Endako Mine.
Miscelaneous Manufacturing	
NPRI Database 1994 - 2008. Selected records where NA12Code_NAICS_E = Manufacturing.	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
Permitted Effluent Permit Information	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)
Municipal Developments	
Website accessed to determine the primary industries in Harrison Hot Springs.	http://www.harrisonhotsprings.ca/PDF/OCP/OCP-HarrisonHotSprings.pdf
Website accessed to determine the primary industries in Pemberton.	http://www.pembertonbc.com/
Website accessed to determine the primary industries in Hope.	http://www.dist.hudsons-hope.bc.ca/economic.html
Website accessed to determine the primary industries in Abbotsford.	http://en.wikipedia.org/wiki/Abbotsford,_British_Columbia
Website accessed to determine the primary industries in Burnaby.	http://www.burnabybchomes.ca/Industry.asp
Website accessed to determine the primary industries in Chilliwack.	http://www.wordiq.com/definition/Chilliwack%2C_British_Columbia
Website accessed to determine the primary industries in Coquitlam.	http://en.wikipedia.org/wiki/Coquitlam,_British_Columbia
Website accessed to determine the primary industries in Mission.	http://en.wikipedia.org/wiki/Mission,_British_Columbia#Government
Website accessed to determine the primary industries in Port Coquitlam.	http://www.city.port-coquitlam.bc.ca/__shared/assets/OCP_Part_4_-__May_20085717.pdf
Website accessed to determine the primary industries in Richmond.	http://www.richmond.ca/discover/about/profile.htm
Website accessed to determine the primary industries in Vancouver.	http://en.wikipedia.org/wiki/Vancouver
Website accessed to determine the primary industries in Cache Creek and Ashcroft and Clinton.	http://discoverthompson-nicola.com/communityProfiles/cacheCreekProfile.pdf
Website accessed to determine the primary industries in Merritt.	http://en.wikipedia.org/wiki/Merritt,_British_Columbia

Appendix 5. Data description and sources for all maps.

Map	Source
Municipal Developments (continued)	
Website accessed to determine the primary industries in Fraser Lake.	http://stuartnechako.ca/fraser-lake/visitors/category/profile
Website accessed to determine the primary industries in Prince George.	http://en.wikipedia.org/wiki/Prince_George,_British_Columbia
Website accessed to determine the primary industries in 100 Mile House.	http://en.wikipedia.org/wiki/100_Mile_House,_British_Columbia
Website accessed to determine the primary industries in Quesnel.	http://www.city.quesnel.bc.ca/DoingBusiness/industry.asp
Website accessed to determine the primary industries in Chase.	http://www.bcadventure.com/adventure/explore/high_country/cities/chase.htm
Website accessed to determine the primary industries in Enderby.	http://www.enderby.com/facts.html
Website accessed to determine the primary industries in Lumby.	http://www.ourbc.com/travel_bc/bc_cities/thompson_okanagan/lumby.htm
Website accessed to determine the primary industries in Salmon Arm.	http://www.vancouverisland.com/regions/towns/?townID=3464
Website accessed to determine the primary industries in Chase.	http://www.bcadventure.com/adventure/explore/high_country/cities/canyons.htm
Website accessed to determine the primary industries in McBride.	http://en.wikipedia.org/wiki/McBride,_British_Columbia
Website accessed to determine the primary industries in Valemount.	http://www.vancouverisland.com/regions/towns/?townID=3473
Website accessed to determine the primary industries in Williams Lake.	http://www.williamslakechamber.com/index.asp?p=238
A listing of Populations as of 2009 of municipalities in British Columbia	Population Stats (2009) accessed on Nov 16 2010, http://www.bcstats.gov.bc.ca/data/pop/pop/estspop.asp#totpop
A listing of Populations as of 2009 of municipalities in British Columbia	http://www.citypopulation.de/Canada-BritishColumbia.html
Pine Beetle	
Forest health data, pest infestation	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordSet=ISO19115&recordUID=4411
Describes Pest Code which is hosted in the Gov. BC Shapefile. Pest Code for Pine Beetle = IBM	http://www.ilmb.gov.bc.ca/risc/pubs/teveg/foresthealth/aerial-04.htm
FADM - Mountain Pine Beetle Salvage Area	file:///G:/MESL%20Data/Projects/Cohen%20Commission/GIS/Data/Shapefiles/BC%20DATA%20DOWNLOAD/FADM_MPBSA/metadata.html

Appendix 5. Data description and sources for all maps.

Map	Source
Pulp and Paper Mills	
NPRI Database 1994 - 2008. Selected records where CS12Description = Paper and Allied Products Industries.	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
Website accessed to determine the principal products produced at Stella-Jones pulpmill.	http://www.stella-jones.com/pdf/notice/STE_AIF_2010_EN.pdf
Website accessed to determine the principal products produced at Kruger Products pulpmill.	http://www.kruger.com/html/en/papiersusages/usines.html
Permitted Effluent Permit Information	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)
Website accessed to determine the principal products produced at Kamloops Cellulose Fibres.	http://www.domtar.com/en/pulp/mills/3593.asp
Website accessed to determine the principal products produced at Cariboo Pulp and Paper Company.	http://www.dmi.ca/about_dmi/dmi_in_bc/caribooPulpPaperCompany.pdf
Provided summaries of selected pulp and paper mill operations	FRAP, Pollution Abatement Technical Summary Report, Oct 1998;
Provided maximum discharge information for Norampack Burnaby	Personal Communication with Greg Wazny
Provided information that the Domtar Vancouver Mill has been shut down for several years.	Personal Communication with David Lloyd, Technical Director, Domtar Pulp Sales
Overview of Buckeye Canada - Delta Division.	www.bkitech.com
Salmonid Enhancement Facilities	
Website was accessed to identifiy major hatchery facilities and spawning channels run by Department of Fisheries and Oceans (DFO), in addition to Community Economic Development Hatcheries, and volunteer-run facilities.	Fisheries and Oceans Canada. 2010. Website accessed at http://www.pac.dfo-mpo.gc.ca/sep-pmvs/hatcheries-ecloseries-eng.htm.
Website accessed to identfiy the locations of salmonid enhancement facilities in the Lower Mainland and the species raised.	http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/fresh-douce/region2-eng.htm
Website accessed to identfiy the location of the salmonid enhancement facility in D'Arcy and the species raised.	http://darcybc.com/

Appendix 5. Data description and sources for all maps.

Map	Source
Salmonid Enhancement Facilities (continued)	
Website accessed to identfiy the locations of salmonid enhancement facilities in the Seton River Watershed and the species raised.	http://www.bchydro.com/bcrp/about/docs/ch11_final.pdf
Website accessed to identfiy the location of the salmonid enhancement facility in Burnaby and the species raised.	http://www.city.burnaby.bc.ca/cityhall/departments/engnrn/engnrn_whtshp/engnrn_whtshp_brnbyl/engnrn_whtshp_brnbyl_envassfish/engnrn_whtshp_brnbyl_envassfish_4.html
Website accessed to identfiy the location of the Fraser Valley Trout hatchery and the species raised.	http://www.gofishbc.com/fvh/default.htm
Website accessed to identfiy the location of the Dunn Creek Hatchery - Simpcw First Nations and the species raised.	http://www.pac.dfo-mpo.gc.ca/sep-pmvs/projects-projets/cedp-pdec/Dunn-eng.htm
Website accessed to identfiy the location of the Chilliwack River hatchery and the species raised.	http://www.pac.dfo-mpo.gc.ca/sep-pmvs/projects-projets/chilliwack/chilliwack-eng.htm
Website accessed to identfiy the location of the Fraser Valley Trout hatchery and the species raised.	http://www.pac.dfo-mpo.gc.ca/sep-pmvs/sci-icp/dir/coulterb_e.htm
Website accessed to identfiy the locations of community run salmonid enhancement projects and the species raised.	http://www.pac.dfo-mpo.gc.ca/sep-pmvs/sci-icp/dir/kambeitz_e.htm
Website accessed to identfiy the locations of the salmonid enhancement facilities in Southern B.C. and the species raised.	http://www.psf.ca/index.php?option=com_content&view=article&id=73&Itemid=127
Website accessed to identfiy the locations of the salmonid enhancement facilities in Prince George and the species raised.	http://www.scwa.bc.ca/
Website accessed to identfiy the locations of Pacific Salmon Hatcheries in British Columbia and the species raised.	http://www.sehab.org/pdf/hatcheries.pdf
Website accessed to identfiy the locations of the salmonid enhancement projects in Musqueam Creek.	http://www.thinksalmon.com/fswp_project/item/musqueam_creek_wild_salmon_habitat_stewardship_restoration_project_hydrolog/
Website accessed to identfiy the location of the salmonid enhancement facilities in Enderby and the species raised.	http://www.travel-british-columbia.com/thompson_okanagan/enderby.aspx
Website accessed to identfiy the locations of the salmonid enhancement facilities, spawning and rearing channels in the Lower Mainland.	http://www3.telus.net/driftwood/lmfish.htm
Permitted Effluent Permit Information	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)

Appendix 5. Data description and sources for all maps.

Map	Source
Spills	
Excel Sheet displaying the spills of 2007	Don Rodden, Supt. Environmental Response, Pacific Region, Coast Guard, Ph. 604-270-3273, don.rodden@dfo-mpo.gc.ca
Incident reports, displaying the causes, materials, amounts, and scenario of the spill.	Ministry of Environment DGIR Incident Reports for the year 2007, provided by Dave Levy via email.
Sawmills	
NPRI Database 1994 - 2008. Selected records where NA14Code_NAICS_E = Sawmills & Wood Preservations, Veneer, Plywood & Engineered Wood Product Mfg.	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
Permitted Effluent Permit Information	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)
Urban	
Baseline Thematic Mapping, from this file was pulled polygons related to the PLU_Label of Urban.	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?from=advancedsearch&edit=true&showall=showall&recordSet=ISO19115&recordUID=33711
NPRI Database 1994 - 2008, Utilized Transportation and Roadways	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.
TANTALIS - Municipalities in BC	https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=50339&recordSet=ISO19115
Volacnoes	
Natural Resources of Canada - Catalogue of Canadian Volcanoes	http://gsc.nrcan.gc.ca/volcanoes/cat/volcano_e.php
Listing of volcanoes in Canada, and links to further details regarding them.	http://en.wikipedia.org/wiki/List_of_volcanoes_in_Canada
Wood Preservation	
NPRI Database 1994 - 2008. Selected records where NA14Code_NAICS_E = Wood Preservation.	NPRI (National Pollutant Release Inventory) 1994 – 2008. 2010. Environment Canada. Database download available at http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=0EC58C98-1.

Appendix 5. Data description and sources for all maps.

Map	Source
Wood Preservation (continued)	
Website accessed to determine the principal products produced at Western Cleanwood Preservers Ltd.	http://www.directory51.com/profile/Western-Cleanwood-Preservers-Ltd-c3611.html
Website accessed to determine the principal products produced at Stella-Jones Inc. (New Westminster Plant).	http://www.stella-jones.com/pdf/notice/STE_AIF_2010_EN.pdf
Website accessed to determine the principal products produced at Western Pacific Wood Preservers Ltd.	http://www.pacificwood.com/product-information
Website accessed to determine the principal products produced at Envirofor Preservers (BC) Ltd.	http://www.taigaforest.com/products/pressure_treated/main.asp
Website accessed to determine the principal products produced at Terminal Forest Products (TFP).	http://www.terminalforest.com/
Website accessed to determine the principal products produced at Riverside Forest Products Ltd.	http://www.shopinkelowna.com/Riverside-Forest-Products-Ltd----Head-Office-/351414.htm
Website accessed to determine the principal products produced at Tolko Industries Ltd.	http://www.ic.gc.ca/app/ccc/srch/nvgt.do?sbPrtl=&prtl=1&estblmntNo=234567007660&profile=cmpltPrfl&profileId=1487&app=sold&lang=eng
Website accessed to determine the principal products produced at Decker Lake Forest Products Ltd.	http://www.hamptonaffiliates.com/subcontent.aspx?SecID=108
Website accessed to determine the principal products produced at Monte Lake Forest Products Inc.	http://www.montelakefp.com/environment.php
Website accessed to determine the principal products produced at Paxton Forest Products Inc.	http://www.montelakefp.com/paxton.php
Website accessed to determine the principal products produced at Canadian Forest Products Ltd.	http://www.canfor.com/products/wood/treatedlumber/default.asp
Website accessed to determine the principal products produced at Northwood Inc.	http://www.canfor.com/company/history.asp
Website accessed to determine the principal products produced at Northwest Wood Preservers.	http://www.bidgroup.ca/nwwp/
Website accessed to determine the principal products produced at Stella-Jones Inc. (Prince George Plant).	http://www.stella-jones.com/pdf/notice/STE_AIF_2010_EN.pdf

Appendix 5. Data description and sources for all maps.

Map	Source
Waste Water Treatment Plants	
Website accessed to determine the types of effluent treatment at the Whistler wastewater treatment plant.	http://www.waterandwastewater.com/plant_directory/Detailed/27.html
Permitted Effluent Permit Information	Ministry of Environment Land and Parks Permits (Emailed via Susan Woodbine)
Website accessed to determine the types of effluent treatment at the Blackburn wastewater treatment plant.	http://icsp.princegeorge.ca/ICSP%20Documents/Blackburn%20Wastewater.pdf
Provided information on Vanderhoofs wastewater treatment plant	Personal communication with Bruce Gaunt, Drinking Water Planner, Public Health Protection, Northern Health 4th Floor, 1600 3rd Ave., Prince George, BC V2L 3G6
Provided maximum allowable permit approved discharge limit for the City of Kamloops	Personal communication with David Paul Teasdale BASc., Certified Level IV WT, USS - Treatment Plants, City of Kamloops BC
Website accessed to determine the types of effluent treatment at the Salmon Arm wastewater treatment plant.	http://salmonarm.fileprosite.com/Documents/DocumentList.aspx?ID=3111
Provided information on the City of Lyttons wastewater treatment plant	Personal communication John MacDougall, City of Lytton, Public Works, lyttonpublicworks@hotmail.com
Provided information on Prince George's BCR Industrial site wastewater treatment plant	Personal communication with Coucillor Debora Munoz, City of Prince George
Effluent Permit information for Harrison Hot Springs, City of Abbotsford, Corix Utilities, Terasen Multi-Utility Services Inc.	Personal communication with Sisto Bosa, Environmental Protection Officer, BC Government
Provided information regarding the joine treatment plant with the local pulp mill in Quesnel	Personal communication with Chris Coben, Utilities Superintendent, City of Quesnel
Provided treatment type and discharge for the District of Hope's wastewater treatment plant	Personal communication with Allan Trick, Utilities Foreman, District of Hope
Provided information on the Regional District of Mulkley-Nechako's wastewater treatment facility.	Personal communication with Janine Dougall, Director of Environmental Services, Regional District of Bulkley-Nechako
Provided treatment type for the Village of McBride's wastewater treatment facility	Personal Communication with Eliana Clements, Chief Administrative Officer, Village of McBride
Provided hardcopy maps of where a selected group of wastewater treatment plants were, and associated information to those plants. (Merritt, Lillooet, Enderby)	Health of the Fraser River Aquatic Ecosystem, Colin Gray and Taina Tuominen, 1999 0162b
Description of the City of Merritt's Waste Water Treatment system	http://www.merritt.ca/siteengine/ActivePage.asp?PageID=96

Appendix 5. Data description and sources for all maps.

Map	Source
Basemap	
Outlined where the sockeye salmon presence is in the Fraser River Basin	FISS Sockeye Presence, FISS Sockeye points, FISS Sockeye Waterbody Polygons, FISS Sockeye Waterbody Points, from the Department of Fisheries and Oceans Canada at http://www.pac.dfo-mpo.gc.ca/gis-sig/themes-eng.htm
Watershed GIS file	GeoBC Geographic Data Discovery Service. 2010. Dataset download available at https://geobc.gov.bc.ca/.
Rivers of BC files	GeoBC Geographic Data Discovery Service. 2010. Dataset download available at https://geobc.gov.bc.ca/.