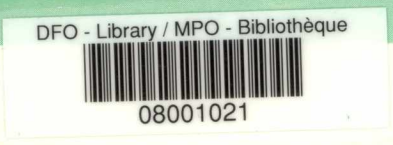




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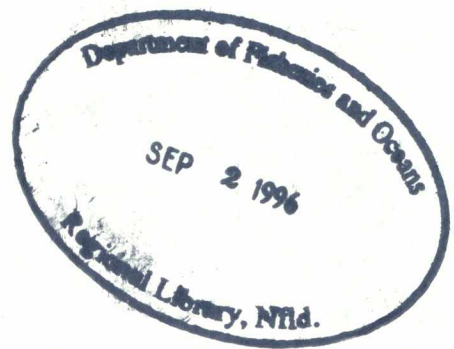


# Hydrology and Water Use for Salmon Streams in the Middle Fraser Habitat Management Area, British Columbia

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1995

HYDROLOGY AND WATER USE FOR SALMON STREAMS IN  
THE MIDDLE FRASER HABITAT MANAGEMENT AREA,  
BRITISH COLUMBIA

by

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## ABSTRACT

The Fraser River Action Plan (FRAP) is developing plans for environmentally sustainable salmon production in streams of the Fraser River watershed. This report focuses on the Middle Fraser Habitat Management Area (HMA). The HMA contains small tributaries of the Fraser River between Prince George and Hope. Hydrology and water use in nineteen salmon streams are discussed.

The Middle Fraser HMA covers a wide range of physiographic, geologic, and climatic conditions. Precipitation ranges from 300 to 2000 mm per year in various parts of the HMA. Stream flows are regulated either by rainfall or snowmelt. Most drainage basins are small and rise steeply to surrounding mountain ranges; mainstem streams and headwaters have steep gradients. Streams that drain the Coast Mountains tend to have flashy water regimes.

The hydrologic regimes and the effects of human development on the regimes are emphasized. Ten indices use hydrologic, water use, and land use data to rank habitat sensitivity of the streams. Some indices express the level of human activity. Some express the state of the stream and its ability to resist change. The most useful indices reflect summer water use, compare low and peak flows to mean flow, and indicate the extent of forest harvesting in the watersheds. The most sensitive streams are those that are most affected by human activity and those naturally sensitive to human impact.

The Middle Fraser HMA is relatively undeveloped. The impact of human activity is felt mainly in lower reaches of the streams. Urbanization and agriculture have little effect on hydrologic regimes of most streams. However, high water demand for agricultural use is a problem on Williams Lake River, Knife Creek, and Texas Creek. Summer flows are low on American, Squeah Lake, Emory, Gordon, Yale, Spuzzum, and Knife Creeks. Winter flows are low on American, Squeah Lake, Yale, and Spuzzum Creeks and Anderson and Williams Lake Rivers. Forest harvesting alters the natural hydrologic regimes significantly in several watersheds in the southern half of the HMA. Most logging has occurred in the last ten years, so there has been little time for significant forest regrowth. At present, Gordon and Utzlius Creeks have more than 20% of their watersheds cut. There are proposals to harvest large areas (5 to 10%) of the watersheds of Anderson River and its tributaries, and Churn, Gaspard, and Knife Creeks.

The report recommends improving stream flow measurements, monitoring and controlling water use, and developing water management plans for the most sensitive streams. It also recommends more detailed reviews of forest harvesting history in affected watersheds, further studies of the effects of forest regrowth on hydrologic regimes, and reorganization of five-year harvesting plans by watershed. This will allow more accurate prediction of the impact of harvesting on hydrology.

## RÉSUMÉ

Le Plan d'action pour le Fraser (FRAP) vise la production de saumon, dans une perspective de développement durable, dans les cours d'eau du bassin hydrographique du Fraser. Le présent rapport porte sur la zone de gestion de l'habitat (ZGH) du cours moyen du Fraser. La ZGH contient les petits affluents du Fraser qui se trouvent entre Prince George et Hope (C.-B.). Ce rapport examine l'hydrologie et l'utilisation de l'eau sur dix-neuf rivières à saumon.

La ZGH du cours moyen du Fraser couvre une vaste gamme de conditions géomorphologiques, géologiques et climatiques. Les précipitations se situent entre 300 et 2 000 mm par an selon les endroits. Les débits sont régis par les pluies ou par la fonte des neiges. La plupart des bassins ont une faible superficie, et leurs flancs escarpés s'élèvent vers les chaînes de montagnes environnantes; les cours d'eau principaux et les ruisseaux d'amont présentent de fortes pentes. Les cours d'eau qui drainent la chaîne Côtière ont en général un régime torrentiel.

Les travaux mettent l'accent sur les régimes hydrologiques et les effets de l'activité humaine sur ces régimes. Dix indices font appel aux données sur l'hydrologie, l'utilisation de l'eau et l'utilisation des terres pour classer les cours d'eau selon la vulnérabilité de leurs habitats. Certains indices expriment le niveau de l'activité humaine; d'autres indiquent l'état du cours d'eau et son aptitude à résister au changement. Les indices les plus utiles reflètent l'utilisation de l'eau en été, comparent les débits minimaux et maximaux au débit moyen, et indiquent l'ampleur de l'exploitation forestière dans les bassins versants. Les cours d'eau les plus vulnérables sont ceux qui sont les plus affectés par l'activité humaine et ceux qui sont naturellement sensibles à l'impact de cette activité.

La ZGH du cours moyen du Fraser est relativement peu développée. C'est surtout dans les tronçons inférieurs des cours d'eau que l'activité humaine se fait sentir. L'urbanisation et l'agriculture ont peu d'effet sur le régime hydrologique de la plupart des cours d'eau. Toutefois, la forte demande en eau à des fins agricoles pose un problème sur la rivière du lac Williams, au ruisseau Knife et au ruisseau Texas. Les débits d'été sont faibles sur le ruisseau American, le ruisseau du lac Squeah et les ruisseaux Emory, Gordon, Yale, Spuzzum et Knife. Les débits d'hiver sont faibles sur les ruisseaux American, du lac Squeah, Yale et Spuzzum, et sur les rivières Anderson et du lac Williams. L'exploitation forestière modifie de façon notable le régime hydrologique naturel dans plusieurs bassins de la moitié sud de la ZGH. La plus grande partie de cette exploitation a eu lieu dans les dix dernières années, période trop courte pour que la régénération de la forêt soit importante. À l'heure actuelle, dans les bassins des ruisseaux Gordon et Utzlius, plus de 20 % de la superficie a été coupée. Des projets prévoient d'exploiter des surfaces importantes (5 à 10 %) des bassins de la rivière Anderson et de ses affluents, et des ruisseaux Chum, Gaspard et Knife.

Le rapport recommande d'améliorer les mesures du débit, de surveiller et de régir l'utilisation de l'eau, et d'élaborer des plans de gestion de l'eau pour les cours d'eau les plus vulnérables. Il recommande aussi d'examiner plus en détail l'histoire de l'exploitation forestière dans les bassins touchés, de poursuivre les recherches concernant les effets de la régénération de la forêt sur le régime hydrologique, et de réorganiser les plans quinquennaux d'exploitation forestière par bassin. Ces mesures permettront de prédire plus précisément les impacts de l'exploitation forestière sur l'hydrologie.

## FOREWORD

This report was commissioned by the Fraser River Action Plan (FRAP). It contains hydrology and land use information that will be useful in reviewing salmon habitat quality and assessing habitat sensitivity.

The Hell's Gate landslide in 1913 decimated sockeye and pink stocks from the upper Fraser River. Habitat degradation and marine exploitation rates have affected some salmon stocks as well. Measures to rebuild salmon stocks began several decades ago, and the stocks have been rebuilding slowly. Stock rebuilding became a higher priority after the signing of the 1985 Canada-U.S.A. Pacific Salmon Treaty. Canada's Green Plan recognizes the importance of good habitat quality in rebuilding stocks. The Department of Fisheries and Oceans incorporated habitat considerations in the Fraser River Green Plan initiative in 1990. This program is now called the Fraser River Action Plan. One of its goals is developing and maintaining sustainable fisheries resources in the Fraser River Basin.

Under FRAP, the Department of Fisheries and Oceans is developing an integrated fisheries resource management plan for the entire Fraser River Basin. The plan provides direction to governments and stakeholders for conserving and restoring habitat and rebuilding salmon stocks. The basin was divided into fifteen Habitat Management Areas (HMAs), based on major river systems and salmon stocks. Within each HMA, the status of salmon habitat, stocks, and habitat restoration and protection priorities will be defined. This information will be used to establish a database and the framework for discussing sustainable development, to which Canada is committed.

Sustainable development is based on two principles: maintaining ecological diversity and maximizing the net economic benefits of the resource. Specific goals are incorporated into Habitat Management Plans and associated DFO decisions and activities. These goals are:

- 1) **Avoiding irreversible man-made changes to fish producing habitats.**  
Habitat alterations that reduce fish production capacity will be avoided if they cannot be reversed within one human generation.
- 2) **Maintaining the genetic diversity of fish stocks.**  
No fish stock will be written off arbitrarily, and small or remnant stocks will be conserved and rebuilt wherever possible.
- 3) **Maintaining the physical and biological diversity of fish habitats.**  
Habitat diversity encourages genetic diversity, alternate life history strategies, and the capacity to survive natural variation in environmental conditions.
- 4) **Providing a net gain in the productive capacity by habitat management.**  
Natural and self-sustaining methods of increasing productive capacity are preferred to those that require human intervention and maintenance.
- 5) **Maximizing the value of commercial, sport, and aboriginal fisheries.**  
Competing uses of the fisheries resources will be quantified by considering tangible and intangible market and extra-market values.
- 6) **Maximizing the non-consumptive values of fishery resources.**

Intangible and cultural values of the fishery resources will be considered when allocating fishery resources.

- 7) **Distributing fishery net benefits in a fair and equitable manner.**  
Local communities should help make decisions about habitat conservation and restoration, stock enhancement, distribution of benefits, and cost-sharing arrangements.

This report is intended to contribute to effective land use planning. In turn, this should protect and manage aquatic habitat successfully and result in sustainable development.

# **1. INTRODUCTION**

## **1.1 Purpose of the Study**

The Fraser River Action Plan, of the Department of Fisheries and Oceans, is developing plans for environmentally sustainable salmon production. Planning is based on fifteen sub-basins -- called Habitat Management Areas (HMA) -- of the Fraser River watershed (Figure 1). This report focuses on the Middle Fraser HMA which includes tributaries to the Fraser River between Prince George and Hope (Figure 2) and covers a broad range of climate and topography.

An understanding of the hydrologic regime of the salmon streams is one important aspect of habitat management planning and our report describes both the regime in the salmon streams and the effect of human development on that regime. Within the Middle Fraser HMA, storage and extraction of flows from surface water for agricultural, municipal or industrial purposes and forest harvesting impacts on floods and low flows are the main hydrologic issues.

The main objective of the report is to express the habitat sensitivity of the salmon streams through various indices that are calculated from the hydrologic, water use and land use data collected for the streams. In this report, we use "sensitivity", in a very broad sense, to refer to the state of those aspects of the hydrologic regime that affect habitat and are altered by human activities. The indices are used to rank the streams within the HMA. The most sensitive streams are those that are most affected by human activities and those that, because of their geomorphic or hydrologic regime, have the least ability to resist human impact.

## **1.2 Scope of the Study**

Our study examines 19 known and presently utilized salmon streams within the Middle Fraser HMA that are listed in SSIS (the Federal/Provincial Stream Information Summary System; Table 1) plus some other streams included for an analysis of timber harvest. Salmon streams in the far north of the HMA, Narcosli and Baker Creeks, were included in a previous report on the West Road Habitat Management Area (NHC and Mr. Roy Hamilton 1992). Note also that Kopp and Menz Creeks have been reversed from SISS in order to correspond with Water Rights Branch maps.

Our analysis is based on information compiled by the Water Survey of Canada, the Ministry of Environment, Lands and Parks and the municipalities and interviews with staff of the various federal and provincial government departments and agencies. Information available prior to 1994 has been summarized in this report. The following tasks were completed during our study:

- 1. Summarize and describe those aspects of the climate, physiography, surficial geology and soils that affect the hydrology of the salmon streams;**
- 2. Describe the local hydrologic regime and prepare estimates of mean annual flows, mean annual floods, mean monthly flows and seasonal 7 day low flows for each of the salmon streams from Water Survey of Canada records, Water Management Branch records or from regional analysis for ungauged streams;**

3. Use Water Rights Branch records to calculate potential licensed demand on surface waters in each of the salmon streams;
4. Review the impact of forest harvesting on hydrology and determine the portion of the watersheds of the salmon streams that are harvested;
5. Use the hydrologic, water use and land use data to calculate sensitivity indices and rank, or prioritize the various salmon streams according to water withdrawals, high flows, low flows and forest harvesting.
6. Summarize the main issues for the salmon streams and discuss technical or management alternatives based on interviews and discussions with government personnel.

The main task was calculating flow characteristics for the 19 salmon streams. The quality of information varied greatly from stream to stream and our method estimated flow characteristics so that streams within the study area could be compared and ranked. The estimated flows are not necessarily the best estimate for any individual stream and should not be used for design of structures or evaluation of projects without further, detailed study of that particular stream.

### **1.3 Organization of the Report**

The report describes each task separately and presents the overall results of the study in the final chapter. Chapter 2 describes the characteristics of the study area; Chapter 3, the methods used to estimate flow characteristics; Chapter 4, the effect of land use on hydrology and the measurement of the effects of development; and Chapter 5, the calculation of licensed demand for surface flows. Table 7 summarizes the data for these investigations for each of the salmon streams.

The sensitivity indices are described in Chapter 6. Table 9 presents the calculated indices that express the sensitivity of each of the salmon streams and Table 10 summarizes the most sensitive streams. Chapter 7 discusses the individual streams in detail and Chapter 8 describes technical and management recommendations for the Habitat Management Area.

### **1.4 Acknowledgements**

Funding for this study was provided by the federal Department of Fisheries and Oceans through the Fraser River Action Plan, a Green Plan Initiative. A number of individuals provided an overall perspective on land and water use and hydrology, as well as information on the salmon streams. We would like to thank Paul Doyle, Ian McGregor and Ron Smith of the Kamloops Office of the Ministry of Environment, Lands and Parks; Ken Soneff, Greg Ashcroft, Marcel Demers and Jack Leggat of the Williams Lake Office of the Ministry of Environment; Robert Edwards, Neil Peters and Peter Caverhill of the Surrey Office of the Ministry of Environment; and Bruce Mac Donald, Pat Harvey, Gordon Kosakoski, Matt Foy and John Patterson of the Department of Fisheries and Oceans. Final preparation of the report for publication was made by Karen Munro.

## 2. THE MIDDLE FRASER HABITAT MANAGEMENT AREA

Physiography and geology act to influence the behaviour of soil and water within the study area and, consequently, the hydrologic characteristics of the salmon streams. Terrain and surficial deposits help determine storm runoff characteristics, infiltration rates, and the susceptibility of stream channels to erosion. Subsurface geologic materials influence the recharge, movement and re-emergence of ground water.

Climate, in combination with physiography and geology, can be used to define broad regions of similar hydrologic behaviour. As is discussed in the following sections, the salmon streams of the Middle Fraser HMA lie within four physiographic regions and also within three ecoregions and seven ecosections (Table 2). The ecosections and physiographic regions correspond fairly well, though the following discussion of physiography and climate is based on the ecosections, which provide the best regionalization of hydrology and climate.

### 2.1 Physiography

The Middle Fraser HMA includes those small tributaries to the Fraser River lying between Hope and Prince George. The largest watershed is of the Williams Lake River with an area of 2,240 km<sup>2</sup> but most of the watersheds have drainage areas of less than 1,000 km<sup>2</sup>. The southern part of the HMA, downstream of Churn Creek, is long and narrow (Figure 3). Elevations in the watersheds rise rapidly from the Fraser River to their divide in the Coast or Cascade Mountains and the main stem streams are often steep.

Within the southern part of the HMA, the Fraser River flows along a major fault system (Fraser River Fault Zone) that separates the Coast Mountains to the west from the Cascade Mountains and the Clear Ranges of the Interior Plateau; and the Camelsfoot Ranges from the Marble Ranges (Figure 3). The Fraser Valley is deep and narrow, though along part of the valley benches of glacial drift and non-glacial sediments are found up to several hundred metres above the river level. There are also wide sections of valley, such as at Lillooet where there are thick deposits of glacial and post-glacial sediments (Ryder and Church 1986).

The Coast Mountains are mostly underlain by granodiorite and quartz diorite. Peaks are highest along the divide between the Stein River and Kwoiek Creek, reaching about 2,900 m. Peak elevations decline to the south, with maximum elevations of around 2,000 m near American and Emory Creeks. Active glaciers and ice-fields are mostly concentrated along the divide between Kwoiek Creek and the Nahatlach River, with drainage to the Kwoiek River.

The Hozameen Ranges of the Cascade Mountains extend northwards along the eastern side of the Fraser River to Lytton. These mountains are underlain by metamorphosed volcanic and sedimentary rocks that have been intruded by granitic batholiths. Maximum elevations are reasonably consistent at around 2,200 to 2,500 m and, at these elevations, peaks show the effects of alpine glaciation with serrate appearance and cirque basins. These mountains were intensely glaciated during the Pleistocene, with maximum ice elevations of around 2,000 m, though there are no active glaciers now.

The Chilcotin Ranges are an eastern subdivision of the Coast Mountains composed largely of sedimentary and volcanic rocks. The Yalakom River, which flows along the Yalakom Fault, separates the Camelsfoot and Chilcotin Ranges. The highest peaks in the Chilcotin Ranges are

about 2,800 m in the upper Yalakom. Higher peaks, such as Big Dog Mountain and Shulaps Peak are serrate in form; lower peaks were rounded by glaciation. Ice reached maximum elevations of about 2,400 m during the most recent advance. None of the salmon streams lie in the Clear or Marble Ranges and they are not described.

Upstream of Churn Creek the Fraser River crosses the Fraser Plateau and the Fraser Basin. Both Williams Lake River and Knife Creek lie in the Basin, and the lower reaches of Churn and Gaspard Creeks are on the Plateau. The Fraser Plateau is a flat to gently-rolling, drift-covered surface at elevations of around 1,200 to 1,500 m. Thick accumulations of glacial drift overlie volcanic bedrock and the drift has been formed into drumlin-like shapes that provide much of the relief on the Plateau. The Fraser Basin is a low-relief surface lying below the general elevation of the plateau, with elevations typically around 900 m. It is also drift-covered and drainage is often poorly-organized with numerous small lakes.

## **2.2 Surficial Geology**

There has been very little work on the Quaternary Geology of the Middle Fraser region by the Geological Survey of Canada or the B.C. Department of Mines. Ryder (1976 and 1981) and Ryder and Church (1986) describe surficial-geology and quaternary history along the Fraser River Valley in the vicinity of Lytton and Lillooet. Piteau (1977) summarizes the engineering geology of the Fraser Canyon and the lower reaches of some salmon streams.

## **2.3 Climate**

There is a broad range of climate and hydrologic regions within the Middle Fraser HMA, ranging from the very dry Interior-type climate near Williams Lake to the the Cordilleran climate near Hope that is affected by both continental and modified maritime conditions. In both the Interior Transition Region and the Eastern Pacific Ranges, in winter, Pacific storms cross the Coast Mountains transporting maritime moisture into the upper watersheds of the salmon streams and producing thick snowpacks and occasional intense fall rainstorms. In the summer, cold low pressure systems entering from the west interact with warm continental air producing very intense but short duration, rainstorms (B.C. Hydro 1986).

There is considerable variation of precipitation from west to east and north to south across the HMA. In the upper watersheds near the Coast Mountains there are thick forests where annual precipitation may be around 2,000 mm. On the east side of the mountains, in the bottom of the Fraser Valley, temperatures rise, and annual precipitation decreases to around 300 to 400 mm (Table 3). Precipitation increases again in the Cascade Mountains but only to about 1,000 mm. Precipitation also declines to the north, and at Williams Lake, it is approximately 400 mm.

Table 4 describes the hydrologic regions associated with the various ecoregions and eco-sections. Examination of Tables 3 and 4 (and regional hydrology studies: Rood 1988) suggests that there are four distinct hydrologic regions in the HMA: the Fraser Basin and Plateau regions, a region including the Central Chilcotin Ranges and part of the Southern Chilcotin Ranges, a region including the Leeward Pacific Ranges and part of the Southern Chilcotin Ranges, and the Eastern Pacific Ranges. These are discussed below.

### 2.3.1 Climate of the Ecoregions

**Fraser Basin:** Mean annual temperature is about 5°C in the valley at Williams Lake. January is by far the coldest month with mean temperatures of -10.2°C and extreme minimum temperatures of about -40°C. July is the warmest month with mean temperatures of 15°C and extreme maximum temperatures of about 36°C. Annual normal precipitation is near 400 mm and is reasonably evenly distributed throughout the year, with about half of the precipitation falling from May through September (Table 3). December also receives moderate precipitation totals and the least precipitation is recorded in January, March and April.

About 30% of the total falls as snow at Williams Lake although the percentage increases with elevation, to about 50% at the airport. Snow accumulates through to April or May and snowmelt is the main source of streamflow.

Rain falls throughout the year but is less common in the winter months. Normal monthly totals are reasonably constant from June through August at about 40 mm and about 50% of the annual rainfall occurs from May through September. June through August also have high evapotranspiration demand and little of the rainfall replenishes groundwater or contributes to streamflow.

Annual runoff is about 50 mm. The annual flood results from snowmelt in the spring and in larger watersheds the maximum annual flows occur in May and June. About 50% of the annual runoff occurs in May, June and July, though storage and release of water affect the pattern on most streams. Maximum daily rainfalls are around 50 mm, and the annual maximum discharge sometimes occurs in the fall in small basins in response to these rainstorms.

Annual minimum flows typically occur in July and August though regulation of flow may produce low flows later in the fall. In some years, minimum flows occur under ice cover, between December and April.

**Southern Chilcotin Ranges:** Mean annual temperature is around 9°C in the valley bottom at Lillooet. January is by far the coldest month with mean temperatures of -5.6°C and extreme minimum temperatures of about -26°C. July is the warmest month with mean temperatures of 21°C and extreme maximum temperatures of about 40°C.

Annual normal precipitation in the Fraser Valley ranges from 300 to 400 mm but this increases inland to 600 mm or so. Precipitation is reasonably evenly distributed throughout the year, with the greatest amount from November through January and the least amount in May and July. About 17% of the total falls as snow at Lillooet but the portion falling as snow increases inland, and with elevation, to about 40% at Bralorne. The greatest monthly snowfall totals generally occur in December and January. Snow accumulates through to April or May and snowmelt is the main source of streamflow.

Rain falls throughout the year but is less common in the winter months. Normal monthly totals are reasonably constant from June through September at about 20 mm, and about 30% of the annual rainfall occurs from May through September. June through September also have high evapotranspiration demand thus little of the rainfall replenishes groundwater or contributes to streamflow.

Annual runoff is about 200 mm. This seems to be quite variable with much lower annual runoff from the Camelsfoot Ranges and slightly higher runoff from the Chilcotin Ranges. The annual flood results from snowmelt in the spring, and in larger watersheds the maximum annual flows occur in May and June. About 50% of the annual runoff occurs in May, June and July. A maximum daily rainfall of 114 mm was recorded at Lillooet in June, and maximums near 70 mm have been recorded at Bralorne in July and September. These intense summer storms, which occur infrequently, may produce flooding after the snowmelt season.

Annual minimum flows typically occur under ice cover, between December and April, though in dry summers minimum discharges in small watersheds may occur instead in July, August or September. In larger watersheds, the minimum discharge nearly always occurs in the winter.

**Pacific Leeward Ranges:** The Pemberton climate stations (which lie to the west of the Pacific Leeward Ranges) seem most representative of the Leeward Ranges. Mean annual temperatures at these valley-bottom stations are similar to Lillooet. Winter temperatures are slightly warmer than Lillooet and summer temperatures are cooler. Annual normal precipitation is around 1,100 mm, with about 25% of the total falling as snow. The portion falling as snow increases substantially with elevation, as does total precipitation, and snowcourses in the upper Bridge and Seton watersheds (McGillivray Pass and Mission Ridge) have normal maximum water equivalents of around 1,000 mm.

Much of the precipitation falls in the winter, as rain at lower elevations and snow at higher elevations. Minimum monthly totals occur in July and less than 20% of the total precipitation falls from May through September. These months also have the highest evapotranspiration demand thus little of the rainfall at lower elevations replenishes groundwater or contributes to streamflow.

The annual flood results from snowmelt and about 64% of the annual runoff in the Upper Bridge River is recorded from May through July (B.C. Hydro 1986). Rainstorms that cross the Coast Mountains occasionally produce large floods in August through October, and the flood of record to Downton Reservoir occurred in October 1984.

Monthly flows typically decline rapidly after August, reaching a minimum in February. Annual minimum discharges occur under ice-cover, from December through March.

**Eastern Pacific Ranges:** Mean annual temperature is around 9°C in the valley of the Fraser River, decreasing to about 1.8°C at the elevation of Allison Pass. January is by far the coldest month with mean temperatures of -2.6°C and extreme minimum temperatures of around -25°C. July is the warmest month with mean temperatures of 18 to 20°C and extreme maximum temperatures of around 40°C.

Annual normal precipitation ranges from 1,200 mm at Hells Gate to up to 1,700 mm at Hope. The greatest totals are from October through March, and July receives the least precipitation. Only about 20% of the annual precipitation falls from May through September (Table 3). About 20% of the total falls as snow in the bottom of the Fraser Valley though this increases to 93% at Allison Pass, at an elevation of 1,300 m. The greatest monthly snowfall totals generally occur in December and January and snowpacks of 1,300 m typically accumulate at these elevations. Snow accumulates through to early May and snowmelt is the main source of streamflow.

Rain falls throughout the year at low and mid-elevations and accumulation and melt of shallow snowpacks contributes to winter flooding. Annual runoff is around 1,200 mm. In most years, the

annual flood results from snowmelt in the spring though the largest floods result from fall rainstorms and rain on snow when Pacific storms spillover the Coast Mountains. These typically occur in October and November, and the largest floods are generated by a period of cold weather and snow accumulation, followed by a rapid rise in freezing levels accompanying intense precipitation.

Annual minimum flows typically occur under ice cover, between December and April, though in dry summers minimum discharges in small watersheds may occur instead in July, August or September. In larger watersheds, the minimum discharge nearly always occurs in the winter.

### **2.3.2 Temporal Variation in Climate**

Long-term climate records are available at a number of stations in the Middle Fraser HMA (Figure 4). Most records show little evidence of trends in temperature or precipitation though both temperature and precipitation apparently increased at Hope during the 1980's. This is an artifact, in part, of re-locating the climate station. Moore (1991) reviewed records at stations north and south of the Middle Fraser HMA and concluded that annual precipitation had remained roughly constant but that a lower portion of the precipitation had fallen as snow since the mid-1970's. There was also an increase in temperature at these stations since the mid-1970's. There has been no comparable analysis of snow fall and accumulation at higher elevations in the Middle Fraser HMA but snow course data at Nahatlach River (1,520 m) shows below-normal accumulation throughout most of the 1980's (Ministry of Environment 1992).

### **2.3.3 Global Warming and Climate Change**

Levy (1992) discusses potential climate changes resulting from global warming and the potential impacts on the hydrologic regimes and salmon production in the Fraser Watershed. The general circulation models used to predict climate changes provide different results and are not intended for regional evaluation of climate change. If global warming occurs, higher winter streamflows may result from an increase in winter precipitation and a decrease in the portion of this precipitation falling as snow. The snowmelt freshet may also occur earlier and summer flows may be lower.

Air temperatures will also increase as a result of global warming. Average stream and groundwater temperatures will increase, following the general pattern for air temperature increases. Increased air temperatures will increase potential evapotranspiration and soil water deficits. While there may only be a small effect on stream discharges from warmer temperatures, increased water demand may be a major factor affecting summer flows.

## **2.4 Groundwater Resources**

The City of Williams Lake has three wells on Scout Island (Atwater *et al* 1994). These wells are at depths of 40 to 60 m in a gravel aquifer overlain by compact silts and sands and have total capacity of around 200 L/s. Withdrawals from these wells may affect flows in the Williams Lake River though this possibility has not been studied. There are no studies of groundwater resources near other salmon streams of the Middle Fraser HMA. However, it is expected that most wells are of low capacity and used for domestic purposes or stock watering.

Groundwater reservoirs (or aquifers) recharge during fall rains and spring snowmelt when vegetation is dormant and evapotranspiration is at a minimum. They discharge during the summer when recharge is small, because precipitation is at a minimum and evapotranspiration consumes much of the rainfall.

It is likely that low flows in many small tributaries are maintained by groundwater discharge during the late summer and early fall and that glacio-fluvial and alluvial fan deposits, particularly those in the bottom of major valleys, may be important sources of groundwater. However, this possibility has not been studied in detail.

## **2.5 Stream Pattern and Hydrology**

Many of the streams have an alluvial fan at their junction with the Fraser River, and gradients are often moderately steep on these fans; for instance, the Coquihalla River has a gradient of 5% through the Town of Hope (Northwest Hydraulic Consultants Ltd 1994) and many of the other streams in the southern part of the HMA are also steep on their fans. Above their fans, the mainstem salmon streams are often very steep or they may flow through a narrow, steep bedrock notch (if they join the Fraser River at grade as does the Anderson River) with near vertical walls that rise a hundred metres or so. Upstream of these steep reaches, the salmon streams often enter a "hanging valley", where gradients are less. The upper courses of the streams are often very steep.

The hydraulic conditions at the mouth of the salmon streams vary greatly over the course of the year in response to the rise of water levels in the Fraser River. Increases in Fraser River levels of up to 8 or 10 m often "drown out" a portion of the lower reaches of the salmon streams. As Fraser River levels drop in the fall, flows are again concentrated in the channel of the salmon stream and fall storms mobilize bed material on the fan and re-shape the channel.

## **2.6 Stream Stability**

From the point of view of habitat management, a stable channel is one that maintains its physical characteristics: it is not eroding, incising (downcutting), widening, straightening, narrowing or aggrading. Stream channels become unstable for a variety of reasons, some of which are due to human activity. For instance, forest harvesting may increase flood flows in streams which, in turn, may cause downcutting, widening and bank and valley wall erosion. Channels may also become unstable because of natural events, such as extreme rainstorms, or on-going channel adjustments related to slope or sediment load.

The stream response to these external factors is affected by channel slope, the size of bed material, the nature of material underlying the channel and channel pattern. In some instances, there may be no immediate response, while in other case, it may be immediate and dramatic. Consequently, it is often difficult to ascertain a particular cause for a particular channel response or particular instability.

The typical salmon stream in the Middle Fraser HMA starts in a steep upland area where the channel is steep and contained in a gully or narrow valley. Sediment is provided to the channel by snow avalanches, and debris slides and flows from valley walls, glacial erosion and stream erosion of valley walls and channel banks. Channel widening and downcutting are the most

likely channel responses to disturbance in these reaches though in bedrock floored canyons little channel adjustment may occur.

The lower reaches of the salmon streams are often flow on their fan. Many of the salmon streams wander in these reaches and bank erosion and channel instability are common, particularly where there is supply of coarse debris from upstream reaches. These reaches are often steep and floored with large bed material. Channel reaches immediately downstream of lakes are often very stable as floods are regulated by lake storage, there is no supply of sediment and the bed material is winnowed to a stable pavement.

Table 5 summarizes reported channel response to disturbance and the kinds of human modification to the channels which are discussed in Sections 7 and 8. Channel response includes channel pattern change (avulsion or channel shifts), bank and valley wall erosion, incision or downcutting, aggradation or channel filling, and bed material changes such as sedimentation and scour. Human modifications include dyking (for flood control), river training (including bank protection, diversions, revetments, spurs or other structures), channel encroachment (by land filling or by narrow dykes), gravel removal (dredging, bar scalping or deepening of the main channel), removal of riparian vegetation and removal of large organic debris. In the Middle Fraser HMA, which is relatively undeveloped, most human interference is in the lower reaches of the streams.

The table is not comprehensive because some channel responses, such as slow downcutting, cannot be identified without detailed measurements. Also, the assessments which are based on interviews, reports and limited field visits, may be inaccurate, out-of-date or may reflect only a site-specific situation.



### 3. CALCULATING FLOW CHARACTERISTICS FOR THE SALMON STREAMS

The following average flow characteristic were estimated for the mouth of each salmon stream (see Table 6 for definitions):

- **Mean Annual Flow**, expresses the total yield of water from the drainage basin and is useful for reservoir design;
- **Mean Annual Flood**, when combined with channel slope, is related to the potential for scour of gravel in the stream during incubation and the potential for channel erosion and enlargement. Peak flows at greater return periods are used for design of instream structures;
- **Mean Monthly flow** for August and September express the average flow of water available during the driest portion of the summer rearing season and during the peak removals for summer irrigation. Low flows in these months reduce rearing habitat, strand juveniles and are associated with high temperatures that reduce habitat quality. Mean monthly flow in February express the average flow of water available during the driest portion of the incubation period. Low flows in this month affect incubating eggs through freezing in de-watered or exposed redds;
- **Seasonal 7 day low flows** for the summer express the minimum flows during the summer rearing season and are used for fish habitat evaluations, calculating water allocations and water quality prescriptions. The 7 day low flows for the winter express the average minimum flow experienced during the winter and are associated with de-watering of redds.

The quality and availability of flow records ranges widely for the salmon streams in the Middle Fraser HMA. Some streams have long-term gauging records at stations that continue to operate, many streams have short-term or seasonal records of moderate quality from the early part of the century, while some streams have little or no information available. The average flow characteristics in the above list, as well as other characteristics, can be reliably estimated for salmon streams with long-term discharge records. Less reliable estimates can be prepared for streams with limited records and the least reliable estimates are for streams with no records.

#### 3.1 Reference Point for Flow Characteristics

All flow characteristics, as well as water licence summaries, were prepared for the mouth of each stream as this was a representative and easily-identified point. Flows at the mouth are representative of the length of the lower reaches of the stream downstream of any major tributaries. If a major tributary enters near the mouth the calculated flow characteristics only represent a limited reach of the lower stream, downstream of its entrance.

The Water Survey of Canada report their data for a specific point on the stream which may be near the mouth of the stream, or a considerable distance upstream. The sites are generally selected for accessibility and for their suitability as gauging sites, rather than other criteria. When the gauging site is near the mouth of the stream we have assumed that the recorded flows also describe flows at the mouth. However, if a major tributary enters between the gauge and the mouth, or if the gauge is well upstream of the mouth, the flows recorded at the gauge were

adjusted to obtain flow characteristics at the mouth either by adding measured tributaries flows or by increasing flows based on the ratio of drainage areas at the mouth and at the gauge (Appendix A).

On ungauged streams, flow characteristics were calculated for the drainage area to the mouth of the stream.

### **3.2 Period of Record for Calculating Flow Characteristics**

In much of British Columbia, there is a consistent pattern of declining annual flows in the late 1940's and 1950's, above average annual flows in the 1960's and 1970's (Barrett 1979) and below average annual flows during the 1980's. Mean annual flows, as well as other flow characteristics, vary from decade to decade. Consequently, it is important when comparing records at different stations to limit flow data to a common period, so that variation between gauges reflects the character of the particular station rather than differences in the period of record.

We have adopted the most recent decade, 1981-90 (inclusive), as our standard period for analysis. In the Middle Fraser HMA, this decade has lower mean annual discharges than were recorded in the 1950's, 1960's or 1970s.

### **3.3 Hydrometric Data in the Middle Fraser HMA**

The Water Survey of Canada is the prime agency collecting and reporting flow data in British Columbia. Gauging stations in the Middle Fraser HMA are described in *Surface Water Data Reference Index: Canada 1991*, published by Environment Canada. A number of these stations are on the salmon streams (Table 1; Figure 3) and 13 of the salmon streams have had at least one operating gauging station. However, only two salmon streams (Coquihalla and Williams Lake Rivers) have nearly complete gauging records from 1981 to 1990 at stations near their mouths. It is on these streams that flow characteristics may be calculated directly from Water Survey of Canada records. These calculations are discussed in Section 3.5.

The other salmon streams typically have either: 1) partial records between 1981 and 1990, 2) partial or complete records from earlier decades, such as the 1910's or 1920's, or 3) no records from the Water Survey of Canada (Table 1). Procedures for estimating flows on these streams are discussed in Section 3.6 and Appendix A.

There are also gauging stations on streams that are not within the boundaries of the study area or are not salmon streams. Where these stations provide useful information on the hydrologic characteristics of watersheds in the Middle Fraser HMA they are used in estimating flow characteristics (Appendix A).

### **3.4 Other Sources of Hydrometric Data**

The Water Management Branch (WMB) of the Ministry of Environment, Lands and Parks operates some gauging stations whose data are reported by the Water Survey of Canada. The WMB also collects miscellaneous measurements to establish flows for approving licensed

extractions, and carries out occasional (regional) data collection programs during droughts. None of the drought measurement programs include salmon streams in the Middle Fraser HMA (Richards 1977; Nyhof 1985; Nyhof 1987).

### **3.5 Gauged Salmon Streams**

The gauged salmon streams are those whose flow characteristics can be calculated directly from Water Survey of Canada records. (Gauges on the salmon streams are shown in Table 7.) Table 6 provides definitions of the flow characteristics used in this report and more detailed descriptions follow in Sections 3.5.1 and 3.5.2.

The gauging stations on the salmon streams either measure natural flows or regulated flows, where regulated flows are those affected by upstream storage or water extractions. **Natural flows** – those that occur in the absence of all regulation or extraction -- are best-suited for the sensitivity indices so that licensed extractions can be expressed as a percentage of the total available flow, rather than measured flow.

#### **3.5.1 Water Extractions and Flow Characteristics**

For streams whose regulation consists of water extractions, the flow characteristics calculated from records were adjusted to represent the natural regime in the stream by adding potential water extractions, as calculated from summaries of water licences, to the flow recorded at the gauge (Figure 5). We have referred to these adjusted flows as **naturalized flows** to distinguish them from measurements of the natural regime.

This approach provides a reasonable estimate of the natural flows in the Middle Fraser HMA because developed storage in most watersheds consists of small, independently-operated reservoirs, because total storage is small in comparison to irrigation requirements and because licensed demand is often low in comparison to flows. In these circumstances, it is reasonable to ignore the contribution of storage to low flows, and naturalized flows may be assumed to represent the natural regime. The naturalized flows are close to the natural flows, but are expected to over-estimate these flows, because of differences between actual and licensed water use upstream of the gauge, flow enhancement by releases from small storage projects and return flows from irrigation diversions. The degree of over-estimation is small for the gauged streams and can be evaluated by comparing storage volumes to irrigation demand and to typical flows in August and September on the salmon streams. Note also that well extractions, which are not licensed, may reduce low flows in some streams.

#### **3.5.2 Storage and Flow Characteristics**

There are no large reservoirs though storage has been developed on lakes in Gaspard, Williams Lake River and Knife Creeks in the northern, drier part of the Middle Fraser HMA. Conservation storage has been developed within the Williams Lake watershed.

Flow recorded at the Water Survey of Canada gauge on Williams Lake River were not adjusted for the effect of storage because there is not enough data to calculate the natural regime.

### 3.5.3 Annual Flow Characteristics

The historic period for the **mean annual flow** is 1981 to 1990, inclusive (see Table 6 for definitions). The historic period for the **mean annual flood** is 1981 to 1990, inclusive. Mean annual flow on Williams Lake River was adjusted for the effect of water extraction (which are a large portion of annual flows) but not adjusted for upstream storage, because of the lack of information on reservoir volumes and release patterns (Section 3.5.1).

### 3.5.4 Seasonal Flow Characteristics

The water year was divided into two seasons: summer (May 1 to October 31) and winter (November 1 to April 30). This division was selected to include all irrigation within one season and separate low flows into two distinct seasons corresponding to different parts of the salmon life cycle. Summer low flows are affected by storage and release of water, irrigation diversion and domestic and waterworks withdrawals. Low flows in the summer reduce rearing habitat, strand juveniles and are associated with high water temperatures.

Winter low flows are only affected by storage and release of water (in a few circumstances) and domestic and waterworks withdrawals. Low flows in the winter affect incubating eggs by de-watering redds and exposing salmon eggs to desiccation and freezing.

Table 7 reports mean August and September flows for the gauged streams. Measured flows were adjusted to naturalized flows by adding potential licensed demands for each month, following the procedures discussed above.

**Summer and winter 7 day low flows** were extracted from Water Survey of Canada records, covering 1981 to 1990, and mean seasonal seven-day low flows calculated as an average of all observations. The mean low flows do not necessarily correspond with the two-year return seven-day low flows. This is because the mean low flow is affected by extreme seven-day low flows occurring within the period of record.

Where necessary, summer 7 day low flows were naturalized by adding the calculated potential demand for September, as these flows typically occur in September. This is a crude adjustment as low flows may occur during periods of limited or no irrigation and the adjustment will over-estimate the natural flows that would occur. Winter 7 day low flows were not adjusted in any fashion.

## 3.6 Gauging Records on the Stream Summary Sheets

The flows recorded at gauging stations on the salmon streams are of interest for more than establishing average flow characteristics at their mouths. The gauging records permit calculation of detailed flow characteristics such as mean annual hydrographs, monthly distributions of annual 7 day low flows, and 7 day low flow frequency curves. These flow characteristics are based on all available, complete years of data at the gauge sites, rather than 1981-90 -- in order

to best estimate the flow characteristics at the gauge -- and are not naturalized because of the difficulty of adjusting flows for each year.

All data are included on the Stream Summary sheets attached as Appendix B. The mean annual hydrographs are calculated from all available complete, continuous years of record at the gauge. All years were used because these gave the best representation of the annual pattern of flow.

The distribution, by month, of the annual 7 day low flows, is based on all complete years of record at the gauge. 7 day low flow frequency curves for these records are also included on the Summary Sheets.

Floods with various return periods were calculated from the annual daily maximum flows with the CFA-88 program, prepared by the Water Survey of Canada, as adapted for micro-computers. Floods of 2, 10, 20, 50 and 100 year return periods are reported in Appendix B.

### **3.7 Ungauged Salmon Streams**

The ungauged salmon streams include all those streams where average flow characteristics for 1981 to 1990 must be estimated rather than calculated from Water Survey of Canada records. A variety of techniques were used to estimate the flows which are discussed in Appendix A.

Flows were estimated for the ungauged streams by transferring measured flows from nearby, similar streams, by adjusting incomplete records on the individual stream or by regional equations that relate flows to basin characteristics. Mean annual flows, mean annual floods, mean monthly flows and mean summer and winter 7 day low flows are estimates of values appropriate for 1981 to 1990.



#### **4. LAND USE**

The natural hydrologic regime of the salmon streams in the Middle Fraser HMA has been altered, to some extent, by land use. Urbanization, agriculture and forest harvesting have the potential to alter the hydrologic regime. Agriculture affects the hydrologic regime by extracting surface and ground water for stock watering, domestic use and irrigation and, in this HMA, it also causes a minor increase in flood discharge in a few salmon streams, through conversion of forest lands. Urbanization primarily affects the hydrologic regime through extractions for waterworks. In the Middle Fraser HMA, urbanization has not had a significant effect on flood discharges in the salmon streams. Agriculture often occupies only a small part of the lower elevations of the watersheds and does not greatly affect hydrology except through surface water extractions. These are discussed in Section 5, "Water Licences".

The removal of timber during forest harvesting (or agricultural land clearing) alters transpiration and the distribution of snow and may often increase rates of melt. These changes in the watershed, coupled with road construction and soil modifications tend to increase water yield (mean annual flow), mean annual floods and summer base flows.

There are secondary effects on stream channels associated with increased flood flows. In suitable materials, channels often enlarge through bank erosion and channel incision. These processes, along with sediment released from harvesting activities, may greatly increase the quantity of sediment transported through the stream.

This section describes the measurement of impact of forest harvesting on the hydrology of the salmon streams through estimation of the rate of cut, or estimation of the equivalent clearcut area (ECA) within the watersheds; and further discusses the changes in hydrological and sedimentological regimes typically associated with forest harvesting.

##### **4.1 Forest Harvesting**

Maps and databases maintained by the Ministry of Forests were used to determine harvested areas in the watersheds of the salmon streams. History Record Reports lists activities in all openings (areas where forest cover has been removed) created prior to 1987 and continue with Small Business Forestry Enterprise Program (SBFEP) openings to 1993. Each opening is described by the region and compartment (the compartment boundaries follow watershed boundaries), a location tag, date of last activity and size of the opening. The openings are listed by compartment and the salmon streams within that compartment are determined. If the compartment includes only one watershed, then all cut blocks are split into 10 year age groups and added to the harvesting in that watershed. Note that Vacant Crown Land (VCL: fire or infestation-related openings) is not included in the total harvest. If two or more watersheds are included in the compartment the location tags (which are usually a watershed or sub-drainage name) are used to allocate the blocks to a particular stream. A few openings have obscure or unidentifiable location tags: these were assigned to the same watershed as the previous opening on the list. The opening are listed in a geographic grouping, so this procedure provides only a small source of error.

The QMF-100 Report describes openings created by major licencees since 1987. Each opening is referenced to a 1:20,000 Map sheet, and has a date of harvest, a size of opening and a licencee. In large watersheds, where the sheet falls entirely within the watershed, all harvested

cutblocks are added to the harvest in that watershed. Where the sheet includes two or more watersheds, the total harvest on the map sheet is calculated, and then harvested areas assigned to each watershed depending on the portion of the 1:20,000 sheet that they occupy. This procedure was sometimes modified to improve the quality of these estimates. If a watershed had no prior and no proposed logging then no cut was assigned to it from the QMF-100 Report. Also the licensee tag was used to re-distribute the logging. If the proposed logging indicated that only one licensee worked within a watershed then the total cut, on the map sheet, by this licensee was added to that one watershed. Errors from this approach affect recent harvesting totals and are expected to be greatest in small watersheds (less than 50 km<sup>2</sup> or so) and minor in moderate and large watersheds.

Proposed harvesting was measured on Five-year Plans available at Ministry of Forests District Offices. The plans typically list block sizes which were totalled for each salmon stream watershed. Only amendments to the proposed logging introduce error into the proposed harvest.

Harvested areas in each watershed are described on Table 7 as:

- **Oldest, Older and Old Harvested Area:** Includes those cutblocks cut between 1952 and 1981, divided into ten year periods. History Record Reports were used to determine the total harvest by period.
- **Recently Harvested Area:** Includes those harvested areas that are less than 10 years old as identified from the History Record and QMF-100 Reports and includes major licences and the Small Business Enterprise Forestry Program.
- **Proposed Harvest:** Identified from five-year plans current to 1993. The data was extracted from the comprehensive plan, prepared by the various Forest Districts, that incorporates all five-year plans submitted by the various logging companies. Salvage logging for beetle-kill or blowdown is additional to the five-year plans but is also incorporated in the proposed harvest.

## 4.2 The Effect of Logging on Hydrology

Haul and skidder road construction compact the surface and increases runoff from the road surface and increases the rapidity of runoff. Ditching along roads concentrates water, generally into fewer channels, and intercepts subsurface flow, increasing the speed of flow to drainage channels. The removal of trees severely reduces or eliminates transpiration, in the short-term. Tree removal also increases air movement and changes soil temperature which tend to increase evaporation from the soil surface, but the overall effect is to reduce evapotranspiration from the soil. In British Columbia, tree harvesting also affects the distribution of snow and the timing of its melt.

### 4.2.1 Forest Harvesting and Streamflow Quantities

Well-designed experiments generally show increased water yield as a response to forest removal, and the increase is generally proportional to the amount of canopy removed (Bosch and Hewlett 1982). The increased flow of water results from increased storage of water in the soil as the result of reduced transpiration following the removal of forest cover. Increases are

observed during the summer low flow season and also during the wet, or high flow season, particularly early in the season when soil storage differences are greatest between the forested and clearcut areas.

In snowmelt-dominated watersheds, clearcut logging produces increases in water yield. In Camp Creek near Penticton, B.C., clearcut logging following Pine Beetle infestation, increased both annual and March to November monthly water yields, with the greatest increases recorded in the months of August and September (Cheng 1990). There was no consistent evidence of increased streamflow in the winter months. Clearcut logging in rainfall-dominated systems also produces increases in water yields. Studies in Carnation Creek indicate increases in annual and summer low flows in a small completely-harvested watershed for at least the first few years after logging (Hetherington 1987).

#### **4.2.2 Forest Harvesting and Flood Flows**

Many studies have demonstrated increased storm volumes and peak flows following forest removal, though there are few results appropriate to the parts of British Columbia where snowmelt is the dominant mechanism for flood generation. Cheng (1990) found increased, and earlier, peak flows in Camp Creek after clearcutting of 30% of the basin area. His finding of a 20% greater, and two weeks earlier, flood peak are roughly comparable with studies in other snowmelt-dominated systems. King (1989) examining streamflow responses in northern Idaho, found increases of 15 to 35% in maximum instantaneous discharges.

Forest harvesting also affects flood flows in rainfall-dominated systems though results are sometimes ambiguous. In Carnation Creek, roads seem to have increased peak flows in a small intensely-harvested tributary though there has no reported effect on flood flows from the overall watershed which is about 40% harvested (Hetherington 1987). Studies in other areas indicate that clearcutting increases small flood peaks but has little effect on the larger peaks flows that occur when soils are thoroughly wet (Wright et al 1990).

Forest harvesting also affects flood flows generated by rain on snow, though studies have generally been conducted in the transient snow zone of the Pacific Coast and their conclusions may not be entirely transferable to the interior. Generally, greater melt rates of shallow, warm snowpacks are expected following forest harvesting because of greater transfer of convective energy from increased wind speeds and turbulence. However, a number of variables, such as antecedent snow conditions, storm characteristics and climate affect the results and few studies have demonstrated increased peak flows (Harr 1986). Beaudry (1981), based on studies in Jamieson Creek in the Seymour watershed, shows that air temperature and the presence of snow in the canopy in the forest affect the relative melt rates and runoff from clearcut and forested sites.

The British Columbia Forest Practices Code and The Southern Interior Watershed Assessment Procedure propose to manage hydrologic impacts through controlling the rate of cut in watersheds to minimize changes to the annual hydrograph. In the Southern Interior, this is accomplished by distributing the cut over a range of elevations and aspects and by controlling the equivalent clearcut area (ECA) within the watershed. The ECA is calculated from the product of the total cut area and a regeneration recovery factor, which reflects the fact that there is near zero hydrologic recovery for regeneration of 3 m regeneration and nearly complete recovery for 9 m regeneration on the block. Intermediate regeneration reduces the hydrologic effect of the

clearcut. Maximum allowable equivalent clearcut areas will vary with basin type and the history of past disturbance, but may range from 20% to 35%.

#### **4.2.3 Forest Harvesting and Sedimentation**

Watershed disturbance during forest harvesting often causes increased fine (suspended) and coarse (bedload) sediment delivery to streams, through erosion of roads and cut-banks, soil disturbance (log skidding, prescribed burning, or scarification), mass soil failures, or increased bank erosion from deposition of debris, increased flood flows or bank instability from the removal of riparian vegetation. Elevated suspended and bed sediment loads and deposition of this material on fans or in low-gradient sections of streams may have greater impact than changes in the hydrologic regime resulting from logging.

The relative importance of various erosion processes, and the various forestry activities, to the total sediment budget of a disturbed watershed depend on the precipitation regime, character of the watershed, and soils and logging practices. Details may only be resolved after extremely detailed study. However, a general appreciation of the nature of sediment sources and sediment delivery processes may be obtained from aerial photographs and reconnaissance studies.

#### **4.3 Physiography**

The following parameter was measured for each of the watersheds:

- **Drainage Area:** Drainage areas upstream of stream gauging sites were extracted from Water Survey of Canada publications. Drainage areas above the mouths of salmon streams were extracted from WSC publications or measured on 1:50,000 or 1:250,000 maps.

## **5. WATER LICENCES**

The Water Rights Branch of the Ministry of Environment maintains a computerized data base of water licences in British Columbia, which includes current licences plus outstanding applications. Most of the outstanding applications on the database are ultimately approved and consequently these are included in the totals on Table 7. Summaries (by licence type) were produced for all salmon streams, as well as streams with long-term Water Survey of Canada gauging stations.

### **5.1 Classification of Water Licences**

Figure 6 reproduces the water licence classification system used by the Water Rights Branch. Water licences are classified into consumptive and non-consumptive uses and further classified by the type of user. Computer-generated summaries, obtained from the Water Rights Branch, Victoria, utilize the main classification on Figure 6, as well as providing more detail on the type of user, producing a total of 73 sub-categories (including non-consumptive uses).

#### **5.1.1 Consumptive Licences**

The computer-generated classification provides more detail than is required so we have reported consumptive licensed extractions from the salmon streams under the categories of Domestic, Waterworks, Irrigation and Industrial. Table 7 reports the sum of all licences, of each type, above the mouth of the salmon stream.

#### **5.1.2 Non-Consumptive Licences**

Non-consumptive water use includes power generation, storage (nonpower and power) and conservation. Conservation licences are totalled and summarized on Table 7. Nearly all the storage licences are non-power licences.

The total non-power storage licences in each salmon stream are listed on Table 8. The total includes all storage for domestic, waterworks, irrigation, and industrial licences; though, in most streams, the majority of the licences are for irrigation. Table 8 also compares the irrigation licences to the non-power storage in each salmon stream. Storage affects flow by being accumulated during the spring freshet and released during low flows, or during the irrigation season. In many watersheds, licenced storage volumes are matched to some irrigation licences, and the net reduction in low flows resulting from diversion for irrigation is, theoretically, less than the total licenced irrigation diversion. This does not work in practice as the upstream storage facilities trap incoming flows during low flows as well as high flows -- reducing downstream flows in addition to extractions -- and leaky dams and evaporative and transmission losses reduce the storage quantity available to compensate for licenced extractions.

## **5.2 Licensed Versus Actual Water Use**

### **5.2.1 Domestic and Waterworks Licences**

Domestic use is only partly consumptive. In summer, although a large portion of the domestic use is for watering of lawns and gardens, some of this water re-enters the stream as return flow.

Waterworks are also only partly consumptive; but in organized areas, water may be diverted out of the basin and return flows may not end up in the same stream, producing a true loss to streamflow. Typically, waterworks are licensed for amounts well in excess of actual extractions. Because licence-holders for large waterworks projects pay a fee based on actual water use, rather than the licensed amount, records are available of the annual volumes of water extracted from streams. We have not obtained these records because waterworks and domestic extractions in salmon streams in the Middle Fraser HMA are insignificant when compared to irrigation use or to streamflow.

### **5.2.2 Irrigation Licences**

A certain percentage of the water diverted for irrigation reenters the stream as return flow. When flood irrigation (by ditches and flumes) was prevalent it was assumed that roughly 30% of the diverted volume returned to the stream. Sprinkler and drip/trickle irrigation are expected to produce considerably less return flow and these are now the dominant methods of irrigating.

Water applied to the land on a particular day will cause return flow some days, weeks or months later. In the Okanagan (Reksten 1976) it is assumed that 12% of the annual return flow occurs in September and 9% in October; and that a small percentage (about 4% per month) occurs through the winter months. Return flow in August and September may reduce the impact of irrigation diversions in those months if the flow is returning to a reach of the stream supporting fish.

Actual irrigation demand can be estimated from the area of irrigated land and a calculated or estimated water duty. The duty -- the water needed for the irrigation season expressed as a depth -- is not known but irrigation licences are typically for 45 cm (18 inches) of water near Williams Lake. The theoretical duty and the actual amount applied can be very different, as a result of farming practices and, as well, the duty varies with location and elevation and from year to year. Year-to-year variations are significant in many areas: for example, from 1975 to 1988, duty in the Vernon Irrigation District varied from 31 to 48 cm (Rood 1989), with the greatest amount required during low flow, dry years; and in dry years the actual extraction approaches the licensed volume.

Irrigation demand can be estimated following the above procedure; however, we prefer to use the water licence summaries for several reasons. First, areas of cultivated farmland do not always correspond with the total irrigation licences and some basins with cultivated land have no licensed irrigation withdrawals. This may result from non-use of licences, diversion of water to farms out of the basin, or inaccuracies in estimating improved farmland. Second, the irrigated portion of improved farmland is only roughly known for the individual salmon streams and, third, duty is only known for a few basins with detailed studies. Finally, the water licences represent,

as discussed in the next section, a potential maximum demand on the salmon streams and provide a comparable standard of comparison from stream to stream.

In the Middle Fraser, irrigation often stops near the end of August, prior to removal of the last crop. Land may be irrigated in September, after removal of the last crop, in order to improve soil moisture before winter. In some years, there may be little or no irrigation withdrawals in September.

### 5.3 Calculation of Licensed Demand

Calculation of licensed demand has the advantage of providing a consistent measure of demand from each stream and, in many instances, the licensed amount may be close to actual use; extractions are greatest in dry years and overuse of some licences may compensate for licences that are only partly used, or not used at all.

The demand calculated from all licences is the maximum potential demand that may be exerted on the stream, if all licences were fully utilized. For streams that are fully recorded, the calculated demand may not increase; on other streams additional licences will likely be issued.

The water licences summarized on Table 7 are expressed in various units, ranging from acre-feet for irrigation and industrial licences, to gallons/day for waterworks, industrial, and domestic licences and  $\text{ft}^3/\text{s}$  for industrial and conservation licences. Licensed amounts expressed as a discharge were converted to litres per second (L/s) using appropriate conversion factors: 1 L/s is equivalent (approximately) to 19,000 imperial gallons/day; 1 L/s is equivalent (approximately) to  $.035 \text{ ft}^3/\text{s}$ .

Licensed amounts expressed as a volume (ac-ft) were converted to cubic decameters ( $\text{dam}^3$ ), where 1  $\text{dam}^3$  is equivalent (approximately) to 0.81 ac-ft. In any time period, the total demand is calculated by adding the demand from waterworks, domestic and industrial licences, which are assumed to be constant throughout the year, to the irrigation demand. Irrigation volumes were estimated by the Ministry of Agriculture, Food and Fish (Abbotsford Office) to be distributed as follows: May (15%), June (15%), July (30%), August (30%) and September (10%). These percentages represent the average distribution of water and may not be appropriate in any particular year, as a result of weather and cropping practices. Monthly irrigation volumes (in  $\text{dam}^3$ ) were converted to discharges (L/s) by multiplying by  $10^6$ , and dividing by the number of seconds in the month.

The total demand varies from month to month as a result of irrigation extractions. Table 7 presents calculated licensed total demand, in L/s, for August, September and February. These months were selected because August and September are months when low flows commonly occur during the irrigation season and February is a typical winter month.



## **6. SENSITIVITY INDICES FOR THE SALMON STREAMS**

We have expressed the habitat sensitivity of the salmon streams through various indices that are calculated from the hydrologic, water use and land use data collected for the streams. The sensitivity indices used here indicate the level of concern for those aspects of the hydrologic regime that affect habitat and which can be altered by human activities. The indices are of two general types:

- Indices that express the level of human activity in the watersheds of the salmon. These include the proportion of the basin of the salmon streams that have been developed and the degree of utilization of water for irrigation, industrial and waterworks; and
- Indices that express the state of the particular stream and its ability to resist further change. These indices express peak flows and low flows as a ratio or percentage of the mean annual flow. Extreme values indicate stressed systems with a limited ability to withstand further hydrologic alteration.

The most useful indices for assessing habitat sensitivity indicate the magnitude of water use during low flows in summer, compare the magnitude of low flows to mean flows, compare peak flows to mean flows and indicate the extent of forest harvesting in the watershed.

The indices are expressed as percentages of mean annual flow, except for peak flows, which are expressed as a ratio of the mean annual flow. The use of percentages and ratios permits easy comparison of streams of different watershed areas and allows ranking of the streams. The most sensitive streams were defined as those with the most extreme indices or those whose indices exceeded some critical value. On Table 9 these streams are shaded: the rationale for selecting the most sensitive streams is discussed separately for each index in the following sections. The following table summarizes the indices:

Index	Definition	Interpretation
1	potential demand in August as a percent of the mean summer 7 day low flow	expresses the maximum portion of flow during the rearing season that is used for water demand
2	as above for September	as above
3	potential demand in August as a percent of mean August flow	expresses the typical portion of flow during the rearing season that is used for water demand
4	as above for September	as above
5	actual summer 7 day average low flow as a percent of mean annual flow	expresses the ability of the system to resist water removals; low values indicate streams with low natural 7 day low flows
6	as above for winter 7 day lows	as above
7	mean annual flood as a ratio of mean annual flow	expresses the peakiness of the stream hydrograph and the potential for scour and erosion
8	recent logged area as a percent of total basin area	roughly expresses the clearcut equivalent area and indicates the extent of hydrograph changes from logging; values exceeding 20% indicate potential changes
9	total logged area as a percent of total basin area	as above
10	recent and proposed logging as a percent of total basin area	as above

## 6.1 Summer Water Demand

Indices 1, 2, 3 and 4 express potential demand in August and September as percentages of various measures of low flow and indicate the total portion of the natural low flows devoted to irrigation and other water uses. Indices 1 and 2 compare potential water demand to mean 7 day summer low flows, which typically occur in August or September. The 7 day low flows used in calculating the indices are "naturalized"; that is, they are estimates of the natural low flow and, consequently, the indices indicate the percentage of the available low flow that could, potentially, be required to meet water demand. Indices 1 and 2 represent *extreme* demands that may occur during the irrigation season. Indices 3 and 4 compare potential demand in August and September to *average* flows in these months and are a measure of the typical portion of flows devoted to irrigation during the late summer.

Demand results from diversion for irrigation, industry and waterworks. Large values of Indices 1 through 4 indicate streams with great potential demand on summer low flows. Most salmon

streams have no water demands and on Table 9 only three streams are shaded, whose demands exceed 5% of summer low flows.

The potential water demand is calculated from the total licences and probably over-estimates the actual water use. The indices also do not account for storage and release in the watershed. Also, small errors in measurement or calculation of 7 day low flows can make large differences in the value of the indices.

## **6.2 Summer and Winter 7 day Low Flows**

Indices 5 and 6 compare seasonal 7 day low flows to mean annual flow, expressing the 7 day low flows as a percentage of mean flow and indicate the ability of the stream to accept water extractions. Low values of the index indicate streams where 7 day low flows are small and where further reductions may significantly affect habitat.

Actual 7 day low flows, as opposed to naturalized flows, were used in the indices so that the indices reflected current conditions in streams with licensed demand and those without licensed demand. The 7 day low flows used in calculating the indices are the recorded low flows on gauged streams, prior to adjustment to reflect upstream storage and diversion of waters. On ungauged streams, with licensed demand, the predicted natural flows were adjusted to actual flows by subtracting the (September) potential water demand. Low values of the indices indicate streams with large water demand or steep recession curves during summer drought.

On Table 9, those salmon streams with low summer 7 day flows, relative to mean flow, are shaded. They mostly lie along the west side of the Fraser River between Hope and Spuzzum and near Williams Lake. The streams near Hope also have the lowest winter 7 day low flows relative to mean flow and, apparently, have very flashy regimes.

Note that many small streams, with drainage areas less than 50 to 100 km<sup>2</sup>, in the region around Williams Lake, have 7 day summer low flows of zero (Nyhof 1987).

## **6.3 Peak Flows**

Index 7 compares the mean annual flood to mean annual flow, expressing the mean annual flood as a ratio of the mean annual flow. Higher values of the index indicate streams with a greater range or variability of flow. Higher values of the index may also indicate, potentially, lower channel stability, though channel slope and bed materials are also very important. Typically, the ratio of mean annual flood to drainage area (and mean annual flow) increases with decreasing drainage area. This occurs because smaller basins are often completely covered by individual storms, whereas not all of the larger basins are exposed and, as a result, have lower mean annual floods per unit area and lower values of Index 7. The salmon streams with the highest values of Index 7 are shaded on Table 7. These are typically the streams draining the west side of the Fraser River between Hope and Spuzzum.

Extreme floods also affect channel stability. Appendix B provides a table showing floods of various return periods for gauged salmon streams in the Middle Fraser HMA.

## 6.4 Logging

Indices 8, 9 and 10 express the area of logging as a percentage of total basin area. Index 9 is the total percentage of the watershed that has been logged (all cutblocks including those blocks with some hydrologic recovery); Index 8 is the percentage of recent logging (less than 10 years old based on silvicultural records). Index 10 expresses the area of recent and proposed logging as a percentage of total basin area and reflects the area of clearcut with little or no hydrologic recovery expected by the end of the five-year plan. The "old logging" includes cutblocks in varying stages of hydrologic recovery, ranging from those with limited or no hydrologic recovery that were recently harvested to some blocks that may be near 9 m regeneration which is often accepted to represent full hydrologic recovery. The percentage that have not recovered and the equivalent clearcut areas (ECA; Section 4.2) of the older logged areas are not known.

It is expected that the Ministry of Forests will ultimately use limits of 25% and 20% (in community watersheds) ECA to control rate-of-cut under their Watershed Assessment Procedure. This degree of clearcutting is expected to produce some changes in the hydrologic regime (Section 4.2). Index 9 is not an ECA values because it is not adjusted for hydrologic recovery of cutblocks and, as a result, may over-estimate the equivalent clearcut area of total harvesting. However, when most of the cutblocks have been harvested in the last few decades, Index 9 may not over estimate the equivalent clearcut area by very much. Indices 8 and 10 represent equivalent clearcut areas.

We have selected total or recent harvesting covering more than 20% of the watershed, which may correspond to an ECA of up to 20%, to indicate that management concern should be raised for fish habitat. A cut of 20% represent the point where effects on the hydrologic regime often become apparent and where changes in the sediment regime of the stream may result. We have also selected a low value so that those streams where changes in the hydrologic regime may be anticipated with further cutting are identified and management options may be considered. Those streams with Indices 8, 9 or 10 greater than 20% are shaded on Table 9.

Total basin area was used rather than forested area for several reasons. The effect on the hydrologic regime depends on the portion of the total basin whose hydrologic response is altered. Often if the forested area is only a small portion of the basin area, clearing a large percentage of the forest will have an undetectable influence on the hydrologic regime. However, if flood flows are mostly generated from the forested area, cutting may greatly alter downstream hydrology. Also, the Ministry of Forests uses total basin area in calculating these indices and we have followed their practice.

## 7. DISCUSSION OF THE SALMON STREAMS

As part of our study we reviewed available reports and studies and discussed the salmon streams with Provincial and Federal government personnel. This section summarizes the stream sensitivity analysis and describes hydrologic constraints, anticipated future conflicts, and opportunities for restoration or enhancement on the individual salmon streams. Our acknowledgements provide a summary of individuals contacted during the study.

### 7.1 Most Sensitive Streams

Table 10 identifies the most sensitive salmon streams in the Middle Fraser Habitat Management Area. Maximum water demand in the salmon streams exceed summer low flows and are also a large portion of mean annual flow in both Williams Lake River and Knife Creek. Irrigation demands are part met through through storage and release of water. The other stream with more than 5% of the summer 7 day low flows utilized by demand is Texas Creek. Most of the salmon streams have insignificant licensed demand.

Summer 7 day low flows are low, in relation to mean flows, on those salmon streams north of Hope that drain the Coast Mountains. These watersheds have a flashy regime and also have low winter 7 day low flows in relation to mean flows, and high peak flows in relation to mean flows.

Only Gordon and Utzlius Creeks currently have more than 20% of their watershed cut. However, a number of watersheds have a large area of proposed cut. These include the Anderson River and its tributaries, and Churn, Gaspard and Knife Creeks.

### 7.2 Discussion by Stream

Our discussions summarize previous studies or personal communications from knowledgeable individuals familiar with the streams and describe hydrologic constraints, anticipated future conflicts, and opportunities for restoration or enhancement. For some streams we have further distilled the available information into recommendations for management of individual streams and general recommendations for management within the Middle Fraser Habitat Management Area (Section 8). We recommend further study and investigation of all the sensitive salmon streams identified on Table 10.

**Coquihalla River:** Anadromous migration, except for winter steelhead, is blocked by the falls at Othello. Downstream of the falls, the main channel is steep, with a gradient averaging about 5%, and velocities are high throughout the channel, though the gradient is least near the Fraser River. Bedload transport is frequent and cobbles and gravel are deposited in the lower gradient reach at the mouth and at a few other upstream locations; the most recent flood filled some large pools, particularly at the mouth of Kawkawa Creek. However, there is no evidence of long-term aggradation along the main channel. Quantities of organic debris enter the Coquihalla River upstream but usually jam in the narrow canyon reaches prior to reaching Hope. These jams are generally removed by B.C. Environment.

Much of the left bank of the lower Coquihalla River has been dyked and rock protection has been placed along the bank. Developments encroach on the channel at several sites (Northwest Hydraulic Consultants Ltd 1994). Current limitations to fish production include: i) a lack of side

channel and off-channel habitat, ii) deposition of fine sediment, which reduces egg to fry survival rates, decreases food production and infills pools, iii) loss of spawning gravels and iv) lack of riparian vegetation.

A re-analysis of the flood hazard along the Coquihalla River indicates that the existing dykes are inadequate to contain the 200-year flood. Consequently, there are various plans to manage flood hazard along the lower river and to modify existing dykes (Northwest Hydraulic Consultants Ltd 1994) over a number of years. There is also pressure to further develop the remaining floodplain lands.

**Kawkawa Creek:** Surface water from the creeks which drain Ogilvie Mountains (on the north side of the watershed) typically go to groundwater at elevations of around 200 to 250 m, at the heads of their fans. These creeks only flow at lower elevations after significant precipitation or snowmelt (Stanley Associates Engineering Ltd 1987). The salmon streams which drain to Kawkawa Lake start from springs on the fan surface. They exhibit a typical groundwater-dominated flow regime, particularly Kopp Creek, which has been gauged. Discharge remains reasonably constant from day-to-day and is consistent over the summer at around 50 to 100 L/s. (Flow measurements on Kopp Creek are somewhat suspect as most values are estimated.) The main discharge from Ogilvie Mountains is to Sucker Creek. Flows in Kopp and Menz Creek are from a glaciofluvial aquifer to the east of the fan.

Flooding and erosion occur along some of the creek channels, primarily as a result of insufficient channel capacity from sediment and debris deposition. Some residents have modified the drainage channels to increase their capacity or have constructed small impoundments. Stanley (1987) proposed various flood control measures including drainage improvements, berms, flumes and debris basins. Menz Creek locally erodes sand and gravel deposits and is affected by development of a gravel pit along the south margin of its watershed.

Residential development around the lake creates the main impact on water quantity and quality and fish habitat in Kawkawa Lake and its tributaries. Water withdrawals from Kopp Creek amount to about 2% of typical low flows. Groundwater development in the watershed would further reduce typical low flows.

There have been a number of enhancement activities along Kawkawa Creek (downstream of Kawkawa Lake) including: construction of a special selective barrier to stop coarse fish, placement of spawning gravels in the lower creek, placement of boulders, and construction of a spawning loop beside the existing channel.

**American Creek:** Spawning is confined to the lower 2 km of the creek. The bed material is mostly large boulders. American Creek has a flashy hydrologic regime, as do the other creeks along the west side of the Fraser River valley.

**Emory Creek:** The lower 1 km of the river is used by pink and chum salmon. Emory Creek is also reported to have a flashy hydrologic regime.

**Gordon Creek:** Limited spawning by pink salmon at the mouth of this creek.

**Yale Creek:** The lower 1 km of the creek is used for spawning by pink and chum salmon. The creek is steep, with bouldery bed material, and flows that are rapid and turbulent. The hydrologic

regime is flashy with low winter and summer low flows in relation to mean flows. There are minor withdrawals for irrigation and waterworks.

**Spuzzum Creek:** There is scattered spawning between the mouth and the CP Railway bridge. Bed material is large and flooding and bank erosion are common. There are withdrawals for irrigation and waterworks from the creek but they do not appreciably affect low flows.

**Anderson River:** The lower reach of the river crosses a large fan downstream of the CN Rail Bridge. The Fraser River floods the fan during freshet and deposits fine sediment and sand. During fall floods, when the Fraser River is low, Anderson River is unstable and changes channels across its fan.

CN Rail recently removed a concrete apron from beneath their bridge, which protected against bed degradation but limited fish access. The apron was replaced by scour protection around the individual piers and river training upstream of the bridge.

The Boxing Day flood of 1980 affected the Anderson River basin, causing landsliding and washing out of roads. These roads have now been re-built.

In many reaches, cutblocks extend to the margins of the channel and riparian vegetation has been removed. Proposed harvesting, according to the current 5-year plan, would involve about 8% of the total area of watershed, though the rate of cut varies from tributary to tributary. By 1997, much of the watershed would be more than 20% logged, though regeneration would somewhat reduce the equivalent clearcut area.

**Nahatlatch River:** The Nahatlatch River is to be a demonstration watershed under the Fraser River Action Plan. In addition, an integrated Resource Management Plan is being prepared for the watershed.

The 1980 Boxing Day flood destroyed two log bridges and damaged a number of culverts in this watershed. These have since been replaced or repaired.

**Stein River:** The Water Management Division feels that a Water Survey of Canada gauge on the Stein River would be valuable because it is the last pristine (unlogged) large watershed along the west side of the Fraser River. The records would provide useful information on the natural regime in this part of the Middle Fraser HMA.

The Lillooet Indian Band plans to remove water from the Stein for domestic and irrigation supply. The water would be carried across the Fraser River by an overhead pipeline: design of the pipeline is well-advanced.

**Texas Creek:** Texas Creek has the same volume of irrigation withdrawals as the Stein River but it has a much smaller watershed. Water withdrawals potentially amount to about 14% of the average summer 7 day low flows. The Water Management Division is not aware of any water conflicts in this watershed.

**Churn Creek:** Pink salmon spawn in the lower 5 km of the creek but with the greatest density in the lowest 2 km. The creek is not greatly affected by water demand, though the Gang Ranch holds several licences on the upper river.

The Black Dome Mine in the upper watershed is not operating and concern has been expressed about water quality and the stability of tailing ponds in Fairless Creek. The mine has been purchased and may re-open. There also has been placer mining in the watershed.

The Ministry of Forests is preparing a LRUP (local resource use plan) to resolve land use issues in upper Chum Creek. Environmental concerns related to forest harvesting include roads located near the main creek which may encroach on or fall into the creek, creek crossings, harvesting on unstable soils, and rate of cut.

The valley walls along lower Chum Creek are unstable and contribute lacustrine sediment to the creek when they fail. Most failures result from toe erosion during the spring freshet. Erosion during occasional fall floods potentially affects incubating pink salmon eggs.

**Williams Lake River:** The river is fully recorded. Most water is extracted from the San Jose River and its tributaries upstream of Williams Lake. There are only a few licences downstream of the lake. The San Jose River is regulated by storage on Lac La Hache. Long stretches of the river go dry during droughts. Overwintering of cattle and feedlots along the San Jose River cause water quality problems.

A control structure at the outlet of Williams Lake has no provision for upstream fish passage: anadromous use is mostly limited to pink salmon spawning near the junction with the Fraser River. Williams Lake River flows in a gully from the outlet of Williams Lake to the Fraser River. The gully is mostly undeveloped but is used informally for recreation. The Rotary Club has removed garbage from the river and constructed trails along the river. Storm sewers discharge directly to the river and snow is dumped into the gully. Both these cause water quality problems.

During droughts there is no outflow from Williams Lake, causing much of the stream bed of Williams Lake River to go dry. There are large year to year variations in recorded outflow in the late summer. Williams Lake is also anoxic in the summer.

**Knife Creek:** Anadromous salmon do not use this creek though it provides good trout habitat. During droughts, the creek continues to flow, even when the San Jose River is dry. The creek is fully recorded but a recent appeal of a licence refusal may lead to an amendment and issuing of further licences. There are both water demand and water quality issues with agriculture.

Riparian vegetation has been removed along part of the creek by ranchers but it retains more riparian vegetation than other tributaries to the San Jose River.

## 8. RESULTS AND CONCLUSIONS

### 8.1 Effects of Development on Hydrology

In the northern half of the Middle Fraser HMA, flows in the salmon streams are greatest during snowmelt in May and June and decline rapidly the late summer, in response to irrigation removals and decreasing soil moisture, often reaching a minimum in August, September or October. The Fraser Basin is very dry: only 30 to 50 mm of precipitation appears as runoff, and only large watersheds sustain flows over the summer. Discharges in the streams are highly variable from year to year; for instance in the 1980's, August discharges varied from 0.008 to 5.34 m<sup>3</sup>/s at the outlet of Williams Lake. Diversions for agriculture account for a very large portion of natural flows.

In the southern half of the HMA, watersheds are transitional between the coastal and the interior type of hydrologic regime. Snowfall accumulates at mid and high elevations, and its melt provides the main source of water. Average streamflows are highest in the summer. However, in some years, the largest flood occurs in the fall as a result of intense rainfall or rain on snow events that occur when warm Pacific storms cover the watersheds. Consequently, these streams often have two freshets, one in the spring and one in the fall.

Minimum flows in these streams typically occur in the winter, often under ice cover, though in some streams, particularly those with small watersheds, minimum flows may occur in the summer. Diversion for irrigation or waterworks affect some streams but there is limited agriculture and less than 5% of low flows are diverted in any of the streams.

Forest harvesting is the main human activity that affects peak discharges and Table 10 identifies those streams where sufficient forest has been harvested to alter the hydrologic regime. Forest harvesting on unstable soils also increases suspended sediment concentrations, which affects downstream habitat.

The following sections provide a summary of the types of development affecting the hydrologic and sediment regime of the salmon streams:

**Surface Water Use:** The major surface water extractions for irrigation from the salmon streams are from Williams Lake River, Knife Creek, Stein River, Texas Creek and Chum Creek. Demands on Williams Lake River and Knife Creek amount to most of the natural late summer flows; on Texas Creek, demand amounts to about 14% of minimum flows; on Stein River and Chum Creek, demand has no appreciable effect on flows.

High water demands for irrigation occur on some non-salmon streams in the southern part of the HMA, particularly Luluwassin and McGillivray Creeks. There is conflict over water on these streams as storage reservoirs developed for irrigation did not fill during the 1980's. This is of concern to the Ministry of Environment and Fisheries and Oceans Canada because the lower reaches of these streams can provide clear-water habitat for downstream migrants.

The Water Management Branch does not keep records of the degree of utilization of the outstanding water licences and some licences may no longer be used. Recent increases in annual fees have led to some licences being abandoned by their holders and increases in application fees have reduced the backlog of applicants. Revision of the Water Act may result

in more fee increases, which could further reduce the number of applications and lead to additional abandonment of under-utilized licences.

Future water demand for irrigation in the Middle Fraser HMA is not known as neither the Water Management Branch nor the Ministry of Agriculture prepare forecasts of agricultural expansion and concomitant requirements for irrigation. The Water Manager in Kamloops reports that very few applications for irrigation licences are being received for streams in the southern half of the HMA and he expects no future demand. Both Williams Lake River and Knife Creek are fully-recorded and restricted from future licencing. However, this restriction can be challenged legally and the streams re-opened to further licencing.

**Ground Water Use:** Little is known of ground water use in the Middle Fraser HMA though it is not thought to affect flows in the salmon streams.

**Storage Developments:** There are no applications before the Water Management Branch for large or medium-sized power projects in the Middle Fraser HMA though there are proposals for several small hydro projects.

Williams Lake River, Knife Creek, Churn Creek and Gaspard Creek have existing storage structures: there are none on any other streams. In these basins, the total developed storage represents about two-thirds of the water requirements for irrigation (Table 8).

**Forestry:** The initial forest harvesting in the Middle Fraser HMA was during construction of the CP Rail line. Kawkawa Lake was logged in the early 1910, with a saw mill on the lake, a log chute and log booming (McCombs and Chittenden 1990). Emory Creek was the first major operation north of Hope and logging began about 1944 with the main harvest by Alaska Pine Company finished by 1957. A pole and tie operation worked the lower Nahatlatch watershed in the early part of the century with first major harvesting starting about 1953. A large forest fire in 1961 slowed operations until about 1969.

The rate of harvesting in the watersheds of the salmon streams has increased in recent years in the Middle Fraser HMA and most cutblocks in the salmon streams were harvested in the last ten years though there are older cutblocks in most of the watersheds (Table 7). Gordon and Utzius Creeks have more than 20% of their watersheds harvested, with most of the logging in the last ten years: re-generation should have somewhat reduced the equivalent clearcut area.

During our interviews, the Ministry of Environment expressed concern about specific logging-related issues -- such as poor road construction, drainage control, road encroachments on streams, and slope failures -- that affect small tributaries to the salmon streams. There was concern that roads were not meeting basic construction and maintenance standards.

There was no concern expressed about direct sediment or hydrology-related forestry impacts on the larger mainstem salmon streams, except in upper Churn Creek. B.C. Environment and DFO are utilizing the Interior Forestry Guidelines to examine rate-of-cut though these guidelines are not yet accepted or approved. Rate-of-cut is generally limited to 25% equivalent clearcut area and in Community Watersheds, a lower value, 20%, is suggested. DFO is also requesting a 30 m windfirm buffer (with selective harvest) along salmon streams and machine reserves along small streams.

The proposed cut over the next five years in the watersheds of the salmon streams ranges from 0% to a maximum of 10% of the watershed area. Most of the salmon streams south of Spuzzum

Creek – except Sowaqua and American Creeks -- have either no proposed cut or a cut of about 1% of the watershed area. Those streams with large proposed cuts include the Anderson River and its tributaries (ranging from 6 to 10%), Churn Creek (10%), Knife Creek (6%), and Gaspard Creek (5%).

Removal of lands from the forestry land base for parks and streamside management zones (SMZ) is an important issue for fisheries. If the annual allowable cut (AAC) is not adjusted following these removals, pressure may be exerted to log sensitive or marginally stable lands to maintain the harvest. This has the potential to greatly increase sediment production and, thus accelerate sedimentation in the salmon streams.

**Flooding, Erosion and Sedimentation:** Some of the salmon streams are unstable, such as the Anderson River, in their lower reaches, or on their fan. Because there is little development, instability in upstream reaches, if it occurs, is generally not reported or addressed by river training works.

Damage to stream banks most commonly results from natural erosion or as a result of removal of riparian vegetation during timber harvesting. Some streams, such as Churn Creek, naturally erode sediment from channel banks and valley walls over much of their course. The extent of erosion, sedimentation and channel instability is not known for most of the salmon streams.

Several salmon streams have reportedly suffered bank and valley wall erosion that has contributed to sedimentation (Table 5). There is no systematic record of these erosion failures nor any coordinated program for remedial measures.

## **8.2 Technical and Management Recommendations**

As well as the specific discussion of individual streams in this section, a number of general recommendations arise from this study that apply to management of the Habitat Management Areas as well as the individual streams. These include legislative, policy and technical issues. Instream flow needs for fish are not addressed in existing legislation and changes are required to ensure that these needs are considered during licensing of waters in salmon streams.

### **8.2.1 Estimation of Flows and Demands in the Salmon Streams**

Flows for the salmon streams were estimated from complete gauging records, partial gauging records, transfer from nearby stations or regional analysis. As discussed, the estimated flows are of variable quality and additional hydrologic studies are warranted, particularly for the most sensitive streams, to confirm the flow estimates.

*We recommend for the ungauged streams that estimated flows, particularly low flows, should be confirmed by measurement programs perhaps in conjunction with the Water Management Division and the Water Survey of Canada. On gauged streams, further analysis of additional gauging records on tributaries or the upper mainstem is warranted, where these are available.*

There are other gaps in technical knowledge which limit our ability to adequately manage the flows of salmon streams:

1. The relationship between actual and licensed withdrawals is not known for various licence types. As well, demand varies from year-to-year, based on a number of factors. *Management of the salmon streams requires some knowledge of the annual variation of demand and we recommend regular monitoring of withdrawals to establish the demand on the most sensitive streams.*
2. Management procedures to ensure adequate instream flows for fish have not been established. *We recommend that instream flow requirements be assessed for the more sensitive salmon streams and that appropriate water management plans be developed in conjunction with other agencies (Hamilton 1992).*

### **8.2.2 Water Licensing and Water Use**

Kopp Creek and the other small tributaries to Kawkawa Lake are an unusual case in that they are groundwater-fed systems with stable flow regimes. Despite the stability, flows are small (less than 90 L/s in the summer) and can be dramatically reduced even by domestic or waterworks licences. Flows are also susceptible to development of groundwater wells in the aquifer to the east of Kawkawa Lake. *We recommend further study of flows in these small systems, particularly of groundwater contributions, and recommend that further licencing of these streams be opposed until the system has been studied in more detail.*

Williams Lake River and Knife Creek in the northern part of Middle Fraser HMA typically have very low flows in July and August despite significant storage development on some streams. On Williams Lake River it may be possible to improve summer flows by developing further storage or by changing the manner in which existing storage is managed. Churn and Gaspard Creeks also have moderate demands and some storage development. *We recommend that further water withdrawals from these stream systems be monitored and opportunities for storage development within these systems be reviewed.*

The salmon streams along the west side of the Fraser Valley, between Hope and Spuzzum have "flashy" regimes and natural low summer and winter low flows in relation to their mean annual flow. Flows are usually not much affected by water demand and there are no outstanding licence applications. However, there remains some potential for future increased water demand. *We recommend that low flows be monitored on these streams and instream flow needs assessed.* If demand increases, low flow agreements, or restrictive licensing, may be used to maintain instream flows. There are opportunities to develop storage in the basins of many of the salmon streams and these should be investigated in conjunction with biological studies. Storage may either supplement existing flows or meet future demand.

There may be management or technical options for improving those streams, listed in the above two tables, that either have the greatest water demands or the lowest flows. In those basins with only limited storage, additional reservoirs may be used to supplement minimum flows in the stream. *We recommend that studies of storage potential, instream flow needs and investigation of losses along the channel should precede agreements on management of instream flows.*

The Water Management Branch classifies streams and restricts further water use in some streams. *We recommend that Fisheries & Oceans Canada review the basis for decisions on restricting or not restricting water use and participate in revising the list of reserved streams.*

*We also recommend that, for salmon streams with high potential utilization, the Water Management Branch and Fisheries and Oceans Canada identify those irrigation licences that are not utilized or are under-utilized and attempt to purchase the licences or persuade owners to abandon them.*

### **8.2.3 Groundwater Extractions**

There are gaps in our technical knowledge that make it difficult to manage the effect of ground water extractions on flows in the salmon streams:

1. Ground water wells are reported on a voluntary-basis and there is no mechanism to track the volume or rate of extraction from different wells; and
2. Subsurface geology and groundwater movement are not always well enough understood to predict the relationship between extractions and reductions in streamflow.

*We recommend that shallow wells be inventoried in basins of those salmon streams whose base flows may be substantially maintained by ground water discharges and that the potential reduction in streamflow from pumping from groundwater be evaluated.*

### **8.2.4 Forest Harvesting**

A number of the salmon streams have insignificant or zero licensed demand and are not likely to experience increased agricultural or water supply demand in the near-future. In these streams, logging is the main land use with the potential to alter the hydrologic or sediment regimes or alter channel morphology. It is generally felt that the hydrologic regime may be preserved or managed by controlling the rate of clearcutting, and consequently, the portion of the basin that is in hydrologic recovery. It is not so easy to control or manage the sediment regime. Individual failures or poorly designed roads may alter downstream suspended sediment concentrations and deteriorate gravel quality. These must be investigated on a site by site basis and managed by following road construction and harvest prescription guidelines provided by the responsible agencies.

Managing the rate of clearcutting in the salmon streams poses a number of technical difficulties, which are discussed below:

1. It is difficult to manage the rate of cut because the Ministry of Forests does not present their existing and proposed cut data by watershed. *We recommend that DFO arrange with the Ministry of Forests to have the proposed cut on five-year plans sorted by watershed. Total previous and proposed cut within the watersheds should be established.*
2. *The relationship between re-growth and hydrologic recovery is not known for the watersheds. Consequently, it is difficult to assess the effective clearcut area of watersheds with cut blocks of varying ages, and varying levels of regrowth, and the potential impact on the hydrologic regime: we recommend that further studies be undertaken.* Research underway in the Stuart-Takla Fisheries/Forestry Interaction Project (Macdonald et al 1992) is examining rate of cut and cumulative impact issues.

Until the issue of hydrologic recovery is resolved, a conservative position on the total cut permitted within individual watersheds should be maintained.

3. Within the basins of the individual salmon streams, the proposed cut should be distributed over the various tributary basins, to maintain the regime of the tributaries, as well as the main stem. *We recommend a detailed review of the history of cut within the watershed of salmon streams where a large percentage of the basin is harvested. Ultimately, a GIS database that includes logging history could be used to calculate clearcut effective area within the tributaries and main stem and to monitor forest harvesting and this is available in some Forest Districts.*

### **8.2.5 Placer Mining**

Overall, the existing system for managing placer mining in B.C. is acceptable to Fisheries & Oceans Canada personnel.

### **8.2.6 Sedimentation and Sediment Sources**

The Ministry of Forests has prepared a policy document on prevention, reporting and mitigation of erosion events (MOF 1992). This document includes; the establishment of Erosion Control Teams; a formal system of reporting and inventorying erosion events; and remedial planning for past and present events. Fisheries & Oceans Canada should ensure that they receive erosion reports and have an opportunity to participate in planning of remedial works, particularly in selecting those sites with highest priority.

Ultimately, the erosion events should be mapped or incorporated into a GIS database for display with respect to habitat along the streams along with anecdotal information on the history of erosion, flooding, sedimentation and channel changes in the salmon streams in the Middle Fraser HMA.

Various individuals in federal and provincial government agencies have personal information that is not mapped or recorded in a fashion whereby it could be utilized in other studies.

Comprehensive planning requires an understanding of channel changes and sedimentation in the salmon streams in the Middle Fraser HMA. *As discussed, some of this information is available from various individuals and we recommend that it be gathered, checked, collated, verified and mapped in some standard format in order to make the data usable.*

The watersheds of some of the salmon streams are small and the stream courses are reasonably short. *We recommend that the information on channel changes be combined with observations on passage at culverts, water extraction points, the state of riparian vegetation and banks, overwintering habitat, etc on a large scale map of the drainage system in a Geographic Information System. A workshop may be a suitable format to further explore this approach.*

## 9. REFERENCES

- Barrett, G. 1979. Changes in the discharge of selected rivers in British Columbia during the period of instrumental record. Unpublished B.Sc. Thesis. Department of Geography, U.B.C. 141 pp.
- Beaudry, P.G. 1981. Effects of forest harvesting on snowmelt during rainfall in coastal British Columbia. Unpublished M.F. Thesis. Forestry Department. University of British Columbia. 182 pp.
- Bosch, J.M. and J.D. Hewlett. 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. *Hydrology* 55: 3-23.
- Cheng, J.D. 1989. Streamflow changes after clear-cut logging of a Pine Beetle-infested watershed in southern British Columbia, Canada. *Water Resources Research* 25(3): 449-456.
- ESSA Environmental and Social Systems Analysts Ltd. 1992. Development of a fish habitat Sensitivity indexing scheme for application in the Fraser River Basin (Draft). Prepared for The Department of Fisheries & Oceans. 42 pp. and Appendices.
- Ginetz, R. and G. Neilsen. 1980. Review of Enhancement Potential for Chinook and Coho Salmon Stocks in the Fraser River Watershed. Fisheries & Oceans Canada. Small Projects Division Memorandum. 17 pp.
- Hamilton, R. 1992. Instream Flow Assessment for Fish Habitat. Prepared for Fisheries and Oceans Canada. 30 pp.
- Harr, R.D. 1986. Effects of clearcutting on rain-on-snow runoff in Western Oregon: a new look at old studies. *Water Resources Research* 22(7): 1095-1100.
- Hetherington, E.D. 1987. Hydrology and logging in the Carnation Creek watershed -- what have we learned? in T.W. Chamberlin (ed). *Proceedings of the Workshop: Applying 15 years of Carnation Creek results*. Carnation Creek Steering Committee. Nanaimo, B.C. pp. 11-15.
- Holland, S.S. 1976. Landforms of British Columbia: a physiographic outline. B.C. Department of Mines and Petroleum Resources Bulletin 48. 138 pp.
- Levy, D. 1992. Potential impacts of global warming on salmon production in the Fraser River Watershed. Canadian Technical Report of Fisheries and Aquatic Sciences 1889. 96 pp.
- Macdonald, J.S., J.C. Scrivener and G. Smith. 1992. The Stuart-Takla fisheries/forestry interaction project: study description and design. Canadian Technical Report of Fisheries and Aquatic Sciences 1899. 39 pp.
- Matthews, W.H. (Compiler). 1986. Physiography of the Canadian Cordillera. Geological Survey of Canada. Map 1701A (Scale 1:5,000,000).

- McCombs, A.M. and W.W. Chittenden. 1990. *The Fraser Valley Challenge: an illustrated history of logging and sawmilling in the Fraser Valley*. Treeline Publishing. 176 pp.
- Ministry of Forests. 1992. *Ministry Policy (Erosion). Timber Harvesting Branch*. March 3, 1992 (Revision 5). 22 pp.
- Monger, J.W. 1990. *Georgia Basin: regional setting and adjacent Coast Mountains geology*. Geological Survey of Canada Paper 90-IF. pp. 95-107.
- Moore, R.D. 1991. *Hydrology and water supply in the Fraser River Basin*. in Dorcey, A. and J.R. Griggs (eds). *Water in Sustainable Development: Exploring our common future in the Fraser River Basin*. Westwater Research Centre. The University of B.C. pp. 21-40.
- Northwest Hydraulic Consultants Ltd. 1994. *Coquihalla River Flood Hazard Management Study*. District of Hope. 43 pp. and Appendices.
- Nyhof, F.J. *Low Flows, Southern Interior, 1987*. Water Management Branch, Ministry of Environment and Parks, Victoria, B.C. 5 pp. and tables.
- Piteau, D.R. 1977. *Regional slope stability controls and engineering geology of the Fraser Canyon, British Columbia*. Geological Society of America. *Reviews in Engineering Geology III*: pp 85-111.
- Richards, R.P. 1977. *1977 Low Flow Monitoring Program*. Water Investigations Branch, Ministry of the Environment. Victoria, B.C.
- Rood, K. 1989. *An Examination of Natural and Regulated Flows in Duteau Creek, British Columbia*. Prepared for Fisheries & Oceans Canada by K. Rood & Associates. 39 pp. and appendices and figures.
- Rood, K. 1988. *Application of Regional Hydrologic Analysis to Salmon-bearing Streams in British Columbia*. Prepared for Fisheries & Oceans Canada by Sutek Services Ltd. 48 pp. and appendices and figures.
- Ryder, J.M. and M. Church. 1986. *The Lillooet Terraces of Fraser River: A Palaeo Environmental Enquiry*. *Canadian Journal of Earth Sciences* 23:869-884
- Ryder, J.M. 1981. *Terrain Inventory and Quaternary Geology, Lytton, British Columbia*. Geological Survey of Canada Paper 79-25. 20 p.
- Wright, K.R., K.H. Sendak, R.M. Rice and R.B. Thomas. 1990. *Logging effects of streamflow: storm runoff at Caspar Creek in Northwestern California*. *Water Resources Bulletin* 26(7): 1657-1667.

## TABLES



**Table 1: Salmon Streams in the Middle Fraser HMA.**

Stream Name	SSIS Number	WSC Gauge Data			Total Drainage Area (km <sup>2</sup> )	Years of Record
		Gauge Name	Gauge No.	Drainage Area (km <sup>2</sup> )		
<b>CODUHALLA RIVER</b>						
1 Coquihalla R.	00-0800	near Hope below Needle Ck. above Alexander Ck.	08MF003 08MF062 08MF068	741 85.5 720	932	1957-69 MC + 1970-83 RC 1965-91 RC 1985-86 R# + 1987-91 RC
2 - Kawkawa Ck.	00-0800-010	-	-	-	9	-
3 - Sucker Ck.	00-0800-010-010	-	-	-	-	-
4 - Steven Ck.	00-0800-010-020	-	-	-	-	-
5 - Kopp Ck.	00-0800-010-030	above Menz Ck.	08MF067	-	-	1982-85 MS
6 - Menz Ck.	00-0800-010-030-01	-	-	-	-	-
1a - Sowaqua Ck.	*	-	-	-	153	-
7 American Ck.	00-0815	near Hope	08MF032	32.4	32	1933-36 MC + 1940 M#
8 Squeah Lake Ck.	00-0834	-	-	-	14	-
9 Emory Ck.	00-0841	near Choate	08MF030	65.3	65	1933-36 MC
10 Gordon Ck.	00-0855	-	-	-	11	-
11 Yale Ck.	00-0860	at Yale	08MF031	37.3	37	1933-36 MC
12 Sawmill Ck.	*	-	-	-	31	-
13 Spuzzum Ck.	00-0900	-	-	-	224	-
<b>ANDERSON RIVER</b>						
14 Anderson R.	00-1000	near Boston Bar	08MF001	492	500	1945-50 MS + 1981-83 RS
14a - Lower Anderson R.	*	-	-	-	350	-
14b - Upper Anderson R.	*	-	-	-	150	-
14c - Utzius Ck.	*	-	-	-	160	-
14d - East Anderson R.	*	-	-	-	125	-
15 Stoyama Ck.	*	-	-	-	38	-
<b>NAHATLACH RIVER</b>						
16 Nahatlatch R.	00-1200	at outlet of Frances Lk near Keefers below Tachewana Ck.	08MF007 08MF008 08MF065	777 1040 715	1256	1912-21 M# 1912-21 MC 1973-91 RC
16a - Lower Nahatlatch R.	*	-	-	-	946	-
16b - Upper Nahatlatch R.	*	-	-	-	310	-
16c - Log Ck.	*	-	-	-	84	-
16d - Kookipi Ck.	*	-	-	-	159	-
16e - Unnamed Ck.	*	-	-	-	53	-
16f - Mehati Ck.	*	-	-	-	293	-
17 Stein R.	00-1400	near Lytton	08MF011	1050	1084	1911-13 MS + 1945 #
18 Texas Ck.	00-1600	near Lillooet	08MF015	163	171	1913-21 MS
19 Churn Ck.	00-2900	near Gang Ranch	08MD012	979	992	1928-30 MS
20 Gaspard Ck.	*	at Gang Ranch below outlet of Gaspar	08MD010 08MD032	- -	943	1928 MS 198201991 RS
21 Williams Lake R.	00-3900	near outlet of Williams	08MC005	2240	2240	1968-72 MS + 1973-91 RC
22 -Knife Ck.	00-3900-250	at 141 Mile House below outlet of Squaw above diversions above Coldspring Ck.	08MC014 08MC038 08MC047 08MC048	- - - -	232	1986-91 RS 1987 RC + 1988 R# 1988-91 RC 1979 MS + 1980 RS

- dash (-) indicates that the stream has not been gauged.
- asterisk (\*) indicates that the watershed is not a SISS stream and is included only for logged area.

**Table 2: Physiography and Ecoregions in the Middle Fraser HMA.**

<i>Stream Name</i>	<i>SSIS Number</i>	<i>Total Drainage Area (km<sup>2</sup>)</i>	<i>Physiographic Region (1)</i>	<i>Ecoregions (2)</i>	<i>Ecosections (3)</i>
<b>COQUIHALLA RIVER</b>					
1 Coquihalla R.	00-0800	932	CM	PR/ITR	EPR/LPR
2 - Kawkawa Ck.	00-0800-010	9	CM	PR	EPR
3 - Sucker Ck.	00-0800-010-010		CM	PR	EPR
4 - Steven Ck.	00-0800-010-020		CM	PR	EPR
5 - Kopp Ck.	00-0800-010-030		CM	PR	EPR
6 - Menz Ck.	00-0800-010-030-010		CM	PR	EPR
1a - Sowaqua Ck.	*	153	CM	PR	EPR
7 American Ck.	00-0815	32	PR	PR	EPR
8 Squeah Lake Ck.	00-0834	14	PR	PR	EPR
9 Emory Ck.	00-0841	65	PR	PR	EPR
10 Gordon Ck.	00-0855	11	PR	PR	EPR
11 Yale Ck.	00-0860	37	PR	PR	EPR
12 Sawmill Ck.	*	31	PR	PR	EPR
13 Spuzzum Ck.	00-0900	224	PR	PR	EPR
<b>ANDERSON RIVER</b>					
14 Anderson R.	00-1000	500	CM	PR/ITR	EPR/LPR
14a - Lower Anderson R.	*	350	CM	PR	EPR
14b - Upper Anderson R.	*	150	CM	ITR	LPR
14c - Utzlius Ck.	*	160	CM	PR	EPR
14d - East Anderson R.	*	125	CM	PR	EPR
15 Stoyama Ck.	*	38	CM	ITR	LPR
<b>NAHATLACH RIVER</b>					
16 Nahatlatch R.	00-1200	1,256	PR	ITR/PR	LPR/EPR
16a - Lower Nahatlatch R.	*	946	PR	ITR	LPR
16b - Upper Nahatlatch R.	*	310	PR	PR	EPR
16c - Log Ck.	*	84	PR	ITR	LPR
16d - Kookipi Ck.	*	159	PR	ITR	LPR
16e - Unnamed Ck.	*	53	PR	PR	EPR
16f - Mehati Ck.	*	293	PR	PR	EPR
17 Stein R.	00-1400	1,084	PR	ITR	SCR/LPR
18 Texas Ck.	00-1600	171	PR	ITR	SCR
19 Churn Ck.	00-2900	992	FP/CR	FP	FRB/CP/CCR
20 Gaspard Ck.	*	943	FP	FP	FRB/CP
21 Williams Lake R.	00-3900	2,240	FB/FP	FP	CB/CP
22 -Knife Ck.	00-3900-250	232	FB/FP	FP	CB/CP

1. Physiographic regions from Matthews (1986). CM are the Cascade Mountains, PR are the Pacific Ranges and CR, the Chilcotin Ranges of the Coast Mountains, FP, the Fraser Plateau, and FB, the Fraser Basin.
2. Ecoregions from Demarchi (1993). PR, the Pacific Ranges, ITR, the Interior Transition Ranges, and FP, the Fraser Plateau.
3. Ecosections from Demarchi (1993). EPR, the Eastern Pacific Ranges, LPR, the Leeward Pacific Ranges, SCR, the Southern Chilcotin Ranges, FRB, the Fraser River Basin, CP, the Chilcotin Plateau, CCR, the Central Chilcotin Ranges, and CB, the Cariboo Basin.

**Table 3: Regional Climate in the Middle Fraser HMA.**

Climate Station	Ecoregion (1)	Physiographic Region (2)	Latitude	Longitude	Elevation (m)	Precipitation (mm) (3)				Mean Annual Temperature
						Annual	May to Sept	Annual Snowfall	Greatest Daily	
<b>Fraser Plateau Ecoregion</b>										
Williams Lake A	CB	FP	52.11	122.40	940	412.8	227.8	198.9	42.7	3.9
Williams Lake Glendale	CB	FP	52.09	122.10	588	386.1	190.7	115.8	32.6	5.4
Ochitree Miocene	CB/CP	FP	52.16	121.48	1128	552.6	256.9	225.8	56.1	3.7
150 Mile House	CB	FP	52.07	121.56	738	414.2	214	144.5	43.9	4.2
100 Mile House	CB	FP	51.39	121.18	1059	386	196	148.9	31.8	4.0
Dog Creek A	FRB	FP	51.38	122.15	1027	388.4	197.9	180	47	4.0
<b>Interior Transition Ranges Ecoregion</b>										
Lillooet Seton BCHA	SCR	PR	50.40	121.55	198	286.5	93.6	48	29.5	8.7
Lillooet	SCR	PR	50.42	121.56	290	391.4	139.7	73.2	114.3	-
Lillooet Cedar Falls	SCR	PR	50.36	121.52	555	405.0	127.6	118.5	51.1	-
Lillooet Russell St	SCR	PR	50.42	121.56	244	341.5	118.7	81.4	47.2	-
Shalath	SCR	PR	50.44	122.13	244	514.2	118.3	110.5	55.1	9.6
Bralome	SCR	PR	50.47	122.49	1015	636.3	156.6	271.3	55.9	4.1
Lytton	SCR	PR	50.14	121.34	175	467.3	92.3	162.5	76.7	10
Pemberton BCFS	EPR/LPR	PR	50.19	122.49	218	1186.9	223.9	310.5	92.2	7.2
Pemberton Meadows	EPR/LPR	PR	50.27	122.56	223	990.2	197.1	283.4	101.6	7.0
<b>Pacific Ranges Ecoregion</b>										
Hells Gate	EPR	PR/CM	49.47	121.27	122	1198.9	176.5	188.5	96.5	9.2
Hope A	EPR	CM	49.22	121.29	39	1715.8	326.5	192.6	142.0	9.7
Hope Kawkawa Lake	EPR	CM	49.23	121.24	152	1556.0	301.6	197.2	111.0	9.3
Allison Pass	EPR	CM	49.08	120.5	1341	1524.5	288.2	1431.5	81.3	1.8

1. CB is the Cariboo Basin; FRB, the Fraser River Basin; SCR, the Southern Chilcotin Ranges; EPR, Eastern Pacific Ranges; LPR, the Leeward Pacific Ranges Ecoregion
2. PR is the Pacific Ranges; CM, the Cascade Mountains; FP, the Fraser Plateau physiographic region.
3. Climate data from the 1951-1980 Canadian Climate Normals.

**Table 4:  
Hydrologic Characteristics of the Ecoregion in the Middle Fraser HMA.**

	<i>Cariboo Basin/ Fraser River Basin Ecoregions</i>	<i>Leeward Pacific Ranges Ecoregion</i>	<i>Southern Chilcotin Ranges Ecoregion</i>	<i>Eastern Pacific Ranges Ecoregion</i>
<i>Mean Annual Runoff (mm)</i>	30 to 50	700	1500	1500
<i>Month with Average Maximum Discharge</i>	April and May	June	July	June; remains high in July
<i>Timing of annual maximum discharge</i>	April and May; Occ. Fall in small watersheds	May and June; sometimes in October	June and July; sometimes August or early Fall	late May to July; sometimes in October & November
<i>Month with Average Minimum Discharge</i>	September	February	February	February
<i>Timing of annual minimum discharge</i>	July and August; sometimes in winter	December through March	November through February	December through March
<i>Typical Stream</i>	Forbes Creek near the mouth 08MCO41	Gates Creek below Haymore Ck 08ME022	Bridge River at Lajoie Falls 08ME004	Nahatlach River below Tachewana Creek 08MF065
<i>Basin Area (km<sup>2</sup>)</i>	83	326	956	715

**Table 5: Channel Stability in the Middle Fraser HMA.**

Stream Name	SSIS Number	Channel Response					Human Modifications						
		Pattern Change	Erosion	Incision	Aggradation	Bed Material		Dyking	River Training	Encroachment	Gravel Removal	Veget. Removal	Debris Removal
						Scour	Sedimentation						
<b>COQUIHALLA RIVER</b>													
1 Coquihalla R.	00-0800		•			•	•	•		•	•		
2 - Kawkawa Ck.	00-0800-010												
3 - Sucker Ck.	00-0800-010-010												
4 - Steven Ck.	00-0800-010-020												
5 - Menz Ck.	00-0800-010-030												
6 - Kopp Ck.	00-0800-010-030-010												
1a - Sowaqua Ck.	*												
7 American Ck.	00-0815												
8 Squeah Lake Ck.	00-0834												
9 Emory Ck.	00-0841												
10 Gordon Ck.	00-0855												
11 Yale Ck.	00-0860												
12 Sawmill Ck.	*												
13 Spuzzum Ck.	00-0900		•				•						
<b>ANDERSON RIVER</b>													
14 Anderson R.	00-1000		•									■	
14a - Lower Anderson R.	*												
14b - Upper Anderson R.	*												
14c - Utzius Ck.	*												
14d - East Anderson R.	*												
15 Stoyama Ck.	*												
<b>NAHATLACH RIVER</b>													
16 Nahatlatch R.	00-1200												
16a - Lower Nahatlatch R.	*												
16b - Upper Nahatlatch R.	*												
16c - Log Ck.	*												
16d - Kookpi Ck.	*												
16e - Unnamed Ck.	*												
16f - Mehatt Ck.	*												
17 Stein R.	00-1400												
18 Texas Ck.	00-1600												
19 Chum Ck.	00-2900		•				•						
20 Gaspard Ck.	*												
21 Williams Lake R.	00-3900											■	
22 -Knife Ck.	00-3900-250											•	

- \* ▲ refers to upper river; ■ to middle river; and ● to lower river or fan.

**Table 6      Definitions of Flow Characteristics**

**Annual flood** - Maximum or "peak" daily flow of the year.

**Annual flow** - average of the daily flows between January 1 and December 31 for a particular year.

**Annual 7 day low flow** - The lowest average flow for 7 consecutive days between January 1 and December 31. Same as "7 day mean low" used in Appendix C.

**Daily flow** - Average flow for the period midnight to midnight.

**Mean annual flood** - Average of the annual floods for a stated historic period.

**Mean annual flow** - Average of the annual flows for a stated historic period.

**Mean annual 7 day low flow** - Average of the 7 day low flows for a stated historic period.

**Mean August flow** - Average of the August flows for a stated historic period.

**Mean September flow** - Average of the September flows for a stated historic period.

**Mean winter 7 day low flow** - Average of the winter 7 day low flows for a stated historic period.

**Naturalized flow** - Measured flows, adjusted with upstream water licenses, to represent the flows that would occur in the absence of regulation and extraction.

**Summer 7 day low flow** - The lowest average for 7 consecutive days between May 1 and October 31.

**Water Demand** - Sum of all the consumptive uses upstream of a reference point, as estimated from water licenses.

**Winter 7 day low flow** - The lowest average flow for 7 consecutive days between November 1 and April 30.

**Unit flow** - The flow at a reference point, usually a Water Survey of Canada station, divided by the basin area above that reference point.

**Table 7: Hydrology of the Salmon Streams in the Middle Fraser HMA.**

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area					Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m3/s)					
			Oldest (pre-63) (km2)	Older (63-72) (km2)	Old (73-82) (km2)	Recent (83-92) (km2)	Proposed (1993-98) (km2)	Domestic (g/day)	Irrigation (ac-ft)	Water-works (g/day)	Industrial (g/day)	Conservation (cfs)	Aug	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly		Mean 7-day Flow	
																	Aug	Sept	Summer	Winter	
<b>COQUIHALLA RIVER</b>																					
Coquihalla R.	08MF003	932	0	4.5	2.5	32.0	7.9	6,750	3	37,000	424,000	60	25	25	25	30.00	234.0	12.00	13.00	5.95	7.80
- Kawkawa Ck.		9	0	0	0	0	0	3,750	0	37,000	9,500	0	3	3	3	0.32		0.3	0.276	0.24	0.4
- Sucker Ck.		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	-	0.11	0.10	0.09	0.15
- Steven Ck.		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	-	0.04	0.03	0.03	0.05
- Kopp Ck.		3	0	0	0	0	0	1,000	0	34,000	5,000	0	2	2	2	0.12	-	0.11	0.10	0.09	0.15
- Menz Ck.		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	-	0.04	0.03	0.03	0.05
- Sowaqua Ck.		153	0	0	0	3.2	5.3	0	0	0	0	0									
American Ck.	08MF032	32	0	0	0	1.8	1.2	1,000	0	0	0	0	0	0	0	3.07	49.2	0.29	0.50	0.20	0.11
Squeah Lake Ck.		14	0	0	0	0	0	0	0	0	0	0	0	0	0	1.36	25.7	0.13	0.22	0.09	0.05
Emory Ck.	08MF030	65	0	0	0.9	3.8	0.6	3,000	0	0	0	0	0	0	0	5.10	68.6	0.64	1.29	0.38	0.39
Gordon Ck.		11	0	0	0	2.3	0	1,500	0	0	0	0	0	0	0	0.83	16.0	0.10	0.21	0.06	0.06
Yale Ck.	08MF031	37	0	0	0	1.8	0.2	2,000	18	25,000	0	0	4	2	1	2.41	49.2	0.35	0.81	0.13	0.17
Sawmill Ck.		31	0	0	0	0	0	3,000	15	0	0	0	2	1	0						
Spuzzum Ck.		224	0	0.5	6.2	9.7	2.8	500	54	47,000	17,000	0	11	6	3	14.46	206.3	2.07	3.63	0.78	1.02
<b>ANDERSON RIVER</b>																					
Anderson R.		500	0	0	16.9	58.3	41.3	0	0	0	0	0	0	0	0	10.24	91.1	2.12	1.55	0.87	0.55
- Lower Anderson R.		350	0	0	16.9	38.9	26.6	0	0	0	0	0	0	0	0						
- Upper Anderson R.		150	0	0	0	19.4	14.7	0	0	0	0	0	0	0	0						
- Utzius Ck.		160	0	0	13.7	23.4	9.8	0	0	0	0	0	0	0	0						
- East Anderson R.		125	0	0	2.7	7.9	11.5	0	0	0	0	0	0	0	0						
Stoyama Ck.		38	0	0	0	2.2	1.2	12,500	0	5,000	53,000	0	4	4	4						

- Gauge numbers in Column 2 indicate that flow characteristics were calculated from those Water Survey of Canada records.
- Logged areas determined as described in Section 4 of the report.
- Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
- Reference for all data in table is the mouth of the salmon stream.
- Licenced demands (L/s) calculated from total water licences as described in Section 5 of the report.
- Naturalized flows are estimates of those that would occur in the absence of all upstream water extractions.

Table 7, continued

Stream Name	WSC Gauge No.	Basin Area (mouth) (km <sup>2</sup> )	Logged Area					Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m <sup>3</sup> /s)						
			Recent (km <sup>2</sup> )	Old (km <sup>2</sup> )	Older (km <sup>2</sup> )	Oldest (km <sup>2</sup> )	Proposed (1992-97) (km <sup>2</sup> )	Domestic (g/day)	Irrigation (ac-ft)	Water-works (g/day)	Industrial (g/day)	Conservation (cfs)	Aug	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7-day Flow Summer	Mean 7-day Flow Winter	
<b>NAHATLATCH RIVER</b>																						
Nahatlatch R.	08MF065	1256	0.2	0.4	4.0	19.4	16.4	6,550	6	0	0	0	0	1	1	0	38.02	229.9	38.47	23.31	12.60	7.59
- Lower Nahatlatch R.		946	0.2	0.4	4.0	16.5	8.2	6,550	6	0	0	0	0	1	1	0						
- Upper Nahatlatch R.		310	0	0	0	3.0	8.2	0	0	0	0	0	0	0	0	0						
- Log Ck.		84	0	0	0	5.0	0															
- Kookipi Ck.		159	0	0	0	2.6	3.8															
- Unnamed Ck.		53	0	0	0	0	0															
- Mehati Ck.		293	0.2	0.4	3.7	0.8	0															
Stein R.		1084	0	0	0	0	0	3,000	886	175,000	0	0	134	51	9	17.5	76.5	17.7	10.4	5.2	3.8	
Texas Ck.		171	0	2.9	1.7	5.1	3.3	2,000	805	0	0	0	113	38	0	2.8	17.5	2.8	1.6	0.8	0.6	
Churn Ck.		992	0	0	9.1	18.5	101.4	18,500	267	0	0	0	38	13	1	6.0	33.3	9.14	5.72	2.88	1.58	
Gaspard Ck.		943	0	25.1	54.8	76.2	46.9															
Williams Lake R.	08MC005	2240	9.5	51.8	67.0	144.8	90.4	98,750	19,206	3,569,000	491,600	0	2916	1118	219	2.6	7.3	4.01	1.58	1.38	0.39	
-Knife Ck.		232	1.6	3.6	5.6	14.0	13.4	5,000	4,503	0	500	0	633	211	0	0.2	2.9	0.67	0.24	0.21	0.05	

- Gauge numbers in Column 2 indicate that flow characteristics were calculated from those Water Survey of Canada records.
- Logged areas determined as described in Section 4 of the report.
- Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
- Reference for all data in table is the mouth of the salmon stream.
- Licenced demands (L/s) calculated from total water licences as described in Section 5 of the report.
- Naturalized flows are estimates of those that would occur in the absence of all upstream water extractions.

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**Table 8: Storage in the Salmon Streams of the Middle Fraser HMA.**

<i>Stream Name</i>	<i>Basin Area (mouth) (km<sup>2</sup>)</i>	<i>Total Non-Power Storage (ac-ft)</i>	<i>Total Conservation Storage (ac-ft)</i>	<i>Total Irrigation Licences (ac-ft)</i>	<i>Percent with Storage (%)</i>
<b>COQUIHALLA RIVER</b>					
Coquihalla R.	932	0	0	3	0
- Kawkawa Ck.	9	0	0	0	0
- Sucker Ck.	3	0	0	0	0
- Steven Ck.	1	0	0	0	0
- Kopp Ck.	3	0	0	0	0
- Menz Ck.	1	0	0	0	0
- Sowaqua Ck.	153	0	0	0	0
American Ck.	32	0	0	0	0
Squeah Lake Ck.	14	0	0	0	0
Emory Ck.	65	0	0	0	0
Gordon Ck.	11	0	0	0	0
Yale Ck.	37	0	0	18	0
Sawmill Ck.	31	0	0	15	0
Spuzzum Ck.	224	0	0	54	0
<b>ANDERSON RIVER</b>					
Anderson R.	500	0	0	0	0
- Lower Anderson R.	350				
- Upper Anderson R.	150				
- Utzlius Ck.	160				
- East Anderson R.	125				
Stoyama Ck.	38	0	0	0	0
<b>NAHATLACH RIVER</b>					
Nahatlatch R.	1,256	0	0	6	0
- Lower Nahatlatch R.	946				
- Upper Nahatlatch R.	310				
- Log Ck.	84				
- Kookipi Ck.	159				
- Unnamed Ck.	53				
- Mehatl Ck.	293				
Stein R.	1,084	0	0	886	0
Texas Ck.	171	0	0	805	0
Churn Ck.	992	165	0	267	62
Gaspard Ck.	943	-	-	-	-
Williams Lake R.	2,240	13,106	2,929	19,206	68
-Knife Ck.	232	3,309	0	4,503	73
<b>TOTAL</b>		<b>13,271</b>	<b>2,929</b>	<b>21,260</b>	<b>62</b>

- Nonpower includes all storage for domestic, waterworks, industrial, and irrigation licences. Conservation licences are not included in the nonpower totals.

- Irrigation licences for each salmon stream are from Table 7.

- Percent with storage calculated by dividing nonpower storage by total irrigation licences for each stream

**Table 9: Sensitivity Indices -- Middle Fraser HMA**

Stream Name	Status	SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	LOGGING		
		Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin	Index 10 Recent & Proposed
<b>COQUIHALLA RIVER</b>											
Coquihalla R.		0%	0%	0%	0%	20%	26%	8	3%	4%	4%
- Kawkawa Ck.		1%	1%	1%	1%	74%	124%	-	0%	0%	0%
- Sucker Ck.		0%	0%	0%	0%	75%	125%	-	0%	0%	0%
- Steven Ck.		0%	0%	0%	0%	75%	125%	-	0%	0%	0%
- Kopp Ck.		2%	2%	2%	2%	73%	123%	-	0%	0%	0%
- Menz Ck.		0%	0%	0%	0%	75%	125%	0	0%	0%	0%
- Sowaqua Ck.									2%	2%	6%
American Ck.		0%	0%	0%	0%	7%	4%	16	6%	6%	9%
Squeah Lake Ck.		0%	0%	0%	0%	7%	4%	19	0%	0%	0%
Emory Ck.		0%	0%	0%	0%	7%	8%	13	6%	7%	7%
Gordon Ck.		0%	0%	0%	0%	7%	8%	19	22%	22%	22%
Yale Ck.		3%	2%	1%	0%	5%	7%	20	5%	5%	5%
Sawmill Ck.									0%	0%	0%
Spuzzum Ck.		1%	1%	1%	0%	5%	7%	14	4%	7%	6%
<b>ANDERSON RIVER</b>											
Anderson R.		0%	0%	0%	0%	9%	5%	9	12%	15%	20%
- Lower Anderson R.									11%	16%	19%
- Upper Anderson R.									13%	13%	23%
- Utzlius Ck.									15%	23%	21%
- East Anderson R.									6%	8%	15%
Stoyama Ck.									6%	6%	9%

-Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; OR, office reserve, no licencing; PWS, possible water shortages, RNW, Refused, no water.

- Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and mean Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Total is total logging; Recent is recent logging; Proposed in proposed cut (1993-1998); Basin is basin area above the mouth.

-Indices expressed as percentages except 7, which is a direct ratio.

-Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 7; values of Indices 8, 9 and 10 exceeding 20% are shaded.

**Table 9: Sensitivity Indices, continued**

Stream Name	Status	SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	LOGGING		
		Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin	Index 10 Recent & Proposed
<b>NAHATLACH RIVER</b>											
Nahatlatch R.		0%	0%	0%	0%	33%	20%	6	2%	2%	3%
- Lower Nahatlatch R.									2%	2%	3%
- Upper Nahatlatch R.									1%	1%	4%
- Log Ck.									6%	6%	6%
- Kookipi Ck.									2%	2%	4%
- Unnamed Ck.									0%	0%	0%
- Mehatl Ck.									0%	2%	0%
Stein R.		3%	1%	1%	0%	29%	21%	4	0%	0%	0%
Texas Ck.		14%	5%	4%	2%	28%	22%	6	3%	6%	5%
Churn Ck.		1%	0%	0%	0%	47%	26%	6	2%	3%	12%
Gaspard Ck.									8%	17%	13%
Williams Lake R.	FR	212%	81%	73%	71%	10%	6%	3	6%	12%	10%
-Knife Ck.	FR	296%	99%	94%	86%	1%	24%	14	6%	11%	12%

-Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; OR, office reserve, no licencing; PWS, possible water shortages, RNW, Refused, no water.

- Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and mean Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Total is total logging; Recent is recent logging; Proposed in proposed cut (1993-1998); Basin is basin area above the mouth.

-Indices expressed as percentages except 7, which is a direct ratio.

-Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 7; values of Indices 8, 9 and 10 exceeding 20% are shaded.

**Table 10: Most Sensitive Streams -- Middle Fraser HMA.**

<i>Water Demand</i>	<i>Summer Low Flows</i>	<i>Winter Low Flows</i>	<i>Forest Harvesting</i>
<i>1 to 4</i>	<i>5</i>	<i>6</i>	<i>8 to 10</i>
Texas Creek	American Ck	American Ck	Gordon Creek
Williams Lake River	Squeah Lk Creek	Squeah Lk Creek	Anderson River
Knife Creek	Emory Ck	Yale Creek	Upper Anderson River
	Gordon Creek	Spuzzum Creek	Utzius Creek
	Yale Creek	Anderson River	
	Spuzzum Creek	Williams Lake River	
	Knife Creek		

FIGURES



**Figure 1: Fraser River Habitat Management Areas**

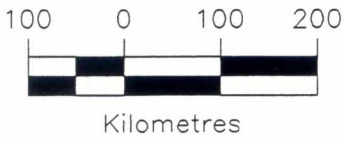


Figure 2a: Salmon Streams in the Middle Fraser HMA

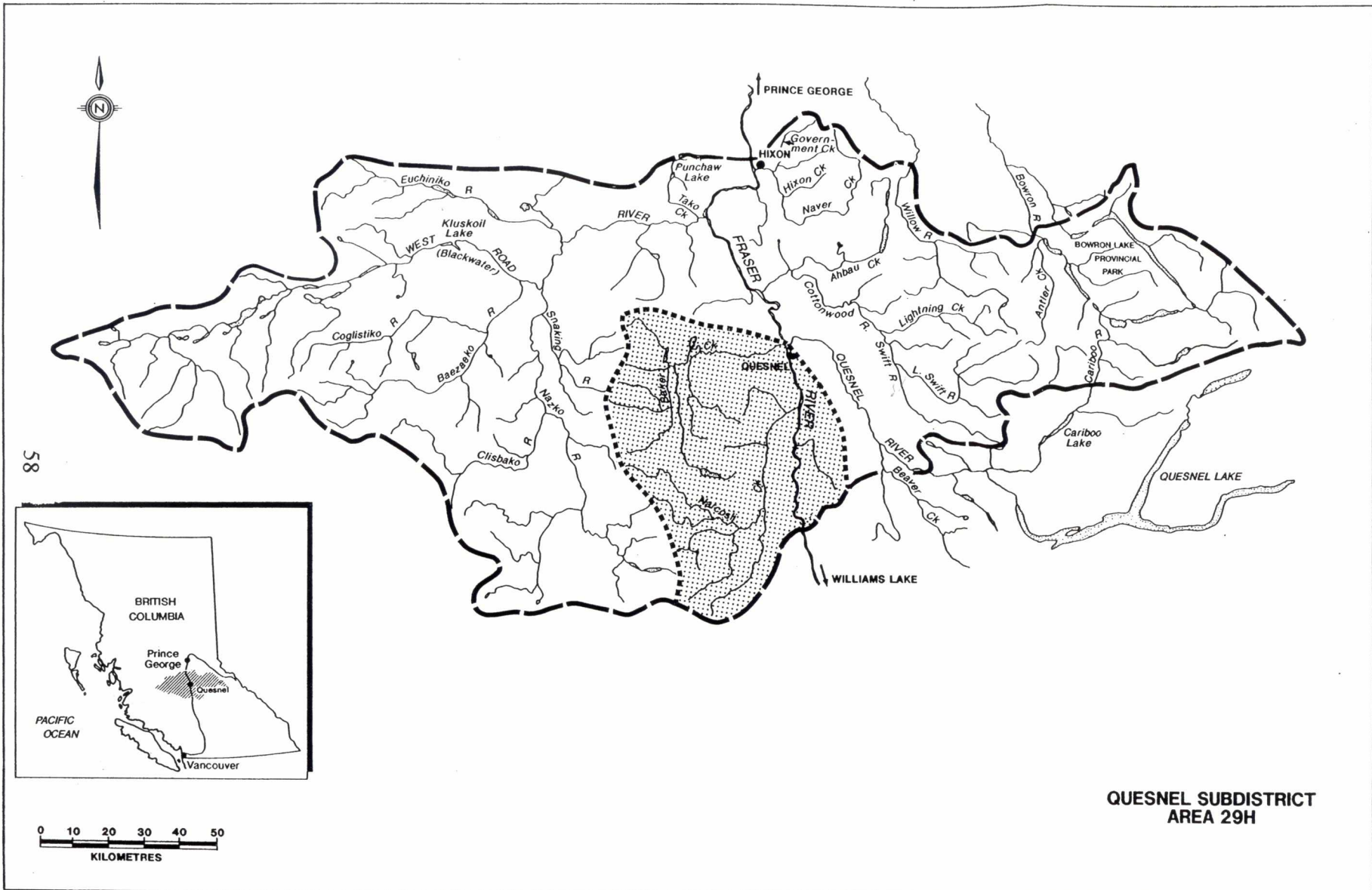


Figure 2b: Salmon Streams in the Middle Fraser HMA

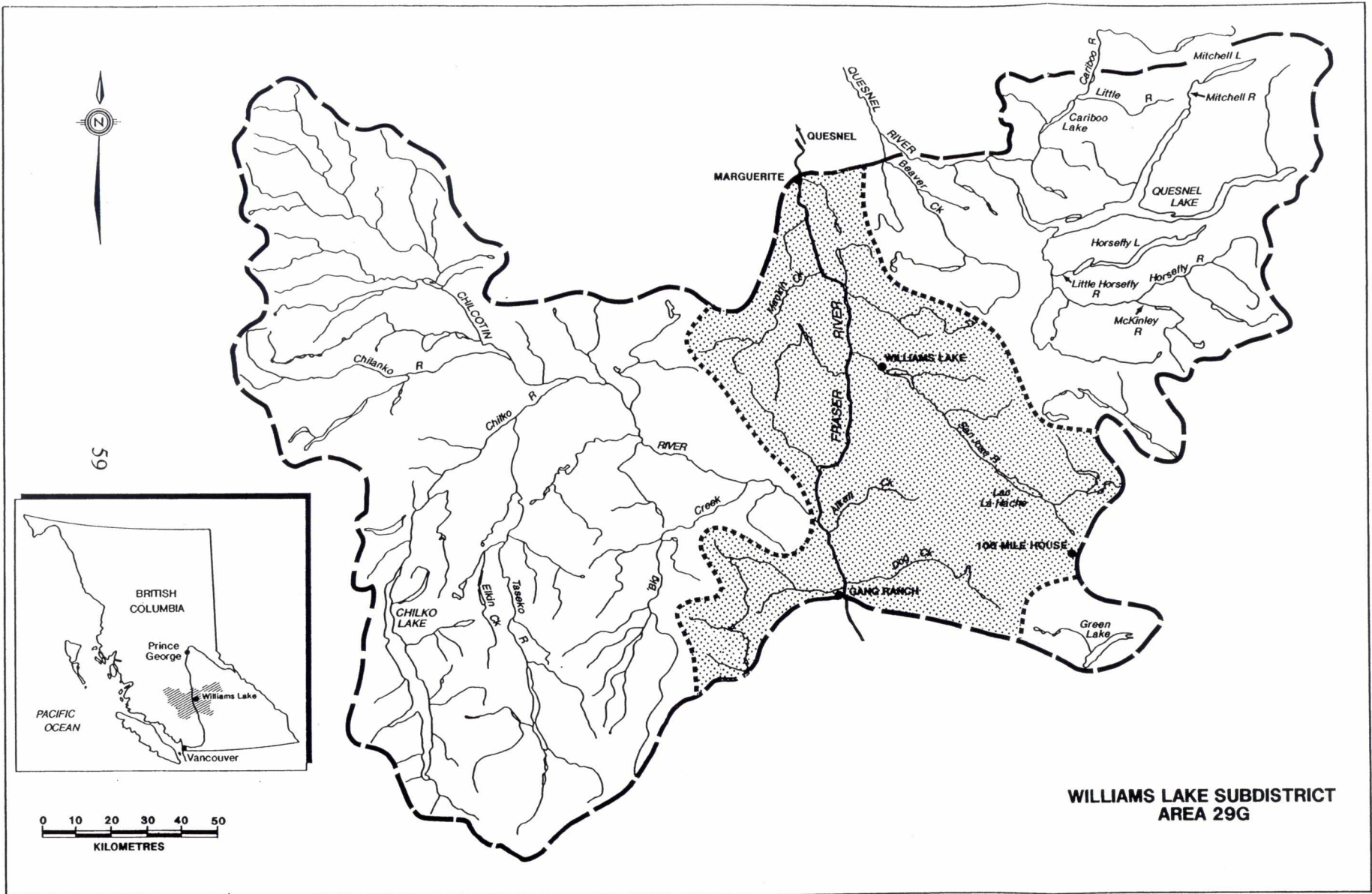
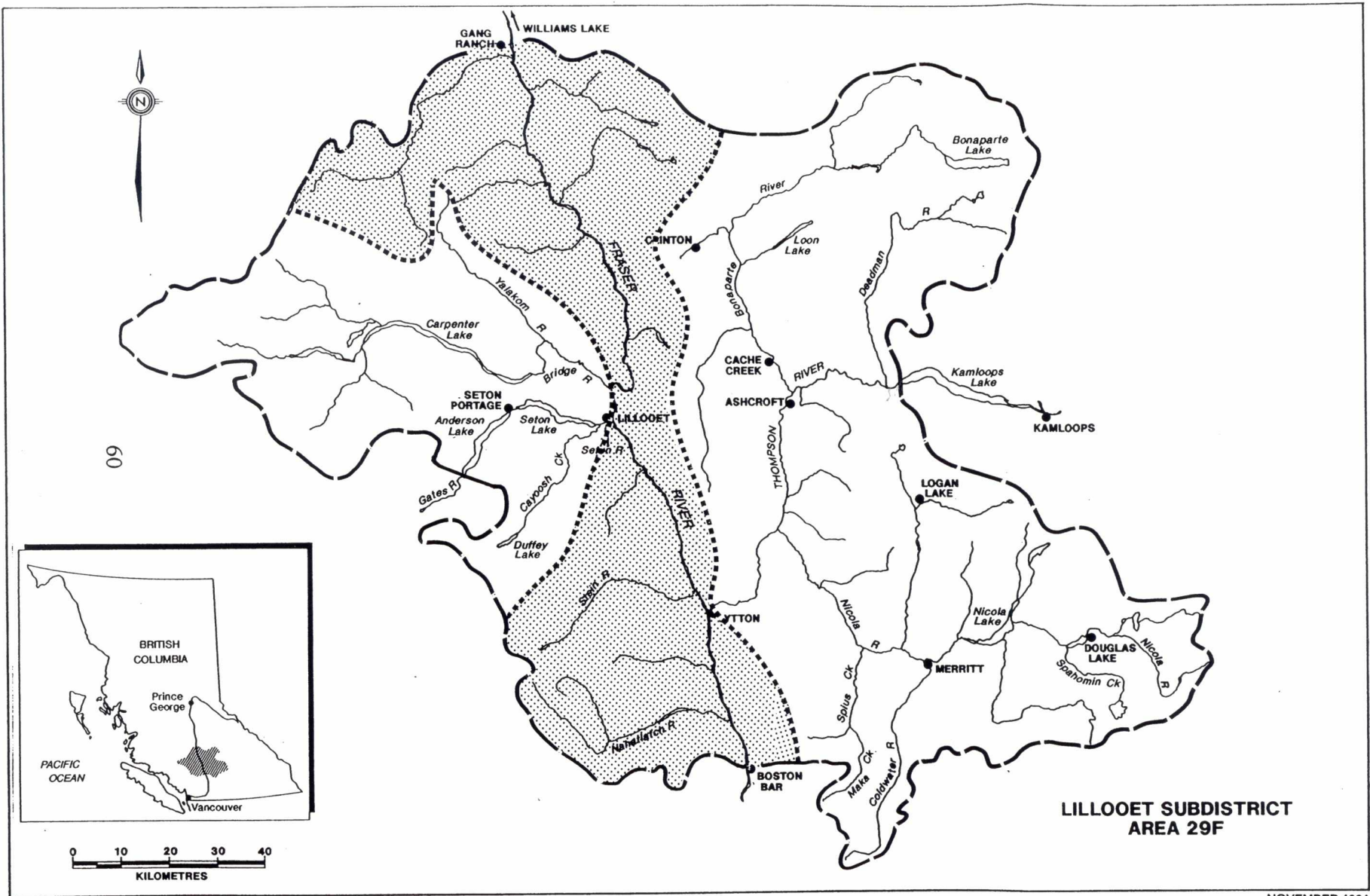


Figure 2c: Salmon Streams in the Middle Fraser HMA



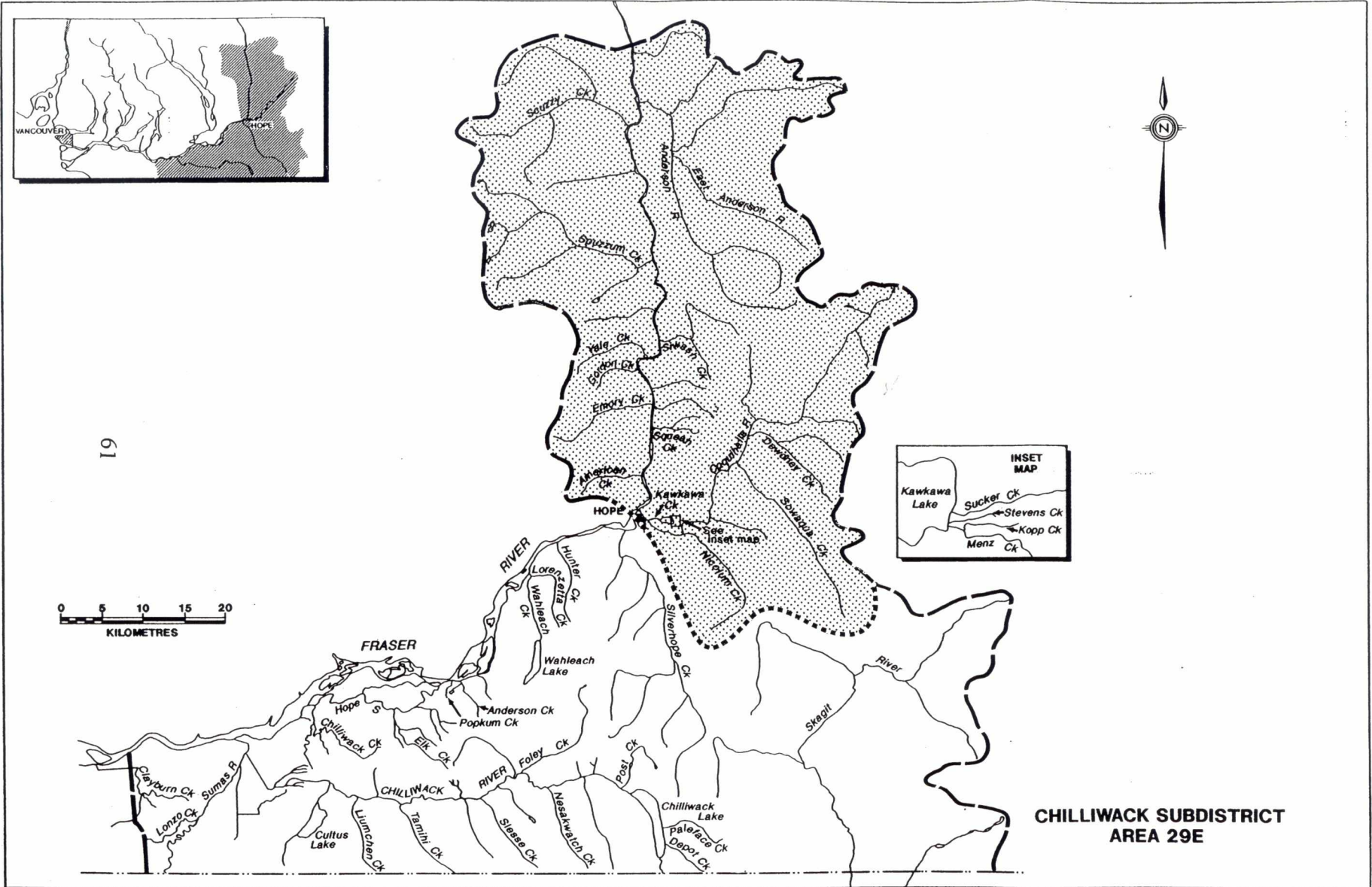
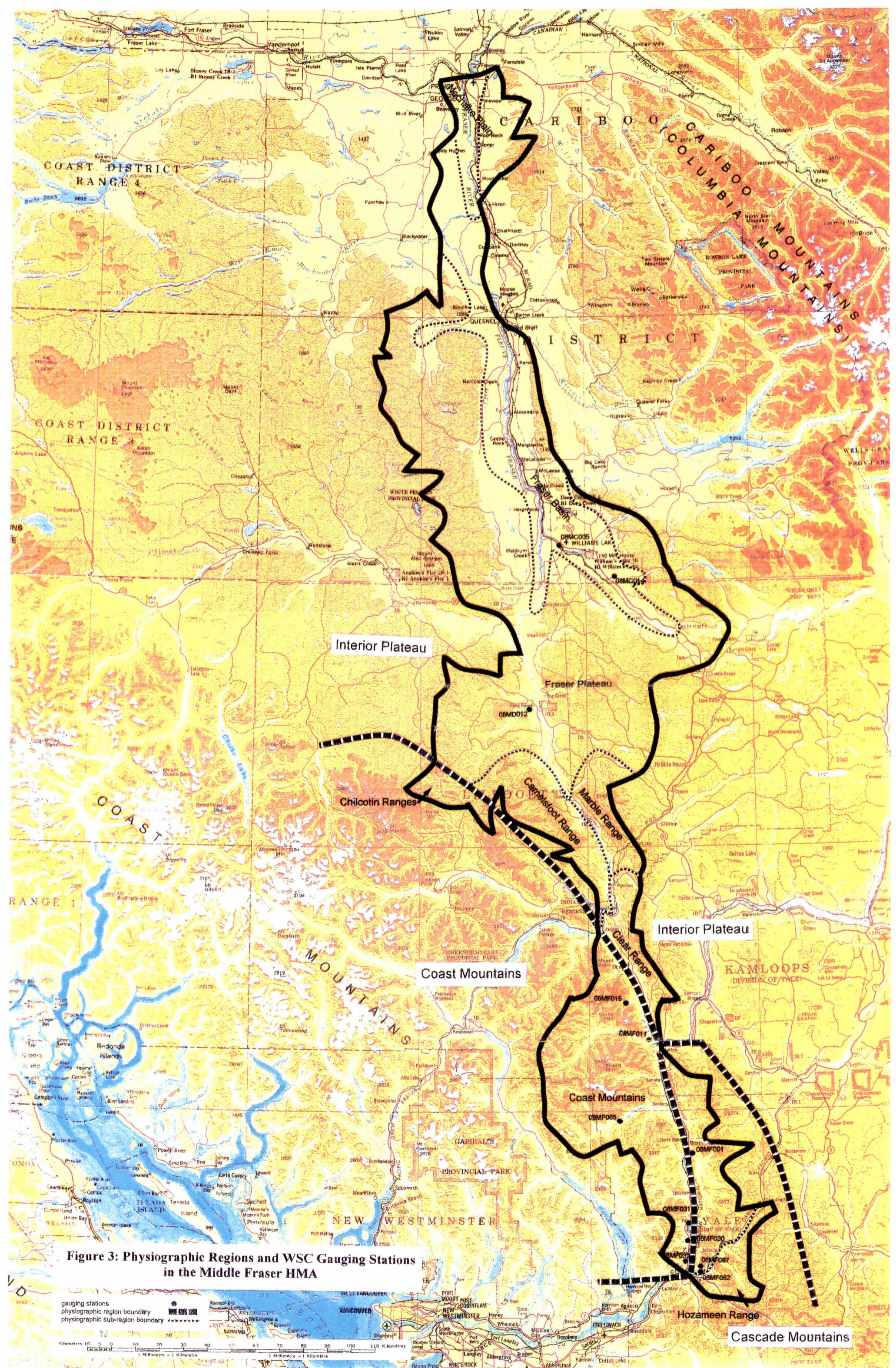


Figure 2d: Salmon Streams in the Middle Fraser HMA



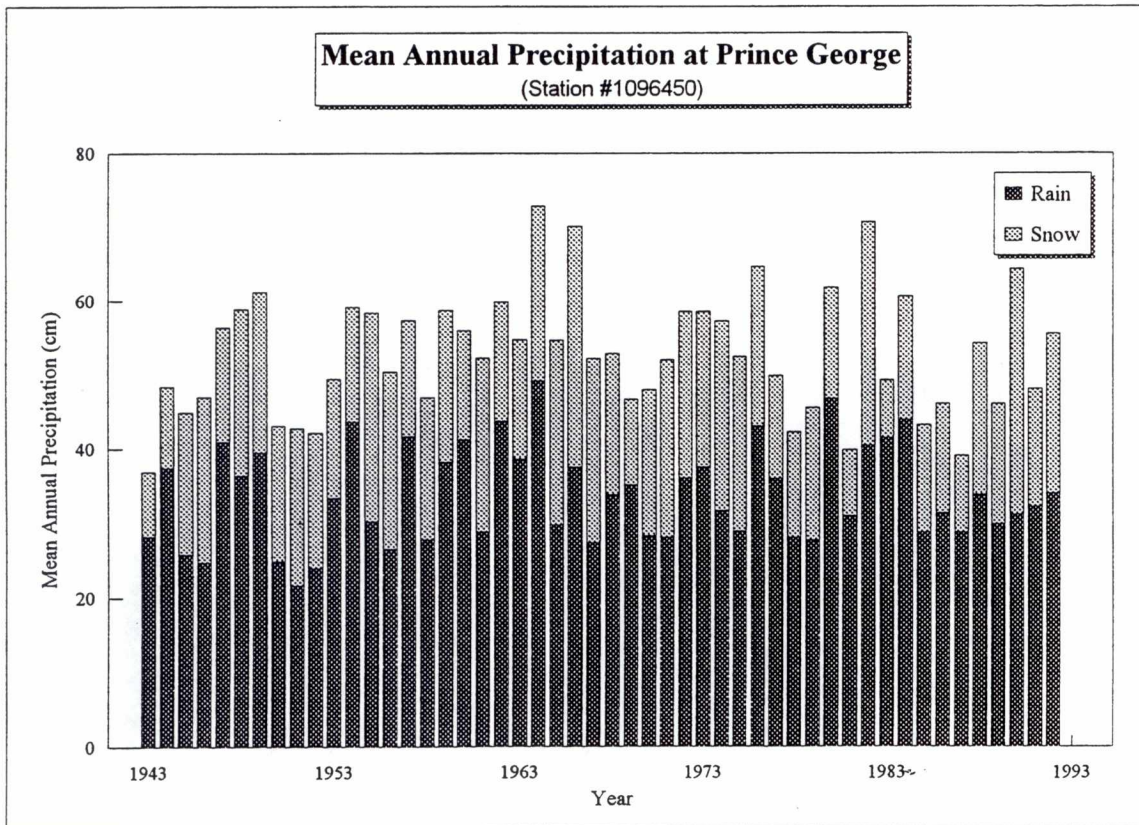
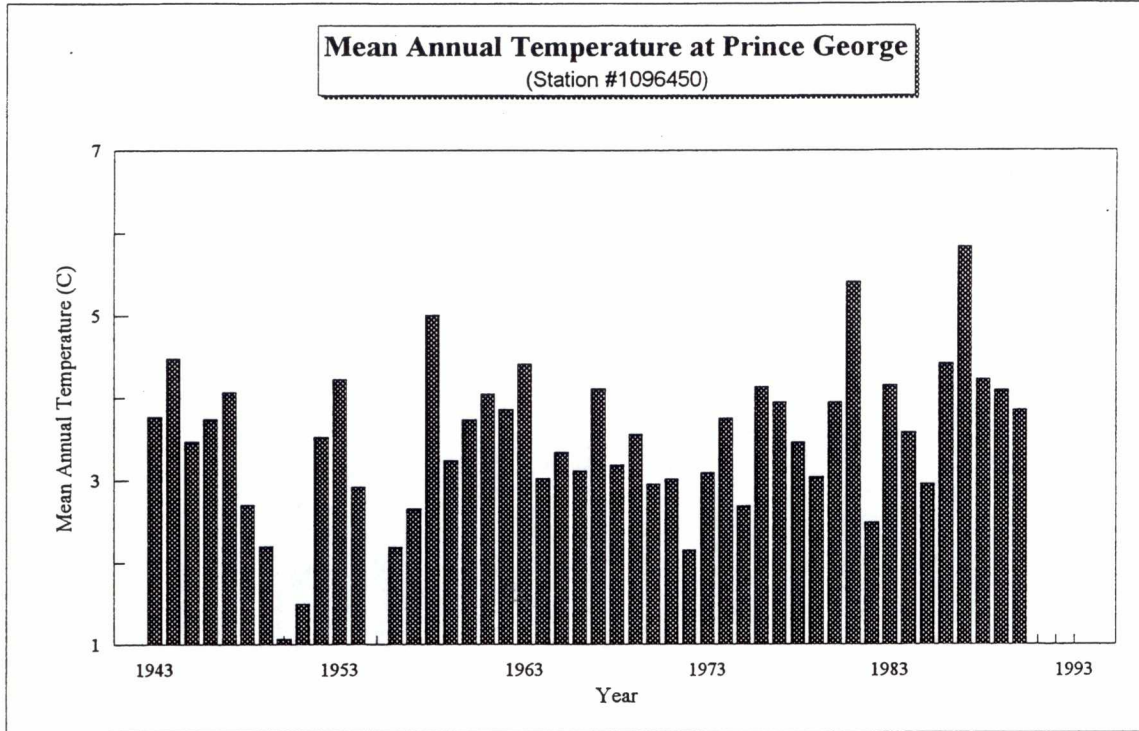
**Figure 3: Physiographic Regions and WSC Gauging Stations in the Middle Fraser HMA**

gauging stations  
 physiographic region boundary  
 physiographic sub-region boundary

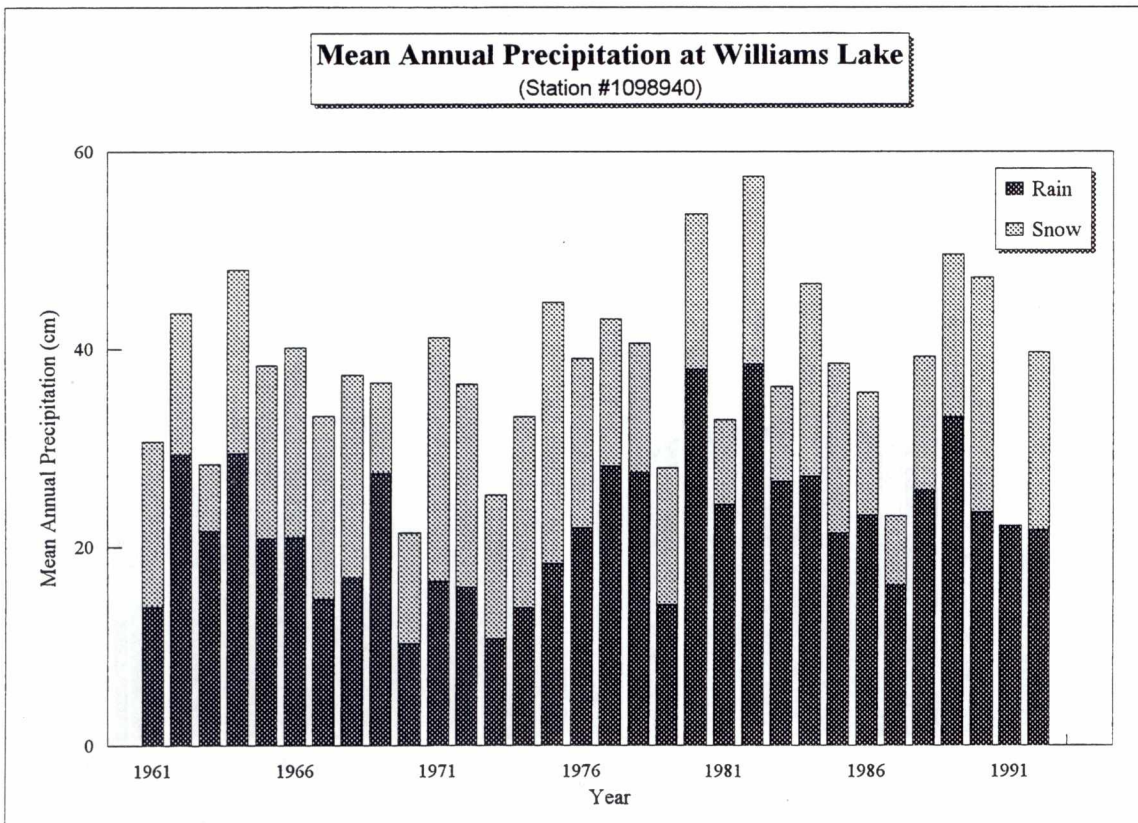
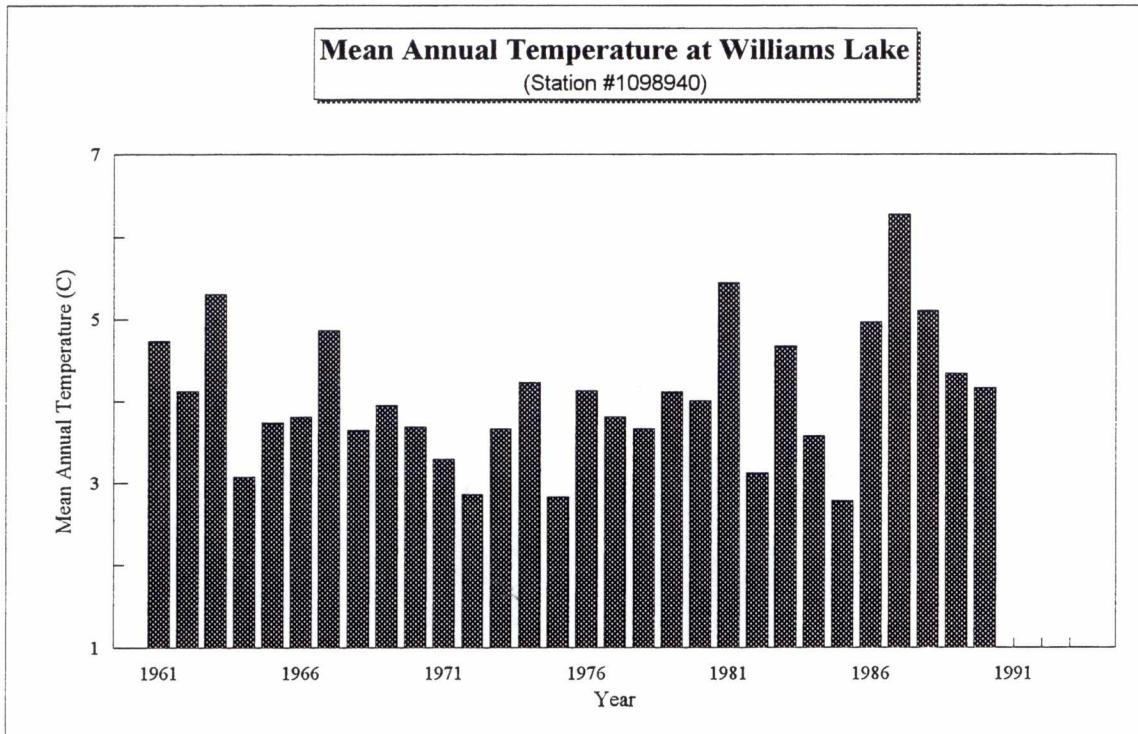
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilometres  
 1 Millimetre = 1 Kilometre

Hozomeen Range  
 Cascade Mountains

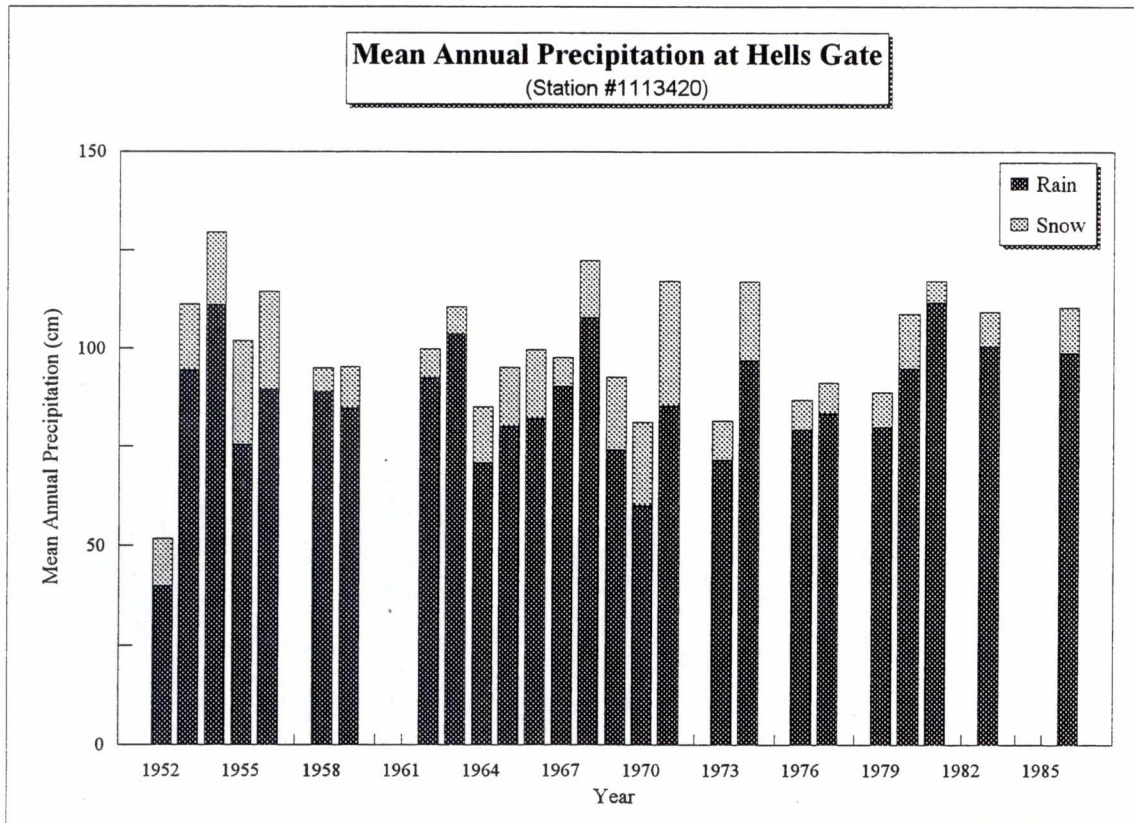
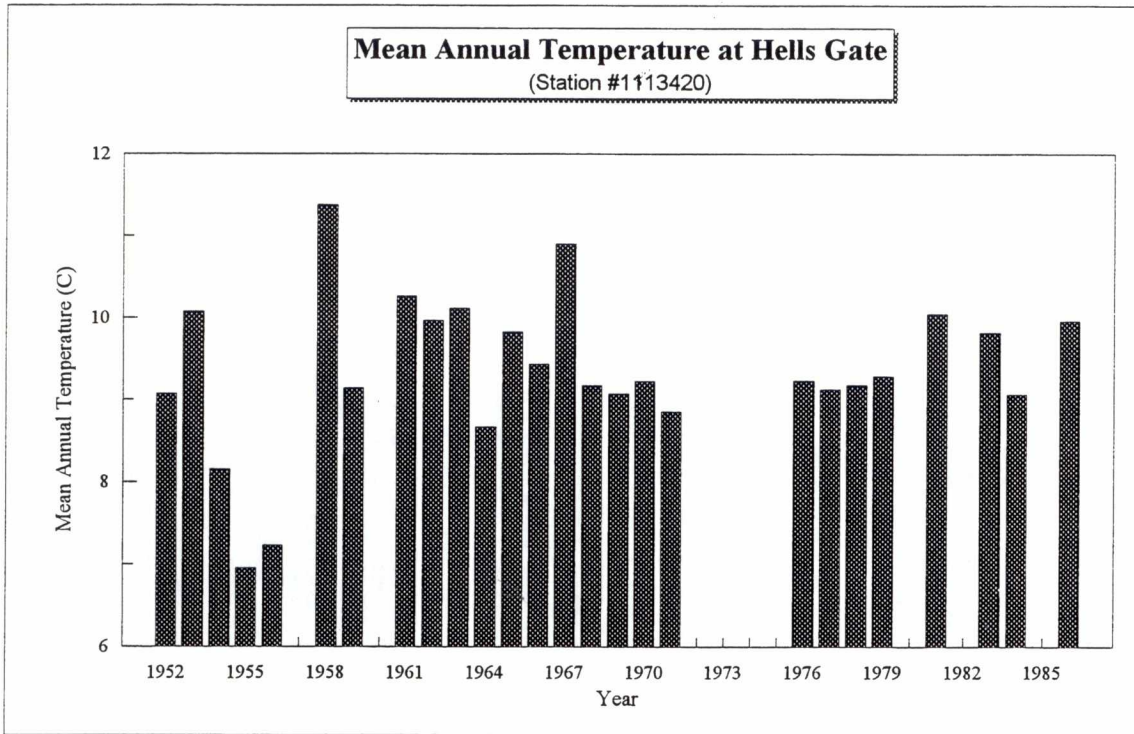
**Figure 4a: Long-Term Temperature and Precipitation Trends at Prince George**



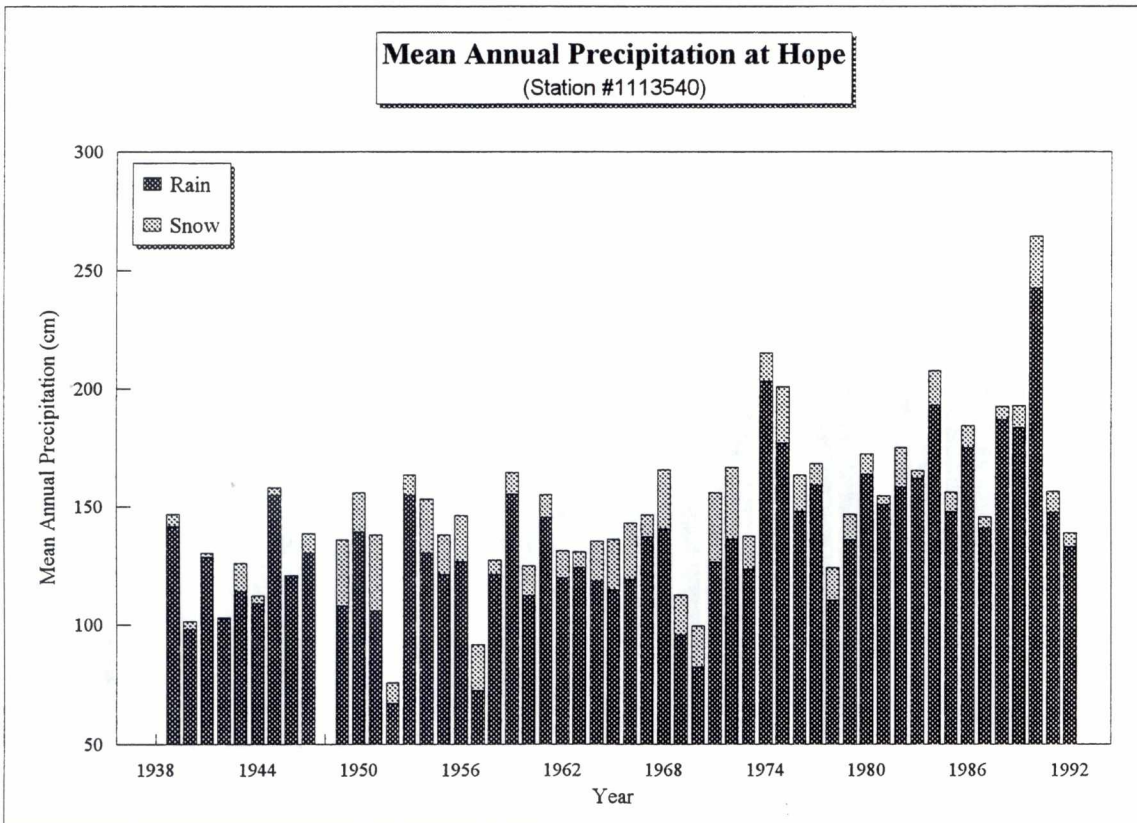
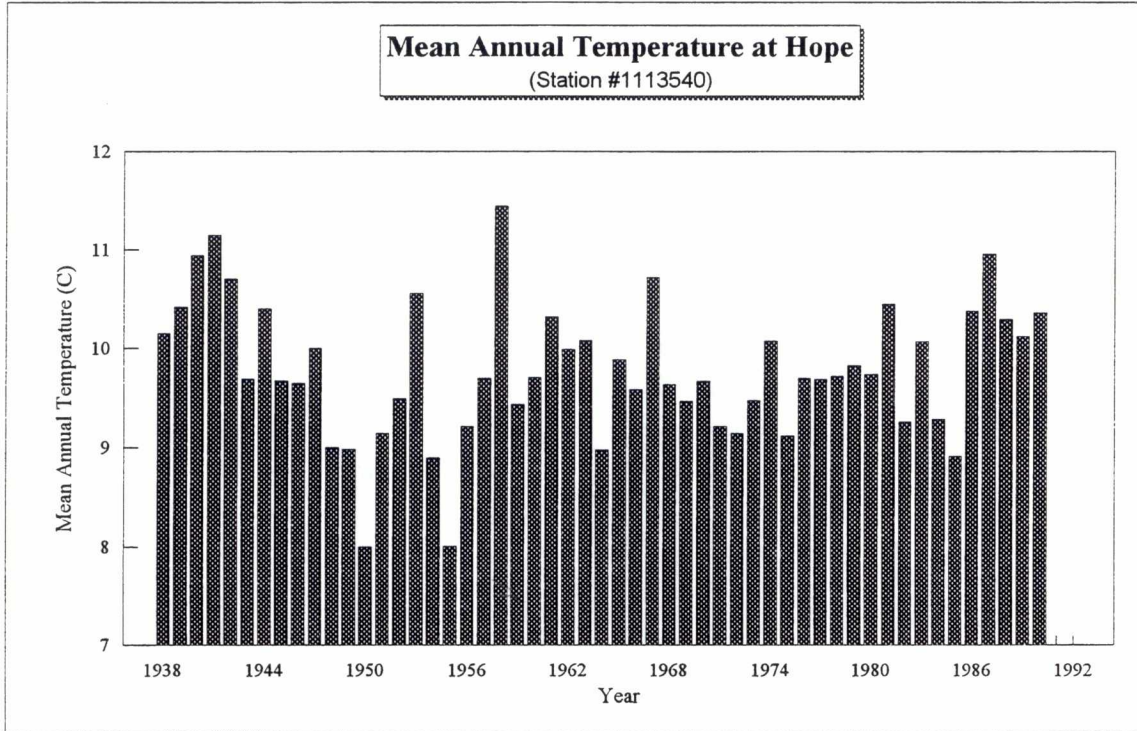
**Figure 4b: Long-Term Temperature and Precipitation Trends at Williams Lake**



**Figure 4c: Long-Term Temperature and Precipitation Trends at Hell's Gate**

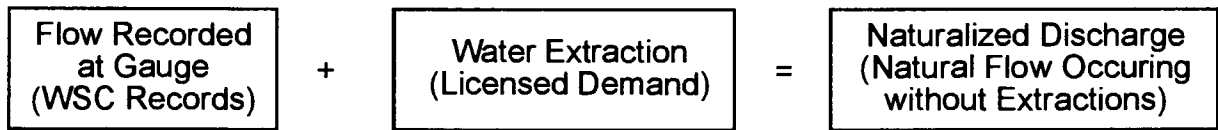


**Figure 4d: Long-Term Temperature and Precipitation Trends at Hope**

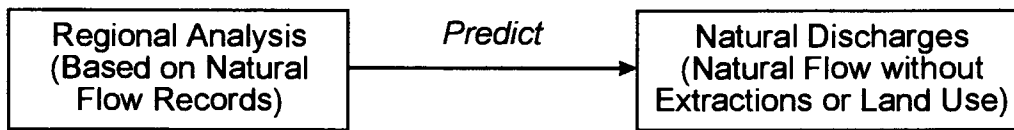


**Figure 5: Calculation of Natural and Naturalized Flows for the Salmon Streams**

*GAUGED STREAMS*



*UNGAUGED STREAMS*



**FIGURE 6: Classification of British Columbia Water Licences**

No.	USE CLASS	DESCRIPTION (uses included)	UNITS
<b>CONSUMPTIVE</b>			
1	Waterworks	- conveyed by local authority (municipality, regional or improvement district) - conveyed by others (individual, utility, Indian band)	gallons/day gallons/year
2	Domestic use		gallons/day
3	Pulpmills		cubic feet/second
4	Industrial	- processing (sawmills, food, manufacturing, etc.) - cooling. - enterprise (hotels, motels, restaurants, etc.) - ponds - watering - bottling for sale - commercial bulk export - mineral water sold in containers and used in bathing pools - all other industrial uses	any
5	Irrigation	- conveyed by local authority (municipal) - private agricultural use	acre-feet
6	Land improvement	e.g. draining property, creating ponds	any
7	Mining	- hydraulic, washing coal, processing ore, placer	any
<b>NON-CONSUMPTIVE</b>			
8	Power generation	- residential, commercial, general	cubic feet/second
9	Storage - nonpower		acre-feet
10	Storage - power		acre-feet
11	Conservation	- storage (e.g. waterfowl habitat enhancement) - use of water (e.g. hatchery) - construction of works in and around a stream (e.g. fish culture, fish ponds, personal)	any

**APPENDIX A**

**PREDICTING FLOWS AT THE MOUTHS OF SALMON STREAMS**

## A. ESTIMATING FLOWS AT THE MOUTH OF UNGAUGED SALMON STREAMS

A number of the salmon streams have been gauged by the Water Survey of Canada at one time or another but only the Coquihalla and Williams Lake Rivers met the requirements for gauged salmon streams, as they have Water Survey of Canada stations operating near their mouths and (nearly) continuous records from 1981 to 1990. The record from Williams Lake River measures a regulated regime, as affected by storage and upstream diversion for irrigation.

The hydrologic characteristics of the other salmon streams were estimated by adjusting Water Survey of Canada gauging records to the mouth of the stream, by transfer of records from nearby gauges or from older records. There are too few gauging stations in the Middle Fraser HMA to develop regression equations relating flow characteristics to basin characteristics for the various hydrologic regions. The following sections describe the procedures used to estimate flows at the mouth of each of the salmon streams.

*Coquihalla River.* Two gauges operated near the mouth of the Coquihalla River during the 1980's: "Coquihalla River near Hope, 08MF003" and Coquihalla River above Alexander Creek, 08MF068". Records are incomplete during the 1980's and the flow characteristics quoted in Table 7 are based on the years from 1973-1980 and 1982.

*Kawkawa Lake Tributaries.* A seasonal gauge operated as "Kopp Creek above Menz Creek, 08MF067" from 1982 to 1985. Kopp Creek and the other tributaries to the lake are all groundwater streams and, as shown by the gauge records, flows are typically near-constant from April through September. Average summer 7 day low flows and average August and September flows were calculated from the available record. Mean flows were estimated from an assumed annual runoff of 1,200 mm (based on the Hope A climate station). It was not possible to estimate winter 7 day low flows or mean annual flood at the gauge.

Average values calculated from the gauge records were transferred, using a ratio of drainage areas, to the mouth of Kopp Creek and to the other tributaries. Average flows in Kawkawa Creek were then calculated as the sum of the inflows from all the headward tributaries.

*American, Squeah Lake, Emory, Gordon, Yale, and Spuzzum Creeks:* These creeks all drain the west side of the Fraser Valley and lie between Hope and Spuzzum. Between 1933 and 1936, the WSC operated the "American Creek near Hope, 08MF032", "Emory Creek near Choate, 08MF030" and "Yale Creek at Yale, 08MF031" gauges. Mean annual flow, mean annual flood, mean monthly discharges and mean 7 day low flows were calculated from these records. The calculated characteristics were adjusted to the 1981 to 1990 period with the "Lillooet River near Pemberton, 08MG005" gauge. The adjustment consisted of determining the ratio of the flow characteristics over the gauging period, and over 1981-1990, at the long-term gauge. These ratios were then applied to the flow characteristics calculated from the older record.

Flow characteristics on American Creek were transferred to Squeah Lake Creek, those on Emory Creek to Gordon Creek and those on Yale Creek to Spuzzum Creeks. The transfer was based on the ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area of the ungauged stream,  $A_g$  is the drainage area of the gauged stream and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics.

*Anderson River.* Anderson River has seasonal records from 1945 to 1950 and 1981 through 1983 at its gauge (near Boston Bar, 08MF001). The Coldwater River, on the east side of the

Cascade Mountains has a similar hydrologic regime and flow characteristics were transferred from the "Coldwater River near Brookmere, 08LG048". The transfer was based on the ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area at the mouth of Anderson River,  $A_g$  is the drainage area at the Coldwater gauge, and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics. The transferred were checked against the seasonal records at this gauge.

*Nahatlatch River:* The "Nahatlach River below Tachewana Creek, 08MF065" gauge records flows from the upper 715 km<sup>2</sup> of the watershed. The upper watershed has much higher runoff than the lower watershed and if flows are transferred from the gauge to the mouth using a ratio of drainage areas and a coefficient of 1.0, they will over-estimate actual flows. Monthly flows at older gauging records ("Nahatlach River at outlet of Frances Lake, 08MF007" and "Nahatlach River near Keefers, 08MF008") were used to develop a regression equation relating flows at Frances Lake to those at the mouth ( $08MF008 = 1.123 \ 08MF007 + 1.97$ ;  $r^2 = 0.99$ ). Mean annual flow, mean annual flood, mean monthly discharges and mean 7 day low flows were calculated from the recent records and transferred to the mouth using the above equation.

*Texas Creek and Stein River:* The "Texas Creek near Lillooet, 08MF015" gauge recorded seasonal flows from 1914 to 1921. Monthly flows at this gauge were correlated with those at the "Nahatlach River at outlet of Frances Lake, 08MF007" gauge producing a reasonable regression equation ( $08MF015 = .086 * 08MF007$ ;  $r^2 = 0.72$ ) and this was used with flow characteristics recorded at gauge below the Tachwana Creek to predict flow characteristics in Texas Creek.

The flows in Texas Creek were then transferred to the Stein River with the ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area at the mouth of Stein River,  $A_g$  is the drainage area at the Texas Creek gauge, and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics. The transferred were checked against the seasonal records on the Stein River. Stein River flows appear to be about half of those on the Nahatlach River.

*Churn Creek:* There are seasonal records at the "Churn Creek near Gang Ranch, 08MD012" gauge from 1928 to 1930. Unfortunately, there is no suitable gauge with overlapping records that also has records from this period. Consequently, flows were transferred from the "Yalakom River above Ore Creek, 08ME025" gauge, whose headwaters drain the same region as Churn Creek. The transfer used the ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area at the mouth of Churn Creek,  $A_g$  is the drainage area at the Yalakom River gauge, and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics. Seasonal records on Churn Creek indicates that this procedure appears to overestimate natural flows at the mouth of Churn Creek.

*Williams Lake River:* The "Williams Lake River near outlet of Williams Lake, 08MC005" gauge records regulated flows at the mouth of the watershed. Annual and other average flows were naturalized following the procedures in Section 3 of this report.

*Knife Creek:* The "Knife Creek at 141 Mile House, 08MC014" gauge records seasonal regulated flows at the mouth of the watershed. These were naturalized following the procedures in Section 3 of this report and used to estimate mean August and September and summer 7 day low flows. Mean annual flows, mean annual floods and winter 7 day low flows were transferred from "Williams Lake River near outlet of Williams Lake, 08MC005" gauge using the ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area at the mouth of Knife Creek,  $A_g$  is the drainage area at the Williams River gauge, and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics.

**Table A1: Procedures for Estimating Flows at the mouths of the Salmon Streams**

Stream Name	WSC Gauging Records		WMB Miscellaneous Measurements	Drainage Area (km <sup>2</sup> )	Mean Annual Flow	Mean Annual Flood	Monthly Discharges		7 Day Low Flows	
	Gauge Name	Drainage Area (km <sup>2</sup> )					Mean August	Mean September	Mean Summer	Mean Winter
<b>COQUIHALLA RIVER</b>										
1 Coquihalla R.	above Alexander Ck	720		932	gauge	gauge	gauge	gauge	gauge	gauge
2 - Kawkawa Ck.			Sept 28/83	9	transfer	transfer	transfer	transfer	transfer	transfer
3 - Sucker Ck.					transfer	transfer	transfer	transfer	transfer	transfer
4 - Steven Ck.					transfer	transfer	transfer	transfer	transfer	transfer
5 - Kopp Ck.	above Menz Creek	-	Sept 27/83		transfer	transfer	transfer	transfer	transfer	transfer
6 - Menz Ck.					regr	regr	gauge	gauge	gauge	gauge
1a - Sowaqua Ck.				153						
7 American Ck.	near Hope	32.4		32	gauge	gauge	gauge	gauge	gauge	gauge
8 Squeah Lake Ck.				14	transfer	transfer	transfer	transfer	transfer	transfer
9 Emory Ck.	near Choate	65.3		65	gauge	gauge	gauge	gauge	gauge	gauge
10 Gordon Ck.				11	transfer	transfer	transfer	transfer	transfer	transfer
11 Yale Ck.	at Yale	37.3		37	gauge	gauge	gauge	gauge	gauge	gauge
12 Sawmill Ck.				31	transfer	transfer	transfer	transfer	transfer	transfer
13 Spuzzum Ck.				224	transfer	transfer	transfer	transfer	transfer	transfer
<b>ANDERSON RIVER</b>										
14 Anderson R.	near Boston Bar	492		500	transfer	transfer	transfer	transfer	gauge	gauge
14a - Lower Anderson R.				350						
14b - Upper Anderson R.				150						
14c - Utzlius Ck.				160						
14d - East Anderson R.				125						
15 Stoyama Ck.				38	transfer	transfer	transfer	transfer	transfer	transfer
<b>NAHATLATCH RIVER</b>										
16 Nahatlatch R.	below Tachewana Ck	715		1,256	gauge	gauge	gauge	gauge	gauge	gauge
16a - Lower Nahatlatch R.				946						
16b - Upper Nahatlatch R.				310						
16c - Log Ck.				84						
16d - Kookipi Ck.				159						
16e - Unnamed Ck.				53						
16f - Mehatl Ck.				293						
17 Stein R.				1,084						
18 Texas Ck.	near Lillooet	163		171	gauge	gauge	gauge	gauge	gauge	gauge
19 Churn Ck.				992						
20 Gaspard Ck.				943						
21 Williams Lake R.	near outlet of Williams Lk	2240		2,240	transfer	transfer	transfer	transfer	transfer	transfer
22 -Knife Ck.	at 141 Mile House	-		232	transfer	transfer	transfer	transfer	transfer	transfer

\* "regr.", refers to calculation from a regional regression equation; "gauge", refers to calculation from available WSC gauging records; "transfer" to adjustment of records from an upstream gauge or gauge on a nearby stream; "misc.", refers to calculation from miscellaneous observations collected by the WMB or others, "subtr." to calculation by subtraction of flow records at downstream and/or tributary gauges.

**APPENDIX B**

**STREAM SUMMARIES**

## **B. STREAM SUMMARIES**

A two page summary has been prepared for each salmon stream. Those streams with six or more complete years of records at a gauge have a detailed summary of hydrology, as described in Section 3 of the main text. Those salmon streams with limited or no gauging records have a less detailed summary.

The stream summary consists of 5 main elements each of which is explained in detail in the following sections. Some of the information is abridged.

### **B.1 Licensed Water Demand**

Total licensed demand above the Water Survey of Canada gauge on the stream, or above the mouth for ungauged streams, are given in the units currently used by the Water Rights Branch. The monthly demand is calculated from the licensed amounts for the three characteristic months of February, August and September and is quoted in litres per second (L/s). The final separate row at the bottom of the table is the mean monthly flow of the stream during the three characteristics months.

### **B.2 Mean Annual Hydrograph**

The mean annual hydrograph is an average of the flow recorded on each day for all complete years of record. In order to provide a smooth hydrograph a nine day running average of the daily values was incorporated. For comparative purposes, the vertical scale is the same for all streams. The mean annual flow is included in a box on the hydrograph; this, together with the percent values on the vertical axis, allows estimation of the flows for various times of the year.

For ungauged streams, the mean annual hydrograph is transferred from a hydrologically-similar, nearby stream.

### **B.3 Sensitivity Indices**

As described in the main text, each index is a ratio or percentage. For example, Index 1 is the ratio of the August water use to the Mean summer 7 day low flow. Index 3 is similar to Index 1 except that it shows the ratio of August water use to the mean August flow.

The bar graphs show how the indices for the stream compare with the indices for the other salmon streams in the HMA. (Streams included for logging analysis only are not used in calculating the sensitivity indices.) For example, if Index 7 is above the median it indicates that peak flows are more severe than average, relative to the other streams.

The bar graph provides a visual summary of the relative sensitivity of the stream to various land and water uses and is incorporated for both the gauged and ungauged streams.

## **B.4 7 Day Low Flows**

***Distribution, by month, of 7 Day Low Flow:*** This bar graph shows the months of the year when the annual 7 day low flow (the lowest consecutive 7 day flow in a calendar year) has occurred. The height of the bar shows the percentage of annual 7 day low flows that have occurred in that month.

The bar graph may not provide a good indication of the distribution of annual 7 day low flows if there are only a few years of record at the gauging station. No distribution is provided for the ungauged streams.

### ***7 Day Low Flow Frequency Curve***

The frequency curve shows an Extreme Value Type III (Gumbel) Distribution fit to the annual 7 day low flows recorded at the gauging station. The curve shows the predicted annual 7 day low flow, in m<sup>3</sup>/s, for return periods up to about 100 years. Note that the confidence in the estimated flow at a given return period depends on the length of record available at the gauging station. For streams with only a few years of record (as shown by the number of data points) the curve is an approximation. Also note that estimates beyond about 50 years are only approximate even when there is ten or twenty years of record. No distribution is produced for the ungauged streams.

**Annual daily floods and 7 day low flows**, for various return periods, are given in a common table.

## **B.5 Summary Notes and Recommendations**

This section provides an abbreviated summary of important activities in the basin, together with suggestions and recommendations where these can be provided.



# COQUIHALLA RIVER

## LICENSED WATER DEMAND

Stream number 00-0800

Water Survey of Canada Station 08MF003

Coquihalla River near Hope

Records 1911 to 1983

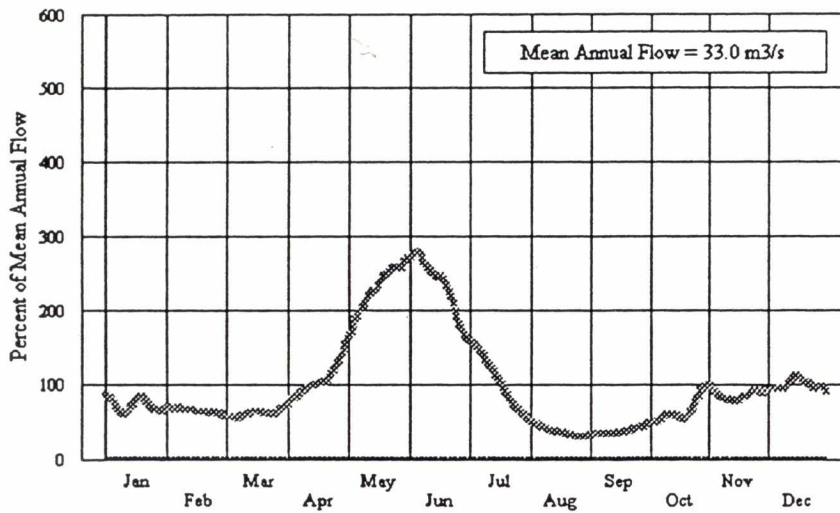
Drainage Area = 741 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	3,000 g/d			
Irrigation	3 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	60 cfs			

Feb Aug Sep

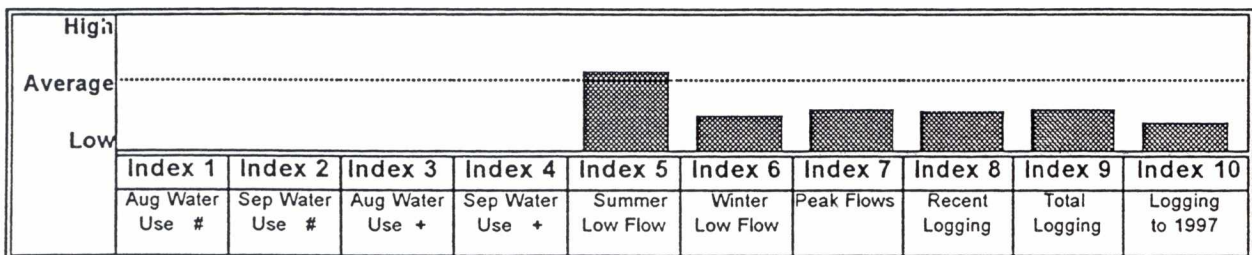
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	21,000	12,000	13,000

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.

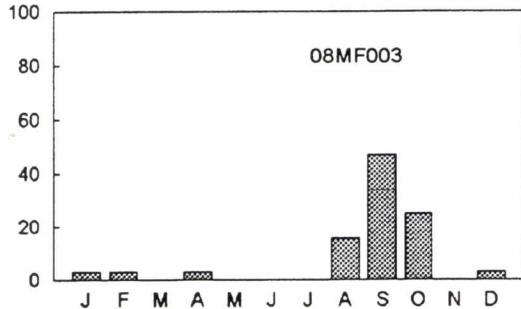


# Water use as a proportion of the 7 day low flow

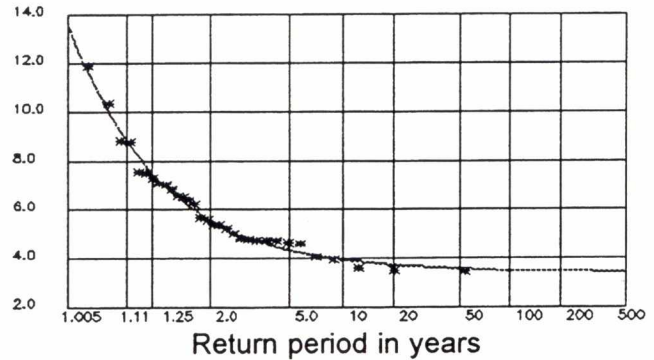
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

*Distribution , by month, of  
7 Day Low Flow (in percent)*



*7 Day Low Flow Frequency Curve  
(Flow in m<sup>3</sup>/s)*



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	5.54 m <sup>3</sup> /s	3.90 m <sup>3</sup> /s	3.69 m <sup>3</sup> /s	3.54 m <sup>3</sup> /s	3.48 m <sup>3</sup> /s
<b>Annual Flood</b>	206 m <sup>3</sup> /s	369 m <sup>3</sup> /s	456 m <sup>3</sup> /s	592 m <sup>3</sup> /s	714 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Except for winter steelhead, anadromous migration up the Coquihalla River is blocked by the falls at Othello. Gradient and water velocities are high downstream of the falls. Quantities of organic debris enter the river but usually jam in the canyon above Hope, from which they are generally removed by the Ministry of Environment.*

*2. A recent flood study indicates that existing dykes are inadequate for the 200 year flood. Various plans to manage floods and modify dykes are being considered. Development has encroached on the channel at several places and there is pressure for further development on the floodplain.*

*3. Current limitations to fish production include lack of side channel habitat, deposition of fine sediment, loss of spawning gravels, and lack of riparian vegetation.*

# KAWKAWA CREEK

## LICENSED WATER DEMAND

Stream number 00-0800-010  
 Ungauged  
 Tributary to Coquihalla River  
 Drainage Area = 9 km<sup>2</sup>

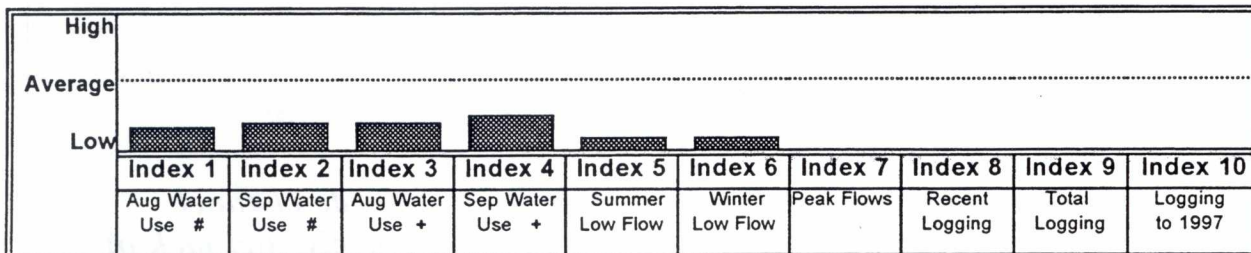
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	3,750 g/d	0.20	0.20	0.20
Irrigation	0 ac.ft.			
Waterworks	37,000 g/d	1.95	1.95	1.95
Industrial	9,500 g/d	0.50	0.50	0.50
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			300	276

## MEAN ANNUAL HYDROGRAPH

(Insufficient data to produce a hydrograph)

## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



- # Water use as a proportion of the 7 day low flow
- + Water use as a proportion of the mean monthly flow for the same month

# KAWKAWA CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Residential development around Kawkawa Lake affects the water quality and fish habitat in both the lake and its tributaries.*
- 2. There have been several enhancement projects along Kawkawa Creek downstream of the lake, including construction of a special, selective barrier to stop coarse fish, placement of spawning gravels, placement of boulders, and construction of a spawning loop adjacent to the main channel.*

# SUCKER CREEK

## LICENSED WATER DEMAND

Stream number 00-0800-010-010

Ungauged

Tributary to Kawkawa Creek

Drainage Area = 3 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		110	100

## MEAN ANNUAL HYDROGRAPH

(Insufficient data to produce a hydrograph)

## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.

High										
Average	-----									
Low	All indices are Low for this stream									
	Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	Index 8	Index 9	Index 10
	Aug Water Use #	Sep Water Use #	Aug Water Use +	Sep Water Use +	Summer Low Flow	Winter Low Flow	Peak Flows	Recent Logging	Total Logging	Logging to 1997

# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# SUCKER CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Sucker Creek, a small tributary of Kawkawa Creek, supports some scattered salmon spawning. There is the potential for it to be affected by residential development.*

# STEVEN CREEK

## LICENSED WATER DEMAND

Stream number 00-0800-010-020

Ungauged

Tributary to Kawkawa Creek

Drainage Area = 1 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

	Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>		40	30

## MEAN ANNUAL HYDROGRAPH

(Insufficient data to produce a hydrograph)

## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.

High										
Average	-----									
Low	All indices are Low for this stream									
	Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	Index 8	Index 9	Index 10
	Aug Water Use #	Sep Water Use #	Aug Water Use +	Sep Water Use +	Summer Low Flow	Winter Low Flow	Peak Flows	Recent Logging	Total Logging	Logging to 1997

# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# STEVEN CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The Department of Fisheries and Oceans has recommended that there be no water withdrawals from Steven Creek (a small tributary of Kawkawa Creek) because of its very low flows. There is the potential for the creek to be affected by residential development and groundwater development.*

# KOPP CREEK

## LICENSED WATER DEMAND

Stream number 00-0800-010-030

Ungauged

Tributary to Kawkawa Creek

Drainage Area = 3 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,000 g/d	0.05	0.05	0.05
Irrigation	0 ac.ft.			
Waterworks	34,000 g/d	1.79	1.79	1.79
Industrial	5,000 g/d	0.26	0.26	0.26
Conservation	0 cfs			

Feb Aug Sep

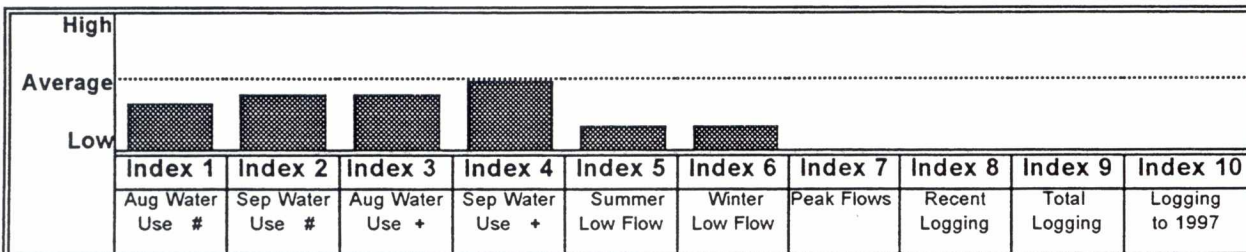
MEAN STREAM FLOW L/S	Feb	Aug	Sep
		110	100

## MEAN ANNUAL HYDROGRAPH

(Insufficient data to produce a hydrograph)

## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# KOPP CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Kopp Creek has a groundwater dominated flow regime, exhibiting relatively constant flows over the summer. Water withdrawals amount to only about 2 % of average low flows.*

# MENZ CREEK

## LICENSED WATER DEMAND

Stream number 00-0800-010-030-010

Ungauged

Tributary to Kopp Creek

Drainage Area = 1 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S		40	30
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## MEAN ANNUAL HYDROGRAPH

(Insufficient data to produce a hydrograph)

## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.

High										
Average	-----									
Low	All indices are Low for this stream									
	Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	Index 8	Index 9	Index 10
	Aug Water Use #	Sep Water Use #	Aug Water Use +	Sep Water Use +	Summer Low Flow	Winter Low Flow	Peak Flows	Recent Logging	Total Logging	Logging to 1997

# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# MENZ CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Flows in Menz Creek are from a glaciofluvial aquifer to the east of a fan formation. Groundwater development would likely directly affect low flows in the creek.*

*2. The creek is being affected by the development of a gravel pit along the south margin of its watershed, and it is locally eroding sand and gravel deposits.*

# AMERICAN CREEK

## LICENSED WATER DEMAND

Stream number 00-0815

Water Survey of Canada Station 08MF032

American Creek near Hope

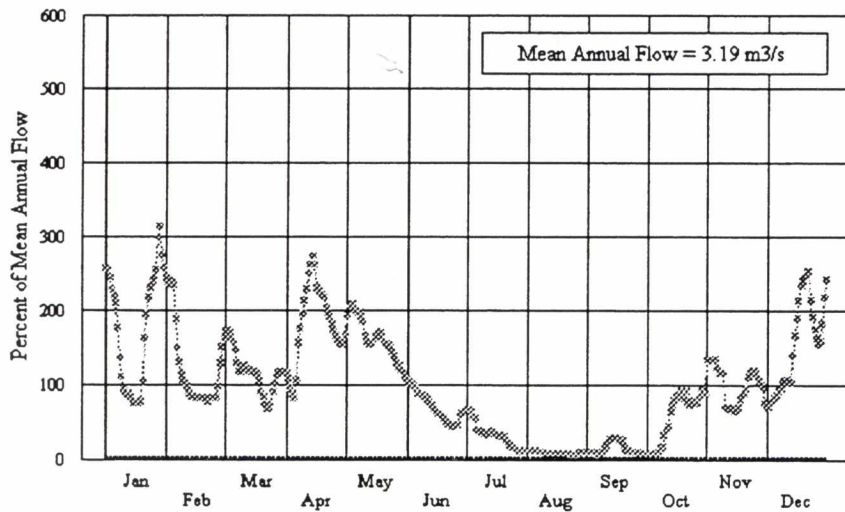
Records 1933 to 1936

Drainage Area = 32.4 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,000 g/d	0.05	0.05	0.05
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

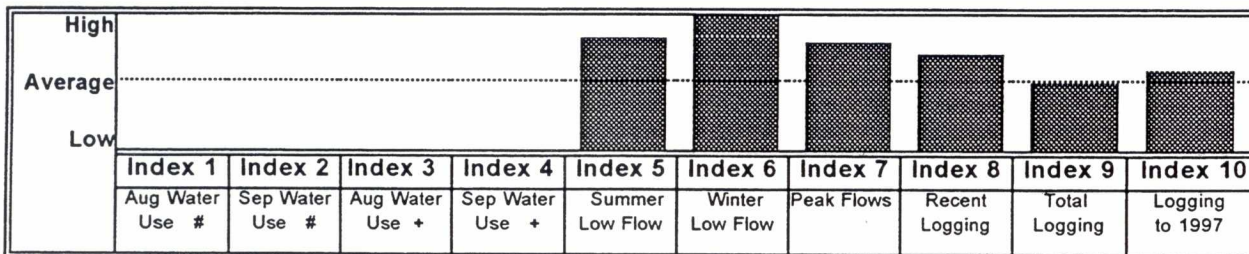
	Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>	<b>4,220</b>	<b>293</b>	<b>502</b>

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# AMERICAN CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. American Creek has a flashy hydrologic regime; bed material consists primarily of large boulders. Spawning is confined to the lower two kilometres.*

# SQUEAH LAKE CREEK

## LICENSED WATER DEMAND

Stream number 00-0834  
 Ungauged  
 Tributary to Fraser River

Drainage Area = 14 km<sup>2</sup>

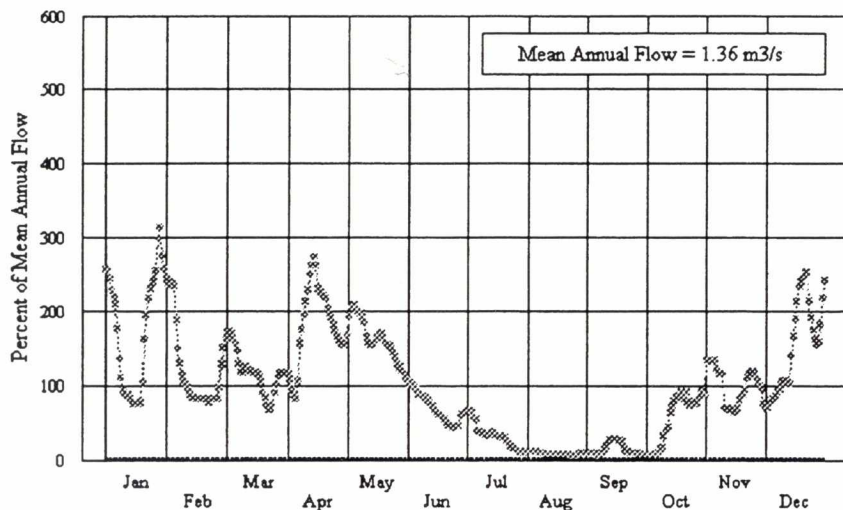
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S		130	220
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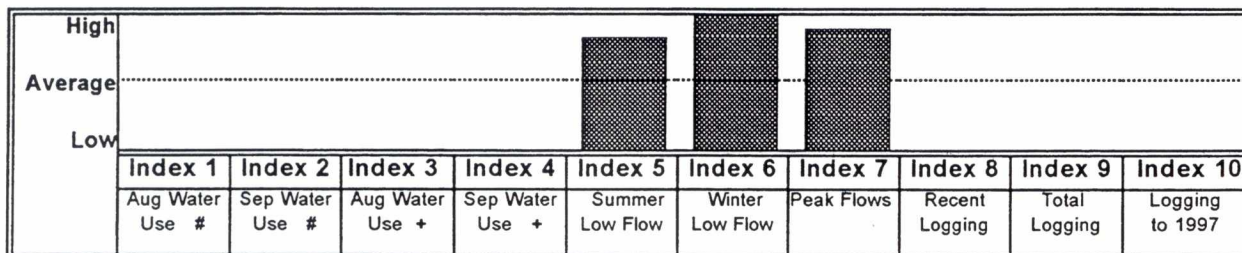
## MEAN ANNUAL HYDROGRAPH

(Estimated, using American Creek station 08MF032)



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# SQUEAH LAKE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Squeah Lake Creek has a flashy hydrologic regime, with low flows in winter and in summer, and high peak flows.*
- 2. There are no records of water licensing or logging.*

# EMORY CREEK

## LICENSED WATER DEMAND

Stream number 00-0841

Water Survey of Canada Station 08MF030

Emory Creek near Choate

Records 1933 to 1936

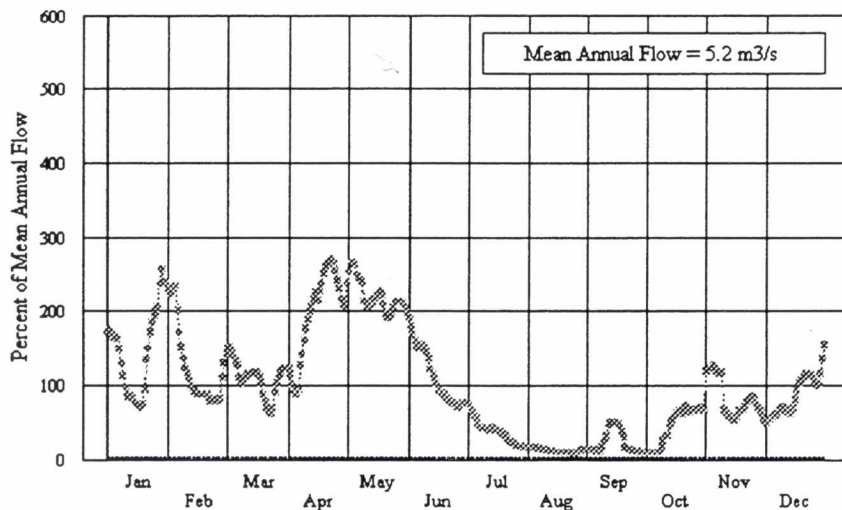
Drainage Area = 65.3 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	3,000 g/d	0.16	0.16	0.16
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

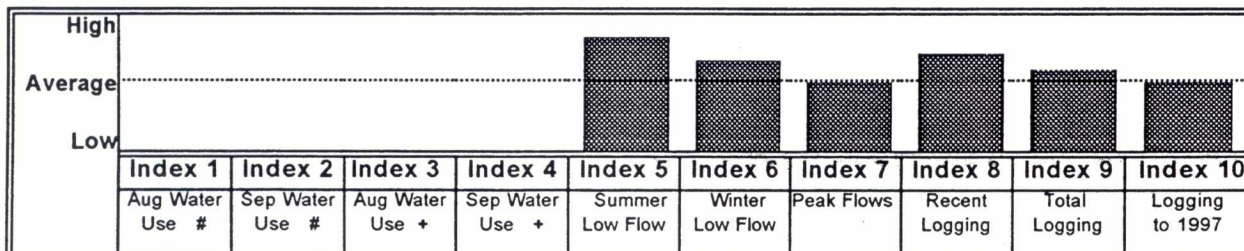
MEAN STREAM FLOW L/S	7,010	638	1,290
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## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# EMORY CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Emory Creek has a flashy hydrologic regime. The lower one kilometre of the creek is used by pink and chum salmon.*

# GORDON CREEK

## LICENSED WATER DEMAND

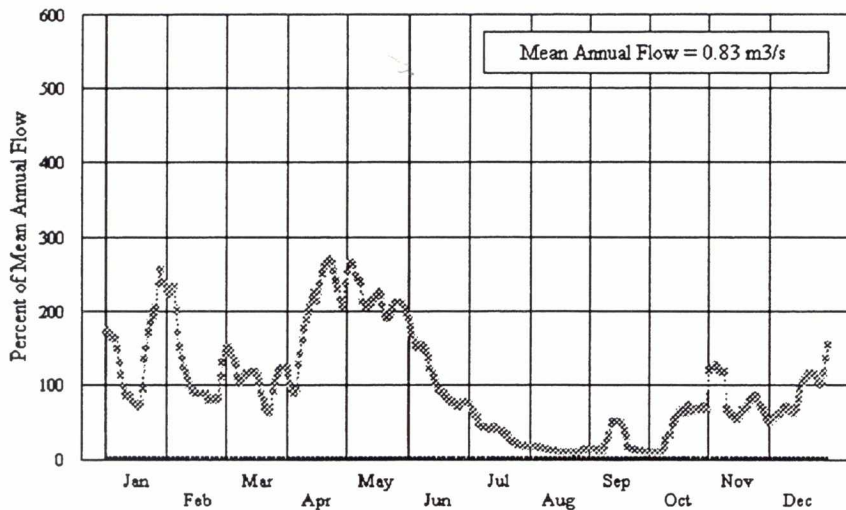
Stream number 00-0855  
 Ungauged  
 Tributary to Fraser River

Drainage Area = 11 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,500 g/d	0.08	0.08	0.08
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			100	210

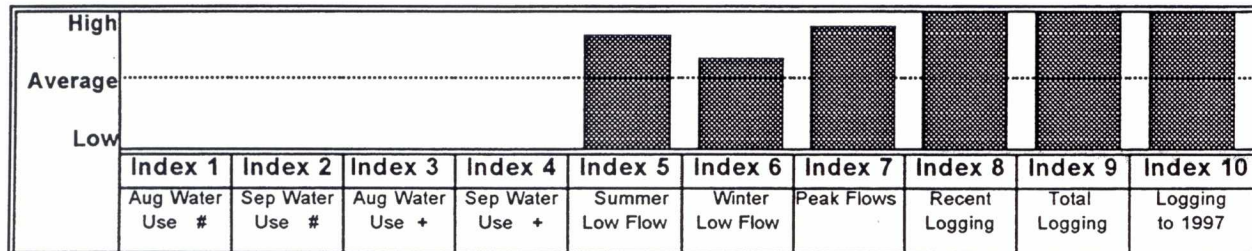
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Emory Creek station 08MF030)



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



- # Water use as a proportion of the 7 day low flow
- + Water use as a proportion of the mean monthly flow for the same month

# GORDON CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Gordon Creek has a flashy hydrologic regime. There is some limited spawning by pink salmon near the mouth.*
- 2. More than 20% of the watershed has been logged, most of it within the last 10 years.*

# YALE CREEK

## LICENSED WATER DEMAND

Stream number 00-0860

Water Survey of Canada Station 08MF031

Yale Creek at Yale

Records 1933 to 1936

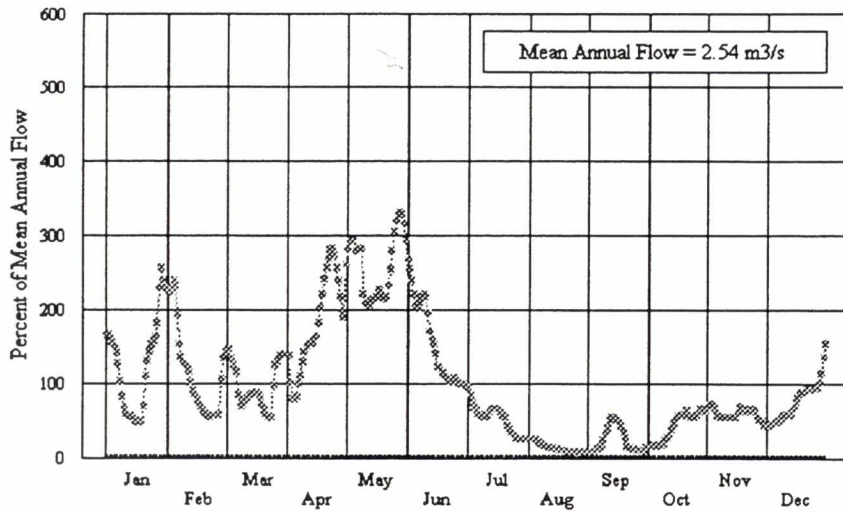
Drainage Area = 37.3 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2,000 g/d	0.11	0.11	0.11
Irrigation	18 ac.ft.		2.49	0.86
Waterworks	25,000 g/d	1.32	1.32	1.32
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

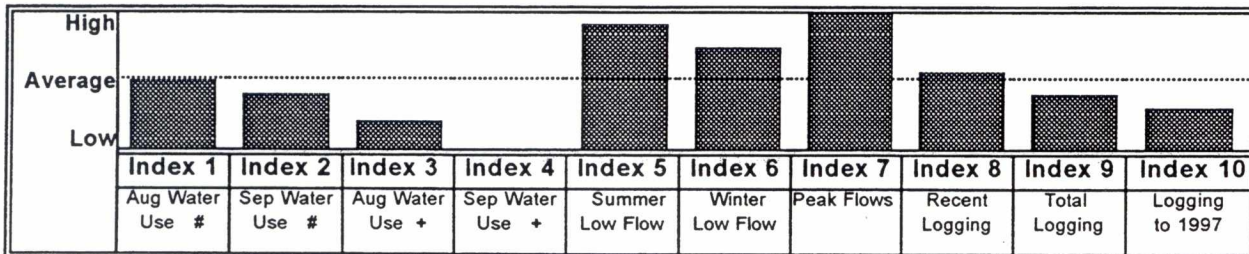
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	3,540	345	605

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# YALE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Yale Creek is steep, with bouldery bed material, and flows that are rapid and turbulent. It has a flashy hydrologic regime, with low flows in winter and in summer, and high peak flows.*

*2. The lower one kilometre of Yale Creek is used by pink and chum salmon.*

# SPUZZUM CREEK

## LICENSED WATER DEMAND

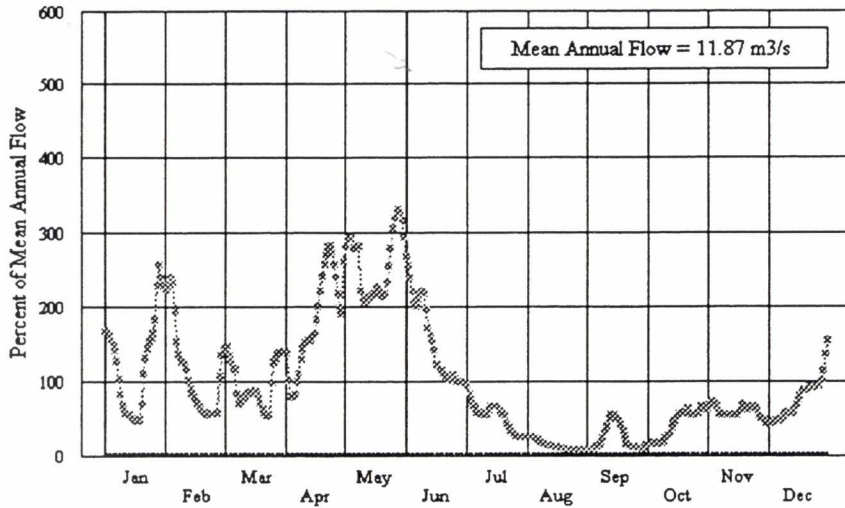
Stream number 00-0900  
 Ungauged  
 Tributary to Fraser River

Drainage Area = 224 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	500 g/d	0.03	0.03	0.03
Irrigation	54 ac.ft.		6.22	2.57
Waterworks	47,000 g/d	2.47	2.47	2.47
Industrial	17,000 g/d	0.89	0.89	0.89
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			1,700	2,980

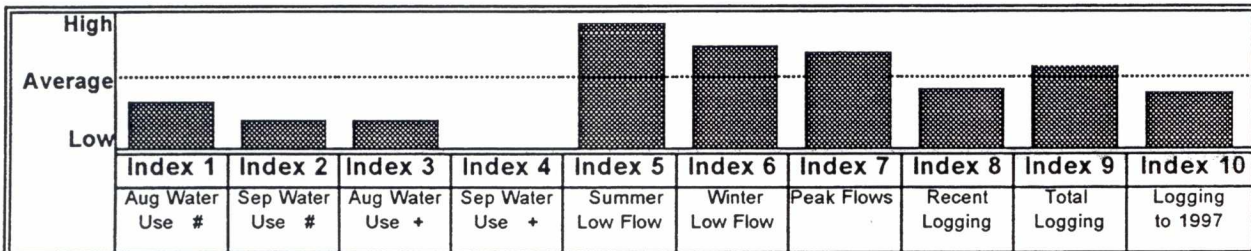
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yale Creek station 08MF031)



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow  
 + Water use as a proportion of the mean monthly flow for the same month

# SPUZZUM CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The bed material of Spuzzum Creek is bouldery; flooding and bank erosion are common.*
- 2. There are withdrawals for irrigation and water works but they do not appreciably affect low flows.*
- 3. There is scattered spawning between the mouth and the C.P. Railway bridge.*

# ANDERSON RIVER

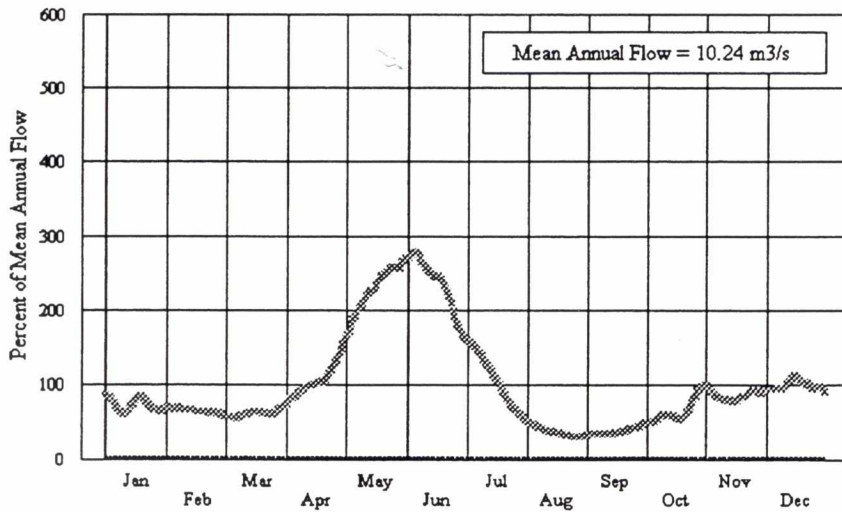
## LICENSED WATER DEMAND

Stream number 00-1000  
 Ungauged  
 Tributary to Fraser River  
 Drainage Area = 500 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			2,120	1,550

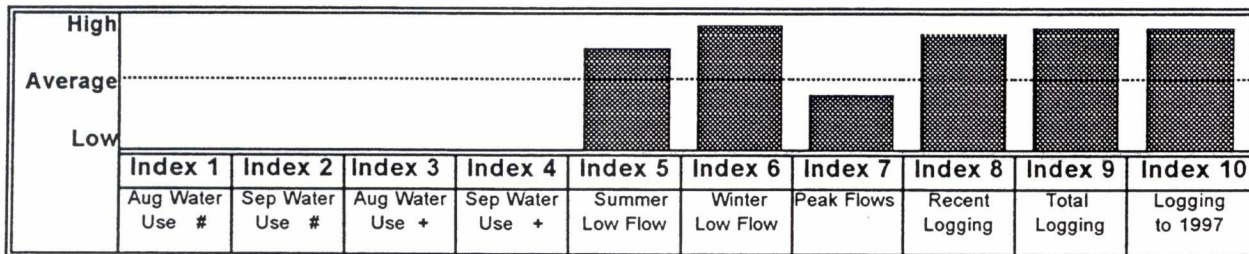
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Coquihalla River station 08MF003)



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow  
 + Water use as a proportion of the mean monthly flow for the same month

# ANDERSON RIVER

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The Boxing Day flood of 1980 caused landslides and washed out roads in the Anderson River Basin. The roads have since been rebuilt.*
- 2. During fall floods, the river downstream of the railway bridge changes course over a large, unstable fan.*
- 3. CN Rail recently removed a concrete apron, which limited fish migration, from beneath their bridge; and replaced it with individual pier protection and upstream training works.*
- 4. According to the present 5-year plan, recent and proposed logged areas will amount to over 20 % of the watershed. In many reaches of the river, timber has been removed down to the river margins and riparian vegetation has been destroyed.*

# NAHATLATCH RIVER

## LICENSED WATER DEMAND

Stream number 00-1200

Water Survey of Canada Station 08MF065

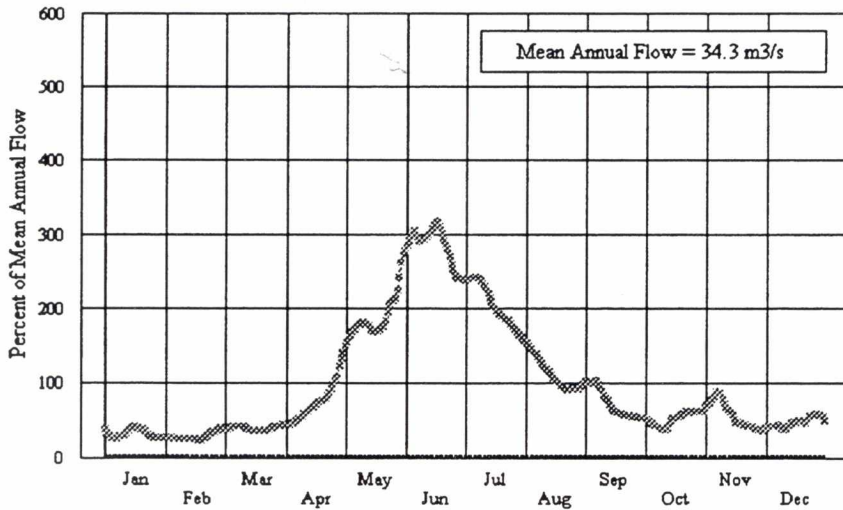
Nahatlatch River below Tachewana Creek

Records 1973 to 1990

Drainage Area = 715 km<sup>2</sup>

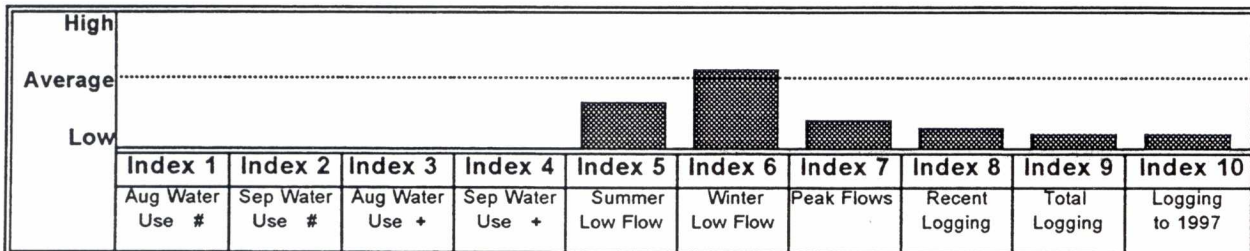
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>		9,860	37,100	23,400

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.

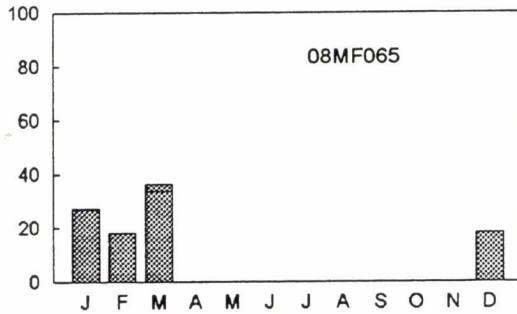


# Water use as a proportion of the 7 day low flow

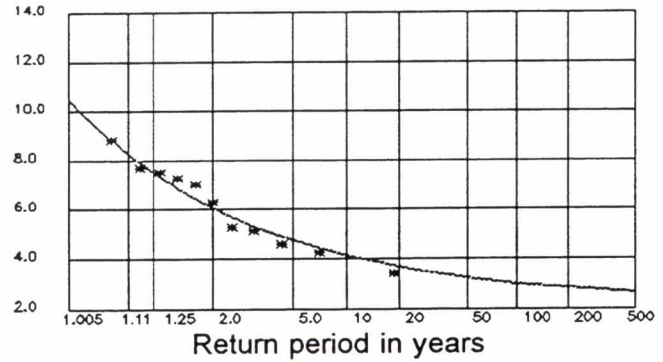
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

*Distribution , by month, of  
7 Day Low Flow (in percent)*



*7 Day Low Flow Frequency Curve  
(Flow in m<sup>3</sup>/s)*



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	6.06 m <sup>3</sup> /s	4.10 m <sup>3</sup> /s	3.65 m <sup>3</sup> /s	3.22 m <sup>3</sup> /s	2.98 m <sup>3</sup> /s
<b>Annual Flood</b>	195 m <sup>3</sup> /s	277 m <sup>3</sup> /s	304 m <sup>3</sup> /s	337 m <sup>3</sup> /s	360 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The 1980 Boxing Day flood destroyed two log bridges and damaged a number of culverts. These have since been replaced or repaired.*

*2. The Nahatlatch River Watershed has been chosen as a demonstration watershed under the Fraser River Action Plan. An Integrated Resource Management Plan is also being prepared.*

# STEIN RIVER

## LICENSED WATER DEMAND

Stream number 00-1400  
 Ungauged  
 Tributary to Fraser River

Drainage Area = 1084 km<sup>2</sup>

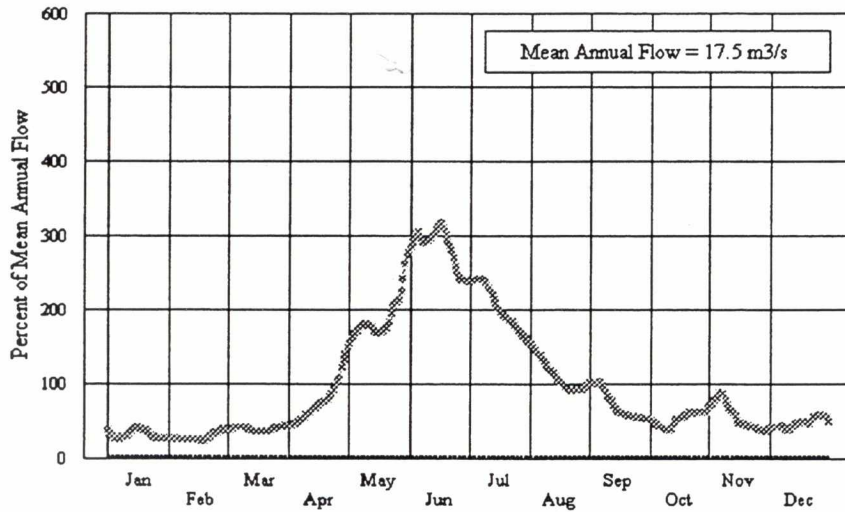
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	3,000 g/d	0.16	0.16	0.16
Irrigation	886 ac.ft.		102.0	42.2
Waterworks	175,000 g/d	9.21	9.21	9.21
Industrial	0 g/d			
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		17,700	10,400

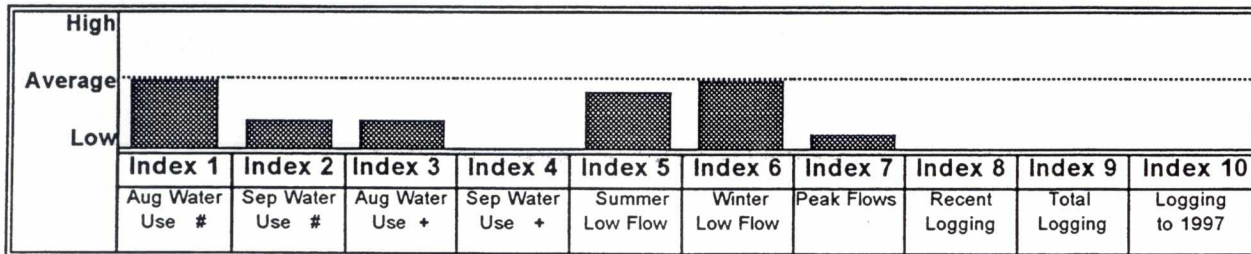
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Nahatlatch River station 08MF065)



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# STEIN RIVER

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The Provincial Water Management Branch has suggested that a Water Survey of Canada gauge on the Stein River would be valuable because it is the last pristine watershed along the west side of the of the Middle Fraser. The gauge would provide useful information on the natural regime.*
- 2. The Lillooet Indian Band is having a pipeline designed to take water from the Stein River for domestic and irrigation purposes.*

# TEXAS CREEK

## LICENSED WATER DEMAND

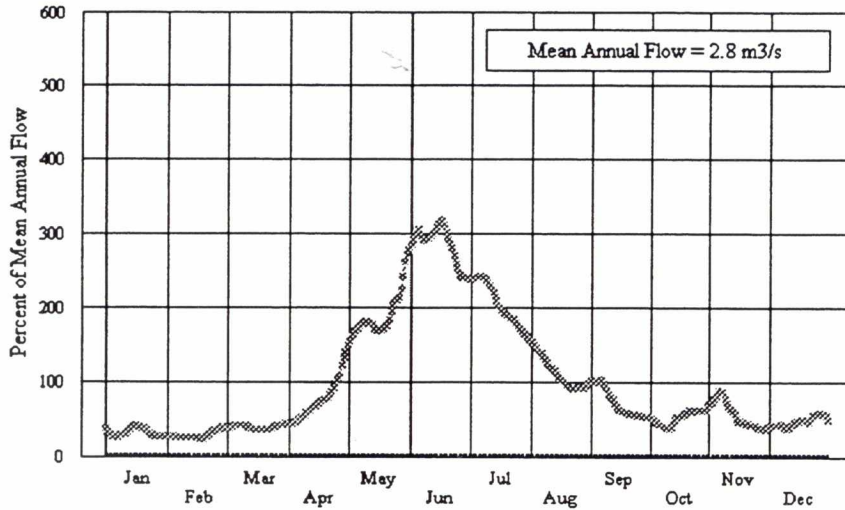
Stream number 00-1600  
 Ungauged  
 Tributary to Fraser River  
 Drainage Area = 171 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2,000 g/d	0.11	0.11	0.11
Irrigation	805 ac.ft.		92.7	38.3
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		2,800	1,600

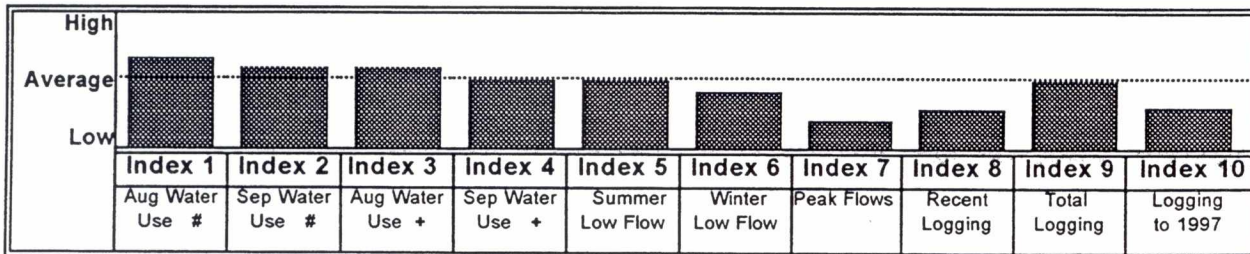
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Nahatlatch River station 08MF065)



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



- # Water use as a proportion of the 7 day low flow
- + Water use as a proportion of the mean monthly flow for the same month

# TEXAS CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Water withdrawals from Texas Creek are significant, amounting to 14% of the average summer 7-day low flow; however, the Water Management Division has not recorded any water use conflicts in the watershed.*

# CHURN CREEK

## LICENSED WATER DEMAND

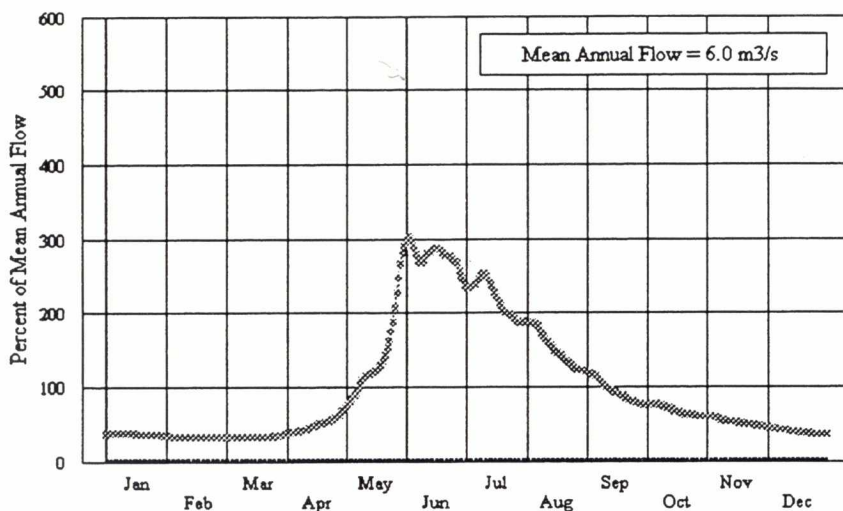
Stream number 00-2900  
 Ungauged  
 Tributary to Fraser River

Drainage Area = 992 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	18,500 g/d	0.97	0.97	0.97
Irrigation	267 ac.ft.		30.74	12.7
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			9,140	5,720

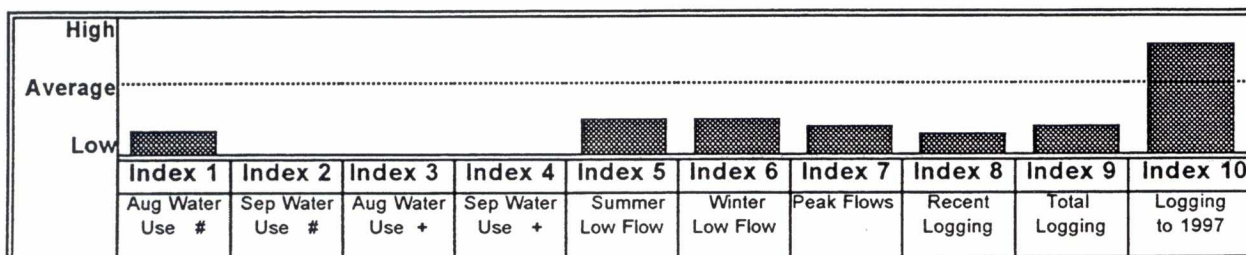
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yalakom River station 08ME025)



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# CHURN CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Valley walls along lower Churn Creek contain unstable lacustrine deposits which erode during high flows and produce fine sediments, which threaten incubating salmon eggs.*
- 2. The Ministry of Forests is preparing an LRUP (Local Resource Use Plan) to help resolve land use problems in the upper Churn Creek Watershed, including: road design, creek crossings, harvesting on unstable soils, and rate of cut.*
- 3. The Black Dome mine in the upper watershed may be reactivated. Concern has been expressed about water quality and the stability of existing tailings ponds in Fairless Creek.*
- 4. Churn Creek is not greatly affected by water demand, although the Gang Ranch holds several licences.*

# WILLIAMS LAKE R.

## LICENSED WATER DEMAND

Stream number 00-3900

Water Survey of Canada Station 08MC005

Williams Lake River at outlet of Williams Lake

Records 1928 to 1990

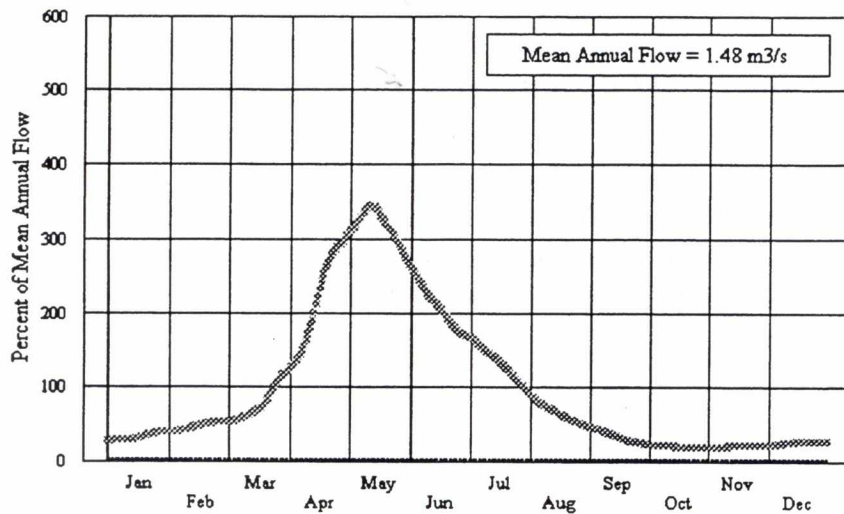
Drainage Area = 2,240 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	94,000 g/d	4.95	4.95	4.95
Irrigation	18,981 ac.ft.		2,623.2	903.3
Waterworks	3,557,000g/d	187.2	187.2	187.2
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

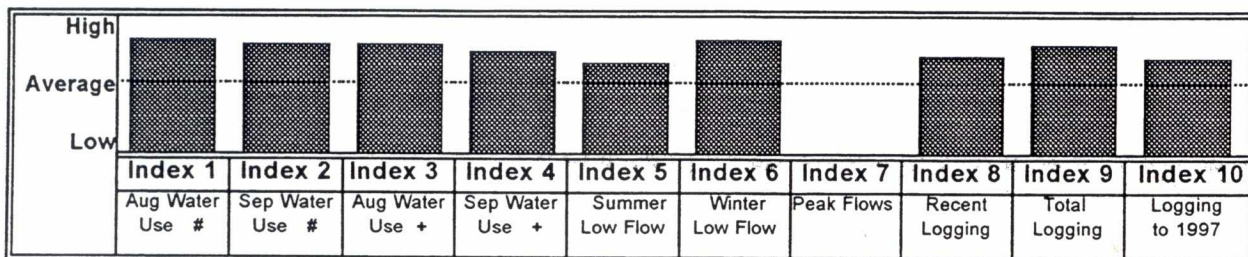
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	662	837	436

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.

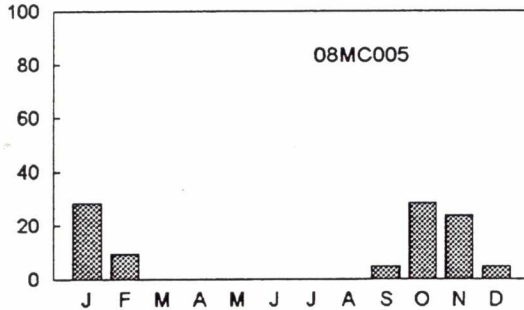


# Water use as a proportion of the 7 day low flow

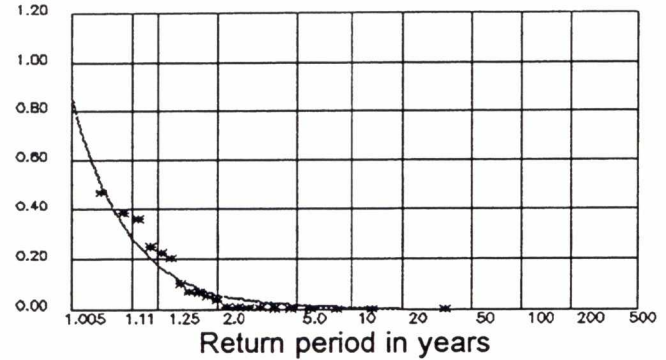
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

*Distribution , by month, of  
7 Day Low Flow (in percent)*



*7 Day Low Flow Frequency Curve  
(Flow in m<sup>3</sup>/s)*



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	0.054 m <sup>3</sup> /s	0.003 m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s
Annual Flood	4.92 m <sup>3</sup> /s	13.9 m <sup>3</sup> /s	17.2 m <sup>3</sup> /s	21.3 m <sup>3</sup> /s	24.2 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Williams Lake River is fully recorded. Most of the water is extracted from the San Jose River and its tributaries upstream of Williams Lake, where, also, overwintering of cattle and feedlots cause water quality problems.*

*2. The control structure at the outlet of Williams Lake has no provision for upstream fish passage. The river flows in a gully from the outlet of the lake to the Fraser River. Water quality problems are created by storm sewer discharge and dumping into the gully. During droughts there is no outflow from the lake, which causes much of the river bed to go dry. Furthermore, the lake becomes anoxic in the summer.*

*3. Anadromous fish use is presently limited to pink salmon spawning near the junction with the Fraser River.*

# KNIFE CREEK

## LICENSED WATER DEMAND

Stream number 00-3900-250

Water Survey of Canada Station 08MC047

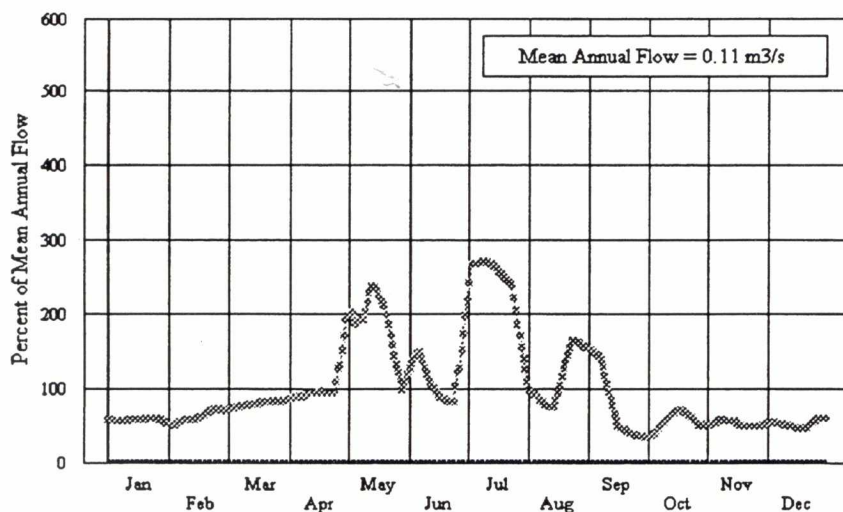
Knife Creek above diversions

Records 1988 to 1990

Drainage Area = km<sup>2</sup>

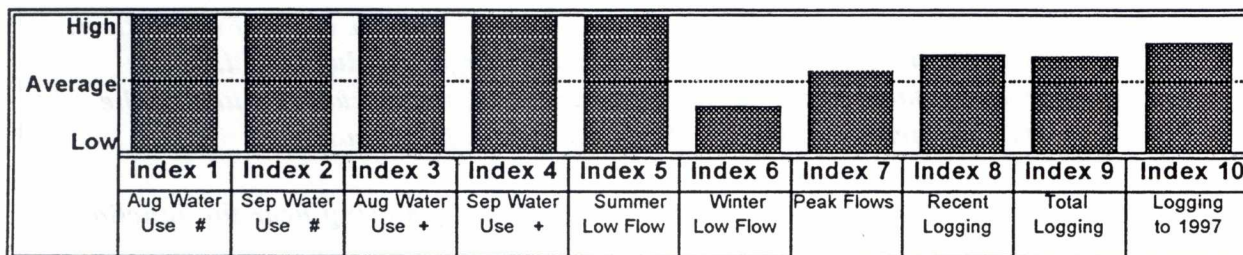
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>		68	101	74

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



# Water use as a proportion of the 7 day low flow

+ Water use as a proportion of the mean monthly flow for the same month

# KNIFE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. During drought, knife creek continues to flow, even though the San Jose River may be dry. The creek is fully recorded but a recent appeal may lead to the issuing of more licences.*

*2. Agricultural demand for water is high. Water quality is being affected by agriculture. Riparian vegetation is being lost.*

*3. Although Knife Creek is not used by salmon, it is considered an important trout stream.*