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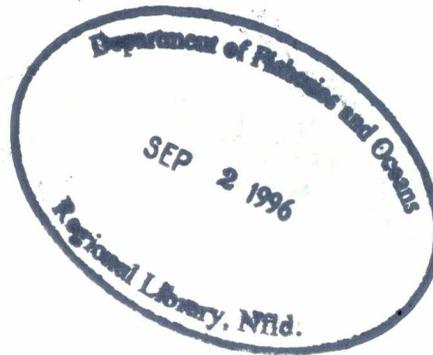
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# Hydrology and Water Use for Salmon Streams in the Quesnel Habitat Management Area, British Columbia

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1995

HYDROLOGY AND WATER USE FOR SALMON STREAMS IN  
THE QUESNEL 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 Quesnel Habitat Management Area (HMA). The HMA includes the Cottonwood, Naver, and Quesnel River watersheds on the east side of the Fraser River, near the town of Quesnel. Hydrology and water use in twenty-eight salmon streams are discussed.

The Quesnel HMA includes three separate physiographic regions, each with distinct climate and flow regime. Most of the streams are on the Cariboo Plateau, where the land is gently rolling upland. Annual precipitation ranges from 500 to 700 mm. Snowmelt results in peak flows from mid-April to mid-June. Low flows occur in August, September, and February. Several streams flow through the Quesnel Highland, where the elevation is higher and the land is more dissected. Annual precipitation, runoff, and peak flows are greater and peak discharge occurs later in the spring than on the Plateau. Minimum flows occur during winter. Some watersheds extend into the Cariboo Mountains, where precipitation is greater, temperatures are lower, and low flows occur during the winter.

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.

Forestry, agriculture, and placer mining affect stream flow. Water extraction for irrigation reduces the already low summer flows on some streams of the Cariboo Plateau. Several other streams and tributaries have many water licenses, but flows have not been reduced substantially. Unrestricted cattle grazing and watering damage streamside areas and contribute sediment to many streams. The greatest impacts of forest harvesting on stream flow occur on streams in the Quesnel Highland and Cariboo Mountains. The Hazeltine and Edney watersheds have harvest rates greater than 20%. Other watersheds have current harvest rates less than 10%. However, proposed cuts of 5 to 15% will affect several streams. There are concerns about road encroachments on streams and slope failures on small tributaries. The main streams show little evidence of sedimentation or altered stream flow attributable to forest harvesting. Placer mining is common on several streams on the Quesnel Highland, and activity may increase when gold prices rise. Some streams have been mined since the time of the Cariboo Gold Rush in the 1860's. Sedimentation can be a problem on streams where inexperienced miners work or where old mines have not been reclaimed.

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. These measures will allow more accurate prediction of the impacts 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) de la Quesnel. La ZGH couvre les bassins des rivières Cottonwood, Naver et Quesnel, sur la rive est du Fraser, près de la ville de Quesnel (C.-B.). Ce rapport examine l'hydrologie et l'utilisation de l'eau sur vingt-huit rivières à saumon.

La ZGH de la Quesnel couvre trois régions géomorphologiques différentes, qui diffèrent par le climat et le régime hydrologique. La plupart des cours d'eau se trouvent sur le plateau Cariboo, formé de hautes terres doucement ondulées. Les précipitations annuelles se situent entre 500 et 700 mm. La fonte des neiges occasionne des débits de pointe de la mi-avril à la mi-juin. Les étiages se produisent en août, septembre et février. Plusieurs des cours d'eau à l'étude traversent les hauteurs de la Quesnel, région de plus forte altitude et au terrain plus accidenté. Les précipitations annuelles, le ruissellement et les débits de pointe y sont plus forts, et les crues s'y produisent plus tard au printemps que sur le plateau. Les étiages y ont lieu en hiver. Certains bassins s'étendent jusque dans les monts Cariboo, où les précipitations sont plus fortes, les températures plus basses, et où les étiages se produisent en hiver.

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 coupe du bois, l'agriculture et l'exploitation des placers ont une incidence sur le débit. Les ponctions d'eau destinée à l'irrigation réduisent les débits estivaux, qui sont déjà faibles dans certains cours d'eau du plateau Cariboo. Plusieurs autres rivières et affluents font l'objet de permis d'exploitation hydraulique, mais les débits n'ont pas été réduits de façon substantielle. Le pacage et l'abreuvement non contrôlés du bétail endommagent les zones proches des berges et apportent des sédiments dans de nombreux cours d'eau. C'est sur les hauteurs de la Quesnel et dans les monts Cariboo que l'impact potentiel de la coupe de bois sur le débit des cours d'eau est le plus fort. Les bassins de la Hazelhine et de l'Edney ont des taux de coupe de plus de 20 %. Dans les autres, les taux actuels sont de moins de 10 %. Toutefois, des projets de coupe de 5 à 15 % vont affecter plusieurs cours d'eau. On s'inquiète de l'effet du tracé des routes sur les cours d'eau, et de l'impact des glissements de terrain sur les petits affluents. On observe sur les principaux cours d'eau peu de signes de sédimentation ou de modification du débit attribuables à l'exploitation forestière. L'exploitation des placers se pratique couramment sur plusieurs cours d'eau des hauteurs de la Quesnel, et cette activité pourrait s'intensifier si le prix de l'or monte. Certains cours d'eau sont exploités depuis la ruée vers l'or des monts Cariboo dans les années 1860. La sédimentation peut poser des problèmes sur les cours d'eau où travaillent des mineurs inexpérimentés ou dans le cas d'anciennes mines qui n'ont pas fait l'objet d'une remise en état.

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 Green Plan Program, is developing plans for environmentally sustainable salmon production. Planning is based on fifteen sub-basins – called Habitat Management Areas (HMA) – within the Fraser River watershed (Figure 1). This report examines the Quesnel HMA which includes the Cottonwood, Naver and Quesnel River watersheds and lies on the east side of the Fraser River near the town of Quesnel.

An understanding of the hydrologic regimes of the salmon streams, and their response to land use activities, is an important aspect of habitat management planning. This report describes both the regimes themselves and the effect of human development on those regimes. Within the Quesnel HMA, agricultural, municipal and industrial extractions from surface waters and the effect of forest harvesting on floods, are the main anthropogenic hydrologic issues affecting the hydrology of the salmon streams.

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 a level of concern for those aspects of the hydrologic regime that affect habitat and are altered by human activities (ESSA 1992). The indices are used to rank the streams within the Quesnel HMA. The most sensitive streams include those that are most affected by human activities and those that, because of their hydrologic regime, have the least ability to resist human impact.

### **1.2 Scope of the Study**

Our study examines 28 salmon streams within the Quesnel HMA that are listed in the Stream Information Summary System (Table 1). Our analysis is based on information compiled by the Triton Environmental Consultants Ltd (1992), Water Survey of Canada, the Ministry of Environment, Lands and Parks and by interviews with staff of the various government departments and agencies. Information available prior to 1993 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 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 the various salmon streams according to water withdrawals, high flows, low flows and forest harvesting.
6. Summarize the main issues in the salmon streams and discuss technical or management alternatives for the salmon streams based on interviews and discussions with government personnel.

The main task was predicting flow characteristics for the 28 salmon streams. Although the quality of information varied greatly from stream to stream, our approach focused on predicting flow characteristics that permitted comparison and ranking of streams within the study area. Predicted flows given in this report 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 Report Structure**

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 areas of forest harvesting; and Chapter 5, the calculation of licensed demand for surface flows. Table 4 summarizes the data for these investigations for each of the salmon streams.

The sensitivity indices are described in Chapter 6. Table 6 presents the 10 sensitivity indices calculated for each of the salmon streams. Chapter 7 describes the individual streams and Chapter 8 describes technical and management alternatives for the salmon streams.

Background information discussed by Triton Environmental Consultants Ltd is not repeated in this report and data taken from their volumes has not been reviewed or verified. References to their data, tables or figures in our text should be understood to refer to the Triton Environmental Consultants Ltd report listed in Chapter 9, "References".

### **1.4 Acknowledgements**

A number of individuals agreed to interviews and provided an overall perspective on land and water use and hydrology in the Quesnel Habitat Management Area, as well as information on the salmon streams. We would like to thank Ken Soneff, Bill Klopp, Jack Leggatt, Greg Ashcroft and Marcel Demers of the Williams Lake office of the Ministry of Environment, Lands and Parks; Uwe Finger, Glen Davidson, Dennis Abelson, Don Cadden and Dave Stevenson of the Prince George Office of the MOELP; and Bruce Mac Donald, Pat Harvey, Ray Finnegan, George Nielsen, Mel Sheng and Ed Woo of The Department of Fisheries and Oceans. Final preparation of the report for publication was made by Karen Munro.

## 2. OVERVIEW OF THE SALMON STREAMS IN THE QUESNEL HMA

Physiography and geology act to influence the behaviour of soil and water 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 Quesnel HMA includes three climatic and physiographic regions, which have different hydrologic regimes, and, as a result, the salmon streams exhibit a range of flow characteristics depending on their location.

### 2.1 Physiography

The Quesnel HMA includes the watersheds of the Cottonwood and Quesnel River and Naver Creek (Figure 1) and lies on the eastern side of the Fraser River near the town of Quesnel. The HMA includes three separate physiographic regions (Matthews 1986) and the drainage basins of the salmon streams often lie within more than one of these regions (Table 1). Most of the salmon streams lie on the Cariboo Plateau or Quesnel Highland and few streams extend into the Cariboo Mountains.

The Cariboo Plateau consists of gently rolling, undissected uplands. Elevations are generally near 1,000 m close to the Fraser River and elevations increase to the east, to range between 1,300 and 1,600 m near the boundary with the Quesnel Highlands. Much of the plateau is underlain by volcanic flows, though the bedrock is mostly covered by glacial drift. The gently rolling surface exhibits steep escarpments along creeks and major river valleys.

The upper portions of the Quesnel and Cariboo watersheds extend into the Cariboo Mountains. Summit levels in the Cariboo Mountains are near 2,500 m and the higher peaks have typical alpine glacial features, such as cirques and sharp, saw-toothed peaks.

The Quesnel Highland lies between the Cariboo Plateau and the Cariboo Mountains. The Highland is highly dissected and the upland areas, which are remnants of the old plateau, rise to elevations of about 2,000 to 2,300 m. Most of the plateau was overridden by ice during the Pleistocene and summits are rounded and the main valleys, such as the Quesnel are glaciated. Many lakes in the main river valleys result from blockage by glacial debris.

### 2.2 Climate and Streamflow

Climate varies within the Quesnel HMA and precipitation generally increases from west to east and annual temperature decreases from west to east, as elevation increases. The variation in precipitation, temperature and elevation produces different climates and hydrologic regimes in the three physiographic regions (Table 2).

**Cariboo Plateau:** Temperature and precipitation measured at the Quesnel or Hixon climate stations (AES 1982) are representative of the climate on the Cariboo Plateau (Figure 3). Annual

normal temperature at these stations are typically near 5°. July and August are the months with the highest temperature averaging near 16°, though maximum daily temperatures reach 36°. January has lowest average temperature of about -10°. Winter minimum temperatures are about -40°.

Annual normal precipitation ranges from 500 to 700 mm and roughly 35% of the total falls as snow (Table 2). Precipitation is distributed fairly evenly throughout the year though the greatest monthly precipitation totals are in January and February (almost entirely snow) and June, July and August (entirely rain). June, July and August also have high evapotranspiration demand and little of the rainfall replenishes groundwater. The months with the least monthly precipitation are March and April.

At Quesnel, the greatest daily rainfall, of 70 mm, was recorded in June. In other months, the maximum recorded daily rainfall is generally between 30 and 40 mm.

Mean annual discharge from basins on the Plateau increases with drainage area. When the annual discharge is expressed as a **mean annual runoff** (i.e. expressed as the equivalent depth of water over the basin area) the values are typically near 100 mm, though they increase to 200 mm for creeks draining higher elevations in the Hixon Creek watershed. Subtracting mean annual runoff from normal precipitation indicates that annual evapotranspiration and losses to groundwater amount to about 400 to 500 mm.

Maximum monthly discharges occur in May, though annual maximum discharges may occur at any time between mid-April and mid-June and generally result from snowmelt or rain on melting snow. In creeks draining higher elevations, the annual daily maximum occasionally occurs in October as a result of rain on snow. Rain on snow in the fall can produce very large flood discharges.

Flows decline over the summer, reaching a minimum in August or September. In most years, flows increase in October and November and then decline throughout the winter, reaching a minimum in February.

**Quesnel Highland:** Temperature and precipitation measured at the Barkerville or Boss Mountain stations (AES 1982) are representative of the climate on the Quesnel Highlands (Figure 2). Temperatures exhibit a similar annual pattern to the stations on the Cariboo Plateau but mean annual temperatures are 2 or 3° colder primarily because of cooler temperatures in summer, where average July and August temperatures are only 12°.

Annual normal precipitation is much greater than on the Plateau and ranges from 1,000 to 1,100 mm. The annual distribution of precipitation is similar to the Plateau with monthly maximums in the winter and summer and minimum in March and April but totals are higher in each month. Maximum daily precipitations are similar to those recorded on the Plateau.

In the Quesnel Highlands mean annual runoff ranges from 600 to 1,000 mm. Subtracting mean annual runoff from normal precipitation indicates that annual evapotranspiration losses and losses to groundwater amount to around 300 mm. Maximum monthly discharges occur in June though annual maximum discharges generally occur at any time between mid-May and mid-June as a result of snowmelt and rain on melting snow. Annual maximums occasionally occur in July and August in response to summer rainstorms.

Flows increase slightly in September and October in the Little Swift River, though this is not observed in all gauged streams in the Highlands. Flows decline after October reaching a monthly minimum in February. Annual minimum discharges are usually recorded between December and March though during very dry summers the annual minimum may occur in August.

***Cariboo Mountains:*** There are no stations recording temperature and precipitation in the Cariboo Mountains and little is known of the climate in this region.

Mean annual runoff in the Caribou Mountains is typically near 1,500 mm (Table 2). Maximum monthly discharges occur in June as a result of snowmelt and discharges remain high throughout July and into August. Maximum daily discharge typically occur between early June and mid-July, though occasionally annual maximums are recorded earlier, in mid- to late-May. Flows decline throughout the late summer and reach a minimum in March. Annual minimum daily discharges are recorded between December and April.



### 3. FLOW CHARACTERISTICS OF THE SALMON STREAMS

The following average flow characteristics, for 1981-1990 (Section 3.3), were estimated for the mouth of each salmon stream and are defined on Table 3:

- **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 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 expresses the average flow of water available during the driest portion of the summer when salmon rearing, adult migration and early spawning may occur. These months also have the greatest removals for irrigation. Low flows in these months reduce rearing habitat, strand juveniles and are associated with high temperatures that reduce habitat quality. Mean monthly discharge in February expresses the average flow of water available during the driest portion of the salmon egg incubation period. Low flows in this month affect incubating eggs through freezing in de-watered or exposed redds;
- **Mean 7 day low flows** for the summer express the average minimum flows during the summer rearing season and are used for fish habitat evaluations, calculating water allocations and water quality prescriptions. Mean 7 day low flows for the winter express the average minimum flow experienced during the winter and are associated with de-watering of redds.

There is a large range in the quality and availability of records on the salmon streams. Some streams have long-term gauging records at stations that continue to operate; other streams have short-term or seasonal records of moderate quality from the 1960's and 1970's; while other streams have little or no information available. The average flow characteristics in the above list, as well as other characteristics, can be very reliably estimated for salmon streams with long-term discharge records. Less reliable estimates are available 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 lower reach of the stream downstream of any major tributaries.

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 for 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 estimates at the mouth either by adding measured tributaries flows or by

increasing discharges 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 and 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. Alteration of water demand and water utilization may also mean that records from the 1960's or 1970's may not be representative of the current regime.

We have adopted the most recent decade, 1981-90 (inclusive), as our standard period for analysis. This period includes a moderate drought in 1987 and a large flood in June 1990 with a return of about 50 years at many gauges.

### **3.3 Hydrometric Data in the Quesnel HMA**

The Water Survey of Canada is the prime agency collecting and reporting discharge data in British Columbia. Gauging stations in the Quesnel HMA are described in *Surface Water Data Reference Index: Canada 1991*, published by Environment Canada. There are 27 active and abandoned stream gauging stations within the Quesnel, Cottonwood and Hixon watersheds. Twelve of the salmon streams have at least some miscellaneous flow measurements (Table 1). However, only six salmon streams (Cottonwood River, upper and lower Quesnel River, Cariboo River, Moffat Creek and McKinley Creek) have complete, or nearly-complete, discharge records for 1981 to 1990 at stations that are close to their mouths. For these streams, flow characteristics may be calculated from Water Survey of Canada records as discussed in Section 3.5.

Three of the salmon streams (Horsefly River, Little Horsefly River, Mitchell River) have lengthy but older gauging records. Nearby stations with overlapping records were used to adjust the hydrologic characteristics at these sites to reflect the hydrologic regime from 1981-1990.

The remaining salmon streams typically have either 1) partial records between 1981 and 1990, 2) partial records from earlier decades, such as the 1960's or 1970's, or 3) no discharge 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 salmon streams. These stations provide useful information on the hydrologic regime of watersheds in the Quesnel HMA and are used in estimating flow characteristics (Appendix A).

### 3.4 Other Sources of Hydrometric Data

The Water Management Branch of the Ministry of Environment operates some gauging stations (whose data are reported by the Water Survey of Canada), collects miscellaneous measurements to establish flows for approving licensed extractions, and carries out occasional (regional) data collection programs during droughts. Their drought programs (Nyhof 1987, Richards 1977) measured low flows on small streams during dry summers. Where possible, these were used to corroborate regional estimates of low flows.

### 3.5 Gauged Salmon Streams

Gauged salmon streams are those whose flow characteristics can be calculated directly from Water Survey of Canada records. (Data for gauged salmon streams are shown shaded in Table 4.) Table 3 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 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 the measured flow.

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

For streams affected by water extractions, the flow characteristics calculated from the discharge 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 4). 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 Quesnel HMA in that developed storage in most watersheds consists of small, independently-operated reservoirs. The total storage is small in comparison to irrigation requirements (Table 5) 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.

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

The largest reservoirs on salmon streams in the Quesnel HMA are operated by Fisheries and Oceans Canada on McKinley Creek and the Mitchell River. Storage in these reservoirs is used to supplement low flows in these streams or downstream main streams. The McKinley Reservoir

releases water in the late summer and early fall to lower water temperatures during sockeye migration and spawning in McKinley and Horsefly Rivers. It is not possible or necessary to calculate natural flows from the flows measured downstream of reservoirs in most cases. The regulated flow regime describes the flows available for instream uses and is only adjusted for the effects of water extraction.

Regulated flows are recorded at the gauge on the McKinley River and incorporated in Table 4. The reservoir has no effect on natural mean annual flows, lowers mean annual floods and raises August and September flows and summer 7 day low flows. Those regulated flows are not adjusted to the natural regime; however, the regulated flows are the best estimates of the new regime in the stream and provide the best value for calculating the effect of irrigation or other extractions on summer flows.

Water is released from the Mitchell Lake Reservoir to raise winter low flows on the Mitchell River. This facility was constructed in 1989 and the new, regulated regime on this river is not recorded at the gauge on Mitchell River, which only operated to 1982. Consequently, the flows reported on Table 4 are natural discharges for the 1981 to 1990 period and underestimate current winter 7 day low flows.

### 3.5.3 Calculation of Annual Flow Characteristics

The historic period for the **mean annual flow** is 1981 to 1990, inclusive (see Table 3 for definitions). No adjustments were needed for the effect of regulation. The historic period for the **mean annual flood** is 1981 to 1990, inclusive. No adjustments were made for the effect of regulation, though it is recognized that natural flood flows are slightly reduced by storage in small reservoirs.

### 3.5.4 Calculation of 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 chosen 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. They also affect late summer/fall migration of adults and early spawning.

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 increasing the incidence of freezing of eggs.

Table 4 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 7 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.

### **3.6 Gauging Records on the Stream Summary Sheets**

The gauging records were used to calculate detailed flow characteristics, such as mean annual hydrographs, monthly distributions of annual 7 day low flows, and 7 day low flow frequency curves for the stream summary sheets. 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 adjusted for upstream storage or water use.

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. Seven day low flow frequency curves are also included on the Summary Sheets.

Floods with various return periods were calculated 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.

### **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 extracted from Water Survey of Canada records. A variety of techniques were used to estimate the flows and these are discussed in detail 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 Quesnel HMA is altered, to some extent, by land use. Urbanization, agriculture and forest harvesting have the potential to alter the hydrologic regime. Urbanization and agriculture mostly affect hydrology by extracting surface and ground water for stock watering, domestic use and irrigation. These land uses also have some limited impact on flood discharges through conversion of forest lands. Surface water extractions are discussed in detail in Section 5 "Water Licensing".

The removal of timber during forest harvesting eliminates transpiration and the cut blocks alter the distribution of snow and may often increase rates of melt. These changes in the watershed, coupled with road construction and soil changes during logging 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 the rate of cut, or estimation of the clearcut equivalent area (CEA) within the watersheds; and further discusses the changes in hydrological and sedimentological regimes typically associated with forest harvesting in the interior of B.C.

### 4.1 Forest Harvesting

Triton interpreted logged cut blocks within the study basins from 1:250,000 Landsat imagery, current to 1989, digitized logged areas and calculated the following parameters:

- **Non-Forested Areas:** Includes exposed bedrock, icefields, treeless biogeoclimatic zones, etc.
- **Green-up Area:** Includes those cutblocks that appear as a medium shade of green on the imagery and are assumed to meet the 7 metre height criterion.
- **Recently Harvested Area:** Includes those cutblocks containing no evidence of vegetation, or that appear as a light green shade on the imagery that is indicative of stands that are significantly less than 30 years old.

The quality of these data are not reported by Triton. However, difficulties in interpreting the status of cut blocks on the Landsat photographs and difficulties in measuring very small areas may lead to inaccuracies in the reported data.

Triton also reports proposed logging for each basin, based on measurements from 5-year plans (1990-1996) submitted by the various logging companies.

## **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.

Clearcut logging in Camp Creek near Penticton, B.C., following Pine Beetle infestation, produced results similar to those recorded in experiments from the western and southeastern United States. Both annual and March to November monthly water yields increased in the clearcut stream 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.

### **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 Interior 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 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 (1985), 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 Ministry of Forests has prepared guidelines for the Kootenay Lake Forest District to control rate of cut in such a manner as to minimize changes to the annual hydrograph in snowmelt-dominated hydrographs (Toews 1990). Changes to the freshet hydrograph are minimized by distributing the cut over a range of elevations and aspects and by controlling the clearcut equivalent area (CEA) within the watershed. The CEA is calculated from the product of the total cut area and a regeneration recovery factor, which ranges from 90% for 3 m regeneration to 0% for 7 m regeneration on the block. This procedure assumes that 7 m regeneration represent full recovery and that intermediate regeneration reduces the hydrologic effect of the clearcut. Maximum allowable clearcut equivalent areas vary with basin type, but range from 25% 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 or landsliding. Elevated suspended 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, 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 Agricultural Land Use**

Triton reports agricultural land use, as measured from 1:250,000 Landsat imagery as the area of "cultivated farmland" within the basins of the various salmon streams. Trends in agricultural land use are based on data contained in the Cariboo Census Division.

#### **4.4 Physiography**

The following parameters were used to describe each of the watersheds:

- **Drainage Area:** Triton extracted drainage areas upstream of stream gauging sites from Water Survey of Canada publications and either measured drainage areas above the mouths of salmon streams or extracted these from SISS records (measured from 1:50,000 NTS maps). The two sources are not always consistent and in some instances the drainage area reported by the Water Survey of Canada is greater than the reported basin area above the stream mouth though the differences amount to only a few percent of the total basin area and are of the size of typical measurement errors. We have used the Triton data on Table 4.

- **Relief:** Defined as the difference between the maximum and minimum elevations in the basin, measured from 1:250,000 topographic maps.
- **Surface Area of Lakes:** The surface area of lakes and reservoirs within each drainage was reported by Triton, as measured from 1:250,000 Landsat Imagery.

## 5. WATER LICENCES

The Water Rights Branch of the Ministry of Environment maintains a computerized data base of water licences in British Columbia. Summaries (by licence type) were produced for all salmon streams, as well as streams with long-term Water Survey of Canada gauging stations. Note that water licences are usually not issued for placer mines and, instead, water use approvals are issued, which are valid for six months and are restricted to removals of less than 0.5 ft<sup>3</sup>/s (14 L/s). However, some large licences have been issued for placer mining in the Quesnel and Cariboo watersheds (Triton 1991).

### 5.1 Classification of Water Licences

Figure 5 reproduces the water licence classification system used by the Water Management 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 shown in Figure 5, but provide 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 (Table 4), under the categories of Domestic, Waterworks, Irrigation and Industrial. Pulp Mills, Land Improvement and Mining licences, which are classified separately by the Water Management Branch, are included under our Industrial category as there are few of these licences in the Quesnel HMA. Table 4 reports the sum of all licences, of each type, above the mouth of each salmon stream.

#### 5.1.2 Placer Mining

Placer miners operate a "closed circuit" water system. Water is extracted from a nearby creek or river during the freshet to fill a headpond for their sluice and, over the course of the season, water is re-cycled from the settling pond to the sluice and back again. Additional water is extracted over the season, as needed, to maintain necessary volumes of water for processing pay gravels.

Water use is partly non-consumptive, as water is lost from the system partly to evaporation from ponds but mostly to return flow to streams through losses to the local groundwater. Water use approvals restrict individual miners to a maximum withdrawal of 14 L/s or a total withdrawal over the season of about 220,000 m<sup>3</sup>. This may be a reasonable estimate of water use over the season by some miners. In the Yukon, many small operations sluice about 500 hours a year utilizing water at about 300 L/s for a grand total of about 500,000 m<sup>3</sup> of process water (Seakem Group Ltd 1992). Note that water use is sporadic and leakage from ponds may supplement natural discharges when sluicing does not occur.

### **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 4. Nearly all the storage licences are non-power licences.

The total non-power storage licences for each salmon stream are listed in Table 5. The total includes all storage for domestic, waterworks, irrigation, industrial and conservation licences; though, in most streams, the majority of the licences are for irrigation. Table 5 also compares the irrigation licences to the non-power storage in each salmon stream. Storage affects discharge by being accumulated during the spring freshet and released during low flows, or during the irrigation season. In many watersheds, licensed 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 licensed 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 licensed 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 Quesnel HMA are mostly insignificant when compared to irrigation use or to streamflow.

### **5.2.2 Irrigation Licences**

A certain percentage of the water diverted for irrigation re-enters 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, which are now the dominant methods of irrigating, use less water and are expected to produce less return flow.

Water applied to the land on a particular day will cause return flow some days, weeks or months later. The Okanagan report assumes about 12% of the annual return flow occurs in September and 9% in October; and also allows for a small percentage (about 4% per month) 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. However, the portion of the "cultivated farmland" reported by Triton which is irrigated is not known and may vary over the Quesnel HMA. In the northern (or north-eastern) basin less of the land is irrigated; some crops are grown without irrigation and probably less "improved pasture" is irrigated. The percent irrigated is approximate because of variations within census areas and uncertainties in the census data.

The duty -- the water needed for the irrigation season expressed as a depth -- is used to calculate the total amount of water needed for irrigation. However, the theoretical duty and the actual amount applied can differ, as a result of farming practices. The duty can also vary with location and elevation, and from year to year. Year-to-year variations are significant: 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.

We have used water licence summaries to estimate irrigation demand, for several reasons. First, areas of irrigated land within the watersheds of the salmon streams are not known and, second, the required duty is not known for the Quesnel HMA. Finally, the water licences represent, as discussed in the next section, a maximum demand on the salmon streams and provide a comparable standard of comparison from stream to stream.

### **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 demand that may be exerted on the stream, if all licences were fully utilized. Some streams are fully recorded and the calculated demand will not increase: on other streams additional licences may be issued. (Those salmon streams with reserve notices or restrictions, issued by the Water Management Branch, are indicated in Table 6.)

The water licences summarized in Table 4 are expressed in various units, ranging from acre-feet for irrigation licences, to gallons/day for waterworks and domestic licences and ft<sup>3</sup>/s for 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 ft<sup>3</sup>/s.

Licensed amounts expressed as a volume (ac-ft) were converted to cubic decameters (dam<sup>3</sup>), where 1 dam<sup>3</sup> 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 are assumed to be distributed in the Quesnel HMA as follows: May (15%), June (25%), July (25%), August (25%) and September (10%). (These percentages were used in the Okanagan Basin Report (1974) and correspond reasonably well with the seasonal distribution of water use by the Vernon Irrigation District (Rood 1989).) Monthly irrigation volumes (in dam<sup>3</sup>) were converted to discharges (L/s) by multiplying by 10<sup>6</sup>, 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 4 presents calculated licensed total demand, in L/s, for August, September and February. These months were chosen because August and September are months when low flows commonly occur during the irrigation season and February is the winter month with the minimum monthly discharge.

## **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 describe the level of concern for those aspects of the hydrologic regime that affect habitat and are also potentially 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 expressions of the proportion of the basin of the salmon streams that have been harvested 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 and extreme values indicate stressed systems with a limited ability to withstand further hydrologic alteration.

It was felt that the most useful indices for assessing habitat sensitivity would 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 logging 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 6 the most sensitive 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 or 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 typical or normal portion of flows devoted to irrigation during the late summer.

Large values of Indices 1 through 4 indicate streams with great potential demand, primarily from irrigation, on summer low flows. On Table 6, those streams whose indices are the top 25% of the values are shaded.

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 6, those streams whose indices are in the lowest 25% of the values are shaded. Most of the streams with low indices have small drainage basins which tend to have a more extreme response to drought. On the Cariboo and Chilcotin Plateaux, measurements by the Water Management Branch indicate that drainage basins up to 50, or more, km<sup>2</sup> may have zero discharge during moderate droughts (Richards 1977; 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 of flow, and, potentially, lower channel stability. This ratio does not vary significantly for stream to stream, partly because in some instances both mean annual flows are transferred to the ungauged streams from a nearby gauged stream. Consequently, ratios on the ungauged streams are the same as those on the gauged streams, and there is no correction for variation of unit annual flood with basin area. (Larger basins have lower unit values because of storm coverage effects.) On Table 6, streams with values of 10 or more for Index 7 are shaded.

Large values of the index may not indicate unstable streams because stability is also affected by the materials in the streambed and the gradient of the stream. Neither of these variables are included in the index.

Extreme floods also affect channel stability. Appendix B includes tables showing floods of various return periods for gauged salmon streams in the Quesnel HMA.

## 6.4 Logging

Indices 8, 9 and 10 express the area of logging as a percentage of total basin area. Index 8 is the percentage of the watershed that has been recently logged (less than 10 years old based on silvicultural records); Index 9 is the percentage of total logging (all cutblocks including those blocks with some hydrologic recovery). 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 "older 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 7 m green-up which is accepted to represent full hydrologic recovery. The percentage that have not recovered and the clearcut equivalent areas (CEA) of both the recent and older logged areas are not known.

The Ministry of Forests often uses limits of 25 to 35% clearcut equivalent area in watersheds. This degree of clearcutting is expected to produce changes in the hydrologic regime (Section 4.2). Indices 8, 9 and 10 are not CEA values because they are not adjusted for hydrologic recovery of cutblocks and, as a result, may slightly over-estimate the clearcut equivalent area of recent logging and certainly over-estimate the CEA of total logging.

We have selected recent harvesting covering more than 20% of the watershed, which may correspond to a CEA 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 recent logging greater than 20% of the basin area are shaded on Table 6.

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. 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. 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

Table 7 identifies the most sensitive salmon streams in the Quesnel Habitat Management Area. Some of these streams have been the subject of studies and reports and have been, or currently are, managed in one fashion or another to benefit salmon. They are a source of on-going concern to Fisheries & Oceans Canada (DFO) or the Ministry of Environment, Lands and Parks (MoELP). As part of our study we reviewed existing reports and studies and discussed the salmon streams with Provincial and Federal government personnel. Our acknowledgements provide a summary of individuals contacted during the study.

### 7.1 Sensitive Streams

The streams that are shaded on Table 6, which are identified as sensitive as a result of high water demand, low flows, high peak flows or recent logging covering more than 20% of the basin, are summarized on Table 7.

Beaver Creek has the greatest water demand in the Quesnel HMA, and total potential demand is estimated to be in excess of the available 7-day low flows. The vast majority of the demand derives from the licensed irrigation withdrawals. Total licensed withdrawals amount to 6,423 ac-feet (Table 3) over the estimated 21,000 acres (8564 ha; Table 3) of cultivated farmland, suggesting that only a small portion of the farmland is actually irrigated on a regular basis. Moffat Creek, which lies on the Cariboo Plateau near Beaver Creek, and Abhau Creek, on the Cariboo Plateau near Quesnel, both have potential demands that could amount to about 10% of their summer seven-day low flows. Irrigation demand on the Horsefly River, Cottonwood River and Naver Creek amounts only to a few percent of the estimated 7 day low flows.

The salmon streams lying entirely on the Cariboo Plateau typically exhibit the lowest ratio of summer 7 day low flow to mean flow, as these salmon streams typically have their annual low flow during the summer. For many of these creeks the summer 7 day low flows are predicted to be only about 10% of the mean annual flow. For streams in the Quesnel Highlands, summer 7 day low flows are generally exceed 25% of the mean annual flow and the percentage is often much higher on systems with large lakes, such as the Little Horsefly or Quesnel Rivers.

Winter 7 day low flows are the smallest percentage of the mean in the small streams draining directly to Quesnel Lake and in Penfold and Cameron Creeks. Over-winter flows are generally around 10 to 15% of the mean annual flow, which in the smaller creeks may only amount to 100 to 300 L/s. Winter 7 day low flows are also about 15% of the mean annual flow in many of the streams on the Cariboo Plateau and the predicted ratios do not vary greatly, though large basins tend to have much greater ratios.

The greatest ratios of peak flows to mean annual flows are also observed in small creeks on the Cariboo Plateau and in the Quesnel Highlands along Quesnel Lake. Ratios in these streams generally exceed 10.

Only Hazeltine and Edney Creeks have recent and proposed logging that exceeds 20% of the total land area. Note that there is no proposed logging in either Hazeltine or Edney Creek. Creeks with large proposed harvests include Cunningham Creek and Killdog Creek and total recent and proposed cut in these basins, and Cottonwood River, approaches 20%.

## 7.2 Discussion by Stream

Our discussions are not comprehensive appraisals of the various sensitive salmon streams but, rather, summarize previous studies or personal communications from knowledgeable individuals familiar with the streams. On some of the streams we have further distilled the available information into recommendations for management of individual streams (Section 8). The recommendations are in no particular order and the streams are not listed in priority order. In some instances, we felt there was insufficient information to develop general recommendations and these were not included for all streams. We recommend further study and investigation of all sensitive salmon streams.

**Cottonwood River:** Placer mining and logging occur mainly in upper tributaries, particularly Lightning Creek. Old abandoned storage structures that were constructed during hydraulic mining still exist although some have been removed by the Province.

Placer mining introduces sediment into the river, primarily as a result of overflow of settling ponds. One court case is pending. Sediment is also contributed by natural slides in the canyon of Cottonwood River. Despite the long history of placer mining in the upper reaches of this system, and the natural failures there is no reported sedimentation of spawning areas in the Cottonwood River.

Several tributaries to the Cottonwood have had greater than 20% of their watersheds cut and in most of the watershed regrowth is less than 10 m high, including: Frye Creek; John Boyd Creek (also placer activity and erodible soils); Umiti Creek; Sovereign Creek; Bendixon Creek; Reddish Creek; and Fontaine Creek (Fisheries & Oceans 1992). A large fire burnt much of Frye Creek basin about 20 years ago. Most of the burnt area has regrown and trees are close to 10 m high, which is the criterion used for hydrologic recovery in this watershed.

Overall, the recent and proposed logging within the Cottonwood Basin exceeds 20% of the total basin area and 26% of the total forested area.

**Abhau Creek:** Low flow problems have not been reported during the summer, though Table 6 indicates that Abhau Creek is potentially sensitive to further water extractions and summer low flows.

High flows are controlled partly by a series of beaver dams and lakes on the mainstem and the tributaries. These beaver dams may also impede upstream migration. Abhau Creek is a historic placer mining stream though only a few mines currently operate in the basin. There is potential for more placer mining with improving gold prices.

The channel is stable though the stream transports a moderate gravel load. Channel erosion occurred during the 1990 flood and some landowners carried out remedial work in the stream.

Lill and Tautz (1983) indicate that surveys are required to identify any enhancement opportunities on Ahbau Creek.

**Lightning Creek:** Lightning Creek has been placer mined continuously since the 1860's and most tributaries have been mined at one time or another. Sediment from historic and recent operations, natural instability and logging may limit spawning habitat in this system. Restoration

should focus on reclamation of historic placer mines, channel stabilization and re-instatement of riparian vegetation.

**Victoria Creek:** The Victoria Creek basin is swampy and logging is concentrated in the first few kilometres from the mouth.

**Naver Creek:** Lorenz (1992) provides a recent summary of placer mining and logging in tributaries of Naver Creek. The report recommends a hydrologic study of tributaries in the watershed and a review of rate of cut in tributaries to Naver Creek, many of which have portions of their watersheds with less than 10 m green up. The report also recommends identification and removal of obstructions to fish passage, control of beaver populations in Meadowbank Creek and investigations during rainfall floods to examine sediment in the main creek and its tributaries.

No low flow problems have been reported in Naver Creek though Laura and Van Buskirk Brooks are fully recorded and Terry Creek is identified as having possible water shortages which may limit offchannel rearing. The June 1990 flood produced some erosion and channel modifications which have been partly repaired by rip rapping. Minor problems on Meadowbank Brook are associated with local landowners and Dunkley Mills.

The Water Management Branch anticipates only limited potential for expansion of irrigation in Naver Creek as much of the arable land is already developed.

**Hixon Creek:** Low flows occurred in 1992 near the town of Hixon. Flows disappeared because of channel widening and gravel deposition, as a result of flooding in June 1990 and spring ice jams in 1992. Grundell Creek, a tributary to Hixon Creek, also potentially has low flow problems (Lorenz 1992).

Hixon Creek occasionally experiences large floods that result from rain on snow on George Mountain. There is some concern that the potential for flood production may be aggravated by large clearcuts in this part of the upper watershed.

Placer operations concentrate upstream of the falls that limit salmon migration. An old hydraulic pit, dating to the 1970's, is located at the base of the falls. Tailings from the pit are entering Hixon Creek and contributing to its instability. The 1990 flood (about 50 year return period) caused lateral erosion along about 2 kilometres of the main channel which was later ripped. Opportunities for habitat complexing exist along the repaired section of channel.

About 5% of the watershed of Hixon Creek has been logged and an additional 5% of the land base is devoted to fields. Most of the harvest is in Grundell Creek, Little Hixon Creek and the headwaters of Hixon Creek. Government Creek remains nearly unlogged and is a recreational area for fishing and hiking.

According to the Ministry of Environment there is a low potential for expansion of irrigation because of limited arable land.

**Lower Quesnel River:** Agricultural use removes large quantities of water from the Lower Quesnel River but no low flow problems result. Several tributary creeks are fully recorded (Barlow Creek, Cannon Creek and Ten Mile Lake) and low flows in these creeks may limit off-channel habitat. There is no impact on the mainstem.

Jawbone Creek has received some sedimentation as a result of a diversion. Lamont (1991) indicates that Weldwood employees used heavy equipment to clean some spawning gravels on the Lower Quesnel River.

**Upper Quesnel River:** Natural slides occur along the upper Quesnel between Morehead Creek and Quesnel Forks. In 1992 a slide blocked the river for a number of hours. Morehead Lake was dammed during the early part of the century and waters diverted and used for hydraulicking at the Bullion Mine.

The Bullion Mine discharged sediment to this reach of the river, increasing sediment concentration roughly 350 ppm over a period of about 20 years (Church 1983). About 15% of the total sediment load, consisting of coarse sediment from the mine, was deposited downstream of Quesnel Forks. The increased sediment altered channel pattern and producing a cycle of aggradation followed by scour through the channel deposits.

**Beaver Creek:** The Water Management Branch classes Beaver Creek as fully recorded with most of the irrigation use downstream of Beaver Lake; twenty of the tributaries are fully recorded or have potential water shortages. There are conflicts with ranchers over water use. Storage in the basin consists mostly of small projects operated by individual ranchers. There are no large storage projects planned but there is a potential to construct these. There is one power licence, dating to the 1960's, that permits diversion of water from the stream, but it is not utilized.

**Cariboo River:** Few irrigation or other water licences have been issued for the Cariboo River as its basin is relatively undeveloped. Placer mining and forestry are the main activities and many tributaries, such as Keithley Creek, have operating placer mines that have been mined since the 1860's. Several of the actively mined tributaries of the Cariboo River, including Little River, Cunningham and Keithley creeks also have high percentages of their basin area recently clearcut. The Ministry of Forests is reviewing rate of cut in Matthew Creek.

A fishway, passable by chinook, operates about 22.8 km upstream from the mouth of the Cariboo River. There may be other impassable obstructions along the river because downstream of Cariboo Lake the river flows over a continuous series of rapids and falls.

Cariboo Lake could be developed for storage for multiple water uses, however B.C. Hydro have an old power reserve on both Cariboo and Quesnel Lakes. The Water Management Branch would like to see the reserve removed because it complicates issuing of licenses in the area.

Gavex Gold (a completed placer mining operation near Quesnel Forks) was not reclaimed and may cause chronic sediment problems.

**Hazeltine Creek:** Recent logging covers over 30% of the basin. As part of the Polley Lake Mine a storage development is planned for Polley Lake to compensate for water use and diversions by the mine. The storage will supplement low flows, mostly to the benefit of species of concern to the Province.

**Edney Creek:** Recent logging covers roughly 30% of the basin but the stream is of little concern to Fisheries & Oceans Canada.

**Horsefly River:** Agriculture extends along the Horsefly River near the town of Horsefly but there are no low flow problems associated with water extractions because they only amount to a small percentage of the total flow. Bank de-stabilization and riparian zone degradation from cattle grazing and watering are important issues associated with agriculture.

Storage in the basin consists of small developments on some of the tributaries and a large structure on McKinley Lake. A large storage project could be developed on Horsefly Lake but recreational use (cottages) along the shoreline would prevent large changes in water levels. Moffat Creek, which enters near the town of Horsefly, is unstable and contributes coarse sediment to the Horsefly River. The reach of the Horsefly that is affected by sediment from Moffat Creek is only used by sockeye spawners in dominant years but is used by chinook each year.

A spawning channel was built near the town of Horsefly in 1989 and a second channel is proposed near the same site. In 1990, flooding on the Horsefly River and sediment from Moffat Creek damaged the first spawning channel. DFO completed remedial work in 1991.

A fishway has also been suggested for the falls on the Horsefly River to permit colonization of the spawning gravels upstream of the falls. Sockeye have been airlifted over the falls in the past. The falls consist of two parts totalling about 35 m in height. International Pacific Salmon Fisheries Commission (IPSFC) studied a fishway proposal and concluded it was too expensive and, perhaps, not feasible.

**Little Horsefly River:** Tributaries to Horsefly Lake present some concerns to Fish & Wildlife staff but there are no major problems on the Little Horsefly River.

In 1980 spawning gravels were placed along the Little Horsefly for kokanee and rainbow trout. These were scarified in 1985 (Lamont 1991).

**Moffat Creek:** Moffat Creek flows across a broad alluvial fan before joining the Horsefly River. The stream is unstable on its fan and considerable quantities of gravel are moved during freshets; gravel and debris removals and channel works are required to maintain channel capacity and protect property. The stream is also a source of sediment to the Horsefly River.

Gravel near the mouth of Moffat Creek supports sockeye spawning in dominant years thus the timing of instream work has to be controlled.

**McKinley Creek:** A temperature control structure was built at the outlet of McKinley Lake in 1968 to cool water over the spawning grounds along the Horsefly River. A spawning channel has been suggested for the site but was rejected because it would use all the flow in the creek.

The five-year plan for this watershed proposes the logging of about 5% of the total watershed area. Some concern has been expressed over windfirm leave strips and sediment production from unstable slopes.

**Mitchell River:** DFO (SEP) built a flow control weir at the outlet of Mitchell Lake to improve incubation flows for sockeye salmon in the Mitchell River. The structure was completed in 1989. A spawning channel near the lake outlet is also being planned.

Mitchell River and Penfold Creeks are also important trout spawning streams. A wildlife management plan which limits logging and other activities near the creek protects both of these streams.

Logging in the Mitchell River watershed is concentrated upstream of Mitchell Lake.

**Penfold Creek:** Proposed logging of the west side of Penfold Creek would require a major bridge over Mitchell River. Sockeye salmon spawn between 5 and 10 km upstream of the confluence with Mitchell River.

**Watt Creek:** Sockeye spawners utilize the lower 300 m of the creek. Beaver dams and log jams are reported.

**Roaring River:** Sockeye salmon utilize the lower 1000 m downstream of the falls for spawning. A low gradient channel reach upstream of a high falls could provide suitable habitat if access was developed.

**Blue Lead Creek:** Logging is planned for Blue Lead Creek and it is also considered for inclusion in an extension of Wells Grey Park. The creek floods in the spring and wanders near its mouth. Sockeye salmon spawn throughout the lower 1.5 km of the stream.

## 8. RESULTS AND CONCLUSIONS

### 8.1 The Effect of Water and Land Use on Hydrology

The Quesnel HMA includes three physiographic regions, each with a reasonably distinct climate and flow regime. Most of the salmon streams are on the Cariboo Plateau. The plateau is characterized by low annual runoff, peak flows from snowmelt in May and June and minimum flows in August or September, when rainfall is low and evapotranspiration demand is high. The summer minimum flows are typically only 10% of the mean annual flow. Irrigation extractions are at a maximum in July and August, during the low flow period, and provide the main human impact on the streams.

A number of the salmon streams lie in the Quesnel Highland which is wetter and colder than the Cariboo Plateau. These streams have much higher annual runoff than streams on the Cariboo Plateau, higher peak discharges, maximum monthly discharges occur about one month later and minimum flow during the year occur mostly in the winter rather than the summer. Summer minimum flows typically exceed 20% of the mean annual flow. Forest harvesting and placer mining are the main human activities with the potential to affect these streams.

The Quesnel and Cariboo Rivers both have parts of their upper drainage basins in the Cariboo Mountains but Mitchell River is the only salmon stream that lies mostly within the Cariboo Mountains. Precipitation is higher and temperatures lower again than in the Quesnel Highlands. Annual minimum flows occur in the winter and provided the main limitation on habitat in the Mitchell River. Forest harvesting is the main human activity with the potential to affect this stream.

The following sections provide a summary of the main issues affecting the hydrologic and sediment regime of the salmon streams and indicate future developments in land use that must be considered when developing fisheries management strategies:

**Water Use:** Beaver Creek is the only salmon stream where a large portion of the natural low flows are required for irrigation extractions. Moffat and Ahbau Creeks have moderate demands on their low flows from irrigation.

Large quantities of water are extracted from the Quesnel River and moderate quantities of water are extracted from the Cottonwood and Horsefly Rivers for irrigation. However, these streams have large drainage basins and the potential demand is only a small portion of the average summer 7 day low flows.

Cottonwood River, Naver Creek, Quesnel River (lower and upper), Beaver Creek, Horsefly River, Little Horsefly River and Wasko Creek

The above salmon streams have small tributaries in their watersheds with restrictions on further licensing though in most cases there are no restrictions for licencing on the main streams. Beaver Creek is the only salmon stream that is fully recorded.

Future water requirements for agriculture or other uses in the Quesnel HMA are not known as neither the Water Management Branch nor the Ministry of Agriculture prepare forecasts of

agricultural expansion and concomitant requirements for irrigation. However, the local Water Managers report that very few applications for irrigation licences are received for the Cottonwood River and Naver Creek basins and they do not anticipate any expansion of agricultural activity within these basins. The Water Manager (MoELP) in Williams Lake reports that the number of irrigation licence applications received generally increases following a moderate drought: prior to 1991/1992 there has been several years of adequate snowpack and this, coupled with a substantial increase in licence fees, has reduced the number of applications received. There is a backlog of unprocessed applications in the Williams Lake Office. The applications were not obtained as part of this study but may be made available at the discretion of the water manager.

**Storage Developments:** There are no applications before the Water Management Branch for large or medium-sized power projects in the Quesnel HMA. The Water Managers are also not aware of any small hydro developments within the Quesnel HMA, though there is an inactive licence on Beaver Creek.

B.C. Hydro maintains a reserve for power development on the Quesnel and Cariboo Rivers and the International Pacific Salmon Fisheries Commission (IPSFC) holds a reserve on Crooked Lake, on McKuskey Creek, in the upper Horsefly Basin. There is also a plan to develop storage on Polley Lake, as part of the Mount Polley Mine Development, to maintain fisheries flows in Hazeltine Creek. This is expected to primarily benefit species managed by MoELP.

Existing storage in the Quesnel HMA consists mostly of small storage structures developed and operated by individual ranchers or by Ducks Unlimited. In most basins, the total developed storage only represents a small portion of the water requirements for irrigation (Table 5). The largest storage reservoirs are operated by Fisheries & Oceans Canada on McKinley and Mitchell Lakes to enhance summer and winter low flows.

A number of storage structures were built to divert water for hydraulic placer mining in the early part of this century. Most of these structures are now abandoned and may no longer be safe. Where they can be identified, the Water Management Branch has removed them but there is no program in place to locate and remove the structures.

**Forestry:** Logging began in mid-1950's with most cutblocks harvested since 1965. Only Hazeltine and Edney Creek have harvests that exceed 20% of their watershed area and in most other watersheds less than 10% of the total area has been harvested, up to 1992. During our interviews, the Ministry of Environment expressed concern about specific logging-related issues – such as road encroachments on streams, and slope failures -- that affect small tributaries to the salmon streams. As of 1993, there is little evidence for or concern about direct sediment or hydrology related forestry impacts on the larger mainstem salmon streams.

The proposed cut over the next five years in the watersheds of the salmon streams ranges from 0% to a maximum of 15% of the watershed area. Those streams with large proposed cuts include Cottonwood Creek (5%), Lightning and Victoria Creeks (6% each), Cunningham Creek (12%), McKinley Creek (5%) and Killdog Creek (15%). During the current five year plan, logging will begin in most of the pristine watersheds that feed Quesnel Lake.

At the end of the five year plan Cottonwood River and Cunningham Creek will be 20% logged and a number of other creeks will have between 10 and 15% of their basin in recent cut. As logging progresses in the Quesnel HMA, forest management strategies will shift from the present

concentration on specific concerns to a strategy that will emphasize re-generation and rate-of-cut to control changes to the hydrologic, sediment, and temperature regimes of the salmon streams.

**Placer Mining:** Many of the streams in the Cottonwood, Naver, Cariboo and Quesnel watersheds were placer-mined in the 1860's as part of the Cariboo Gold Rush and have been mined sporadically or continuously since. Records of placer gold production from 1871 to 1945 in the Cariboo Mining District (Holland 1986) indicates those salmon streams which have been historically disturbed by placer mining. Sediment effluent from the Bullion Mine on the upper Quesnel produced a cycle of aggradation and degradation on the Quesnel River downstream of Quesnel Forks. The Cottonwood River, Cunningham Creek, Cariboo River, Hixon Creek, Horsefly River, Keithley Creek, Lightning Creek and Quesnel River all produced over 5,000 ounces of gold to 1945 with Lightning being, by far, the major producer. Triton (1992) summarizes those creeks that have active placer mining.

Since the revisions to the Placer Mining Act in 1989, the industry is managed by the Resource Management Section of the Ministry of Energy, Mines and Petroleum Resources. Overall, there have been few problems with the current management framework though the level of activity is low in the Cariboo because of low gold prices. There is concern that increasing prices will bring an influx of inexperienced miners that are unfamiliar with sediment control and mining techniques. One other concern is related to mines that were abandoned prior to the revisions to the act and are not re-claimed. These un-reclaimed sites may be chronic sediment sources. As discussed earlier, there are also some old storage ponds -- associated with hydraulic mining -- that have not been properly abandoned.

**Flooding, Erosion and Sedimentation:** There is little evidence of long-term sedimentation in any of the salmon streams, though both the Cottonwood and Horsefly Rivers were mentioned as sites where there may have been some deterioration of gravel quality over a number of years. The issue has not been studied in detail.

Overall, the salmon streams are mostly stable, though Moffat Creek and Hixon Creek are moderately unstable in their lower reaches. Despite the roughly 50-year return period flood in June 1990, there was little evidence of major erosion or channel shifting, except on Moffat and Hixon Creeks.

## **8.2 Technical and Management Recommendations**

As well as the specific discussion of individual streams in the following sections a number of general recommendations arise from this study that apply to management of the Habitat Management Area 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 in previous sections

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 that estimated flows on the ungauged streams, particularly low flows, should be confirmed by measurement programs perhaps in conjunction with the Water Management Branch 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.

Gaps in technical information limit our ability to adequately manage, and prioritize, the salmon streams:

1. The relationship between actual and licensed withdrawals, for various licence types, is not known. 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 actual demand on the most sensitive streams.
2. Instream flow needs for fish, or other uses, have not been established for the salmon streams. If instream flow requirements are better known, these can be used as critical values for the various indices which will improve their interpretation.

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

In preparing management plans, differences within the Habitat Management Area should be considered. Salmon streams on the Cariboo Plateau have moderate-sized basins, limited storage, and, in a few instances, large potential water demands. Storage development, riparian zone management, and erosion control are important issues.

Salmon streams in the Quesnel Highlands have small potential water demands. Storage development; managing rates of forest harvesting; and sediment and erosion control, particularly of abandoned and current placer mines, are important issues.

**Ahbau Creek, Beaver Creek, and Moffat Creek**

The salmon streams listed above have a considerable portion of typical summer flows potentially utilized by licensed demand, principally irrigation, and are under the greatest threat from water use. Further water withdrawals from these stream systems -- even with compensating storage -- should be opposed until actual licensed demand is established and water management options for the stream system are reviewed. Opportunities for storage development within these systems -- particularly Beaver Creek -- should be reviewed.

**Victoria Creek, Hixon Creek, Hazeltine Creek, and Edney Creek**

The salmon streams listed above do not have high water demand but have low summer flows in relation to their mean annual flow. The potential for future increased water demand should be examined and instream flows assessed. If demand is expected to increase, minimum flow agreements, or restrictive licensing, may be used to maintain instream flows. Storage

opportunities in the basin should be investigated either to supplement existing flows or to meet future demand.

Cottonwood River, Lightning Creek, Little River, Cunningham Creek, Wasko Creek  
Lynx Creek, Killdog Creek, and Summit Creek

The streams listed above have the lowest winter 7 day flows in relation to mean annual discharge. Most of these creeks have small basins, are located in the Quesnel Highlands, and are relatively unaffected by licensed demand. However, withdrawals from these systems that reduce winter stream flows should be opposed until flows are confirmed and water management options reviewed.

There may be technical options for improving those streams with the greatest potential water demands. In some basins additional reservoirs may be used to supplement minimum flows in the stream. Studies of storage potential, instream flow needs and investigation of losses along the channel should precede agreements on management of instream flows (Hamilton 1992). Fisheries & Oceans may participate in developing extra storage, or improving existing storage, to provide additional water for release during periods of low flow. In both instances, it should be ensured that some contractual relationship clearly spells out the reservoir operator's obligations.

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.

### **8.2.3 Forest Harvesting**

Most of the salmon streams (except Ahbau, Beaver and Moffat Creeks) 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. The review prepared for Cottonwood River provides a good example (Lorenz 1992). 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.

#### **8.2.4 Placer Mining**

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

#### **8.2.5 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.

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## TABLES



**Table 1: Salmon Streams in the Quesnel HMA.**

Stream Name	SSIS Number	Water Survey of Canada Gauging Records			Region
		Station	Number	Area (km <sup>2</sup> s)	
Cottonwood River	00-5100	near Cinema	08KE009	1,910	CP/QH
Abau Creek	00-5100-100				CP
Lightning Ck	00-5100-400	at wingdam	08KE004	204	QH
Victoria Ck	00-5100-500				CP
Naver Creek	00-5400	at Hixon	08KE014	658	CP
Hixon Creek	00-5400-050				CP
Quesnel R (lower)	06	near Quesnel	08KH006	11,500	CP
Quesnel R (upper)	06	at Likely	08KH001	5,930	QH/CM
Beaver Ck	06-2270	at outlet of Beaver Lk	08KH021	847	CP
Cariboo River	06-3810	near Keithley Creek	08KH013	2,870	QH/CM
		below Kangaroo Ck	08KH003	3,260	
Little River	06-3810-250				QH
Cunningham Ck	06-3810-400				QH
Hazeltine Ck	06-4810				CP
Edney Creek	06-4810-030				CP
Horsefly River	06-5460	at Horsefly	08KH007	2,310	CP/QH
		above McKinley Ck	08KH010	785	
Little Horsefly R	06-5460-145	near Horsefly	08KH008	422	CP/QH
		above Gruhs Lake	08KH025	416	
Moffat Ck	06-5460-190	near Horsefly	08KH019	539	CP
McKinley Ck	06-5460-480	below outlet of	08KH020	430	CP/QH
		McKinley Lake			
Mitchell River	06-6960	at outlet Mitchell Lk	08KH014	245	CM
Penfold Ck	06-6960-020				QH
Cameron Ck	06-6960-180				QH
Watt Creek	06-6980				QH
Roaring River	06-7020				QH
Wasko Creek	06-7650				QH
Lynx Creek	06-9050				QH
Killdog Creek	06-9740				QH
Blue Lead Creek	06-9860				QH
Summit Creek	06-9890				QH

1. CP, Cariboo Plateau; QH, Quesnel Highlands; CM, Cariboo Mountains.

**Table 2: Hydrology of the Various Physiographic Regions**

	<i>Caribou Plateau</i>	<i>Quesnel Highlands</i>	<i>Caribou Mountains</i>
<b>Mean Annual Runoff (mm)</b>	<b>100 to 200</b>	<b>600 to 1,000</b>	<b>near 1,500</b>
<b>Month with Average Maximum Discharge</b>	<b>May (April in small basins)</b>	<b>June</b>	<b>June; remains high in July and August</b>
<b>Timing of annual maximum discharge</b>	<b>mid-April to mid-June; sometimes in October from rain or snow</b>	<b>mid-May to mid-June; sometimes in July and August from rainfall</b>	<b>early June to mid-July</b>
<b>Month with Average Minimum Discharge</b>	<b>February; sometimes August in smaller streams</b>	<b>February</b>	<b>March</b>
<b>Timing of annual minimum discharge</b>	<b>late summer or early fall and winter</b>	<b>December to March sometimes in August</b>	<b>December to March</b>
<b>Typical Stream</b>	<b>Naver Creek at Hixon, 08KE014</b>	<b>Little Swift River at the mouth, 08KE024</b>	<b>Mitchell River at the outlet of Mitchell Lake, 08KH014</b>
<b>Basin Area (km<sup>2</sup>)</b>	<b>658</b>	<b>133</b>	<b>245</b>

**Table 3: 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 summer 7 day low flow** - Average of the summer 7 day low 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 licences, to represent the flows that would occur in the absence of regulation and extraction.

**Summer 7 day low flow** - The lowest average flow 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 licences.

**Winter 7 day low flow** - The 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 4: Hydrology of Salmon Streams in the Quesnel HMA

Stream Name	WSC Gauge No.	Basin Area (mouth) (km <sup>2</sup> )	Forested Area (km <sup>2</sup> )	Logged Area			Improved Farmland (1990) (km <sup>2</sup> )	Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m <sup>3</sup> /s)					
				Recent (km <sup>2</sup> )	Older (km <sup>2</sup> )	Proposed (1990-96) (km <sup>2</sup> )		Domes- tic (g/day)	Irrig- ation (ac-ft)	Water- works (g/day)	Indus- trial (g/day)	Conser- vation (cfs)	Aug	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7-day Flow Summer	Mean 7-day Flow Winter
Cottonwood R	08KE009	2,460	1934	403.38	52.19	111.12	54.65	47,001	610	40,000	15,000	0	72	29	0	26.0	234.0	9.26	9.09	4.15	3.51
Abau Creek		505	389	31.2	33.8	15.5	36.33	1,000	582	0	31,501	0	68	27	0	3.0	27.3	1.36	1.25	0.39	0.57
Lightning Ck	08KE004	243	214	17.8	41.6	13.07	3.64	1,000	0	0	4,000	0	0	0	0	5.0	49.9	2.43	2.47	1.32	0.67
Victoria Ck		305	305	3.41	0	18.58	0	0	0	0	0	0	0	0	0	1.7	16.3	0.71	0.64	0.19	0.31
Naver Creek	08KE014	900	682	77.73	65.86	31.56	70.69	16,000	317	0	102,500	0	38	15	1	6.4	48.1	2.85	2.66	0.91	1.15
Hixon Creek		238	208	11.52	0	3.42	17.54	6,000	0	0	20,000	0	0	0	0	1.3	12.6	0.52	0.46	0.13	0.23
Quesnel R (lower)	08KH006	11,730	-	11.7	22.3	-	155.04	121,900	9,875	1,748,000	330,775	238	1165	472	10	237.2	804.6	309	204	118.67	62.37
Quesnel R (upper)	08KH001	5,950	-	127.6	18.46	-	56.61	30,150	1,495	0	316,885	178	176	72	2	130.3	418.8	190	119	60.67	32.57
Beaver Ck	08KH021	1,561	1270	127.6	18.46	39.62	85.64	25,250	6,243	0	24,500	0	731	292	0	4.9	44.4	1.57	0.85	0.60	0.50
Cariboo River	08KH003	3,253	2054	338.23	16.22	89.04	0.26	11,000	2	0	2,500	0	0	0	0	94.5	421.0	113	78	44.20	17.30
Little River		378	332	27.32	0	9.74	0	0	0	0	0	0	0	0	0	7.8	77.6	3.78	3.84	2.06	1.04
Cunningham Ck		168	142	11.54	0	21.05	0	0	0	0	0	0	0	0	0	3.5	34.4	1.68	1.70	0.91	0.46
Hazeltine Ck		124	67	48.79	3.6	0	0	0	0	0	0	0	0	0	0	0.2	2.3	0.06	0.05	0.01	0.03
Edney Creek		86	47	39	0	0	0	0	0	0	0	0	0	0	0	0.5	5.1	0.16	0.15	0.04	0.08
Horsetfy River	08KH007	2,860	2021	236	10.64	84.57	44.82	14,500	1,486	0	100,100	123	174	70	1	33.2	183.0	29.46	19.31	11.52	6.88
Little Horsetfy R	08KH008	465	389	20.98	0	9.66	4.78	3,500	279	0	20,000	0	33	13	0	4.0	11.2	5.78	4.04	2.29	2.17
Moffat Ck	08KH019	551	461	54.82	0	16.78	14.68	1,500	525	0	10,000	0	61	25	0	3.3	23.2	1.94	1.40	0.64	0.74
McKinley Ck	08KH020	450	348	56.84	0	24.43	11.54	2,000	0	0	0	60	0	0	0	5.1	28.2	2.68	1.98	1.16	1.20

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- Shading indicates gauged salmon streams.
- Forested areas, logged areas and improved farmland from Triton (1991)
- 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 body of report.
- Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 4: Continued

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Forested Area (km2)	Logged Area			Improved Farmland (km2)	Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m3/s)					
				Recent (km2)	Older (km2)	Proposed (1990-96) (km2)		Domestic (g/day)	Irrigation (ac-ft)	Waterworks (g/day)	Industrial (g/day)	Conservation (cfs)	Aug	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7-day Summer	Mean 7-day Winter
Mitchell River	08KH014	574	266	3.77	0	10.93	0	0	0	0	0	0	0	0	0	18.5	75.0	28.24	18.74	8.09	2.92
Penfold Ck		199	112	0	0	3.59	0	0	0	0	0	0	0	0	0	4.7	36.6	3.71	2.61	2.06	0.68
Cameron Ck		71	41	1.81	0	2.13	0	0	0	0	0	0	0	0	0	1.7	13.1	1.33	0.93	0.73	0.24
Watt Creek		66	32	0	0	0	0	0	0	0	0	0	0	0	0	1.6	12.2	1.24	0.87	0.68	0.23
Roaring River		148	71	3.61	0	0.71	0	500	0	0	0	0	0	0	0	3.5	27.2	2.76	1.94	1.53	0.50
Wasko Creek		115	81	0	0	3.25	0	500	0	0	0	0	0	0	0	2.4	23.5	1.15	1.16	0.62	0.32
Lynx Creek		67	33	0	0	0	0	0	0	0	0	0	0	0	0	1.4	13.7	0.67	0.68	0.36	0.18
Killdog Creek		40	40	0	0	5.98	0	0	0	0	0	0	0	0	0	0.8	8.2	0.40	0.41	0.22	0.11
Blue Lead Creek		91	47	0	0	3.59	0	0	0	0	0	0	0	0	0	2.1	16.7	1.70	1.19	0.94	0.31
Summit Creek		40	34	0	0	0	0	0	0	0	0	0	0	0	0	0.8	8.2	0.40	0.41	0.22	0.11

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- Shading indicates gauged salmon streams.
- Forested areas, logged areas and improved farmland from Triton (1991)
- 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 body of report.
- Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

Table 5: Storage on Salmon Streams in the Quesnel HMA

Stream Name	Basin Area (mouth) (km <sup>2</sup> )	Total Non-Power Storage (ac-ft)	Total Conservation Storage (ac-ft)	Total Irrigation Licences (ac-ft)	Percent with Storage (%)
Cottonwood R	2,460	315	0	610	52
Abau Creek	505	310	0	582	53
Lightning Ck	243	0	0	0	0
Victoria Ck	305	0	0	0	0
Naver Creek	900	0	64	317	0
Hixon Creek	238	0	0	0	0
Quesnel R (lower)	11,730	2,294	125	9,875	23
Quesnel R (upper)	5,950	276	125	1,495	18
Beaver Ck	1,561	1,518	0	6,243	24
Cariboo River	3,253	0	0	2	0
Little River	378	0	0	0	0
Cunningham Ck	168	0	0	0	0
Hazeltine Ck	124	0	0	0	0
Edney Creek	86	0	0	0	0
Horsefly River	2,860	286	3,825	1,486	19
Little Horsefly R	465	146	150	279	52
Moffat Ck	551	0	0	525	0
McKinley Ck	450	0	3,675	0	0
Mitchell River	574	0	36,000	0	0
Penfold Ck	199	0	0	0	0
Cameron Ck	71	0	0	0	0
Watt Creek	66	0	0	0	0
Roaring River	148	0	0	0	0
Wasko Creek	115	0	0	0	0
Lynx Creek	67	0	0	0	0
Killdog Creek	40	0	0	0	0
Blue Lead Creek	91	0	0	0	0
Summit Creek	40	0	0	0	0

- "Non-power includes all storage for domestic, waterworks, industrial, and irrigation licences.
- Irrigation licences for each salmon stream from Table 4.
- Percent with storage calculated from by dividing non-power storage by total irrigation licences for each stream.

Table 6: Sensitivity Indices for the Quesnel HMA

Stream Name	Status	SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	LOGGING		
		Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	Index 8	Index 9	Index 10
		Aug Use/ Sum Q7L2	Sept Use/ Sum Q7L2	Aug Use/ mean Aug	Sept Use/ mean Sept	Sum Q7L2/ QAA	Win Q7L2/ QAA	Q2/ QAA	Recent/ Basin	Total/ Basin	Recent & Proposed
Cottonwood River		2	1	1	0	16	14	9	16	19	21
Abau Creek		17	7	5	2	12	19	9	6	13	9
Lightning Ck		0	0	0	0	26	13	10	7	24	13
Victoria Ck		0	0	0	0	11	18	9	1	1	7
Naver Creek		4	2	1	1	14	18	7	9	16	12
Hixon Creek		0	0	0	0	10	18	10	5	5	6
Quesnel R (lower)		1	0	0	0	50	26	3	0	0	0
Quesnel R (upper)		0	0	0	0	47	25	3	2	2	2
Beaver Ck	RES	122	49	47	35	6	10	9	8	9	11
Cariboo River		0	0	0	0	47	18	4	10	11	13
Little River		0	0	0	0	26	13	10	7	7	10
Cunningham Ck		0	0	0	0	26	13	10	7	7	19
Hazeltine Ck		0	0	0	0	5	15	11	39	42	39
Edney Creek		0	0	0	0	8	17	11	45	45	45
Horsefly River		2	1	1	0	35	21	6	8	9	11
Little Horsefly R		1	1	1	0	57	55	3	5	5	7
Moffat Ck		10	4	3	2	19	23	7	10	10	13
McKinley Ck		0	0	0	0	23	24	6	13	13	18

- Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; RES, reserved, no licencing; PWS, possible water shortages.
- 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 Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Recent and Total are recent and total logging areas in the basin; 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 6; values of Index 7 of 10 or more are shaded; and values of Index 8 exceeding 20% are shaded.

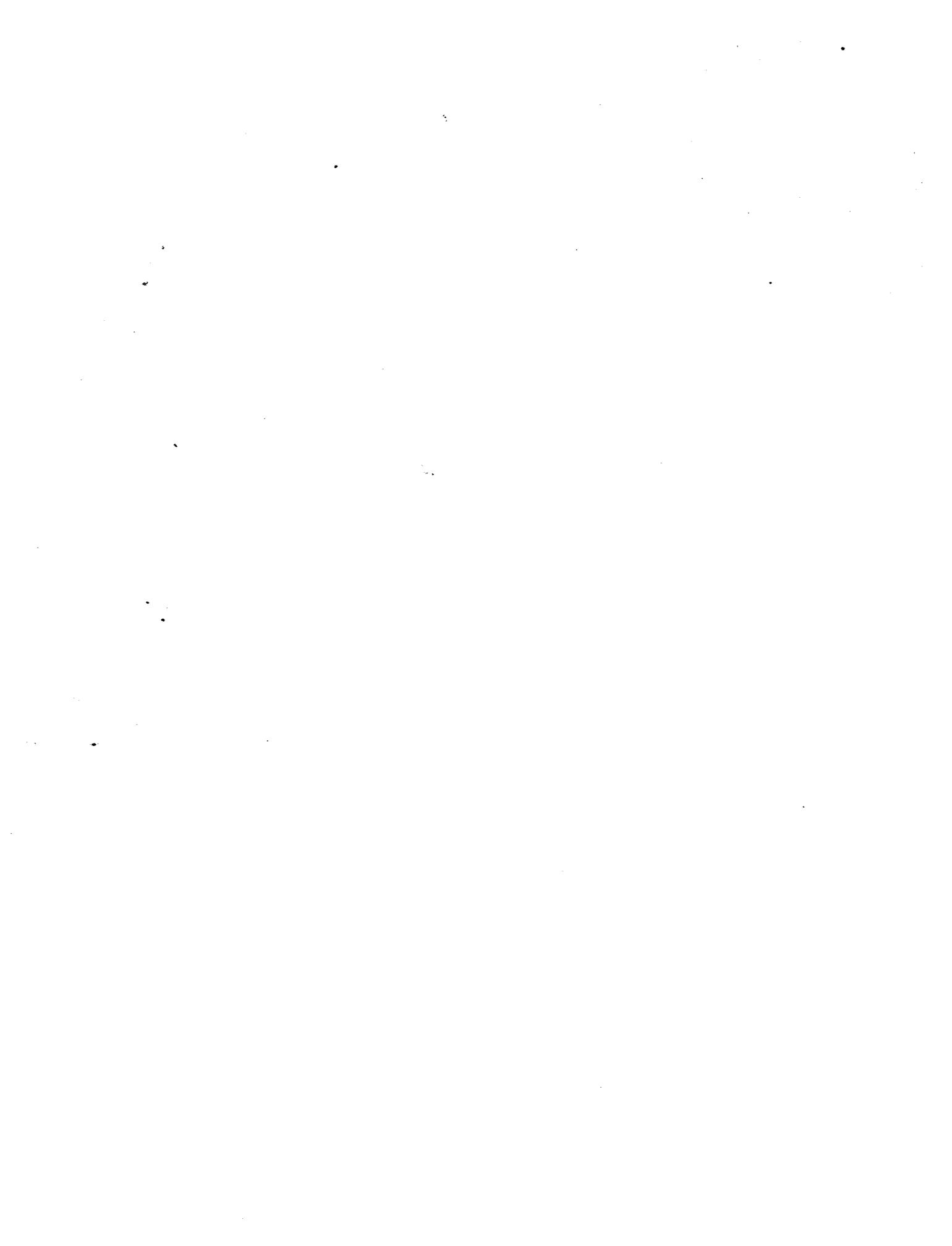
Table 6: Sensitivity Indices for the Quesnel HMA

Stream Name	Status	SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	LOGGING		
		Index 1	Index 2	Index 3	Index 4	Index 5	Index 6	Index 7	Index 8	Index 9	Index 10
		Aug Use/ Sum Q7L2	Sept Use/ Sum Q7L2	Aug Use/ mean Aug	Sept Use/ mean Sept	Sum Q7L2/ QAA	Win Q7L2/ QAA	Q2/ QAA	Recent/ Basin	Total/ Basin	Recent & Proposed
Mitchell River		0	0	0	0	44	16	4	1	1	3
Perfold Ck		0	0	0	0	44	14	8	0	0	2
Cameron Ck		0	0	0	0	44	14	8	3	3	6
Watt Creek		0	0	0	0	44	14	8	0	0	0
Roaring River		0	0	0	0	44	14	8	2	2	3
Wasko Creek		0	0	0	0	26	13	10	0	0	3
Lynx Creek		0	0	0	0	26	13	10	0	0	0
Killdog Creek		0	0	0	0	26	13	10	0	0	15
Blue Lead Creek		0	0	0	0	44	14	8	0	0	4
Summit Creek		0	0	0	0	26	13	10	0	0	0

- Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; RES, reserved, no licencing; PWS, possible water shortages.
- 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 Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Recent and Total are recent and total logging areas in the basin; 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 6; values of Index 7 of 10 or more are shaded; and values of Index 8 exceeding 20% are shaded.

Table 7: Sensitive Salmon Streams in the Quesnel HMA

<b>Water Demand</b>	<b>Summer Low Flows</b>	<b>Winter Low Flows</b>	<b>Peak Flows</b>	<b>Logging</b>
<i>Indices 1 to 4</i>	<i>Indices 5</i>	<i>Indices 6</i>	<i>Indices 7</i>	<i>Indices 8 to 10</i>
Abhau Ck	Abhau Ck	Lightning Ck	Lightning Ck	Hazeltine Ck
Beaver Ck	Victoria Ck	Beaver Ck	Hixon Ck	Edney Ck
Moffat Ck	Naver Ck	Little R	Little River	
	Hixon Ck	Cunningham Ck	Cunningham Ck	
	Beaver Ck	Wasko Ck	Hazeltine Ck	
	Hazeltine Ck	Lynx Ck	Edney Ck	
	Edney Ck	Killdog Ck	Wasko Ck	
		Summit Ck	Lynx Ck	
			Killdog Ck	
			Summit Ck	



## FIGURES



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

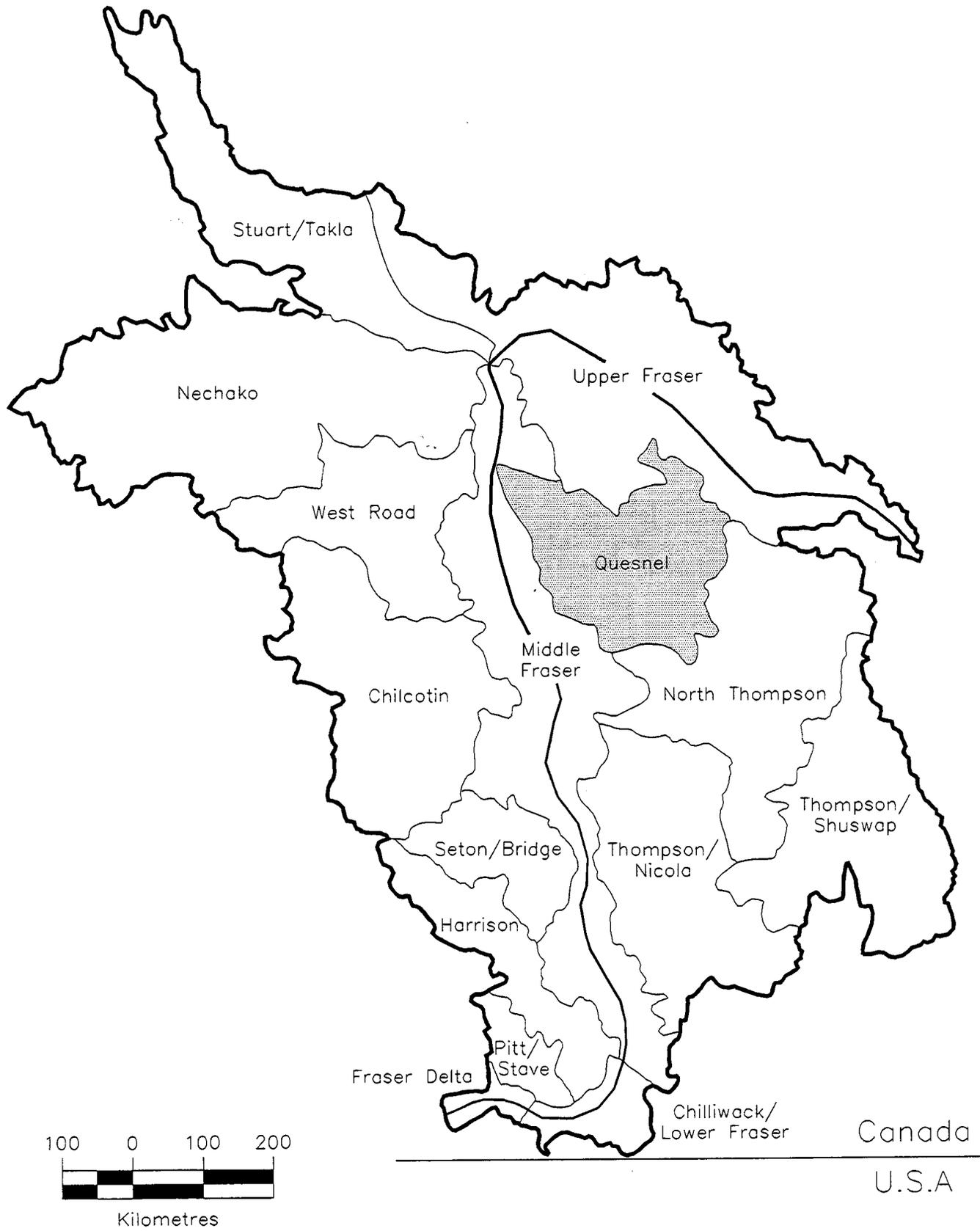


Figure 2: Salmon Streams in the Quesnel HMA

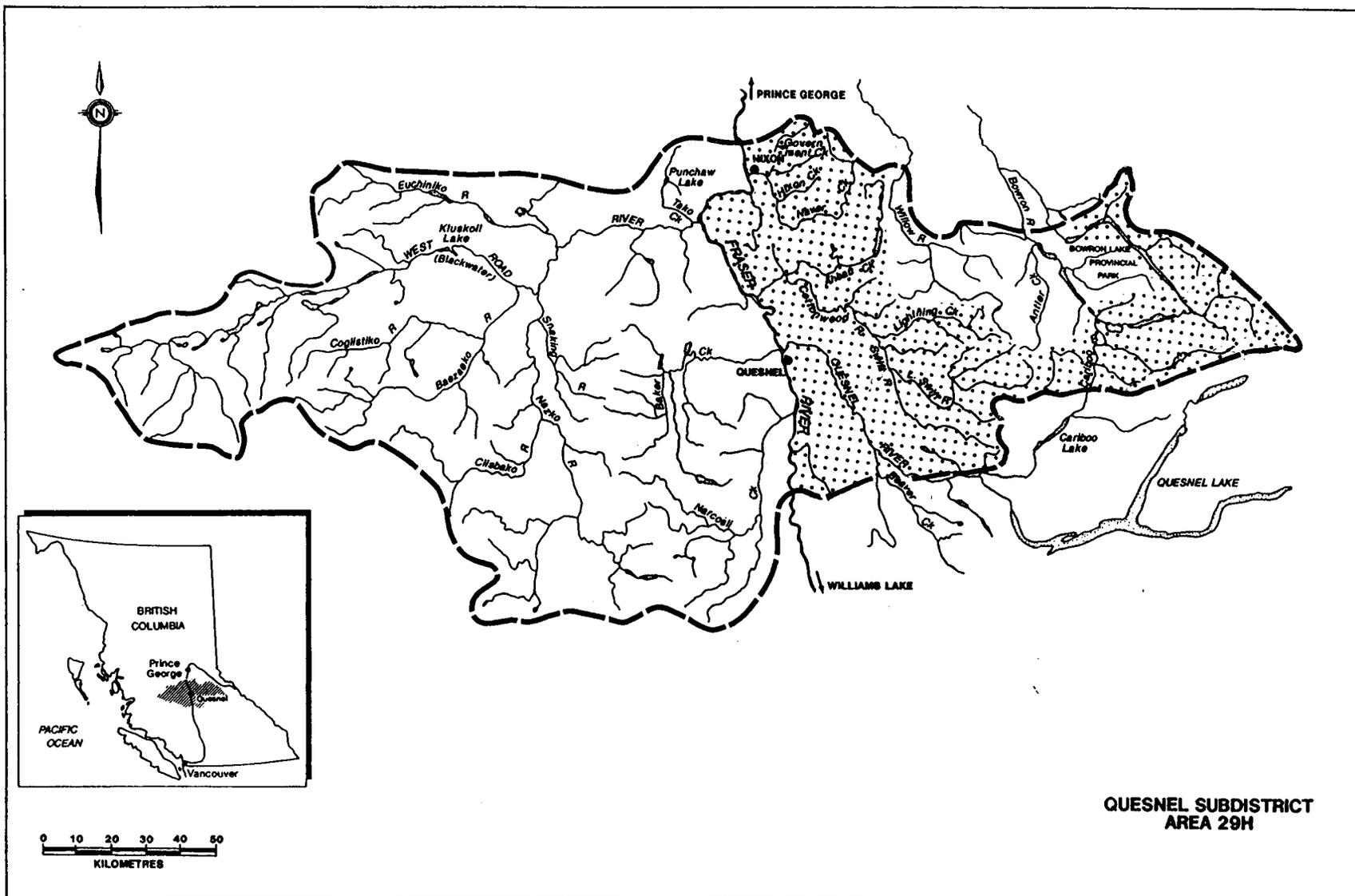




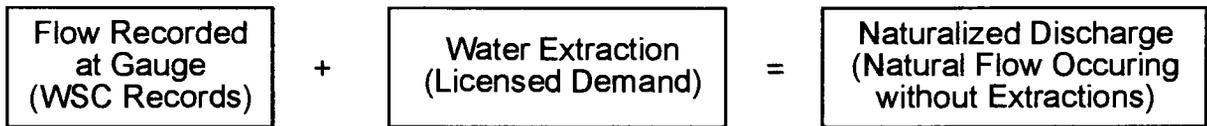
Figure 3: Physiography and Gauging Stations in the Quesnel HMA



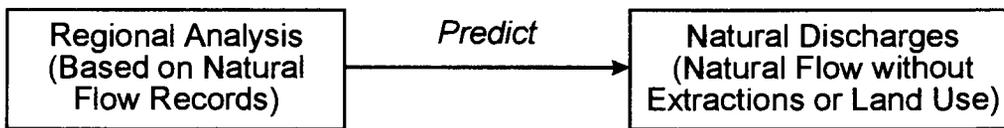
● gauging stations  
▬▬▬▬▬▬ physiographic boundary

**Figure 4: Calculation of Natural and Naturalized Flows for the Salmon Streams**

*GAUGED STREAMS*



*UNGAUGED STREAMS*



**FIGURE 5: 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. PREDICTING FLOWS AT THE MOUTHS OF SALMON STREAMS

This appendix describes the procedures used to estimate flow characteristics for those salmon stream without gauging records and to adjust flow characteristics for those salmon streams with stream gauging records that are not near the mouth. Table A1 summarizes the methods used for the individual streams.

Regional hydrologic analysis was the preferred method for estimating flows. There were sufficient numbers of gauging stations to apply this technique to the Cariboo Plateau. However, there are too few gauging stations to apply it to the Quesnel Highlands or the Cariboo Mountains. In these regions, flow characteristics were estimated by transfer from a similar, nearby gauged stream.

### A.1 Cariboo Mountains

*Mitchell River:* Records at the Mitchell River at outlet of Mitchell Lake (08KH014) extend from 1961 to 1982. All years of record were included in calculation of flow characteristics at the station and the characteristics were not adjusted to 1981-1990. Mean annual, mean monthly and 7 day low flows at the mouth of Mitchell River were estimated by adding discharges from Penfold and Cameron Creeks to those measured at the station at the outlet of Mitchell Lake. This procedure may slightly under-estimate 7 day low flows at the mouth as it assumes that minimum flows occur at the same time in each drainage basin.

Mean annual floods were adjusted from the gauge to the mouth using the ratio  $(A_m/A_g)^n$ ; where  $A_m$  is the drainage area at the mouth,  $A_g$  is the drainage area at the gauge and  $n$  is equal to 0.6 for mean annual flood.

### A.2 Quesnel Highlands

Gauging stations in the Quesnel Highlands include Little Swift River at the mouth (133 km<sup>2</sup>); MacKay River at the mouth (144 km<sup>2</sup>); Horsefly River above McKinley Creek (785 km<sup>2</sup>); and Cariboo River below Kangaroo Creek (08KH003). The Little Swift and MacKay rivers, which have the smallest drainage areas, are most similar to the ungauged salmon streams in the upper Cariboo River and around Quesnel Lake.

The Little Swift has near-complete records from 1981-1990. MacKay River records extend from 1971-1985; flow characteristics calculated from these records were adjusted to 1981-1990 with the Horsefly River above McKinley Creek records. The adjustment consisted of determining the ratio of the flow characteristic over the gauging period at the MacKay River to that over 1981-1990 at the Horsefly River gauge and applying this ratio to the MacKay flow characteristics.

The Little Swift and MacKay rivers have somewhat different flow characteristics despite their similar size. MacKay River has a steeper watershed, with greater elevations, and has a slightly greater annual flow, a similar but later mean annual flood, and higher discharges in August and September flows. Flow characteristics from the MacKay River were used, with the ratio of drainage areas, to estimate flows on the Roaring River and Penfold, Cameron, Watt, Lynx, and Blue Lead Creeks. Little Swift River flow characteristics were used for Little River and Lightning, Cunningham, Wasko, and Summit Creeks.

The only Quesnel Highland stream that required adjustment of its Water Survey of Canada records is the Cottonwood River, and the adjustments are described below:

*Cottonwood River.* The mean annual, mean monthly and 7 day low flows at the mouth of the Cottonwood River were estimated by adding flows from Ahbau River to those extracted from the gauging station. This procedure may under-estimate 7 day low flows at the mouth as it assumes that minimum flows occur at the same time in each drainage basin.

Mean annual floods were adjusted from the gauge to the mouth using the ratio  $(A_m/A_g)^n$ ; where  $A_m$  is the drainage area at the mouth,  $A_g$  is the drainage area at the gauge and  $n$  is equal to 0.6 for mean annual flood.

### **A.3 Cariboo Plateau**

Regional hydrologic analysis was used to predict flows in ungauged streams on the Cariboo Plateau. This procedure predicts the flow characteristics of ungauged watersheds by developing relationships between flow characteristics, climate and hydrology in watershed with gauging stations. The simplest and best relationships occur within regions that are reasonably homogeneous with respect to flow-generating mechanisms, climate and physiography.

#### **A.3.1 Criteria for Selecting Gauging Records**

The general criteria for selecting gauging records for correlation or regression analysis with climate and physiographic data are:

1. All stations should have a complete or nearly complete record of flows during a common base period. In this report, our base period is 1981 to 1990, inclusive;
2. The length of the base period should be at least 10 years, though some compromise is necessary between long base periods and the number of stations available for inclusion in the analysis;
3. Drainage areas at the gauging sites should exceed 100 km<sup>2</sup> and be less than several thousand km<sup>2</sup>. The lower limit avoids local anomalies, the upper limit avoids artificially high correlations induced by including large drainage areas that encompass most of the region;
4. The records should all be independent. Where there are multiple records on one stream, only one record should be used or the records should be subtracted to produce flow estimates for the independent portions of the total basin area; and
5. There should be no upstream regulation, water use, or diversion out of the basin.

The above list is ideal; the following section discusses relaxing these criteria to provide sufficient stations for an adequate statistical analysis. Typically, a minimum of ten gauging records are required for adequate regression analysis.

### **A.3.2 Water Survey of Canada Records in the Cariboo Plateau**

Table A2 lists the Water Survey of Canada stations in the Highlands region that were selected for analysis. These stations do not all meet the criteria discussed in Section E.2.1. Stations smaller than 100 km<sup>2</sup> are included in the analysis; these were included because the majority of the ungauged salmon streams have small watersheds. A number of the stations do not have complete records during the 1980's and it was necessary to include these older records in order to have sufficient data points for analysis. All older records were adjusted to the 1980's with the Baker Creek gauge. The adjustment consisted of determining the ratio of the flow characteristic over the gauging period, and over 1981-1990, at the Baker Creek gauge and applying the ratio of the two to characteristics from the older record.

Water is extracted from some streams upstream of their gauges. Flows were adjusted following the procedures outlined in Chapter 2 of the report, utilizing summaries of water licences obtained from the Water Management Branch.

All the gauged streams are independent and require no adjustment. Baker Creek was judged to be different from the other streams on the Cariboo Plateau and its data was not included in the regression analysis discussed in the following sections.

### **A.3.3 Climate and Physiographic Data**

Physiographic and climatic variables that are related to flow characteristics are listed on Table A.3. The physiographic variables collected for the watersheds of the selected gauging stations are: drainage basin area, area of lakes, maximum and minimum elevations, and the area above 1,050 m (3,500 ft). Elevation range was calculated from the minimum and maximum elevations.

May to September precipitation was calculated from manuscript maps (1:125,000) prepared by the Climatology Unit of the Waste Management Branch. Basin areas were superimposed on these maps and the areas lying between individual isohyets was estimated. Average seasonal precipitation was calculated from an areally-weighted average of the contour mid-points and are reported to the nearest 25 mm.

### **A.3.4 Regression analysis of flow characteristics using physiographic and climatic variables**

**Procedures:** The following procedures were used in developing regression models for each of the streamflow variables:

1. Bi-variate correlations between the independent variables and the chosen flow characteristic -- both logarithmic transformed and non-transformed -- were used to identify those variables significantly correlated with the flow characteristic. ( $R^2$  must exceed 0.6 for a significant correlation with 9 cases.);
2. A correlation matrix was prepared for the significant independent variables. Intercorrelated independent variables produce little improvement in the explanation level of multiple regression models.

3. The multi-variate relationship with the highest  $r^2$  and the lowest standard error, for each flow characteristic, was determined.
4. The relationship was used to predict flow characteristics at ungauged streams.

**Mean Annual Flows and Mean Annual Floods:** Basin area was significantly correlated with both flows: other variables exhibited near-zero or zero correlation. Correlations were stronger with logarithmically-transformed variables and thus a logarithmic transform was used in developing the regression equations.

Constants and coefficients for the preferred regression equations, relating the logarithms of mean annual flow and mean annual flood to the logarithms of basin area are described in the following table:

Variable	Constant	Coefficient	$r^2$	SE <sub>y</sub>	N
Mean Flow	-2.568	1.128	0.96	0.206	9
Mean Flood	-1.3252	1.0212	0.94	0.237	9

**Mean Monthly Flows:** Basin area was significantly correlated with mean August and September flows, as was the percentage of lakes and the percentage of area above 1,050 m. Other variables exhibited near-zero or zero correlation. Basin area and area above 1050 m are inter-correlated and area above 1,000 m was dropped. Correlations were stronger with logarithmically-transformed variables and thus a logarithmic transform was used in developing the regression equations.

Constants and coefficients for the preferred regression equations, relating the logarithms of mean August and September flows to the logarithms of basin area and % lakes were developed. The equations predicted declining discharge with increasing % lakes -- which is not physically reasonable -- and this variable was also dropped from the equation. The resulting bi-variate relationships are described in the following table. Standard errors of these equations, expressed in logarithms in the table, are equivalent to percent standard errors of, roughly, +70%, -40%. Similar percent standard errors were found during a regional analysis of monthly flows on Vancouver Island (Rood 1988).

Month	Constant	Coefficient	$r^2$	SE <sub>y</sub>	N
August	-3.4506	1.3119	0.96	.233	9
Sept	-3.3454	1.2866	0.96	.239	9

**Seven Day Low Flows:** Basin area was significantly correlated with summer and winter 7 day low flows, as was the percentage of basin area above 1,050 m. Other variables exhibited near-zero or zero correlation. Basin area and area above 1,050 m are inter-correlated and area over 1,050 m was dropped in favour of a bi-variate model. Correlations were stronger with

logarithmically-transformed variables and thus a logarithmic transform was used in developing the regression equations.

The constants and coefficients for the preferred regression equations, relating the logarithms of summer and winter mean 7 day low flows to the logarithm of basin area are described in the following table. Standard errors of these equations, expressed in logarithms in the table, are equivalent to percent standard errors of, roughly, +100% and -50% for summer 7 day low flows and +30% and -20% for winter 7 day low flows.

Flow	Constant	Coefficient	$r^2$	SE <sub>y</sub>	N
Summer	-4.3269	1.4501	0.98	0.290	9
Winter	-3.4965	1.2045	0.99	0.108	9

### A.3.5 Predicting Flow Characteristics in Ungauged Salmon Streams

The equations from the above sections were used to predict mean annual flows, mean annual floods, mean monthly and mean 7 day low flows for the ungauged salmon streams. Where there are no gauging records for the salmon stream, the results of the regression equations are used in Table 4. For salmon streams with short-term records collected by the Water Survey of Canada or with low flow measurements collected by the Water Management Branch, the predicted values were compared to the measured values. If the predicted values differed greatly from the measured values, the measured values were generally accepted, or an average of the two sets of values was included on Table 4.

The data set used to develop the regression equations mostly includes basins lying near or around Quesnel, or between Quesnel and Prince George. The equations provide reasonable predictions for ungauged salmon streams lying in this part of the Quesnel HMA but they provide poorer predictions for salmon streams in the more distant portions of the HMA.

It was felt that the predicted values from the equations for mean monthly flows and mean 7 day low flows did not match well with measurements at the gauge on Beaver Creek. Consequently, data at the mouth of Beaver Creek were derived as follows:

*Beaver Creek:* Mean annual flows at the mouth of Beaver Creek were calculated by assuming an annual runoff of 100 mm from the watershed. Mean annual floods, mean monthly and mean 7 day low flows were calculated from the limited gauging records and adjusted from the gauge to the mouth using the ratio  $(A_m/A_g)^n$ ; where  $A_m$  is the drainage area at the mouth,  $A_g$  is the drainage area at the gauge and  $n$  is equal to 0.6 for mean annual flood and 1.0 for all other mean flows.



Table A1: Estimating Flows in the Quesnel HMA

Stream Name	SSIS Number	Water Survey of Canada Gauging Records			Source of Discharge Data at the stream mouth
		Station	Number	Area (km <sup>2</sup> )	
Cottonwood River	00-5100	near Cinema	08KE009	1,910	adjust data from 08KE009 station
Ahbau Creek	00-5100-100				regional analysis
Lightning Ck	00-5100-400	at wingdam	08KE004	204	transfer from Little Swift (08KE024)
Victoria Ck	00-5100-500				regional analysis
Naver Creek	00-5400	at Hixon	08KE014	658	regional analysis
Hixon Creek	00-5400-050				regional analysis
Quesnel R (lower)	06	near Quesnel	08KH006	11,500	use data from 08KH006 station
Quesnel R (upper)	06	at Likely	08KH001	5,930	use data from 08KH001 station
Beaver Ck	06-2270	at outlet of Beaver Lk	08KH021	847	adjust data from 08KL021 station
Cariboo River	06-3810	below Kangaroo Ck	08KH003	3,260	use data from 08KH003 station
Little River	06-3810-250				transfer from Little Swift (08KE024)
Cunningham Ck	06-3810-400				transfer from Little Swift (08KE024)
Hazeltine Ck	06-4810				regional analysis
Edney Creek	06-4810-030				regional analysis
Horsefly River	06-5460	at Horsefly	08KH007	2,310	adjust data from 08KH007 station
Little Horsefly R	06-5460-145	near Horsefly	08KH008	422	adjust data from 08KH008 station
Moffat Ck	06-5460-190	near Horsefly	08KH019	539	use data from 08KH019 station
McKinley Ck	06-5460-480	below outlet of McKinley Lake	08KH020	430	use data from 08KH020 station
Mitchell River	06-6960	at outlet Mitchell Lk	08KH014	245	adjust data from 08KH014 station
Penfold Ck	06-6960-020				transfer from MacKay (08KH022)
Cameron Ck	06-6960-180				transfer from MacKay (08KH022)
Watt Creek	06-6980				transfer from MacKay (08KH022)
Roaring River	06-7020				transfer from MacKay (08KH022)
Wasko Creek	06-7650				transfer from Little Swift (08KE024)
Lynx Creek	06-9050				transfer from MacKay (08KH022)
Killdog Creek	06-9740				transfer from Little Swift (08KE024)
Blue Lead Creek	06-9860				transfer from MacKay (08KH022)
Summit Creek	06-9890				transfer from Little Swift (08KE024)

Table A2: Cariboo Plateau Stations with Natural or near-natural flow

Station	Gauge No.	Basin Area (km <sup>2</sup> )	Period of Record	Comments
Baker Ck at Quesnel	08KE016	1570	63-91MC	
Moffat Ck near Horsefly*	08KH019	539	64-66MS; 67-91RC	
Barlow Ck near Quesnel	08KH018	69.9	63-74MC	
Dragon Ck above Dragon Lk	08KH023	7.3	71-81MC; 88-91MS	
Tabor Ck at Highway # 97	08KE028	113	74-81RC	
Cale Ck near Red Rock	08KE015	188	56-66MC; 67-68MS; 69-74MC	
Naver Ck at Hixon	08KE014	658	56-57MC; 58-63MS; 64-75MC	
Chilako R near Prince George	08JC005	3390	60-63MC; 64-65MS; 66-74MC	
Cottonwood R near Cinema	08KE009	1910	54-56MS; 57-64RS; 65-67RC; 68-91MC	

1. R refers to recording gauges, M to manual; C to continuous records, S to seasonal.

**Table A3: Physiography, Climate and Flow Characteristics for WSC stations in the Cariboo Plateau**

Station	Basin Area (km <sup>2</sup> )	Lake Area (km <sup>2</sup> )	Elevation in Basin (m)			May – Sept Precip (mm)	Mean 7 day Low Flows		Mean Monthly Flows	
			Max	Min	Range		Summer (m <sup>3</sup> /s)	Winter (m <sup>3</sup> /s)	August (m <sup>3</sup> /s)	September (m <sup>3</sup> /s)
Baker Ck at Quesnel*	1570	17.1	2155	792	1362	330	0.70	0.72	2.03	1.46
Moffat Ck near Horsefly	539	3.2	792	549	244	267	0.62	0.74	1.88	1.38
Barlow Ck near Quesnel	69.9	0.1	1286	640	646	254	0.02	0.03	0.05	0.09
Dragon Ck above Dragon Lk	7.3	3.75	1257	579	678	279	0.001	0.004	0.005	0.004
Tabor Ck at Highway # 7	113	1	1372	579	792	279	0.02	0.10	0.15	0.19
Cale Ck near Red Rock	188	2.57	1676	549	1128	330	0.08	0.16	0.72	0.88
Naver Ck at Hixon	658	53	1494	579	914	203	0.58	0.83	2.17	2.97
Chilako R near Prince George	3390	21.77	1925	579	1346	381	5.35	4.91	7.64	6.86
Cottonwood R near Cinema	1910	0.3	1925	579	1346	325	4.12	3.48	9.19	9.06

– Baker Creek records were not used in developing the regression equations of Appendix A.

**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. 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 streams in the Quesnel Habitat Management Area. 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. In general, it is apparent that in this HMA, the 7 day low flows typically occur in January to March and in August and September.

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  $m^3/s$ , 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 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.

# COTTONWOOD RIVER

## LICENSED WATER DEMAND

Stream number 00-5100

Water Survey of Canada Station 08KE009

Cottonwood River near Cinema

Records 1954 to 1992

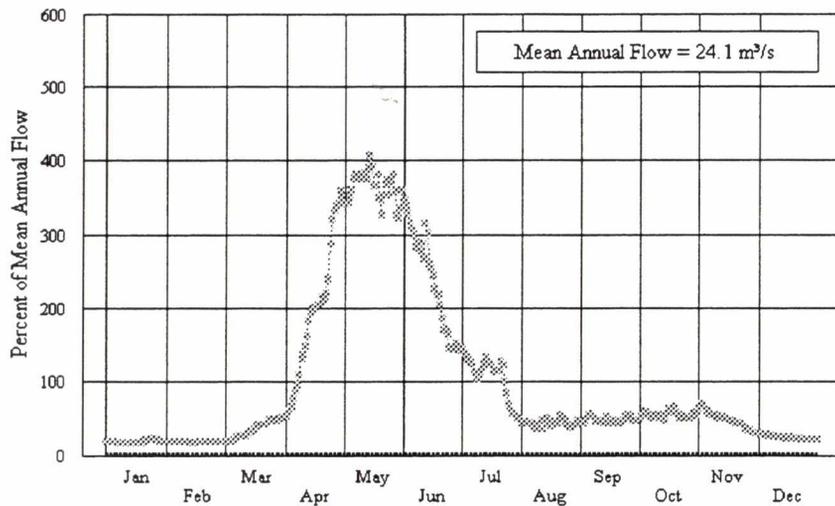
Drainage Area = 1910 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	47,001 g/d	2.5	2.5	2.5
Irrigation	610 ac.ft.	0	70.3	29.0
Waterworks	40,000 g/d	2.1	2.1	2.1
Industrial	15,000 g/d	0.8	0.8	0.8
Conservation	0 cfs	0	0	0

Feb Aug Sep

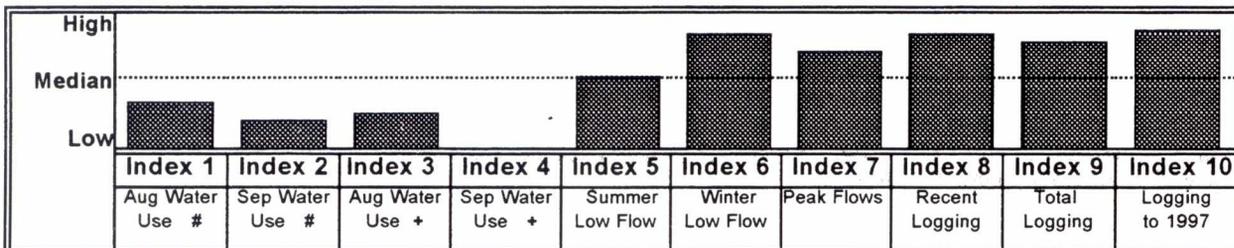
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	4,820	14,100	14,200

## 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.

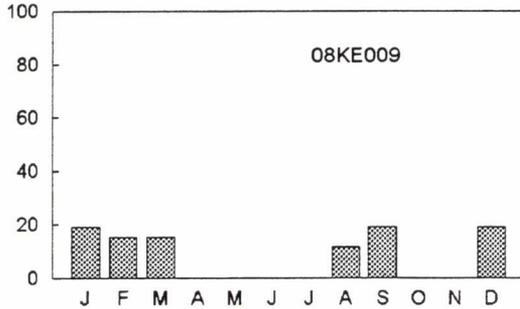


# Water use as a proportion of the 7 day low flow

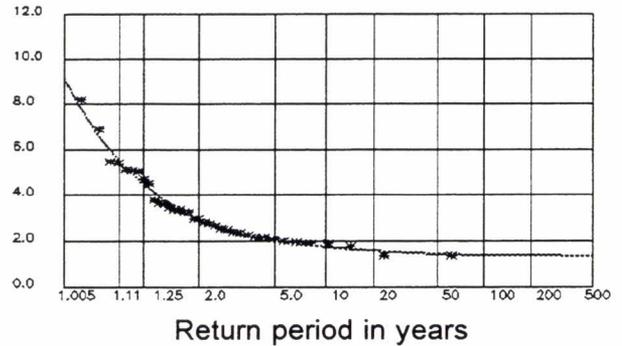
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	2.68 m <sup>3</sup> /s	1.68 m <sup>3</sup> /s	1.52 m <sup>3</sup> /s	1.39 m <sup>3</sup> /s	1.33 m <sup>3</sup> /s
<b>Annual Flood</b>	187 m <sup>3</sup> /s	298m <sup>3</sup> /s	341 m <sup>3</sup> /s	397 m <sup>3</sup> /s	440 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The rate of forest harvesting; particularly in Frye Creek, John Boyd Creek, Umiti Creek, Sovereign Creek, Bendixon Creek, Reddish Creek, and Fontaine Creeks; should be closely watched. Recent and proposed logging exceed 20% of the Cottonwood basin area.*

*2. Placer Mining on John Boyd Creek is extensive and may become a more serious problem in the future.*

*3. There may be potential in colonizing Swift River above the falls*

# AHBAU CREEK

## LICENSED WATER DEMAND

Stream number 00-5100-100

Ungaged

Flows into Cottonwood River near Quesnel

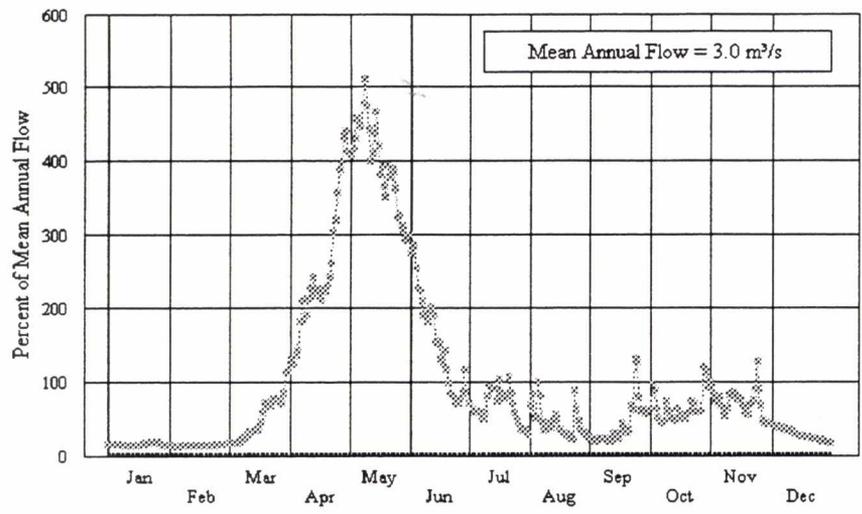
Drainage Area = 505 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,000 g/d	0.05	0.05	0.05
Irrigation	582 ac.ft.	0	67.0	27.7
Waterworks	0 g/d	0	0	0
Industrial	31,501 g/d	1.66	1.66	1.66
Conservation	0 cfs			

	Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>		1,360	1,250

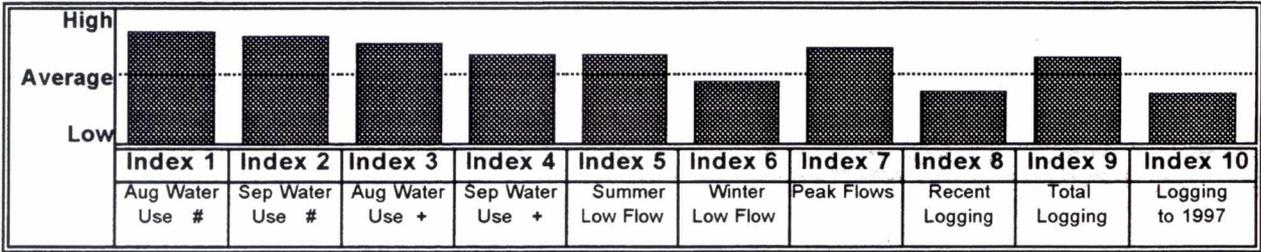
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Naver Creek station 08KE014)



## 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

# AHBAU CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Low flow problems have not yet been reported but licensed water use is relatively high, indicating a potential for problems.*
- 2. High flows are attenuated by beaver dams and lakes, although the beaver dams may be impeding upstream migration.*
- 3. Lill and Tautz (1983) indicated that surveys are required to identify any enhancement opportunities.*

# LIGHTNING CREEK

## LICENSED WATER DEMAND

Stream number 00-5100-400

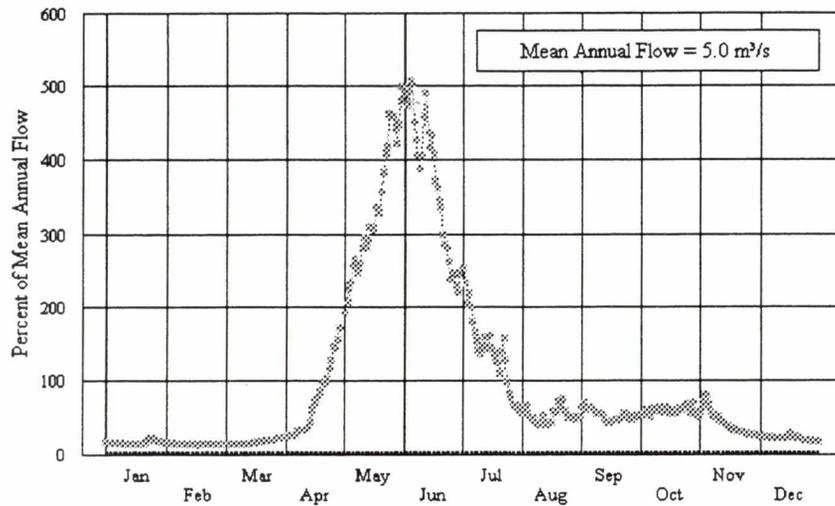
Flows into Cottonwood River near Quesnel

Drainage Area = 243 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.	0	0	0
Waterworks	0 g/d	0	0	0
Industrial	4,000 g/d	0.21	0.21	0.21
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			2,430	2,470

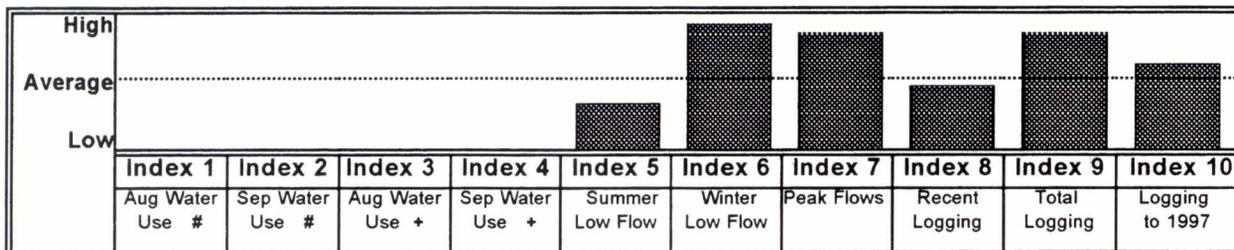
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Little Swift River station 08KE024)



## 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

# LIGHTNING CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Lightning Creek has been placer mined continuously since the 1860's; and most tributaries have been mined at one time or another.*
- 2. Sediment from historic and recent placer mining and logging operations, together with natural instability, may be limiting spawning habitat.*
- 3. Restoration should be directed towards reclamation of placer mining sites, channel stabilization, and reinstatement of riparian vegetation.*

# VICTORIA CREEK

## LICENSED WATER DEMAND

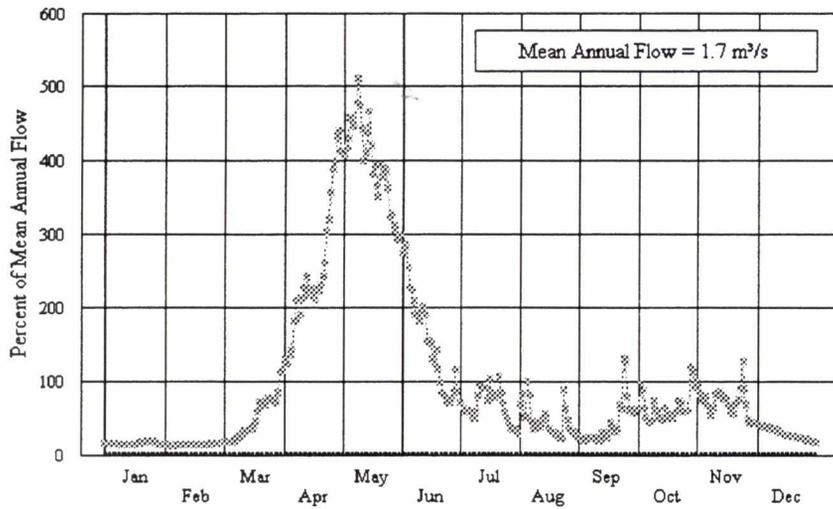
Stream number 00-5100-500  
 Ungauged  
 Tributary to Cottonwood River

Drainage Area = 305 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>			710	640

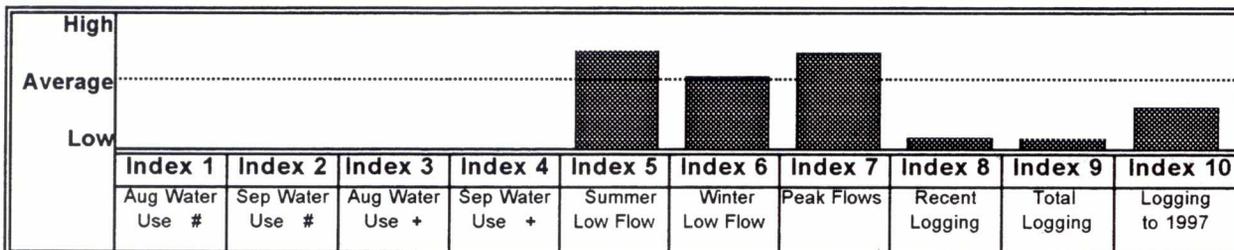
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Naver Creek station 08KE014)



## 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

# VICTORIA CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The Victoria Creek basin is swampy, with logging activity concentrated in the first few kilometres from the mouth.*

# NAVER CREEK

## LICENSED WATER DEMAND

Stream number 00-5400

Water Survey of Canada Station 08KE014

Naver Creek at Hixon

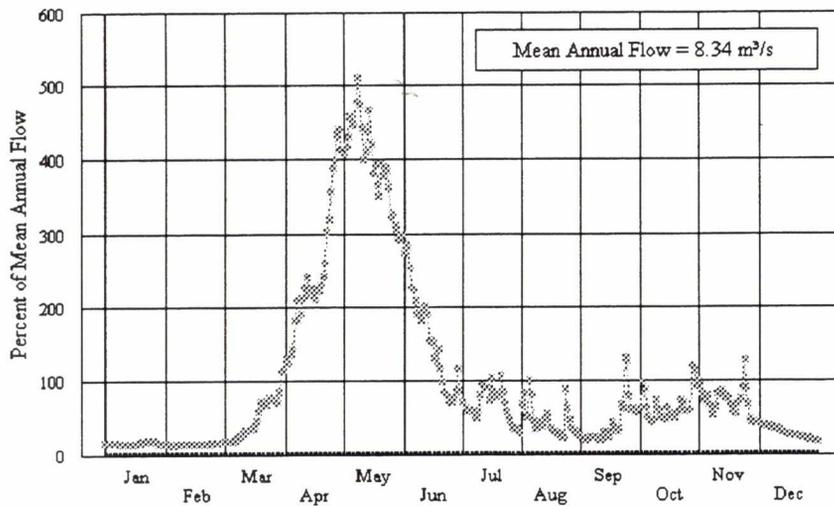
Records 1956 to 1975

Drainage Area = 658 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	16,000 g/d	0.84	0.84	0.84
Irrigation	317 ac.ft.	0	36.5	15.1
Waterworks	0 g/d	0	0	0
Industrial	102,500 g/d	5.4	5.4	5.4
Conservation	0 cfs	0	0	0

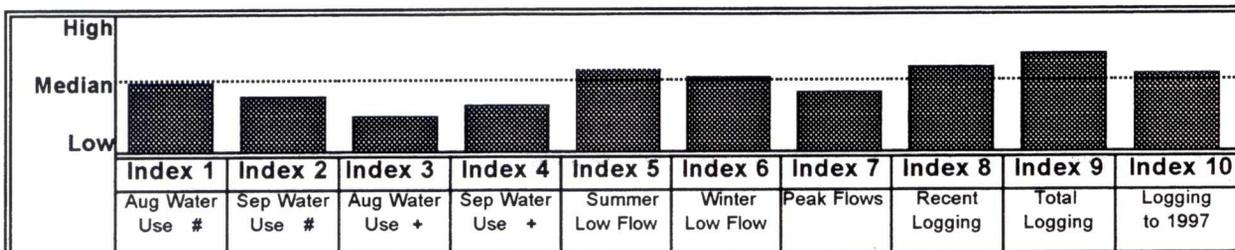
	Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>	1,220	3,910	3,280

## 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.

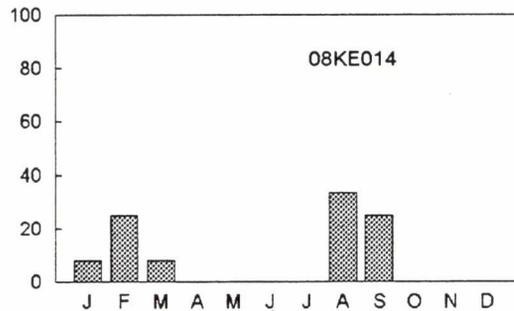


# Water use as a proportion of the 7 day low flow

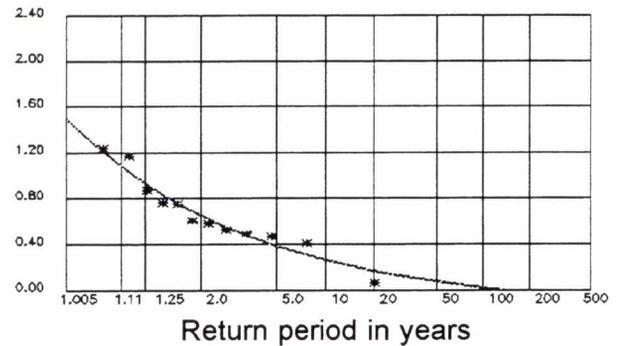
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	0.65 m <sup>3</sup> /s	0.26 m <sup>3</sup> /s	0.16 m <sup>3</sup> /s	0.07 m <sup>3</sup> /s	0.02 m <sup>3</sup> /s
<b>Annual Flood</b>	77.6 m <sup>3</sup> /s	110 m <sup>3</sup> /s	123 m <sup>3</sup> /s	135 m <sup>3</sup> /s	144 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The report by Lorenz (1990) recommends hydrological and sedimentation studies and a review of the rate of forest harvesting for some of the tributaries of Naver Creek.*

*2. The Lorenz report also recommends identification and removal of fish passage obstructions, and beaver control.*

# HIXON CREEK

## LICENSED WATER DEMAND

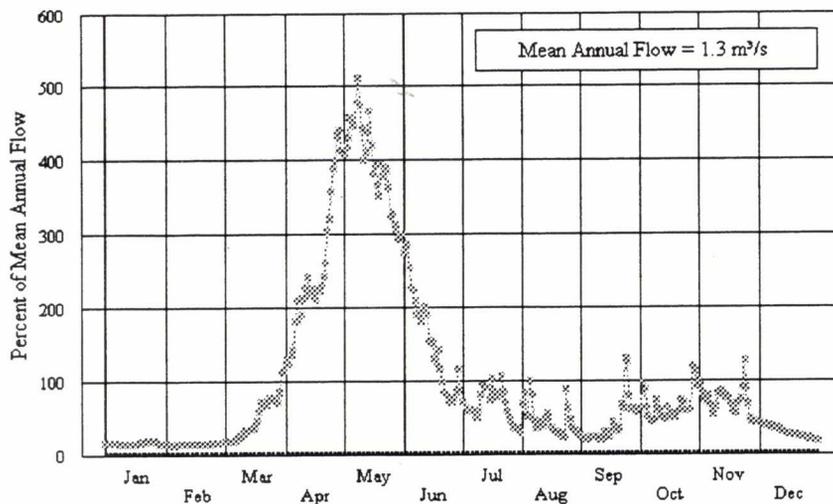
Stream number 00-5400-050  
 Ungauged  
 Flows into Naver Creek

Drainage Area = 238 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	6,000 g/d	0.32	0.32	0.32
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	20,000 g/d	1.05	1.05	1.05
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			520	460

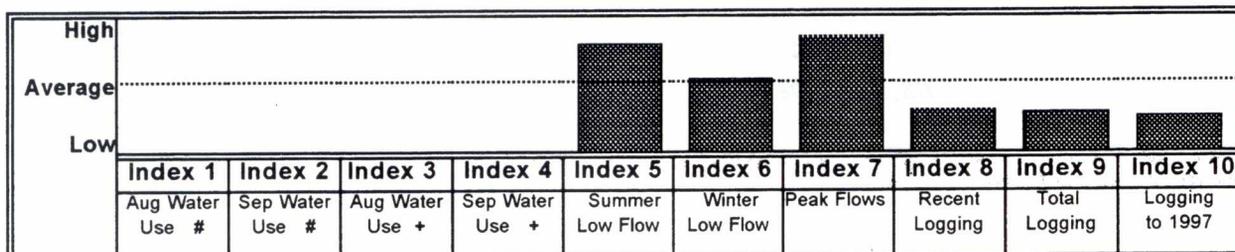
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Naver Creek station 08KE014)



## 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

# HIXON CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Hixon Creek occasionally experiences large floods, resulting from rain on snow events on George Mountain, that may be aggravated by large clearcuts in the upper watershed. Serious channel erosion has occurred.*

*2. Placer operations concentrate upstream of the falls that limit salmon migration, but tailings from an old placer operation at the base of the falls are entering the creek, contributing to its instability. About two kilometres of the main channel have had to be riprapped. Opportunities for habitat complexing exist along this stabilized section.*

*3. According to the Ministry of Environment and Parks, there is low potential for expansion of irrigation because of limited arable land.*

# QUESNEL RIVER (LOWER)

Stream number 06

Water Survey of Canada Station 08KH006

Quesnel River near Quesnel

Records 1939 to 1992

Drainage Area = 11,500 km<sup>2</sup>

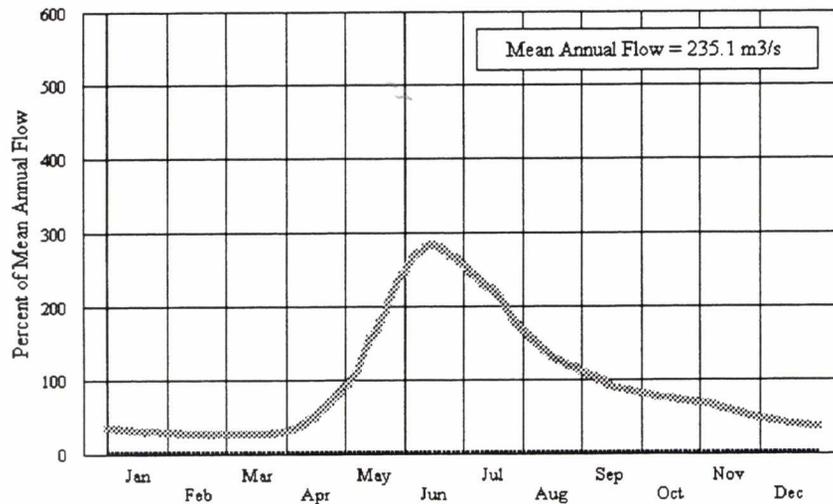
## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	121,900 g/d	6.41	6.41	6.41
Irrigation	9,875 ac.ft.	0	1,137	470
Waterworks	1,748,000g/d	92.0	92.0	92.0
Industrial	330,775 g/d	17.4	17.4	17.4
Conservation	238 cfs			

Feb Aug Sep

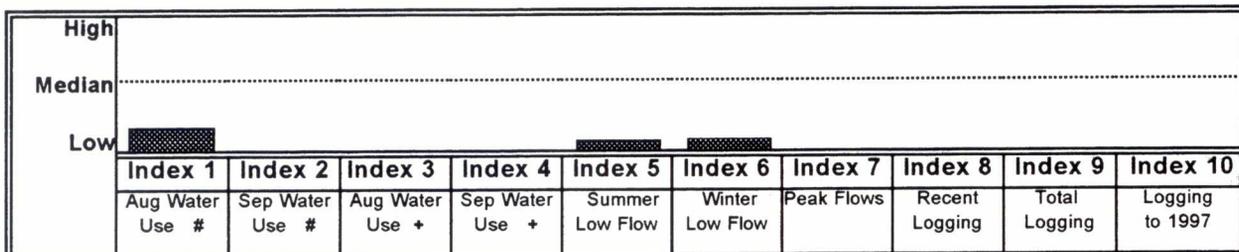
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	63,900	317,000	222000

## 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.

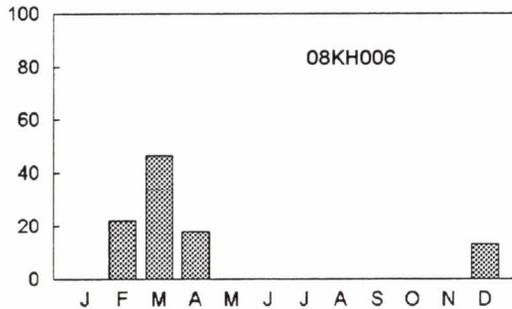


# Water use as a proportion of the 7 day low flow

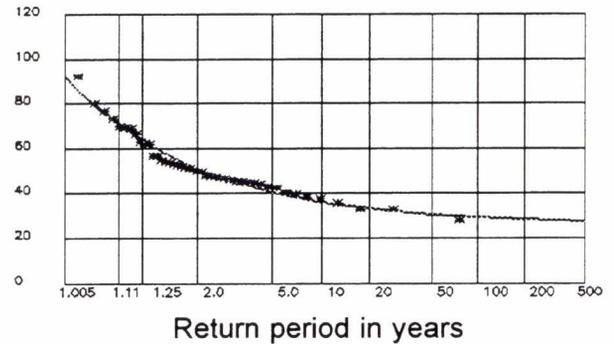
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	50.8 m <sup>3</sup> /s	36.0 m <sup>3</sup> /s	33.1 m <sup>3</sup> /s	30.6 m <sup>3</sup> /s	29.3 m <sup>3</sup> /s
<b>Annual Flood</b>	759 m <sup>3</sup> /s	974 m <sup>3</sup> /s	1050 m <sup>3</sup> /s	1160 m <sup>3</sup> /s	1227 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. High intensity of irrigation use along the Lower Quesnel has resulted in water shortages in several of the tributaries, but flow in the main channel has not been seriously affected.*

# QUESNEL RIVER (UPPER)

Stream number 06

Water Survey of Canada Station 08KH001

Quesnel River at Likely

Records 1924 to 1992

Drainage Area = 5,930 km<sup>2</sup>

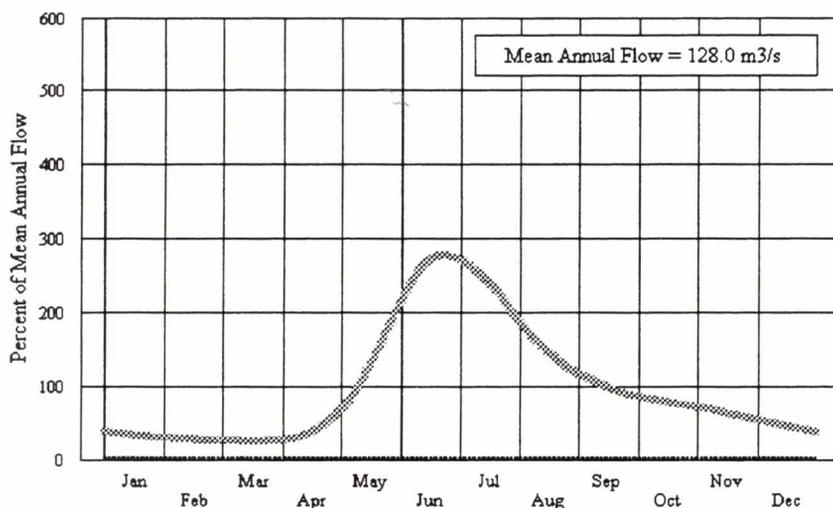
## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	30,150 g/d	1.59	1.59	1.59
Irrigation	1,495 ac.ft.	0	172.2	71.2
Waterworks	0 g/d	0	0	0
Industrial	316,885 g/d	16.7	16.7	16.7
Conservation	178 cfs			

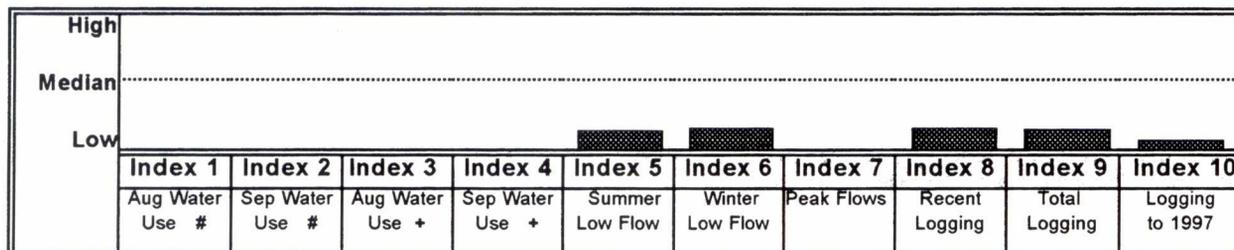
	Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>	36,800	186,000	125,000

## 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.

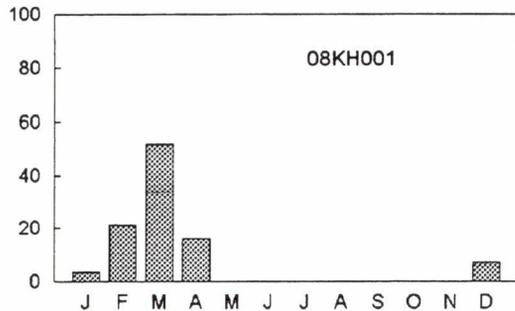


# Water use as a proportion of the 7 day low flow

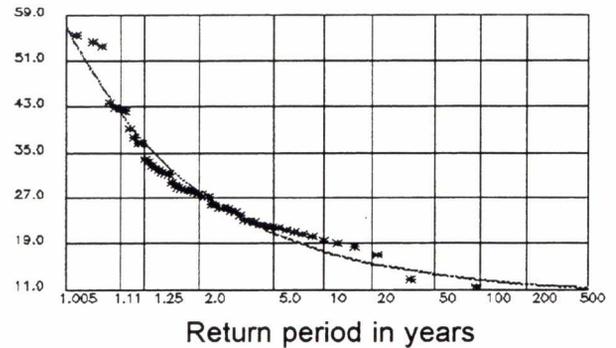
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	28.0 m <sup>3</sup> /s	17.4 m <sup>3</sup> /s	15.3 m <sup>3</sup> /s	13.4 m <sup>3</sup> /s	12.5 m <sup>3</sup> /s
<b>Annual Flood</b>	394 m <sup>3</sup> /s	513 m <sup>3</sup> /s	550 m <sup>3</sup> /s	605 m <sup>3</sup> /s	640 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Frequent natural slides and old mining activity (Bullion Mine) has resulted in sediment build up in the reach between Morehead Creek and Quesnel Forks.*
- 2. There may be potential for multiple water use storage in Quesnel Lake,, but an old reserve by B.C.Hydro would have to be modified or removed.*

# BEAVER CREEK

## LICENSED WATER DEMAND

Stream number 06-2270

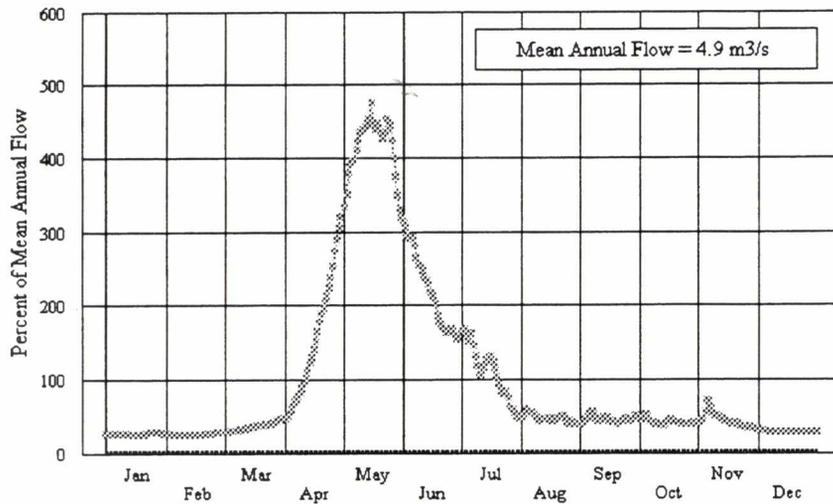
Beaver Creek, tributary to Quesnel River

Drainage Area = 1561 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	25,250 g/d	1.33	1.33	1.33
Irrigation	6,243 ac.ft.	0	719	297
Waterworks	0 g/d	0	0	0
Industrial	24,500 g/d	1.29	1.29	1.29
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			1,570	850

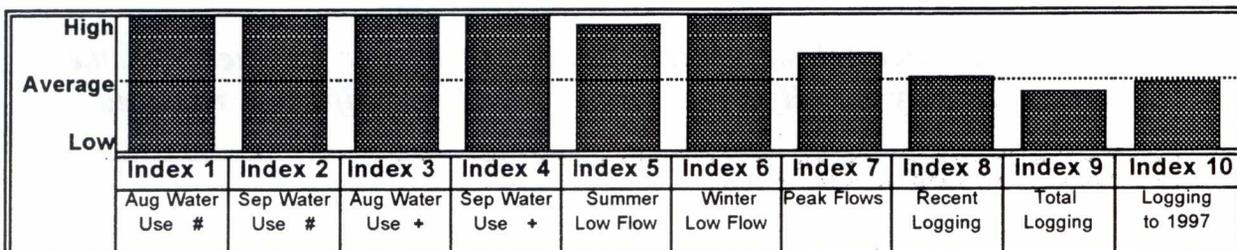
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Moffat Creek station 08KH019)



## 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

# BEAVER CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Beaver Creek is classed as fully recorded. Many of its tributaries are also fully recorded or have potential water shortages. Storage in the basin consists mainly of small projects operated by individual ranchers. No large storage projects are planned but there is potential for them.*

*2. Further licensing should be opposed until actual licensed demand is established and water management options, including storage development, are reviewed.*

# CARIBOO RIVER

## LICENSED WATER DEMAND

Stream number 06 - 3810

Water Survey of Canada Station 08KH003

Cariboo River below Kangaroo Creek

Records 1926 to 1992

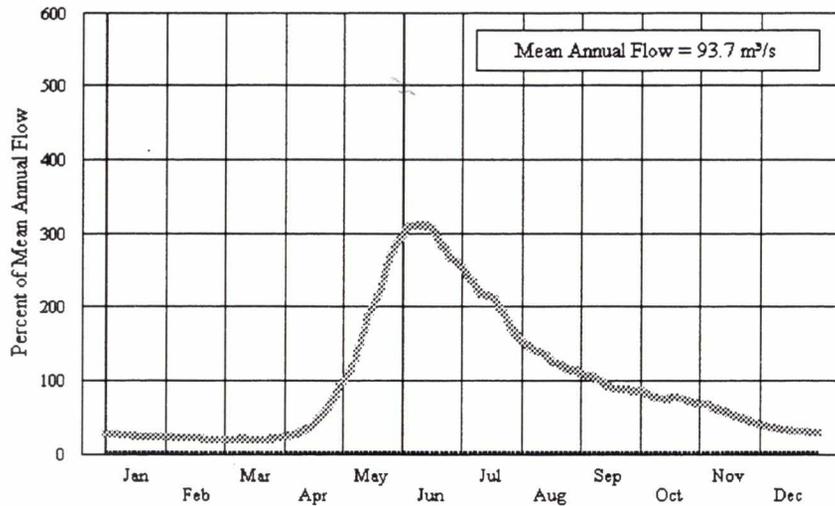
Drainage Area = 3,260 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	11,000 g/d	0.6	9.6	0.6
Irrigation	2 ac.ft.	0	0.23	0.10
Waterworks	0 g/d	0	0	0
Industrial	2,500 g/d	0.13	0.13	0.13
Conservation	0 cfs	0	0	0

Feb Aug Sep

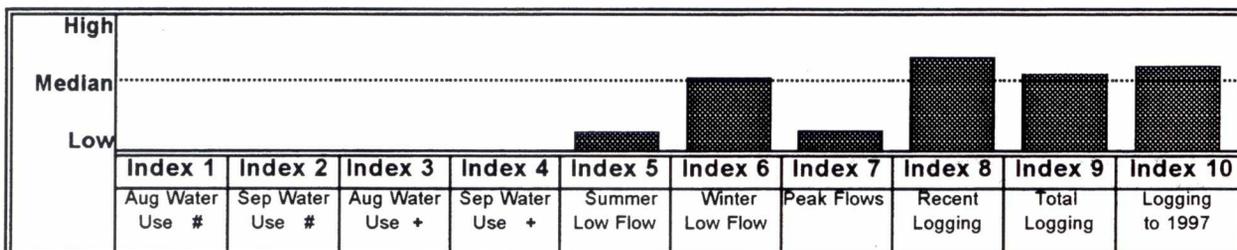
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	19,900	121,000	87,500

## 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.

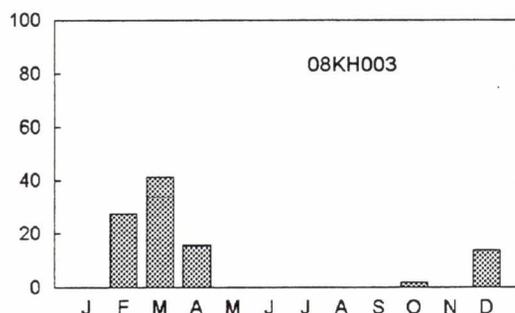


# Water use as a proportion of the 7 day low flow

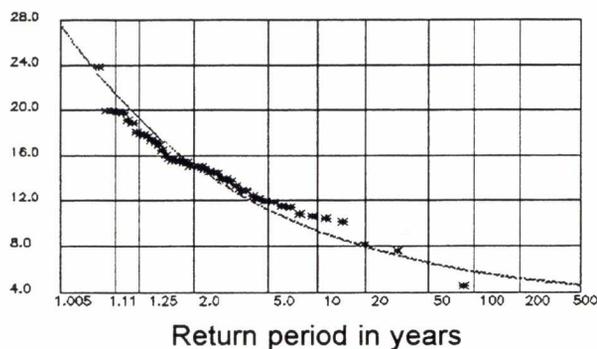
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	15.1 m <sup>3</sup> /s	11.2 m <sup>3</sup> /s	7.9 m <sup>3</sup> /s	6.5 m <sup>3</sup> /s	5.8 m <sup>3</sup> /s
<b>Annual Flood</b>	390 m <sup>3</sup> /s	502 m <sup>3</sup> /s	540 m <sup>3</sup> /s	593 m <sup>3</sup> /s	627 m <sup>3</sup> /s

## TECHNICAL AND MANAGEMENT RECOMMENDATIONS

- 1. Considerable placer mining and logging is taking place on the tributaries of Cariboo River ( particularly Keithley Creek, Little River and Cunningham Creek)*
- 2. There is storage potential in Cariboo Lake which could be developed for multiple water use, but an old reserve held by B.C.Hydro would have to be modified or removed.*
- 3. There is an existing fishway about 23 km upstream from the mouth, passable by chinook. A review of other possible obstructions may be warranted as there is a series of rapids and falls below Cariboo Lake.*

# LITTLE RIVER

## LICENSED WATER DEMAND

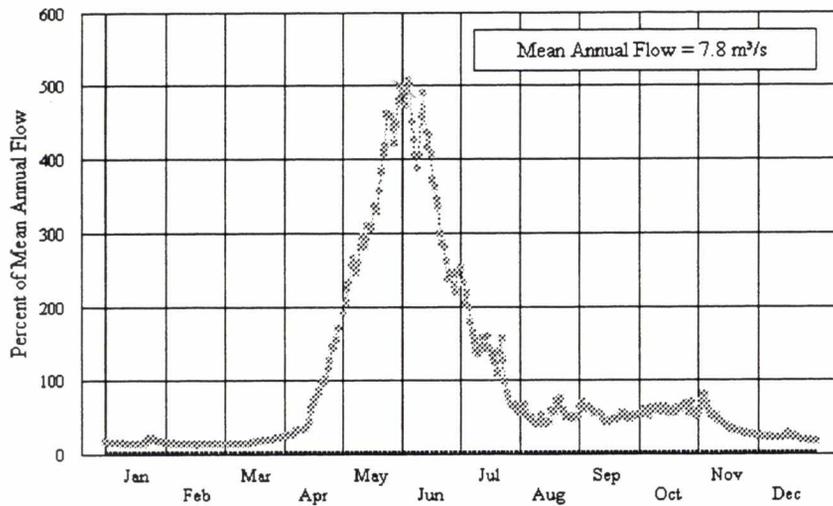
Stream number 06-3810-250  
 Ungauged  
 Tributary to Cariboo River

Drainage Area = 378 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			
<b>MEAN STREAM FLOW L/S</b>			3,780	3,840

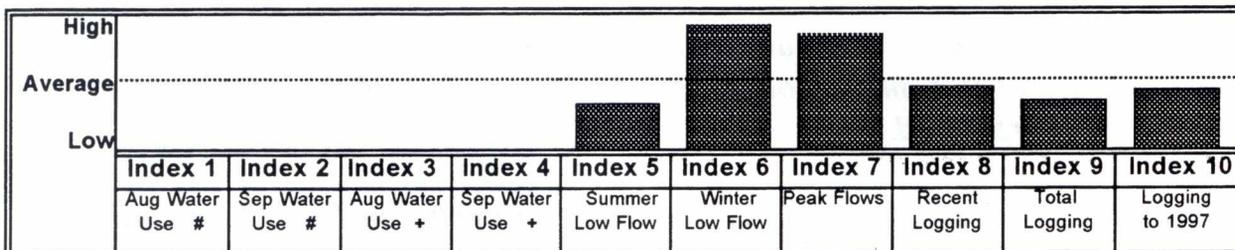
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Little Swift River station 08KE024)



## 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

# LITTLE RIVER

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Little River has relatively severe winter low flows and peak flows. Any water licensing that would reduce winter stream flows should be opposed until flows are confirmed and water management options are reviewed.*

# CUNNINGHAM CREEK

## LICENSED WATER DEMAND

Stream number 06-3810-400

Ungauged

Tributary to Cariboo River

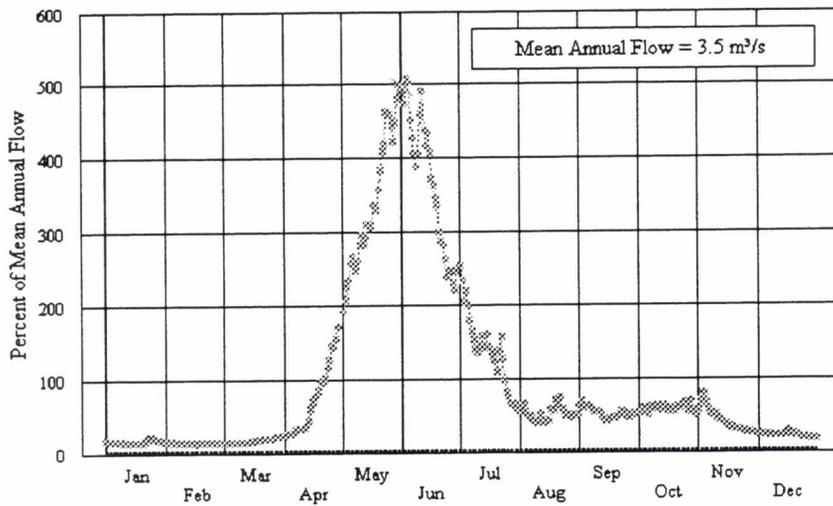
Drainage Area = 168 km<sup>2</sup>

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>		1,680	1,700

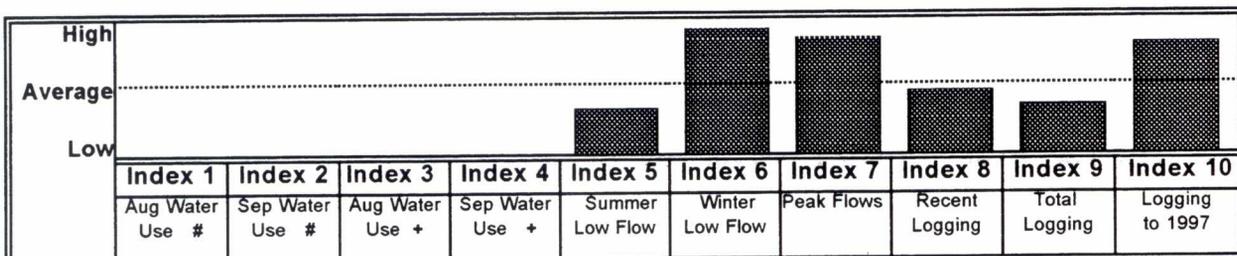
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Little Swift River station 08KE024)



## 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

# CUNNINGHAM CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Cunningham Creek has relatively severe winter low flows and peak flows. Any water licensing that would reduce winter stream flows should be opposed until flows are confirmed and water management options are reviewed.*

*2. Logging proposed for the watershed will result in clearcut approaching 20 %.*

# HAZELTINE CREEK

## LICENSED WATER DEMAND

Stream number 06-4810  
 Ungauged  
 Tributary to Quesnel River  
  
 Drainage Area = 124 km<sup>2</sup>

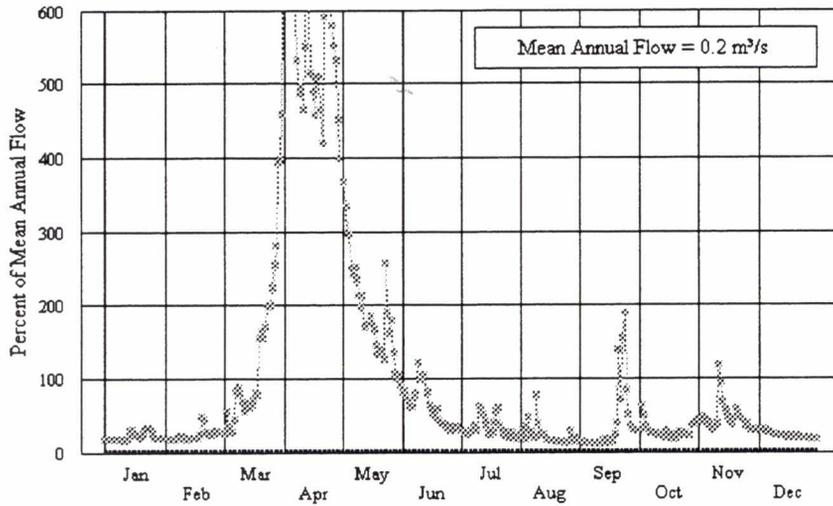
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		60	50

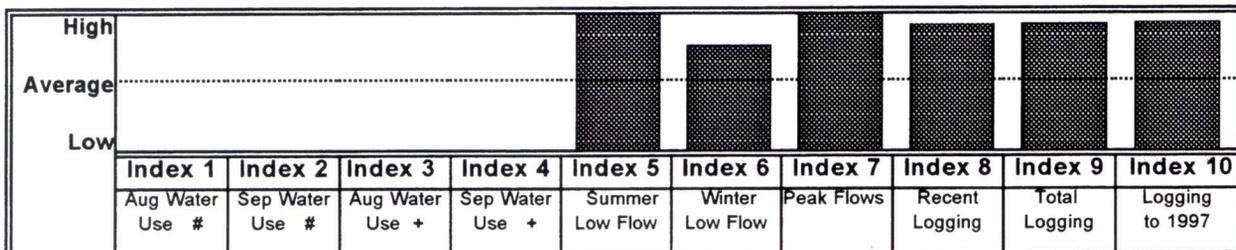
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Barlow Creek station 08KH018)



## 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

# HAZELTINE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Hazeltine Creek is subject to severe low and high flows. The potential for future water demand should be examined and instream flows assessed as restrictive licensing may be necessary.*
- 2. A storage development is planned for Polley Lake to compensate for water use by the Polley Lake mine. Low flows will be supplemented.*
- 3. Hazeltine Creek basin is one of the most heavily logged areas; over 30% has been recently logged.*

# EDNEY CREEK

## LICENSED WATER DEMAND

Stream number 06-4810-030

Ungauged

Tributary to Hazeltine Creek

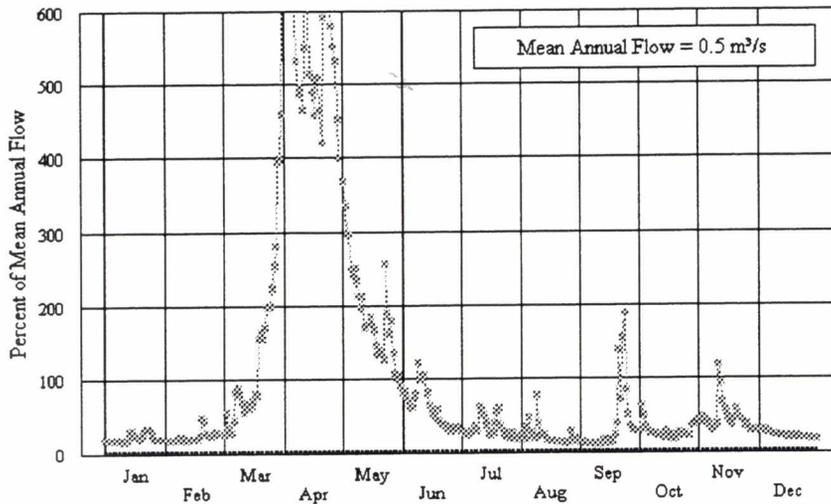
Drainage Area = 86 km<sup>2</sup>

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			

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		160	150

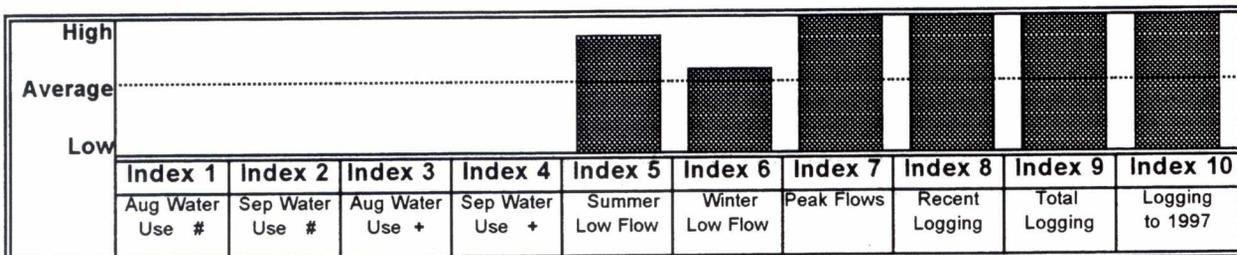
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Barlow Creek station 08KH018)



## 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

# EDNEY CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Edney Creek has relatively severe summer low flows and peak flows, but there are no water licences. The potential for future water demand should be examined and instream flows assessed. Restrictive licensing may be necessary.*

*2. Recent logging is extensive, covering about 30% of the basin area.*

# HORSEFLY RIVER

## LICENSED WATER DEMAND

Stream number 06 - 5460

Water Survey of Canada Station 08KH007

Horsefly River at Horsefly

Records 1946 to 1959

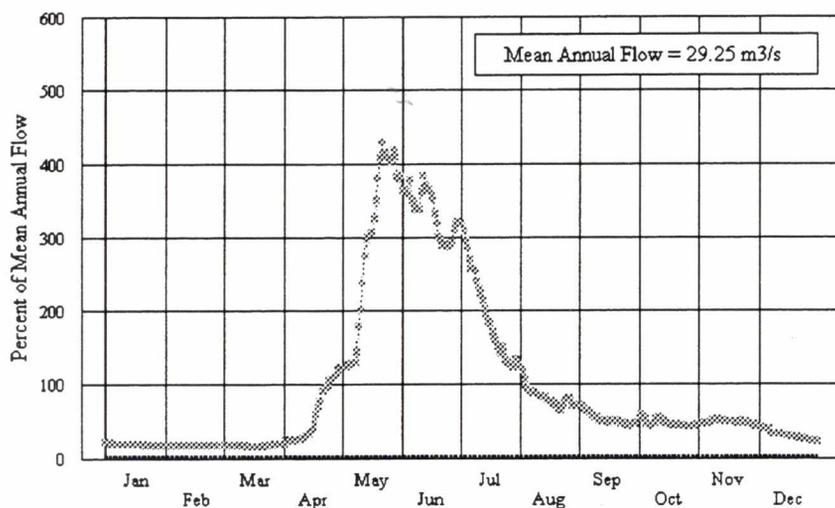
Drainage Area = 2,310 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	14,500 g/d	0.76	0.76	0.76
Irrigation	1,486 ac.ft.	0	171.2	70.7
Waterworks	0 g/d	0	0	0
Industrial	100,100 g/d	5.27	5.27	5.27
Conservation	123 cfs			

Feb Aug Sep

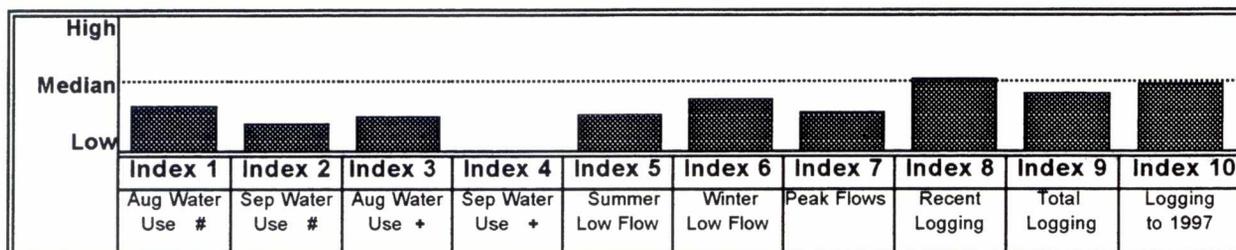
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	5,200	23,500	15,200

## 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.

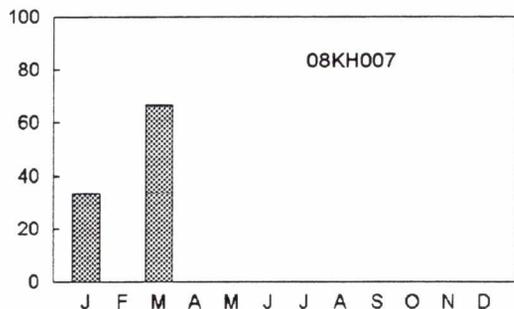


# Water use as a proportion of the 7 day low flow

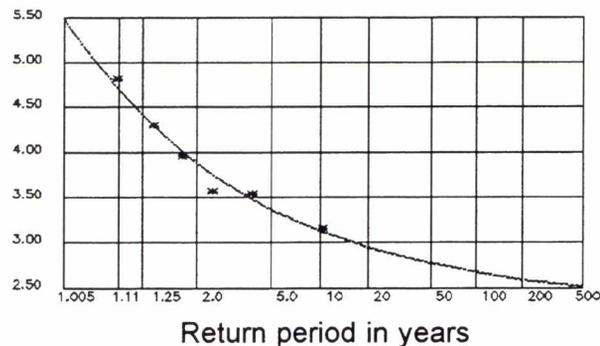
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	3.9 m <sup>3</sup> /s	3.1 m <sup>3</sup> /s	2.9 m <sup>3</sup> /s	2.8 m <sup>3</sup> /s	2.7 m <sup>3</sup> /s
<b>Annual Flood</b>	155 m <sup>3</sup> /s	203 m <sup>3</sup> /s	223 m <sup>3</sup> /s	253 m <sup>3</sup> /s	277 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Although there is considerable agricultural development along the lower Horsefly River, low flows do not seem to be a problem. There are storage developments on some of the tributaries and there may be opportunity for more. Horsefly Lake could supply considerable storage, except that it may be limited by lakeshore development.*

*2. A proposal for a fishway at the falls on the Horsefly River has been studied but it was found to be too expensive.*

# LITTLE HORSEFLY

## LICENSED WATER DEMAND

Stream number 06 - 5460 - 145

Water Survey of Canada Station 08KH008

Little Horsefly River near Horsefly

Records 1949 to 1958

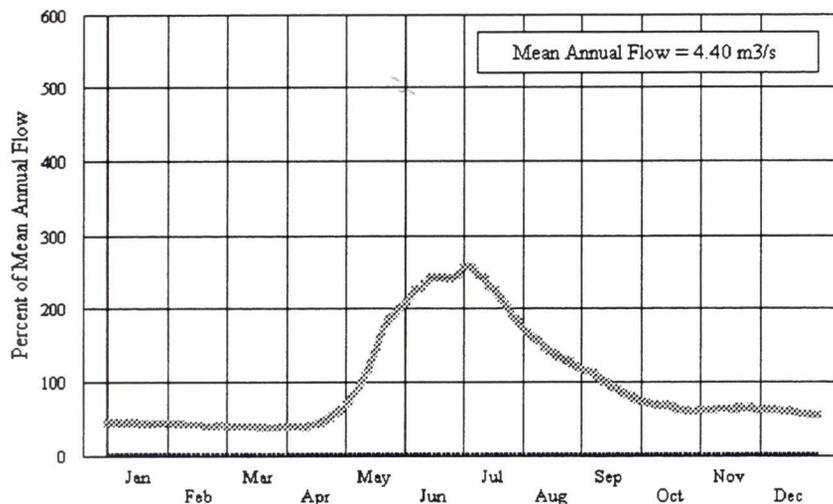
Drainage Area = 422 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	3,500 g/d	0.18	0.18	0.18
Irrigation	279 ac.ft.	0	32.1	13.3
Waterworks	0 g/d	0	0	0
Industrial	20,000 g/d	1.05	1.05	1.05
Conservation	0 cfs	0	0	0

Feb Aug Sep

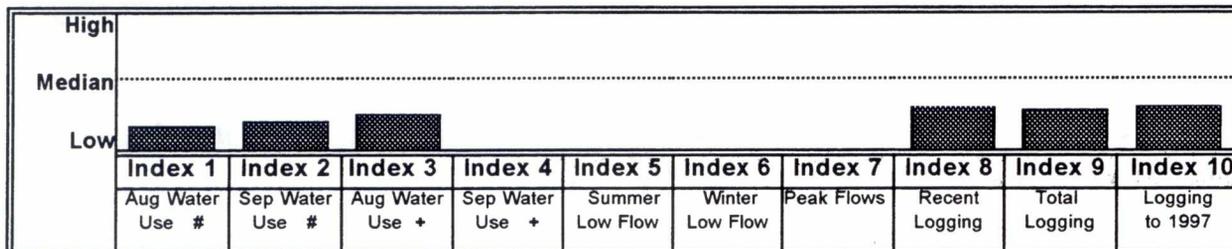
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	2,030	6,250	4,240

## 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.

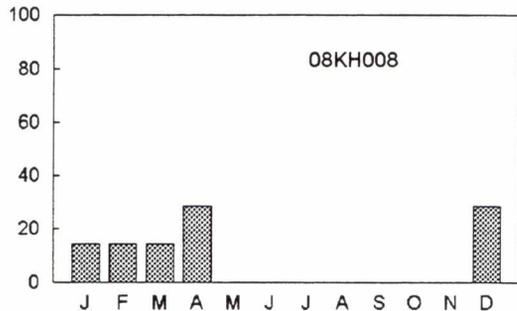


# Water use as a proportion of the 7 day low flow

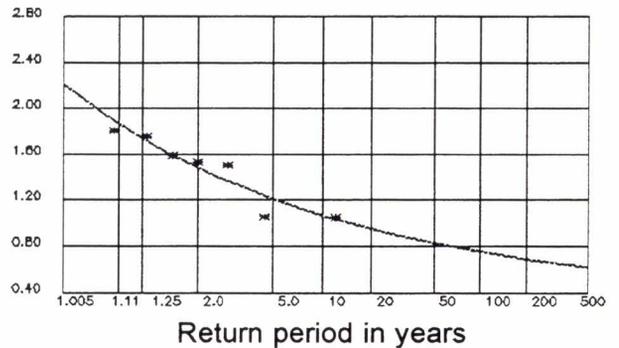
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	1.48 m <sup>3</sup> /s	1.06 m <sup>3</sup> /s	.95 m <sup>3</sup> /s	.82 m <sup>3</sup> /s	.75 m <sup>3</sup> /s
<b>Annual Flood</b>	11.1 m <sup>3</sup> /s	19.5 m <sup>3</sup> /s	23.0 m <sup>3</sup> /s	28.0 m <sup>3</sup> /s	32.1 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Grazing and, possibly, recreational activity have been reported as potential problems.*

# MOFFAT CREEK

## LICENSED WATER DEMAND

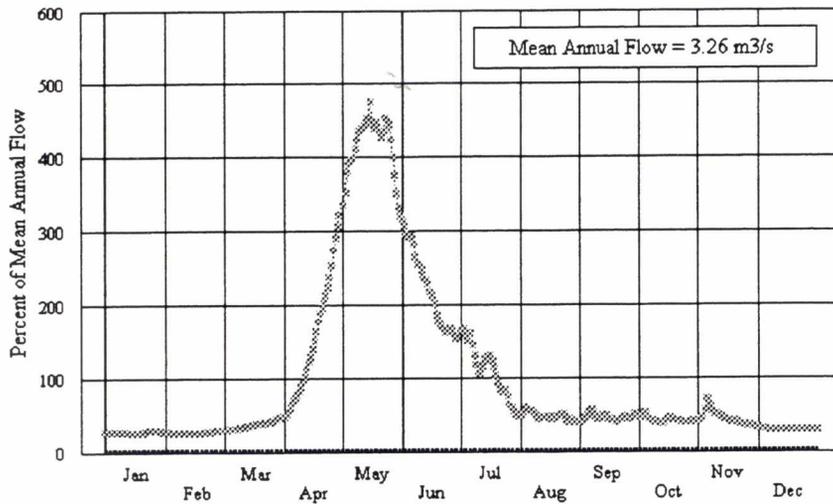
Stream number 06 - 5460 - 190  
 Water Survey of Canada Station 08KH019  
 Moffat Creek near Horsefly  
 Records 1964 to 1992  
 Drainage Area = 539 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,500 g/d	0.08	0.08	0.08
Irrigation	525 ac.ft.	0	60.5	25.0
Waterworks	0 g/d	0	0	0
Industrial	10,000 g/d	0.53	0.53	0.53
Conservation	0 cfs	0	0	0

Feb Aug Sep

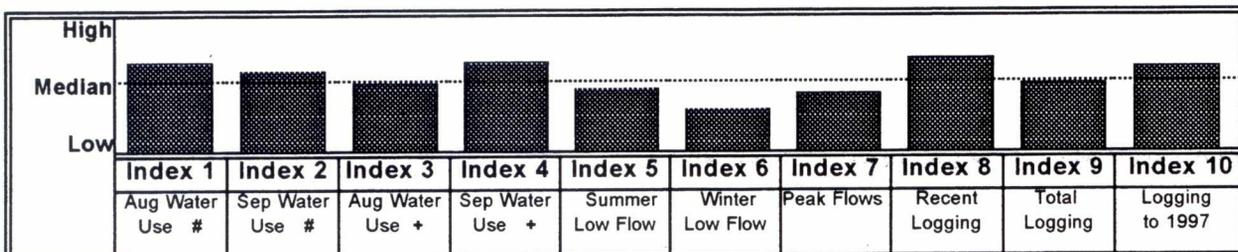
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	868	1,800	1,560

## 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.

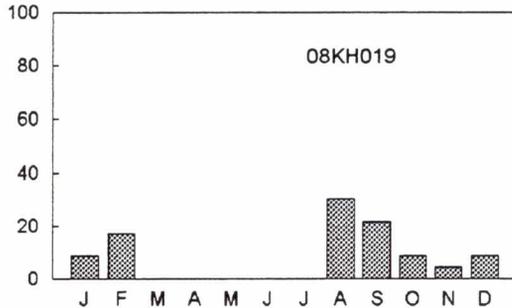


# Water use as a proportion of the 7 day low flow

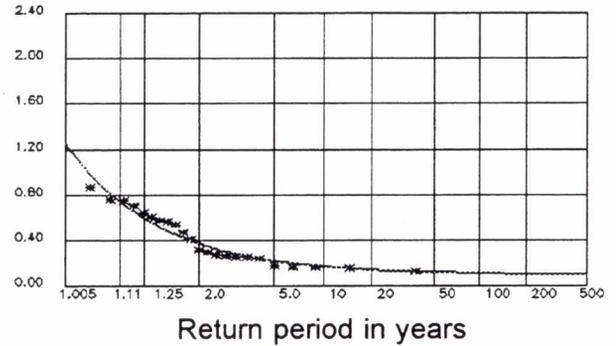
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	0.37 m <sup>3</sup> /s	0.16 m <sup>3</sup> /s	0.13 m <sup>3</sup> /s	0.11 m <sup>3</sup> /s	0.10 m <sup>3</sup> /s
<b>Annual Flood</b>	22.0 m <sup>3</sup> /s	35.8 m <sup>3</sup> /s	41.4 m <sup>3</sup> /s	48.9 m <sup>3</sup> /s	54.7 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Major gravel deposition and movement occurs on a broad fan near the mouth of Moffat Creek. Gravel removals and channel works are required to protect property but must be controlled because the gravels support a considerable amount of spawning.*

# McKINLEY CREEK

## LICENSED WATER DEMAND

Stream number 06 - 5460 - 480

Water Survey of Canada Station 08KH020

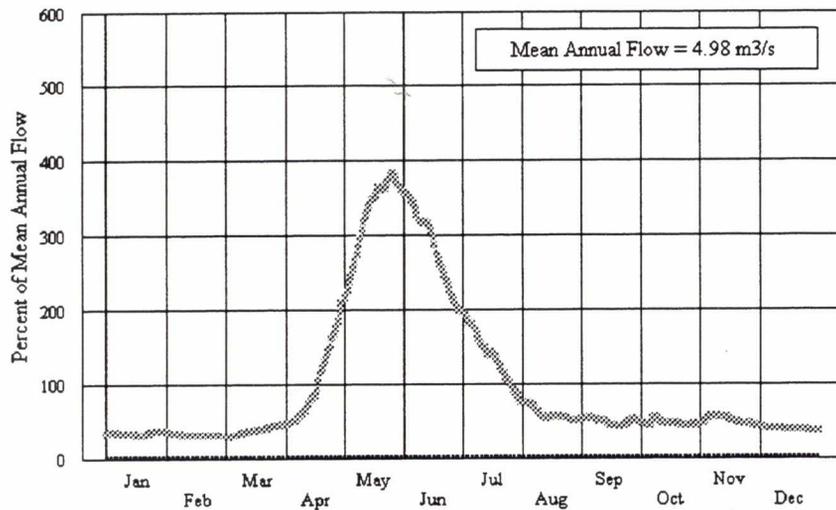
McKinley Creek below outlet of McKinley Lake

Records 1964 to 1992

Drainage Area = 430 km<sup>2</sup>

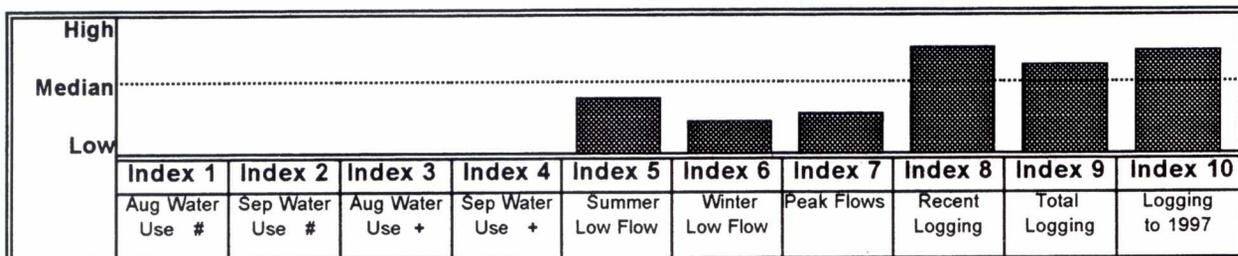
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2,000 g/d	0.11	0.11	0.11
Irrigation	0 ac.ft.	0	0	0
Waterworks	0 g/d	0	0	0
Industrial	0 g/d	0	0	0
Conservation	60 cfs	1700	1700	1700
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>		1,570	2,940	2,410

## 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.

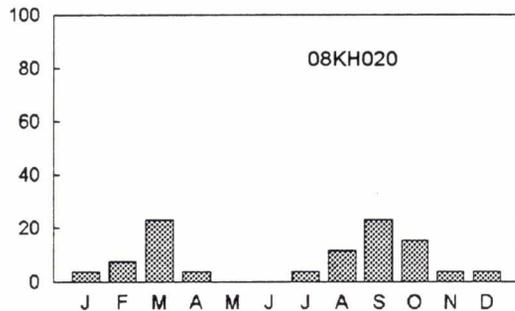


# Water use as a proportion of the 7 day low flow

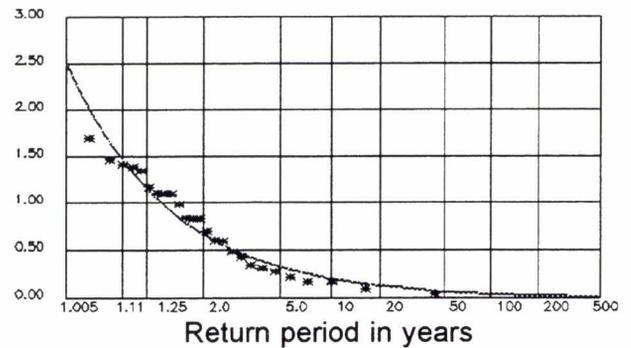
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	0.66 m <sup>3</sup> /s	0.19 m <sup>3</sup> /s	0.12 m <sup>3</sup> /s	0.06 m <sup>3</sup> /s	0.04 m <sup>3</sup> /s
<b>Annual Flood</b>	23.3 m <sup>3</sup> /s	38.2 m <sup>3</sup> /s	45.0 m <sup>3</sup> /s	54.9 m <sup>3</sup> /s	63.0 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. A structure was built in 1968 at the outlet of McKinley Lake to control temperatures in Horsefly River. A spawning channel proposed for McKinley Creek some time ago was rejected because of insufficient flow in the creek.*

# MITCHELL RIVER

## LICENSED WATER DEMAND

Stream number 06 - 6960

Water Survey of Canada Station 08KH014

Mitchell River at outlet of Mitchell Lake

Records 1961 to 1982

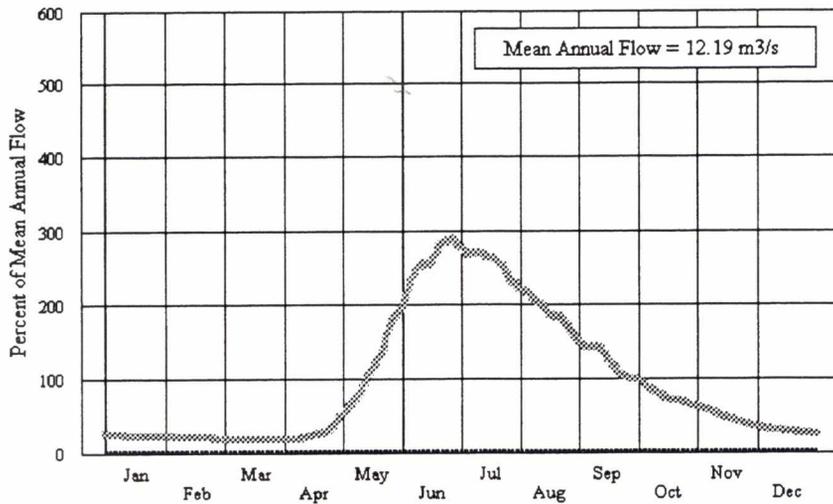
Drainage Area = 245 km<sup>2</sup>

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

Feb Aug Sep

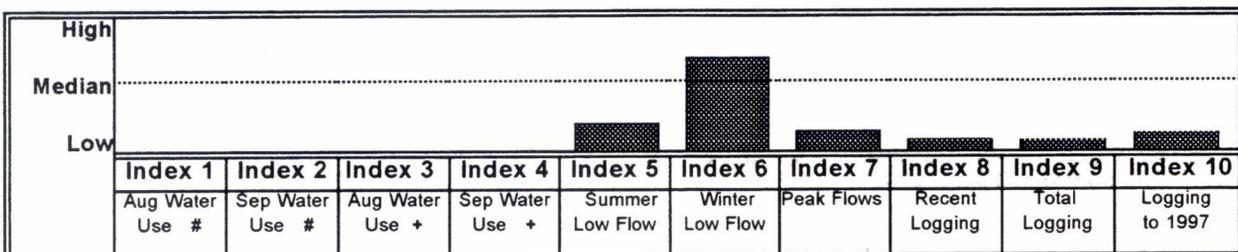
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	2,610	23,200	15,200

## 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.

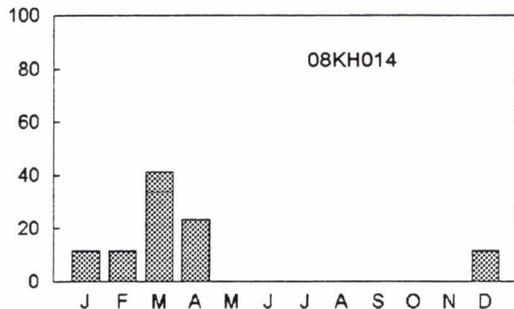


# Water use as a proportion of the 7 day low flow

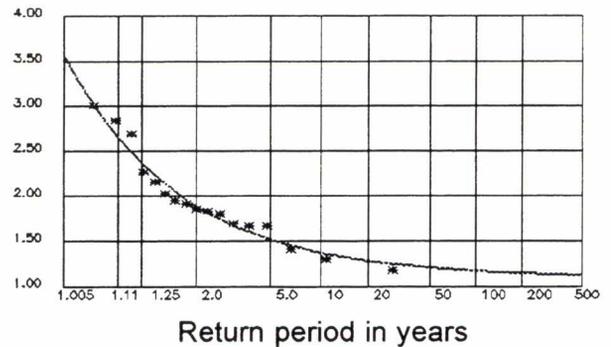
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	1.89 m <sup>3</sup> /s	1.37 m <sup>3</sup> /s	1.28 m <sup>3</sup> /s	1.20 m <sup>3</sup> /s	1.16 m <sup>3</sup> /s
<b>Annual Flood</b>	44.7m <sup>3</sup> /s	55.9 m <sup>3</sup> /s	59.2 m <sup>3</sup> /s	62.9 m <sup>3</sup> /s	65.3 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

- A structure was built at the outlet of Mitchell Lake in 1989 to improve incubation flows in the Mitchell River. A new spawning channel below the lake is being planned.*

# PENFOLD CREEK

## LICENSED WATER DEMAND

Stream number 06-6960-020

Ungauged

Tributary to Mitchell River

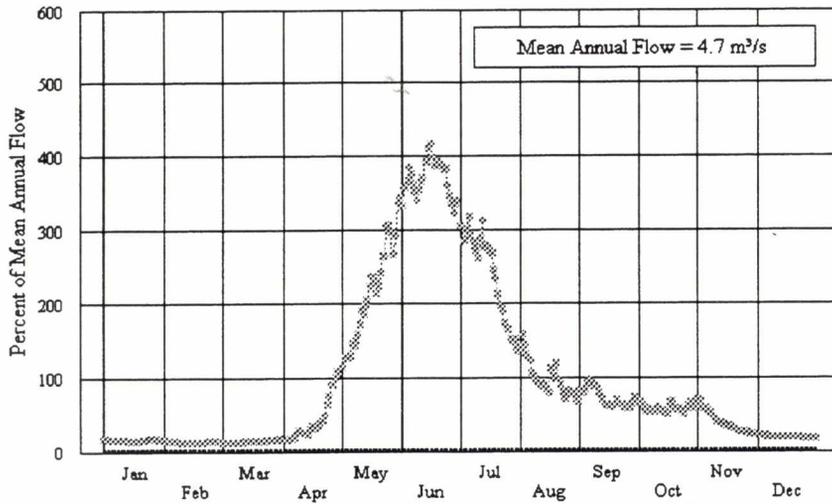
Drainage Area = 199 km<sup>2</sup>

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>		3,710	2,610

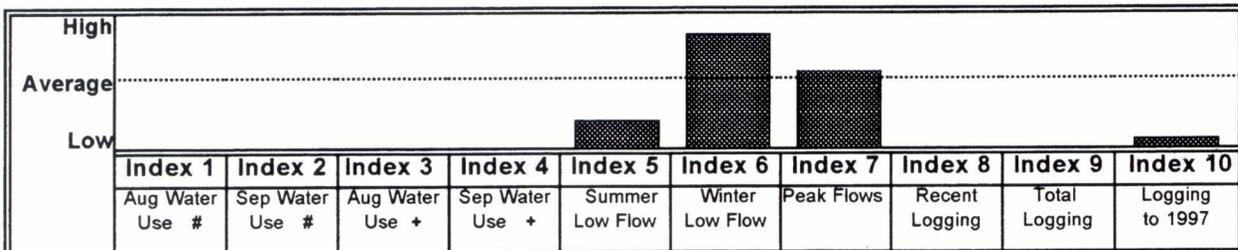
## MEAN ANNUAL HYDROGRAPH

(Estimated, using MacKay River station 08KE022)



## 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

# PENFOLD CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The Penfold Creek watershed is presently undeveloped, with no logging or water licences; however, there is a proposal to log part of the area and this would require a major bridge over the Mitchell River.*

*2. Sockeye spawn 5 to 10 kilometres upstream from the confluence with Mitchell River.*

# CAMERON CREEK

## LICENSED WATER DEMAND

Stream number 06-6960-180

Ungauged

Tributary to Mitchell River

Drainage Area = 71 km<sup>2</sup>

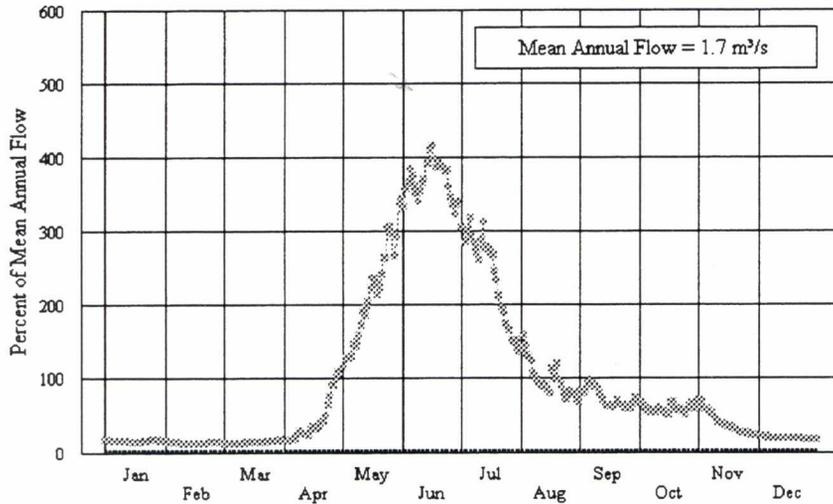
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		1,330	930

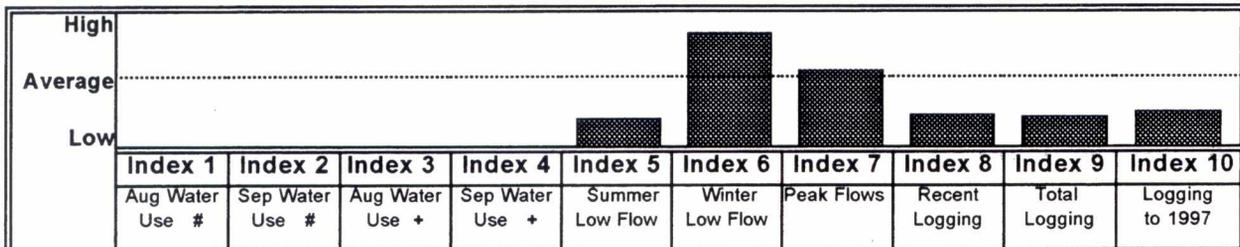
## MEAN ANNUAL HYDROGRAPH

(Estimated, using MacKay River station 08KH022)



## 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

# CAMERON CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Cameron Creek has relatively severe winter low flows but there are no water licences, as yet. Recent and proposed logging are moderate.*

# WATT CREEK

## LICENSED WATER DEMAND

Stream number 06-6980  
 Ungauged  
 Tributary to Quesnel River

Drainage Area = 66 km<sup>2</sup>

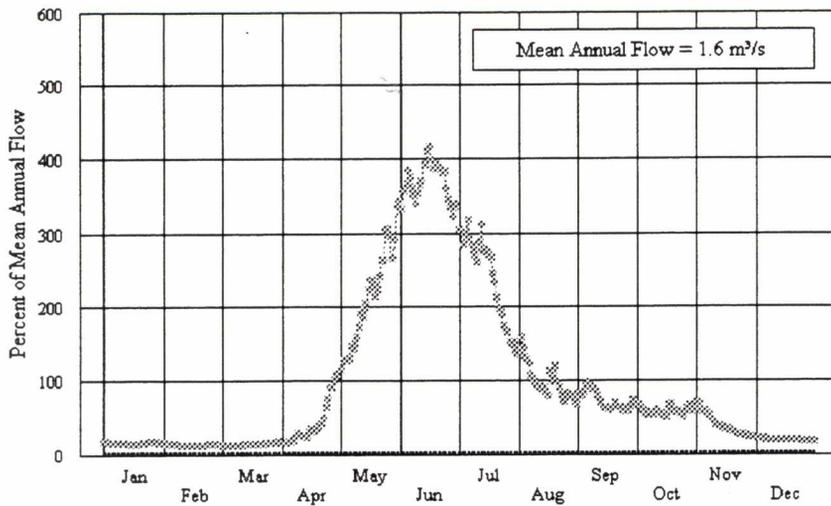
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		1,240	870

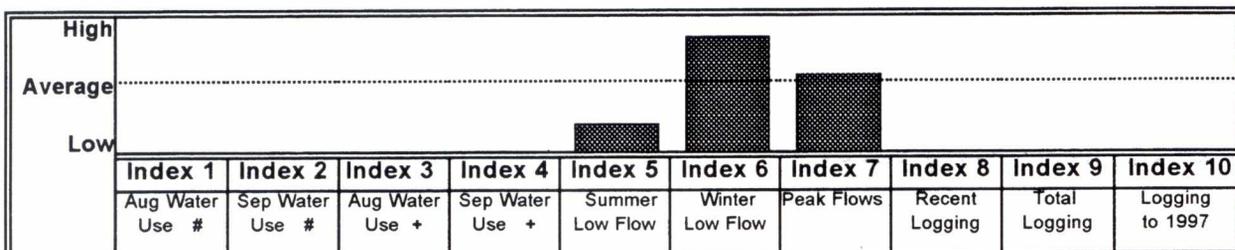
## MEAN ANNUAL HYDROGRAPH

(Estimated, using MacKay River station 08KH022)



## 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

# WATT CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Watt Creek has relatively severe winter low flows but there are no water licences or logging, as yet. Sockeye spawners utilize the lower 300 metres of the creek. Beaver jams and log jams have been reported.*

# ROARING RIVER

## LICENSED WATER DEMAND

Stream number 06-7020  
 Ungauged  
 Tributary to Quesnel River

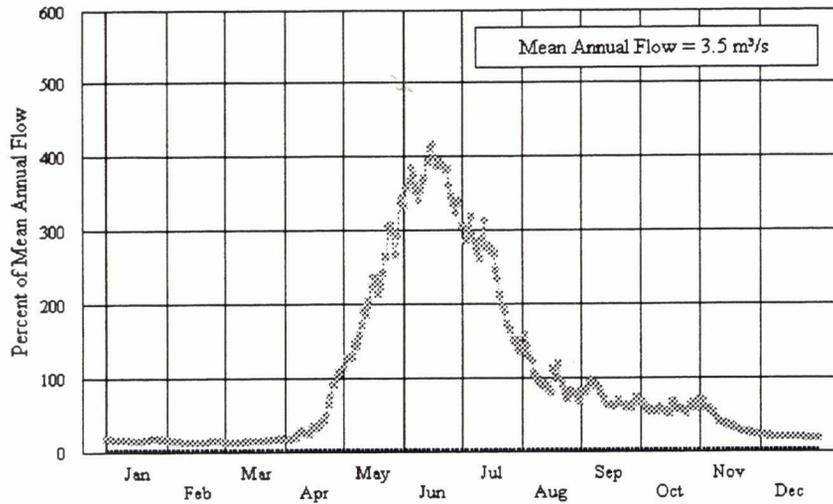
Drainage Area = 148 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	500 g/d	0.03	0.03	0.03
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		2,760	1,940

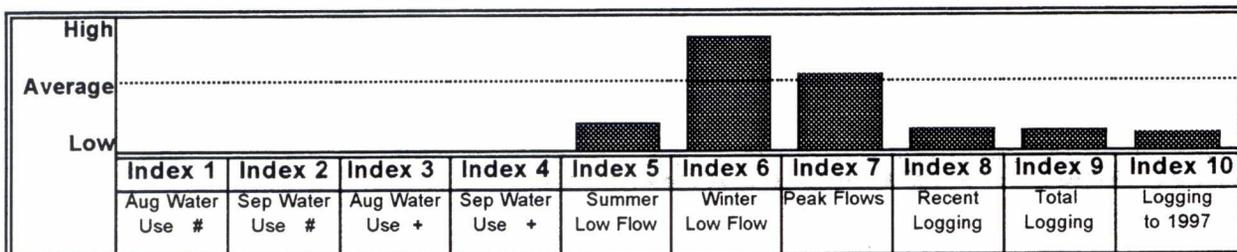
## MEAN ANNUAL HYDROGRAPH

(Estimated, using MacKay River station 08KH022)



## 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

# ROARING RIVER

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Roaring River has relatively severe winter low flows but there are no water licences and logging is moderate.*

*2. Sockeye spawners utilize the lower 1000 metres of the river downstream of the falls. A low gradient channel above the falls would provide good habitat if access could be developed.*

# WASKO CREEK

## LICENSED WATER DEMAND

Stream number 06-7650  
 Ungauged  
 Tributary to Quesnel River

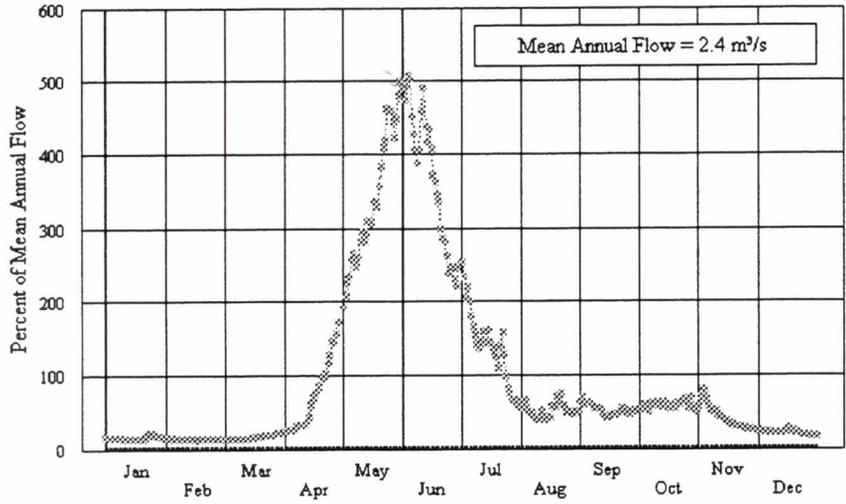
Drainage Area = 115 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	500 g/d	0.03	0.03	0.03
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		1,150	1,160

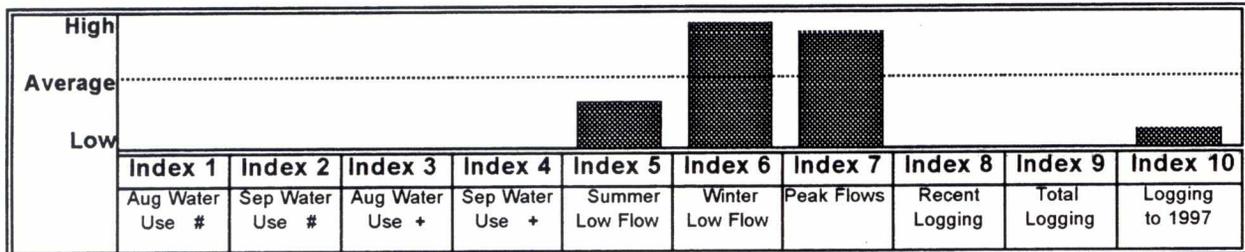
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Little Swift River station 08KE024)



## 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

# WASKO CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Wasko Creek has relatively severe winter low flows and peak flows but there are only a few domestic water licences. Some logging is proposed.*

# LYNX CREEK

## LICENSED WATER DEMAND

Stream number 06-9050  
 Ungauged  
 Tributary to Quesnel River

Drainage Area = 67 km<sup>2</sup>

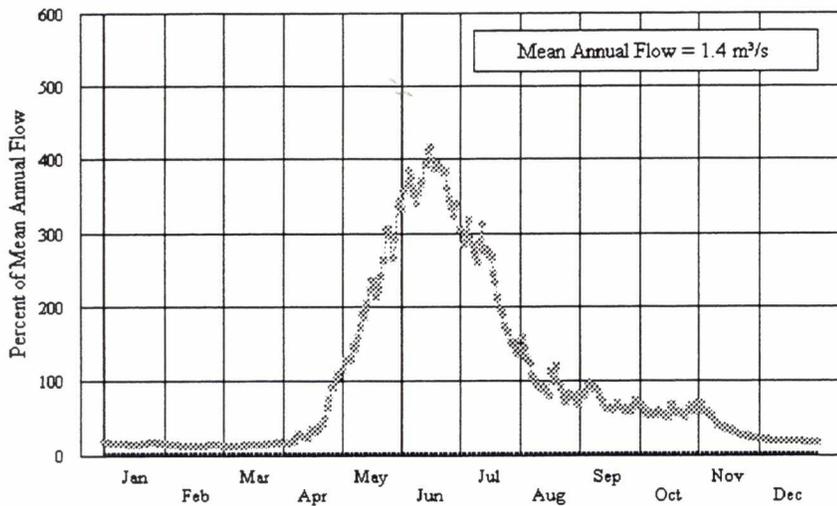
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		670	680

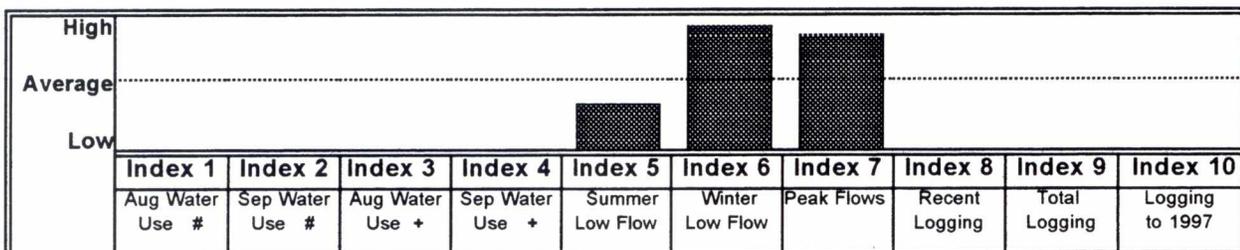
## MEAN ANNUAL HYDROGRAPH

(Estimated, using MacKay River station 08KH022)



## 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

# LYNX CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Lynx Creek has relatively severe winter low flows and peak flows but there are no water licences or logging.*

# KILLDOG CREEK

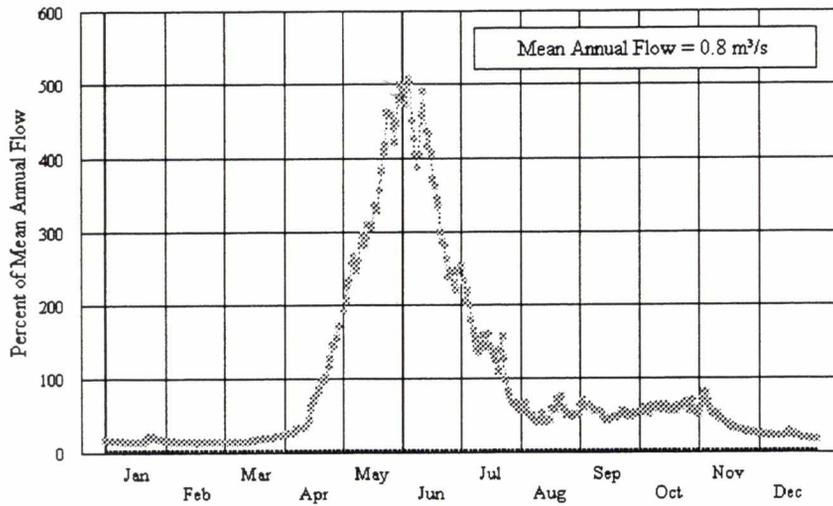
## LICENSED WATER DEMAND

Stream number 06-9740  
 Ungauged  
 Tributary to Quesnel River  
 Drainage Area = 40 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>			400	410

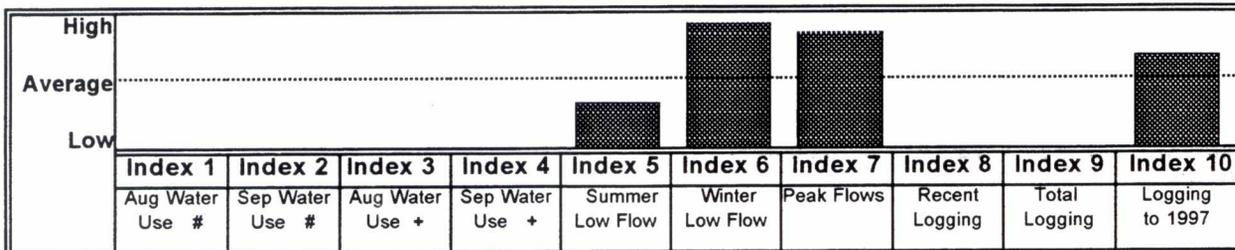
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Little Swift River station 08KE024)



## 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

# KILLDOG CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Killdog Creek has relatively severe winter low flows and peak flows but there are no water licences or logging, as yet. A considerable amount of logging is being proposed.*

# BLUE LEAD CREEK

## LICENSED WATER DEMAND

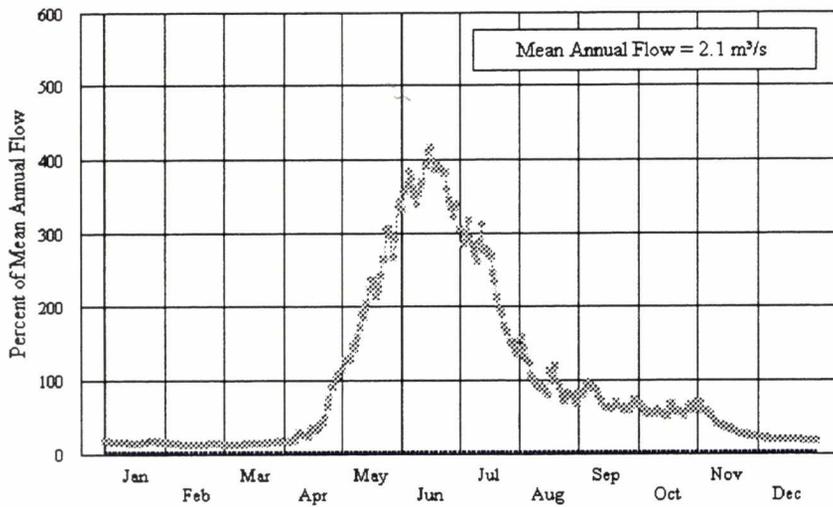
Stream number 06-9860  
 Ungauged  
 Tributary to Quesnel River

Drainage Area = 91 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>			1,700	1,190

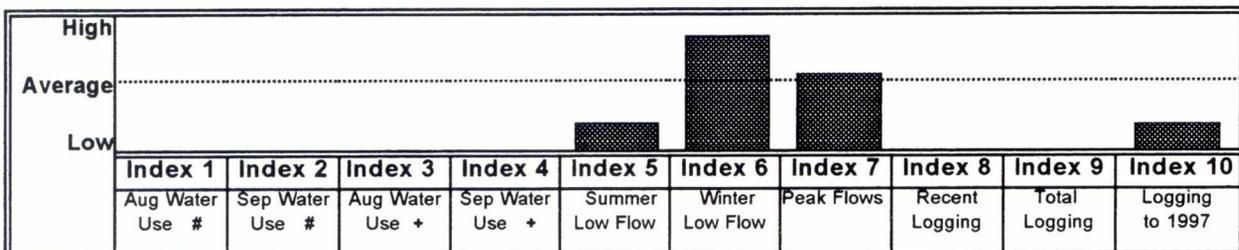
## MEAN ANNUAL HYDROGRAPH

(Estimated, using MacKay River station 08KH022)



## 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

# BLUE LEAD CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Blue Lead Creek has relatively severe winter low flows but there are no water licences or logging, as yet.*
- 2. Some logging is being proposed, but the creek is also being considered for inclusion in an extension of Wells Grey Park.*
- 3. The creek floods in the spring and wanders near its mouth. Sockeye salmon spawn throughout the lower 1.5 km.*

# SUMMIT CREEK

## LICENSED WATER DEMAND

Stream number 06-9890  
 Ungauged  
 Tributary to Quesnel River

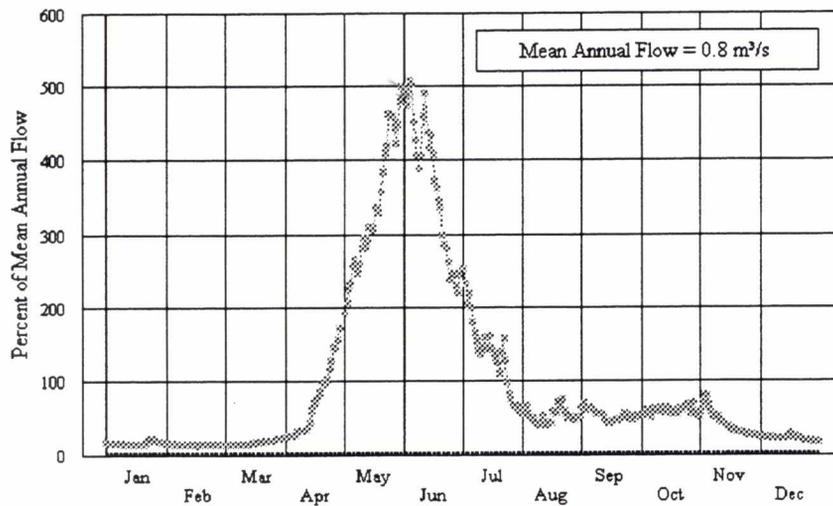
Drainage Area = 40 km<sup>2</sup>

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		400	410

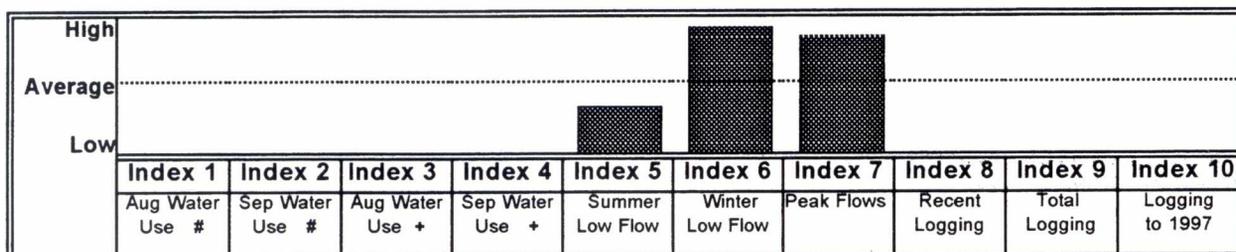
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Little Swift River station 08KE024)



## 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

# SUMMIT CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Summit Creek has relatively severe winter low flows and peak flows but there are no water licences or logging, and no logging has been proposed.*