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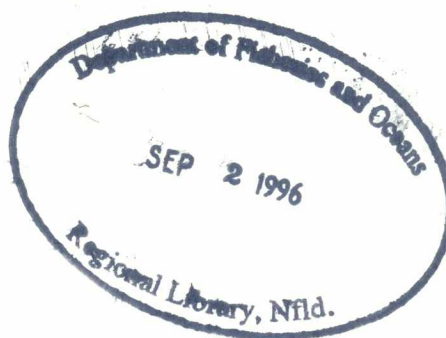
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# Hydrology and Water Use for Salmon Streams in the Harrison Habitat Management Area, British Columbia

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1995

HYDROLOGY AND WATER USE FOR SALMON STREAMS IN  
THE HARRISON 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 Harrison Habitat Management Area (HMA). The HMA contains the watersheds of the Harrison and Lillooet Rivers and drains to the lower Fraser River opposite Chilliwack. Hydrology and water use in thirty-five salmon streams are discussed.

The Harrison HMA lies within the Coast Mountains and drains through the Fraser Lowland. The upper Lillooet River originates at a glacier. Annual precipitation is about 1100 to 2000 mm. Much of the precipitation falls during winter as rain or snow. Peak stream flow occurs from May to July, due to snowmelt, and during fall and early winter, due to heavy rain storms. Streams in the northern part of the HMA have minimum flows in February. Those in the southern part have minimum flows in late summer and early fall. Fall floods often cause erosion or deposition of sediment and gravel.

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 and 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.

Water withdrawals for irrigation are largest for streams in the Pemberton Valley, but do not have a great impact on stream flow. Summer flows are much lower in southern streams; agricultural water use is significant on Maria Slough. Forest harvesting in several watersheds has affected more than 20% of the area. Although there has been significant regrowth and stream flow recovery in some watersheds, addition of coarse sediment continues to affect stream channels. Logging on privately owned land can have substantial impacts, but there are no records of this activity. Proposed cuts are low for most watersheds, but are very high for Bear and Mystery Creeks. Several streams are unstable in the lower reaches or on their fans. Natural events or poor forestry and development practices can contribute sediment. The Lillooet River has been modified to reduce flooding.

The report recommends improving stream flow measurement, monitoring and controlling water use, and developing water management plans for the most sensitive streams. Stream flow requirements of fish should be better studied. A formal system should be developed for reporting incidents of erosion. The report also recommends distributing proposed forest harvesting over the various tributary basins, to maintain flow regimes, and organizing 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 Harrison, qui couvre les bassins des rivières Harrison et Lillooet et dont les eaux se déversent dans le cours inférieur du Fraser en face de Chilliwack (C.-B.). Ce rapport examine l'hydrologie et l'utilisation de l'eau sur trente-cinq rivières à saumon.

La ZGH de la Harrison s'étend dans la chaîne Côtière et draine les basses terres du Fraser. Les précipitations annuelles se situent entre 1 000 et 2 000 mm, dont une bonne partie tombe en hiver sous forme de pluie ou de neige. On observe des débits de pointe de mai à juin à cause de la fonte des neiges, et pendant l'automne et le début de l'hiver, à cause de violents orages. Les cours d'eau de la partie nord de la ZGH ont des étiages en février; ceux de la partie sud à la fin de l'été et au début de l'automne. Les crues de l'automne causent souvent de l'érosion et des dépôts de sédiments et de gravier.

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.

C'est dans les cours d'eau de la vallée de la Pemberton que les ponctions d'eau destinée à l'irrigation sont les plus grandes, mais elles n'ont qu'une faible incidence sur le débit. Les débits d'été sont beaucoup plus faibles dans les cours d'eau du sud; l'utilisation de l'eau à des fins agricoles est importante dans le Maria Slough. L'exploitation forestière dans plusieurs bassins a touché plus de 20 % de la superficie. Bien qu'on observe une régénération importante et un rétablissement des débits dans certains bassins, l'apport de sédiments grossiers continue à affecter les chenaux. La coupe sur des terres privées a eu des impacts, mais on n'a aucun dossier sur les opérations privées. L'importance des coupes proposées est faible dans la plupart des bassins, mais très élevée pour les ruisseaux Bear et Mystery. Plusieurs cours d'eau sont instables dans leurs tronçons inférieurs ou à l'embouchure. Des phénomènes naturels ou de mauvaises pratiques de foresterie ou d'aménagement peuvent causer de la sédimentation. On a modifié le cours de la Lillooet pour réduire les inondations.

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 est nécessaire de mieux étudier les besoins du poisson en matière de débit. Il serait bon d'établir un système officiel pour signaler les cas d'érosion. Le rapport recommande aussi de répartir les projets d'exploitation forestière sur les divers bassins tributaires, de maintenir les débits et d'établir des plans quinquennaux d'exploitation forestière par bassin. Ces mesures permettront de prédire plus précisément les impacts de l'exploitation forestière sur l'hydrologie.

## FOREWORD

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

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

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

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

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

- 6) **Maximizing the non-consumptive values of fishery resources.**  
Intangible and cultural values of the fishery resources will be considered when allocating fishery resources.
- 7) **Distributing fishery net benefits in a fair and equitable manner.**  
Local communities should help make decisions about habitat conservation and restoration, stock enhancement, distribution of benefits, and cost-sharing arrangements.

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

## **1. INTRODUCTION**

### **1.1 Purpose of the Study**

The Fraser River Action Plan, of the Department of Fisheries and Oceans, is developing plans for environmentally sustainable salmon production. Planning is based on fifteen sub-basins -- called Habitat Management Areas (HMA) -- of the Fraser River watershed (Figure 1). This report focuses on the Harrison HMA which includes the watersheds of the Harrison and Lillooet Rivers and drains to the lower Fraser River opposite Chilliwack (Figure 2).

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

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

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

Our study examines 35 known and presently utilized salmon streams within the Harrison HMA that are listed in SSIS (the Federal/Provincial Stream Information Summary System; Table 1). Our analysis is based on information compiled by the Water Survey of Canada, the Ministry of Environment, Lands and Parks and the municipalities, and interviews with staff of federal and provincial government departments and agencies. Information available prior to 1994 has been summarized in this report. The following tasks were completed:

1. Summarize and describe those aspects of the climate, physiography, surficial geology and soils that affect the hydrology of the salmon streams;
2. Describe the local hydrologic regime and prepare estimates of mean annual flows, mean annual floods, mean monthly flows and seasonal 7 day low flows for each of the salmon streams from Water Survey of Canada records, Water Management Branch records or from regional analysis for ungauged streams;
3. Use Water Rights Branch records to calculate potential licence demand on surface waters in each of the salmon streams;
4. Review the impact of forest harvesting on hydrology and determine the portion of the watersheds of the salmon streams that are harvested;

5. Use the hydrologic, water use and land use data to calculate sensitivity indices and rank, or prioritize the various salmon streams according to water withdrawals, high flows, low flows and logging.
6. Summarize the main issues for the salmon streams and discuss technical or management alternatives based on interviews and discussions with government personnel.

The main task was calculating flow characteristics for the 35 salmon streams. The quality of information varied greatly from stream to stream; therefore, our method estimated flow characteristics so that streams within the study area could be compared and ranked. The estimated flows are not necessarily the best estimate for any individual stream and should not be used for design of structures or evaluation of projects without further, detailed study of that particular stream.

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

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

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

### **1.4 Acknowledgements**

Funding for this study was provided by the federal Department of Fisheries and Oceans through the Fraser River Action Plan, a federal Green Plan Initiative. A number of individuals provided an overall perspective on land and water use and hydrology, as well as information on the salmon streams. We would like to thank Robert Edwards, Neil Peters, Peter Caverhill and Bruce Usher of the Surrey Office of B.C. Environment; Sylvia Le Tay of the Chilliwack Office of B.C. Environment; and Konrad Johansen, Lee Dutta, Marissa Bryne, Bruce Reid, Karen Hutton and Matt Foy of the Department of Fisheries and Oceans. Final preparation of the report for publication was made by Karen Munro.

## **2. THE HARRISON HABITAT MANAGEMENT AREA**

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

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

### **2.1 Physiography**

The Hamison HMA includes the Hamison River watershed and has total area of about 8,324 km<sup>2</sup>. Nearly all of the HMA lies within the Coast Mountains, either in the southern Fiord Ranges or the Pacific Ranges (Matthews 1986) though a small part of the HMA lies in the Fraser Lowland, which is generally separated from the Coast Mountains along the 2,000 foot (600 m) contour (Figure 3).

Harrison Lake, Lillooet Lake and the Lillooet River lie in a major northwest-southeast trending that is eroded along the typical structural grain of the Coast Mountains. The bottom of the main valley near Pemberton is wide, at around 300 m elevation and the adjacent mountain peaks are around 2,500 to 2,800 m high, with maximum elevations exceeding 3,000 m in the upper Lillooet watershed. Most of the bedrock is plutonic (Roddick, Muller and Okulvitch 1979). The geology differs somewhat on the east and west sides of Harrison Lake, which lies in the Harrison Lake Fault System, with schistose rocks along the main valley which contain occurrences of gold-bearing ores (Ray and Coombes 1985). There are metamorphic and sedimentary rocks exposed along the north side of the Lillooet River valley and quaternary volcanics at the Mount Meager Volcanic Complex which are important source of sediment to the upper Lillooet River (Jordan 1987).

The Hamison watershed was repeatedly glaciated during the Pleistocene and the last ice sheet in the valley reached elevations of around 2,000 m (Matthews 1958). Higher peaks are sculpted by alpine glaciation and subaerial erosion; lower peaks are often rounded and flattened. The major river valleys are filled with glacial and recent alluvial deposits but there is often only thin glacial deposits on valley walls and at higher elevations, bedrock is exposed.

The upper Lillooet River originates at Lillooet Glacier which lies along the crest of the Coast Mountains and the salmon streams on the south side of the Lillooet Valley (Ryan and Green Rivers and Miller and Pemberton Creeks), and Sloquet and Big Silver Creek watersheds also have active glaciers. The glaciers are an important source of sediment supply to streams and also exert a significant influence on hydrology with melt of ice and high elevation snow often maintaining moderate flows into the late summer or early fall.

## 2.2 Surficial Geology

There has been very little work on the Quaternary Geology of the Harrison region by the Geological Survey of Canada or the B.C. Department of Mines. Ryder (1981) and Eisbacher (1983) provide an overview of the glacial geomorphology of parts of the southern Coast Mountains. Jordan (1987) and Jordan and Slaymaker (1991) describe geologic hazards and source of sediment to the Lillooet River upstream of Pemberton and describe some historic changes in the river channel.

## 2.3 Climate

### 2.3.1 Climate of the HMA

The climate of the Harrison HMA ranges from a modified maritime to a cordilleran climate that is affected by both continental and modified maritime conditions. Hydrologic regimes in the two climate types are quite different, primarily as a result of snow accumulation in the cordilleran (Pacific Ranges) zone and winter rainfall and snow accumulation in the modified maritime (Southern Fiord Ranges) zone. There also some variation of precipitation totals from north to south within the HMA. Precipitation and temperature decline along the valley bottom reaching a minimum near Pemberton (Table 3).

Table 4 describes the hydrologic regions associated with the various ecoregions and ecosections. Examination of Tables 3 and 4 (and regional hydrology studies: Rood 1988) suggests that there are two distinct hydrologic regions in the HMA: the Pacific Ranges and southern Fiord Ranges (including the Lower Mainland) regions. These are discussed below:

**Pacific Ranges:** The Pemberton climate stations (Table 3) seem most representative of the Pacific Ranges. Mean annual temperature is around 7°C in the valley bottom at Pemberton, decreasing to about 6°C at the elevation of Alta Lake. January is by far the coldest month with mean temperatures of -6°C and extreme minimum temperatures of around -40°C. July is the warmest month with mean daily temperatures of 18°C and extreme maximum temperatures of around 40°C.

Annual normal precipitation is around 1,100 mm, with about 25% of the total falling as snow. The portion falling as snow increases substantially with elevation, as does total precipitation, and the Tenquille Lake snowcourse in the Lillooet River Basin (1D06; 1,600 m) has a normal maximum water equivalents of around 1,200 mm.

Much of the precipitation falls in the winter, as rain at lower elevations and as snow at mid and high elevations. While rain sometimes falls at elevations as high as 2,500 m, though typically snow accumulation dominates above elevations of about 1,200 m (Jordan 1987). Minimum monthly totals occur in July and less than 20% of the total precipitation falls from May through September. These months also have the highest evapotranspiration demand and little of the rainfall at lower elevations replenishes groundwater or contributes to streamflow. Mean annual runoff in the upper Lillooet River and its glaciated tributaries is around 1,800 mm and there must be substantially greater snow accumulation at higher elevations than is recorded at the snowcourses or the climate stations in order to provide this water.

The annual flood often results from snowmelt and most of the annual runoff occurs from May through July. However, the largest annual floods occur when rainstorms cross the Coast Mountains in the fall and early winter. The October 1984 storm produced the flood of record on the Lillooet River.

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

**Southern Fiord Ranges:** Mean annual temperature is around 10°C in the valley of the Fraser River at Agassiz. January is the coldest month with mean temperatures of 1.2°C and extreme minimum temperatures of around -25°C. July is the warmest month with mean temperatures of 18°C and extreme maximum temperatures of around 40°C. Temperatures are warmer than in the valley bottom at Pemberton.

Annual normal precipitation is near 1,700 mm in the Fraser Valley, along the front of the Coast Mountains (Table 3). The greatest totals fall from October through March and July receives the least precipitation. Only about 20% of the annual precipitation falls from May through September (Table 3). Annual normal snowfall is less than 10% of the total precipitation. Nearby snowcourses indicate that there is little accumulation at elevations below 500 m or so but that at 1,200 m elevation (Stave Lake 1D08) normal maximum water equivalents are around 1,800 mm with significant snowpack remaining into June.

Rain falls throughout the year at low and mid-elevations and accumulation and melt of shallow snowpacks contributes to winter flooding. Annual runoff is around 3,300 mm in watersheds, like the Chehalis River, that extend to high elevations; though in smaller watersheds, such as Weaver Creek, annual runoff is closer to 1,600 mm. In all watersheds, the annual flood results from fall rainstorms and rain on snow when Pacific storms are forced over the southern face of the Coast Mountains. November and December are the months with the average maximum discharge. In the larger watersheds, such as the Chehalis River, snowmelt often produces a freshet in May and June.

Annual minimum flows typically occur in the late summer and early fall, though in the larger watershed these may occur in late winter during a cold, dry period.

### 2.3.2 Temporal Variation in Climate

Long-term climate records are available at several stations near the Harrison (Figure 4). Moore (1991) reviewed records at Agassiz, one of the few stations with good quality, long term records and concluded that annual precipitation had remained roughly constant but that a lower portion of the precipitation had fallen as snow since the mid-1970's. (Note that snowfall is only a very small part of the total precipitation at this station.) He also observed an increase in temperature at this station since the mid-1970's.

Moore's analysis also indicates a distinct decline in runoff during 1977-1988, when compared to 1960-1976. This decline in runoff seems to be connected to a reduced winter snowpack resulting from warmer temperatures. Moore does not include a formal analysis of snow survey stations in the Pitt/Stave HMA but snow course data at Nahatlach River (1,520 m), just east of the HMA, shows below-normal accumulation throughout most of the 1980's (Ministry of Environment 1992).

### **2.2.3 Global Warming and Climate Change**

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

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

### **2.4 Groundwater Resources**

The Chehalis River fan is the only significant aquifer in the lower Fraser River Valley that lies within the Harrison HMA (Atwater *et al* 1994). Shallow, high production wells in this thin aquifer on the Chehalis River fan provide water to the Chehalis River Hatchery. This aquifer is recharged from the Chehalis River and groundwater extractions reduce flows in the Chehalis River.

There is little knowledge of groundwater resources in rest of the Harrison HMA. It is expected that groundwater reservoirs (or aquifers) recharge during fall rains and spring snowmelt when vegetation is dormant and evapotranspiration is at a minimum. Groundwater reservoirs discharge during the summer when inflows to the reservoir are small because precipitation is at a minimum and evapotranspiration consumes much of the rainfall.

It is likely that glacio-fluvial sediments, recent alluvium, and tributary fan deposits, particularly those in the bottom of the Harrison and Lillooet Valleys, may be important source of groundwater. However, this possibility has not been studied in detail.

### **2.5 Main Stream Pattern**

The pattern of the upper Lillooet River changes from a braided, cobble-bed channel in its upper reaches, near its sediment sources, to a wandering gravel-bed channel, to a low gradient meandering channel upstream of Lillooet Lake. There is a corresponding change in the sediments on the floodplain which range from "gravelly" to silty near Lillooet Lake (Kuurne 1980). Most tributary streams have built alluvial fans into the Pemberton Valley and provide coarse material to the main river. As well, some small streams produce debris torrents which enter the Lillooet River (Jordan 1987). Jordan and Slaymaker (1991) discuss the relative importance of the various sediment sources to the total load of the Lillooet River.

The Lillooet River appears to have aggraded since de-glaciation as there are no terraces or other evidence to indicate a period of incision (Jordan 1987). It is actively building a delta in Lillooet Lake and based on accumulation of sediment here, the average suspended load of the river has

been estimated at about 1.1 million m<sup>3</sup> (Gilbert 1973). However, the delta has advanced rapidly since 1952 in response to engineering works on the river. The river also moves a substantial quantity of coarse gravel and cobble load (Sutek 1988) which is deposited along the lower reaches of the river.

The Lillooet River has been modified to reduce flooding. Following a major flood in 1940, a program of dyking and river straightening (through cutoffs) was undertaken. High water levels were reduced on Lillooet Lake by about 2.5 m by dredging a constriction about 20 km from the head of the lake. Upstream of Ryan River, six cut-offs were used to move the Lillooet River to its left valley wall and about 17 km were removed from the thalweg length. Straightening and the consequent increase in slope normally lead to channel degradation but this has not been confirmed by survey. The Water Management Branch attributes the lack of degradation to resistant materials underlying the channel bed, a cycle of degradation followed by aggradation, or to lateral adjustments to the engineering modifications.

Gravel accumulation is a problem along the Lillooet River and from 1980 to 1987, public and private operations removed about 420,000 m<sup>3</sup> of gravel from the main river and its tributaries (Sutek 1988). These removals continue but they do not appear to have initiated channel downcutting or degradation (Sutek 1988).

Little is known of the reach of the Lillooet River between Lillooet Lake and Harrison Lake. Between Lillooet Lake and Tenas Lake the river is stable with a boulder and cobble substrate. The reach downstream of Tenas Lake is also stable with a bouldery substrate, except downstream of tributaries which deposit cobble and gravel in the river. Downstream of Sloquet Creek, the substrate is gravel and the river has a braided pattern.

The Hamison River, immediately downstream of Harrison Lake, is also very stable, with coarse bed material. It is confined by bedrock upstream of Chehalis Village. The Harrison Rapids, at the Chehalis River fan, provide an important control on water levels at low flows in the Harrison River.

## **2.6 Stream Stability**

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

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

The typical salmon stream in the Hamison HMA starts in a steep upland area where the channel is steep and contained in a gully or narrow valley. Sediment is provided to the channel by snow

avalanches, debris slides and flows from valley walls, glacial erosion and stream erosion of valley walls and channel banks. Channel widening and downcutting are the most likely channel responses to disturbance in these reaches though in bedrock floored canyons little channel adjustment may occur.

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

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

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

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

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

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

The quality and availability of flow records ranges widely for the salmon streams in the Harrison HMA. A few streams have long-term gauging records at stations that continue to operate, some streams have short-term or seasonal records of moderate quality from the 1950's or 1960's, while most streams have no information available. The average flow characteristics in the above list, as well as other characteristics, can be reliably estimated for salmon streams with long-term discharge records. Less reliable estimates can be prepared for streams with limited records and the least reliable estimates are for streams with no records.

#### 3.1 Reference Point for Flow Characteristics

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

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

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

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

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

In much of British Columbia, there is a consistent pattern of declining annual flows in the late 1940's and 1950's, above average annual flows in the 1960's and 1970's (Barrett 1979) and below average annual flows during the 1980's. However, the Lillooet River, which is 22% glacierized, does not follow this trend, though mean annual flows, as well as other flow characteristics, do vary from decade to decade (Figure 5). Consequently, it is important when comparing records at different stations to limit flow data to a common period, so that variation between gauges reflects the character of the particular station rather than differences in the period of record.

We have adopted the most recent decade, 1981-90 (inclusive), as our standard period for analysis. In the Lillooet River watershed, this decade includes the flood of record in October 1984 which may have had a return period of over 200 years and there also have been other unusually large floods during this decade.

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

The Water Survey of Canada is the prime agency collecting and reporting flow data in British Columbia. Gauging stations in the Harrison HMA are described in *Surface Water Data Reference Index: Canada 1991*, published by Environment Canada. A number of these stations are on the salmon streams (Table 1; Figure 3) and 9 of the salmon streams have had at least one operating gauging station. However, only two salmon streams (Harrison River and upper Lillooet River) have nearly complete gauging records from 1981 to 1990 at stations near their mouths. It is only on these streams that flow characteristics may be calculated directly from Water Survey of Canada records. These calculations are discussed in Section 3.5.

The other salmon streams typically have either: 1) partial records between 1981 and 1990, 2) partial or complete records from earlier decades, such as the 1930's through 1960's, or 3) most commonly, no records from the Water Survey of Canada (Table 1). Procedures for estimating flows on these streams are discussed in Section 3.6 and Appendix A.

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

### 3.4 Other Sources of Hydrometric Data

The Water Management Branch (WMB) of the Ministry of Environment, Lands and Parks operates some gauging stations whose data are reported by the Water Survey of Canada. The WMB also collects miscellaneous measurements to establish flows for approving licensed extractions, and carries out occasional (regional) data collection programs during droughts. None of the drought measurement programs include salmon streams in the Harrison HMA (Richards 1977; Nyhof 1985; Nyhof 1987).

### 3.5 Gauged Salmon Streams

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

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

#### 3.5.1 Water Extractions and Flow Characteristics

For a stream with water removals, the flow characteristics calculated from records were adjusted to represent the natural regime in the stream by adding potential water extractions, as calculated from summaries of water licences, to the flow recorded at the gauge (Figure 6). We have referred to the adjusted flows as **naturalized flows** to distinguish them from measurements of the natural regimes.

This approach provides a reasonable estimate of the natural flows in the Harrison HMA because developed storage in most watersheds consists of small, independently-operated reservoirs, because total storage is small in comparison to irrigation requirements (Table 8) and because licensed demand is often low in comparison to flows. In these circumstances, it is reasonable to ignore the contribution of storage to low flows, and naturalized flows may be assumed to represent the natural regime. The naturalized flows are close to the natural flows, but are expected to over-estimate these flows, because of differences between actual and licensed water use upstream of the gauge, flow enhancement by releases from small storage projects and return flows from irrigation diversions. The degree of over-estimation is small for the gauged streams and can be evaluated by comparing storage volumes to irrigation demand and to typical flows in August and September on the salmon streams. Note also that well extractions, which are not licensed, may reduce low flows in some streams.

#### 3.5.2 Storage and Flow Characteristics

The Department of Fisheries and Oceans holds a storage licence for Weaver Lake. Storage is used to provide water to their spawning channel on Weaver Creek.

### **3.5.3 Annual Flow Characteristics**

The historic period for the **mean annual flow** is 1981 to 1990, inclusive (see Table 6 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, based on the negligible effects of storage contribution (Section 3.5.1).

### **3.5.4 Seasonal Flow Characteristics**

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

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

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

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

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

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

The flows recorded at gauging stations on the salmon streams are of interest for more than establishing average flow characteristics at their mouths. The gauging records permit calculation of detailed flow characteristics such as mean annual hydrographs, monthly distributions of annual 7 day low flows, and 7 day low flow frequency curves. These flow characteristics are based on all available, complete years of data at the gauge sites, rather than 1981-90 -- in order to best estimate the flow characteristics at the gauge -- and are not naturalized because of the difficulty of adjusting flows for each year.

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

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

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

### **3.7 Ungauged Salmon Streams**

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

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

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

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

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

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

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

The QMF-100 Report describes openings created by major licensees since 1987. Each opening is referenced to a 1:20,000 Map sheet, and has a date of harvest, a size of opening and a licensee. In large watersheds, where the sheet falls entirely within the watershed, all harvested cutblocks are added to the harvest in that watershed. Where the sheet includes two more

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

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

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

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

## 4.2 The Effect of Logging on Hydrology

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

### 4.2.1 Forest Harvesting and Streamflow Quantities

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

particularly early in the season when soil storage differences are greatest between the forested and clearcut areas.

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

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

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

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

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

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

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

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

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

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

#### **4.3 Physiography**

The following parameter was measured for each of the watersheds:

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

## **5. WATER LICENCES**

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

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

Figure 7 reproduces the 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 on Figure 7, as well as providing more detail on the type of user, producing a total of 73 sub-categories (including non-consumptive uses).

#### **5.1.1 Consumptive Licences**

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

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

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

The total non-power storage licences in each salmon stream are listed on Table 8. The total includes all storage for domestic, waterworks, irrigation, and industrial licences; though, in most streams, the majority of the licences are for irrigation. Table 8 also compares the irrigation licences to the non-power storage in each salmon stream. Storage affects flow by being accumulated during the spring freshet and released during low flows, or during the irrigation season. In many watersheds, 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 Harrison HMA are insignificant when compared to irrigation use or to streamflow.

### **5.2.2 Irrigation Licences**

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

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

Actual irrigation demand can be estimated from the area of irrigated land and a calculated or estimated water duty. The duty -- the water needed for the irrigation season expressed as a depth-- is not known but irrigation licences are typically for 30 cm (12 inches) of water. The theoretical duty and the actual amount applied can be very different, as a result of farming practices and, as well, the duty varies with location and elevation and from year to year. Year-to-year variations are significant in many areas: for example, from 1975 to 1988, duty in the Vernon Irrigation District varied from 31 to 48 cm (Rood 1989), with the greatest amount required during low flow, dry years; and in dry years the actual extraction approaches the licensed volume.

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

### 5.3 Calculation of Licensed Demand

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

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

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

Licensed amounts expressed as a volume (ac-ft) were converted to cubic decameters ( $\text{dam}^3$ ), where  $1 \text{ dam}^3$  is equivalent (approximately) to 0.81 ac-ft. In any time period, the total demand is calculated by adding the demand from waterworks, domestic and industrial licences, which are assumed to be constant throughout the year, to the irrigation demand. Irrigation volumes in the southern part of the HMA are assumed to be distributed as follows: May (10%), June (15%), July (30%), August (30%) and September (15%) based on a report by UMA Engineering Ltd (1988). In the Pemberton Valley volumes are assumed to be distributed as : May (10%), June (20%), July (30%), August (30%), and September (10%). These estimates were provided by the Ministry of Agriculture, Food and Fisheries and are based on typical experience. Percent use by month often varies greatly from year-to-year, particularly in May and June. Monthly irrigation volumes (in  $\text{dam}^3$ ) were converted to discharges (L/s) by multiplying by  $10^6$ , and dividing by the number of seconds in the month.

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



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

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

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

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

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

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 equivalent clearcut area and indicates the extent of hydrograph changes from logging; values exceeding 20% indicate potential changes
9	total logged area as a percent of total basin area	as above
10	recent and proposed logging as a percent of total basin area	as above

## 6.1 Summer Water Demand

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

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

streams in the Harrison HMA have no water demands and on Table 9 only six streams are shaded, whose potential demand exceed 5% of summer 7 day low flows.

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

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

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

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

On Table 9, those salmon streams with low summer 7 day flows, relative to mean flow, are shaded. They lie at the south end of the HMA on the Fraser Lowland, near the Fraser River. Precipitation on the watersheds of these streams is mostly rainfall and flows drop rapidly during July and August. The salmon streams near Pemberton, where winters are cold and snowfall is an important component of the precipitation regime, have the lowest winter 7 day low flows relative to mean flow.

## **6.3 Peak Flows**

Index 7 compares the mean annual flood to mean annual flow, expressing the mean annual flood as a ratio of the mean annual flow. Higher values of the index indicate streams with a greater range or variability of flow. Higher values of the index may also indicate, potentially, lower channel stability, though channel slope and bed materials are also very important. Typically, the ratio of mean annual flood to drainage area increases with decreasing drainage area. This occurs because smaller basins are often completely covered by individual storms, whereas not all of the larger basins are exposed and, as a result, have lower mean annual floods per unit area. The greatest values of Index 7 occur in the small streams near Harrison Hot Springs, particularly Weaver Creek and its tributaries. On Table 9, those streams whose value of Index 7 lies in the top 25% are shaded.

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

## 6.4 Logging

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

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

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

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

## 7. SENSITIVITY OF THE SALMON STREAMS

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

### 7.1 Most Sensitive Streams

Table 10 identifies the most sensitive salmon streams in the Harrison Habitat Management Area. The streams in the Pemberton Valley have the greatest volume of irrigation diversions but these streams have large watersheds, and a hydrologic regime where flows often remain high in the late summer. In the Pemberton Valley, the potential demand from irrigation amounts to less than 1% of summer 7 day low flows. It is streams near Harrison Hot Springs, where low flows occur in late summer, that have the greatest portion of their summer low flows utilized to meet water demands. Irrigation on Maria Slough potentially uses up to 25% of low flows, and a waterworks licence on Sakwi Creek (which has storage of about 2.1 acre-feet) potentially utilizes a large portion of the low flows on Sakwi Creek, and also reduces summer low flows further downstream, on Weaver and Morris Creeks. Flows along part of Sakwi Creek are also reduced by a conservation diversion from Sakwi Creek to the Weaver Creek spawning channel. Industrial demand potentially utilizes a large portion of summer 7 day low flows on Trout Lake Creek.

Summer 7 day low flows are low, in relation to mean flows, on those salmon streams in the southern Fiord Ranges, particularly those in low-lying watersheds around Harrison Hot Springs. Small streams draining to the Pemberton Valley have the lowest winter 7 day low flows, in relation to mean flows. In this region, low flows always occur in late winter under ice.

Chehalis River and Statlu, Bear, Mystery, Big Silver and Railroad Creeks have more than 20% of their total watersheds cut. The cut in the Chehalis watershed and on Railroad Creek was mostly during the 1960's and 1970's and there may be significant recovery since then. Harvesting on Bear, Mystery and Big Silver Creeks is more recent and is mostly from the 1980's.

### 7.2 The Salmon Streams

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

**Maria Slough:** The upper end of Maria Slough was blocked by a CP Rail embankment near the turn of the century. The embankment acts as a dyke that provides flood protection to much of Seabird Island. Hay & Company Consultants Ltd (1992) note that blocking this channel may have aggravated erosion along the outside of Seabird Island. The downstream end of the slough is flooded by high water on the Fraser River.

Groundwater upwelling provides coho habitat along the slough. The groundwater apparently comes from the steep slopes near the head of the slough though some may leak through the CP Rail embankment, particularly at high Fraser River levels. Flows are small in comparison to the capacity of the channel and velocities are always low.

Riparian vegetation has been removed along one bank of the slough though it remains on the other. The Seabird Band wishes to cross the slough at several narrow sections and has considered construction of small weirs to create pools and riffles along the slough in order to improve the channel for recreation as part of a golf course development. The band also plans to remove gravels from the slough. There are no formal plans for these developments. A road and powerline run along one side of the slough and there is moderately heavy agricultural demand on summer low flows.

Apparently, chinook spawn at culvert outlets where gravel accumulates. There is potential to increase the spawning area by diverting or channelizing the flow.

**Hicks Creek:** The creek flows from Hicks Lake into Maria Slough. Water removals for irrigation are quoted as a problem in the Stream Summary Catalogue (Subdistrict #29D) but the Water Rights Branch records no licences on the stream. The Salmon Enhancement Program (SEP) constructed a groundwater spawning channel along Hicks Creek in 1985 and flows in this creek are maintained by groundwater.

**Mahood Creek:** The Ministry of Forests silviculture records show no harvesting on Crown Lands within the watershed but, apparently, there is some logging and timber sale on private land. Flooding and erosion are the main problems in Mahood Creek but siltation is the main problem further downstream, in Johnson Slough.

**Ruby Creek:** Ruby Creek extends to higher elevations than Mahood Creek or other neighbouring streams and is reported to have extreme peak flows and a very flashy flood hydrograph. The Ministry of Forests silvicultural records show no historic logging on Crown Land in this watershed prior to the 1980's though the Stream Summary Catalogue identifies historic logging as a factor in gravel loss in the system. About 400 hectares of harvesting are proposed under the current five-year plan.

The Ministry of Transportation and Highways removed gravel from the fan in 1973 for use in expansion of Highway 7 (Kellerhals Engineering Services Ltd 1987). In recent years, the fan of Ruby Creek has been expanding into the Fraser River, partly because spring freshets on the main river have not removed the material. Although the fan is used for pink salmon spawning there is interest in removing some of the accumulated gravel.

**Harrison River:** The Harrison River downstream of Harrison Lake is gravel-bedded, straight and confined by bedrock through much of its course upstream of Chehalis Village. Harrison Rapids, at the Chehalis fan, provides an important control on water levels at low discharges; during spring they are "drowned out" by backwater from the Fraser River. The rapids and the lower portion of the river, which are part of the spawning area of the Harrison River, have been dredged to maintain a navigation channel (Saxvik 1967).

**Squawkum Creek:** Squawkum Creek drains through Lake Erroch to Harrison Bay. Septic fields and sewage discharge from cottages and homes around the lake affect water quality. Kerr Wood Liedal Associates Ltd (1992) have examined flood and debris management on the next

creek to the north (which is also called by Squawkum Creek). Tributaries to this creek move large quantities of coarse sediment as a result of forest harvesting problems. Debris is removed, from time to time, by the Ministry of Transportation and Highways. The lower portions of these creeks are channelized to prevent flooding.

The Stream Summary Catalogue (Mission Subdistrict) reports critical low flows in Squawkum Creek downstream of Lake Erroch.

**Chehalis River:** The river flows out of a canyon onto its alluvial fan, just upstream of the Morris Valley Road bridge. The fan is wide, gradients are low and the river currently occupies the extreme western edge.

The Chehalis River is laterally and vertically unstable and has a history of abrupt channel changes or avulsions on its fan. Surveys of Indian Reserves and Township Maps from the early 1900's show the Chehalis in a radically different course, lying west of the Chehalis Hatchery and then crossing the northwest corner of Chehalis I.R. #5, though it was in its current course by about 1949 (NHC 1991). During the flood of November 1989, the Chehalis re-opened its eastern branch which leads to Smokehouse Slough and, at low flows, this channel now carries the majority of the discharge. The entrance is partially blocked by a logjam but a major flood could cause the river to re-occupy this channel.

The Chehalis has increased its width and sinuosity since the 1940's, which is consistent with slow aggradation of the channel bed. The slow aggradation is confirmed by a comparison of surveys from 1957 and 1990 (Kerr Wood Leidal Associates Ltd 1990), with bed elevations rising from 0.5 to up to 2 m in the vicinity of the Hatchery.

The right bank near the Chehalis Hatchery and downstream of Pretty Creek has eroded and is now partly protected by a rock revetment. The revetment downstream of Pretty Creek did not extend far enough downstream and is being outflanked by the Chehalis River. A dyke has also been built along the left bank at the Inter-Varsity Christian Fellowship Camp and the Chehalis Band constructed a setback dyke along the boundary of their reserve (David Nairne & Associates Ltd 1989). A berm now surrounds the hatchery.

The Department of Fisheries and Oceans regularly removes gravel in order to maintain a channel leading to their hatchery. During low flows, much of the discharge moves through the thick gravels on the channel bed and the gravel removals are needed to maintain flow. Upstream losses of water to Smokehouse Slough also affect low discharges.

It is expected that aggradation will continue on the Chehalis fan causing flooding, erosion and low flow problems and, eventually, leading to a major channel avulsion.

**Coho Creek:** SEP has constructed a groundwater-fed spawning channel in the upper part of the creek; there is a forestry campsite near the mouth of the creek. Summer flows are considered to be stable because they are groundwater-derived, though the Stream Summary Catalogue reports rearing limitations because of low flows.

The watershed was reportedly logged prior to 1963; however, there is no record of any harvesting in the Ministry of Forests silvicultural system.

**Morris, Weaver and Sakwi Creeks:** Weaver flows into Morris Lake, at the upstream end of Morris Slough and Morris Creek. The slough was previously used as a log dump.

Weaver Creek originates at Weaver Lake and is joined by its main tributary, Sakwi Creek, upstream of the Weaver Creek spawning channel. The north part of Sakwi Creek was logged prior to 1963 which caused extensive erosion, particularly on the west slopes of the canyon below Hemlock Valley (NHC 1988). Roads, trails and clearing for the Hemlock Valley Ski Resort, located at the head of Sakwi Creek, in the 1970's also appeared to cause substantial erosion and sediment input to the creek. All these activities caused heavy input of gravel and logging debris to Sakwi and Weaver Creeks. Weaver Creek, downstream of Hudon Bridge, has been dredged annually for a number of years, with the removal volume averaging near 20,000 m<sup>3</sup>, in order to maintain access to the spawning channel. Dredged material has been used to dyke Weaver Creek to prevent water and sediment from entering the spawning channel. NHC (1988) designed an upstream debris basin which does not appear to have been built.

The spawning channel is designed for a discharge of 0.56 m<sup>3</sup>/s (20 cfs) during spawning and 0.38 m<sup>3</sup>/s (10 cfs) during incubation (IPSFC 1964). Water is taken from storage developed on Weaver Lake and from a diversion on Sakwi Creek. The channel was developed in part because of damage to Weaver and Sakwi Creeks from sedimentation.

Weaver Creek has reported low flow problems and was dry during the 1952 drought. Sediment accumulation aggravates the low flow problem through loss of surface water to the channel bed. The water stored in Weaver Creek and diverted from Sakwi Creek to the Weaver Creek spawning channel supplements low flows in Weaver Creek during part of the year and the naturalized low flows quoted in Table 7 underestimate flows when the diversions are operating.

**Miami Creek:** Miami Creek flows north from the agricultural area around Agassiz to Harrison Hot Springs. The upper reaches of the creek are ditched and treated as a drainage system.

The Village of Harrison has constructed a new floodbox which lowered water levels by about 1 m and fish spawned for the first time in many years. The Village wishes to maintain high water levels in the lower creek for recreation. There is a lack of riparian vegetation along this reach and the high water levels, combined with nutrients from upstream, have caused eutrophication and chronic weed growth. The weeds are removed mechanically by a floating cutter.

**Trout Lake Creek:** The lower reach of Trout Lake Creek is encroached upon by a subdivision with limited setback from the creek, and some walls have been built along the creek to floodproof residential properties. The creek seems to move a large quantity of bedload; consequently, the channel is aggrading and its delta is building up: the Ministry of Transportation and Highways removes gravel from beneath their bridge. Apparently, one of the upper tributaries is prone to debris flows.

**Twenty Mile Creek:** Transports large quantities of coarse sediment on its fan. The Ministry of Transportation and Highways regularly cleans debris from under their bridge.

**Big Silver Creek:** A recent project enhanced spawning near the mouth of Big Silver Creek. The left channel substrate was mostly large rock but the right channel had good spawning gravels. Gravels were scalped at the top end of the right channel and flows diverted from the left channel in order to maximize spawning habitat in the right channel.

Forest companies are harvesting the hillslopes in this watershed. They would like to extend the harvesting into the lower reaches along the main channel but the Department of Fisheries and Oceans is opposed.

**Douglas Creek:** The lower reaches of this creek are channelized but the upper reaches are relatively unaffected.

**Lillooet River:** The Lillooet River has been modified to reduce flooding problems. Following a major flood in 1940, a program of dyking and river straightening (through cutoffs) was undertaken and high water levels were reduced on Lillooet Lake by about 2.5 m by dredging improvements to a constriction about 20 km from the head of the lake. Upstream of Ryan River, six cut-offs were used to move the Lillooet River to its left valley wall and shorten the river by about 17 km. Straightening and the consequent increase in slope generally result in channel degradation but this has not been confirmed by survey. The Water Management Branch attributes the lack of degradation to resistant materials underlying the channel bed, the steep channel, a cycle of degradation followed by aggradation, or to lateral adjustments to the engineering modifications.

Gravel accumulation is a problem along the Lillooet River; between 1980 and 1987, public and private operations removed about 420,000 m<sup>3</sup> of gravel from the main river and its tributaries (Sutek 1988). These removals continue but they do not appear to have initiated channel downcutting or degradation (Sutek 1988).

**Green River:** Green River is the largest tributary to the upper Lillooet River. Over much of its course it is confined by bedrock walls, landslide and talus deposits though the lower reaches spread out in several distributary channels before joining the Lillooet River. In this lower reach there is the Balacava golf course development, future industrial expansion and, in the long term, housing, all of which may affect the river. Most of the demand for industrial water shown on Table 7 is from licence applications which have not yet been approved.

**Miller Creek:** This creek is dyked where it crosses its fan and appears to have been stable for several decades (Jordan 1987). The dyke, however, was overtopped during the 1984 flood.

**Ryan River:** The Ryan River is a major right-bank tributary which parallels the Lillooet River for about 10 km before they join. (The confluence was move several kilometres downstream by the construction of an artificial channel for the Lillooet River.) The upper Ryan River carries large quantities of coarse debris which has built a small gravel fan in the Pemberton Valley.

Two small debris-torrent prone creeks enter the Ryan River just downstream of the small gravel fan. The upstream creek had debris torrents in both 1975 and 1984, blocking the course of the Ryan River, causing substantial aggradation on its fan, and overtopping the dykes along the river. The torrents produced considerable changes in the course of the Ryan River (Jordan 1987) for a km or so downstream of the entry point.



## 8. RESULTS AND CONCLUSIONS

### 8.1 Effects of Development on Hydrology

In the upper Lillooet River, flows in the salmon streams are greatest during snowmelt in May and June and remain high throughout the summer, particularly in those tributaries with glacierized watersheds. The watersheds are in a moderately wet area and annual runoff ranges from 1,500 to 2,000 mm. Water demand for irrigation exceeds several hundred L/s but they are only a small percentage of flows, usually less than 1%. Minimum flows in these streams occur from January to April, often under ice-cover.

The annual flood in these streams often results from snowmelt but the largest floods occur during rainstorms or rain on snow in the fall. These floods transport large quantities of sediment and often re-arrange, aggrade or erode the channels of the streams. Stream stability seems to have a more important effect on fish production than water use.

In the southern half of the HMA, watersheds are exposed to a modified maritime climate. Snow accumulates at high elevations, and snowmelt provides water in the spring, but average streamflows are highest in November and December as a result of rainfall runoff from Pacific storms that regularly cross the watersheds. Annual floods occur in the fall and winter during these rainstorms and the largest floods often have a snowmelt component. Sediment transport during these floods has an important effect on stream channel and gravels are often accumulating in the lowest reaches of the stream channels.

Minimum flows in these streams typically occur in the late summer, particularly for those salmon streams with small watersheds. Diversion for irrigation or waterworks affect some streams but on many streams there is either no or only very limited agriculture and less than 5% of low flows are consumed. It is only on Maria Slough that agriculture removals affect low flows.

Forest harvesting is the main human activity that affects peak discharges and Table 10 identifies those streams where sufficient forest has been harvested to alter the hydrologic regime. The watersheds of many streams were harvested prior to the 1960's. While this harvesting has little effect on the existing hydrologic regime because of regeneration, coarse sediment contributed to streams is often still affecting stream channels. Forest harvesting on unstable soils also increases suspended sediment concentration, which affects downstream habitat.

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

**Surface Water Use:** The major surface water extractions for irrigation from the salmon streams are from streams in the Pemberton Valley. However, these demands are an insignificant portion of summer low flows. Demand on Maria Slough uses a large portion of the summer 7 day low flows. Diversion from Sakwi Creek for a spawning channel also utilizes a large portion of available flows, as does an industrial licence on Trout Lake Creek.

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

annual fees for water use and this may also reduce applications and, potentially, lead to abandonment of under-utilized licences.

Future water demand for irrigation is not known for the Harrison HMA as neither the Water Management Branch nor the Ministry of Agriculture prepare forecasts of agricultural expansion and concomitant requirements for irrigation. However, there are very few applications for irrigation licences for streams in the HMA and no future demand is expected.

**Ground Water Use:** Little is known of ground water use in the Harrison HMA though it is not thought to have a significant effect on many of the salmon streams. Groundwater extractions reduce flows in the Chehalis River.

**Storage Developments:** There are no applications before the Water Management Branch for large or medium-sized power projects in the Harrison HMA.

**Forestry:** Harvesting in salmon streams near the Fraser Valley began in the early part of the twentieth century. While this harvesting no longer affects the hydrologic regime because of regeneration, coarse sediment added to streams may still be affecting stream stability. Many streams also have cutblocks that were harvested 30 or 40 years ago. Chehalis River and Statlu Creek, Bear, Mystery, Big Silver, and Railroad Creeks have more than 20% of their watersheds harvested but some of the logging took place a number of years ago and re-generation should have reduced the equivalent clearcut area.

Logging began in the Lillooet River watershed in about 1958 (Nesbitt-Porter 1985) and proceeded at an average rate of about 250 ha/year. Most of the merchantable timber in the Lillooet River watershed is below 1,200 m elevation and only about 20 to 30% of the watershed area has timber that is suitable for harvest.

The various interviewees did not express concern about direct sediment or hydrology-related forestry impacts on the larger mainstem salmon streams, though the Stream Summary Catalogue identifies a number of smaller salmon streams that may have been affected by logging; either by changes in flow regime, sediment deposition or erosion. B.C. Environment and DFO are utilizing the Interior Forestry Guidelines to examine rate-of-cut though these guidelines are not yet accepted or approved. Rate-of-cut is generally limited to 25% equivalent clearcut area and 20% in Community Watersheds. DFO is also requesting a 30 m windfirm buffer (with selective harvest) along salmon streams and machine reserves along small streams.

The proposed cut over the next five years in the watersheds of the salmon streams ranges from 0% to a maximum of 29% (Bear Creek) of the watershed area. The salmon streams in the Pemberton Valley mostly have proposed cuts of less than 1% of watershed area. Those streams with the largest proposed cuts include Ruby Creek (5%), Pretty Creek (5%), Coho Creek (4%), Mystery Creek (29%), and Cogburn Creek (4%).

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

**Flooding, Erosion and Sedimentation:** A number of the salmon streams are unstable in their lower reaches, or on their fans. On many streams, the upper reaches are confined by bedrock or glacial deposits and the stream is not free to change its course or erode its banks. In many instances, the instability results from deposition of coarse sediment on the channel bed. These sediments are a result of natural events on some streams but sediment delivery often seems to be aggravated by poor forestry and development practices. Coarse sediment is transferred slowly along the channel and increased sediment delivery may affect the stream for many years after forest harvesting or other developments are completed.

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

## **8.2 Technical and Management Recommendations**

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

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

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

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

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

1. The relationship between actual and licensed withdrawals is not known for various licence types and the monthly distribution of irrigation demand is also not well 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 seasonal distribution and annual variation of demand and we recommend regular monitoring of withdrawals to establish these on the most sensitive streams.*
2. Management procedures to ensure adequate instream flows for fish have not been established. *We recommend that instream flow requirements be assessed for the more sensitive salmon streams and that appropriate water management plans be developed in conjunction with other agencies (Hamilton 1992).*

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

Maria Slough is a groundwater-fed stream that is the only salmon stream affected by removals for irrigation. Further removals from this stream should be opposed until instream flow requirements and the available flows are better understood. Water demand on Sakwi and upper Weaver Creeks partly results from diversion of water to the Weaver Creek spawning channel. Further licensing on these creeks should also be opposed, particularly as the available flows are constrained by sub-gravel flow. *We recommend further study of flows in these small systems, particularly of groundwater contributions, and recommend that further licensing of these streams be opposed until the system has been studied in more detail.*

The streams in the Pemberton Valley have the greatest demands but these are only a small portion of the summer 7 day low flows. There is also expected to be little future irrigation demand in this valley. However, water extractions that reduce winter 7 day low flows may be more critical, as these are the minimum flows during the year. *We recommend that further water withdrawals from these stream systems be monitored.*

The salmon streams near Harrison Hot Springs have natural summer low flows that are small in relation to their mean annual flow and discharges are often further reduced by losses to sub-gravel flows on their fans. Flows are usually not much affected by water demand and there are no outstanding licence applications. However, there remains some potential for future increased water demand. *We recommend that low flows be monitored on these streams and instream flow needs assessed.* If demand increases, low flow agreements, or restrictive licensing, may be used to maintain instream flows. There are opportunities to develop storage in the basins of many of the salmon streams and these should be investigated in conjunction with biological studies. Storage may either supplement existing flows or meet future demand.

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

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

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

## **8.2.3 Groundwater Extractions**

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

1. Ground water wells are reported on a voluntary-basis and there is no mechanism to track the volume or rate of extraction from different wells; and

2. Subsurface geology and groundwater movement are not always well enough understood to predict the relationship between extractions and reductions in streamflow.

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

#### **8.2.4 Forest Harvesting**

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

In the Hamison HMA it was difficult to establish the area of cut within the small watersheds near the Fraser Valley because of cut on private land which is not included in the Ministry of Forests database and because errors are introduced in assigning cut from the QMF-100 reports to the individual watersheds. *We recommend that further analysis be completed of the rate of cut in salmon streams with small watersheds.*

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 and results from Carnation Creek may also be helpful in addressing this issue.

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

3. Within the basins of the individual salmon streams, the proposed cut should be distributed over the various tributary basins, to maintain the regime of the tributaries, as well as the main stem. *We recommend a detailed review of the history of cut within the watershed of salmon streams where a large percentage of the basin is harvested.*

Ultimately, a GIS database that includes logging history could be used to calculate clearcut effective area within the tributaries and main stem and to monitor forest harvesting.

#### **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 along with anecdotal information on the history of erosion, flooding, sedimentation and channel changes in the salmon streams in the Harrison HMA. Various individuals in federal and provincial government agencies have personal information that is not mapped or recorded in a fashion whereby it could be utilized in other studies.

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

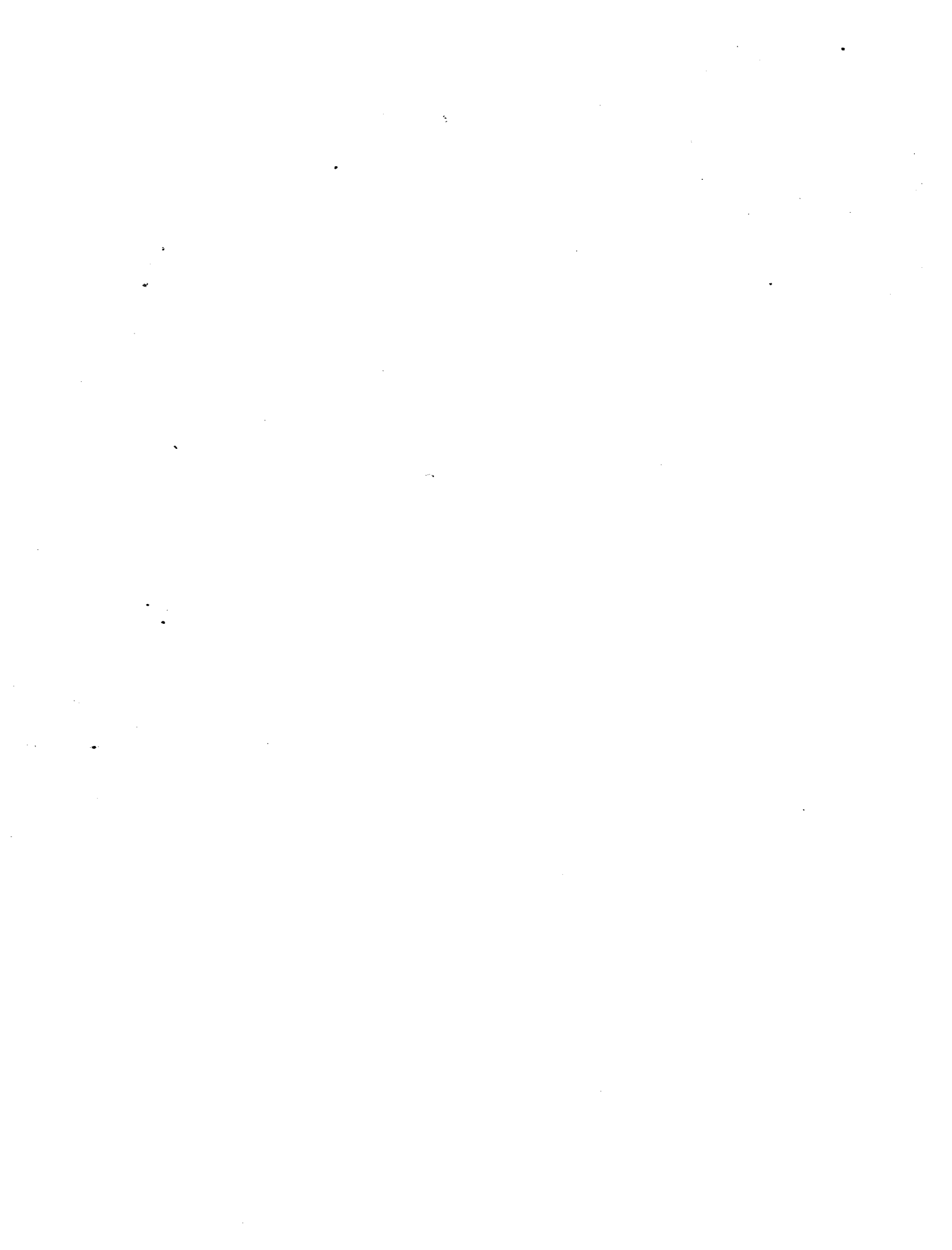
The watersheds of some of the salmon streams are small and the stream courses are reasonably short. *We recommend that the information on channel changes be combined with observations on passage at culverts, water extraction points, the state of riparian vegetation and banks, overwintering habitat, etc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

## 9. REFERENCES

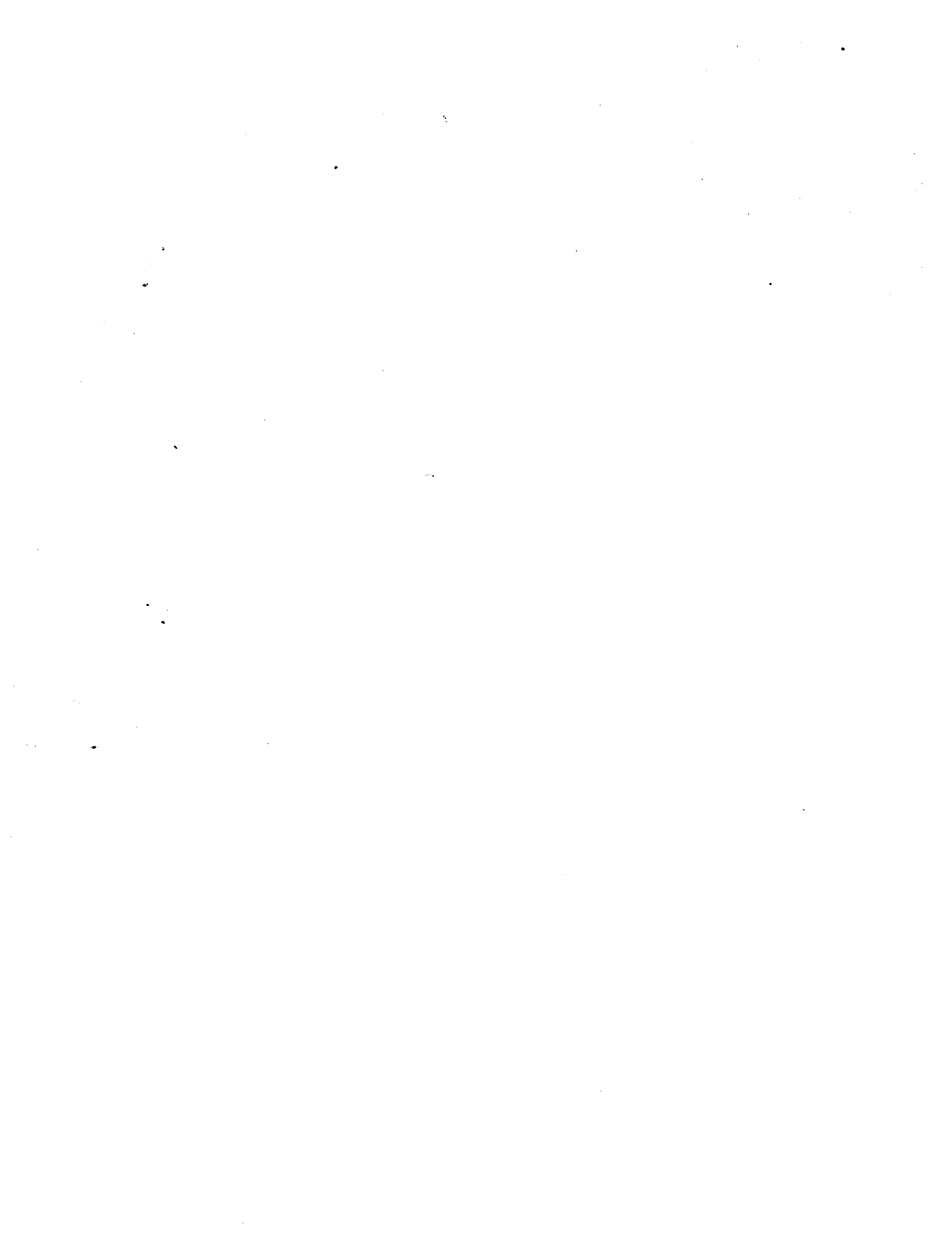
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## TABLES



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

Stream Name	SSIS Number	WSC Gauge Data			Total Drainage Area (km <sup>2</sup> )	Years of Record
		Gauge Name	Gauge No.	Drainage Area (km <sup>2</sup> )		
1 Maria Slough	00-0700	near Agassiz	08MF052	-	33	1960-64 MS
2 - Hicks Ck.	00-0700-070	-	-	-	8	-
3 Mahood Ck.	00-0740	-	-	-	27	-
4 Ruby Ck.	00-0750	-	-	-	84	-
<b>HARRISON RIVER</b>						
5 Harrison R.	01-0000-000-000-000-993	near Harrison Hot Springs	08MG013	7,870	8,324	1951 MC +1952-91 RC
		at Harrison Mills	08MG014	-		1938-84 RC
		above Morris Ck.	08MG015	-		1962-64 RC
		opposite Chehalis R.	08MG016	-		1962-63 RC
		below Morris Ck.	08MG022	7,950		1973-88 RC
6 - Squakum Ck.	01-0100	-	-	-	7	-
7 - Chehalis R.	01-0400	near Harrison Mills	08MG001	383	392	1979-81 MC + 1985-91 R
		below Statlu Ck.	08MG023	357		1981 # + 1982-83 RC
8 - Pretty Ck.	01-0400-020	-	-	-	9	-
9 - Coho Ck.	01-0400-080	-	-	-	9	-
10 - Statlu Ck.	*	-	-	-	112	-
11 - Morris Ck.	01-0500	-	-	-	52	-
12 - Weaver Ck.	01-0500-010	near Harrison Hot Springs	08MG009	42	47	1945-58 MC + 1960-64 M
13 - Steelhead Ck.	01-0500-010-005	-	-	-	4	-
14 - Sakwi Ck.	01-0500-010-010	-	-	-	14	-
15 - East Ck.	01-0500-015	-	-	-	6	-
16 - Miami Ck.	01-0600	near Harrison Hot Springs	08MG017	-	19	1959-64 MS
		near Agassiz	08MG018	-		1959-64 MS
17 - Trout Lake Ck.	01-0700	-	-	-	24	-
18 Bear Ck.	*	-	-	-	34	-
19 - Mystery Ck.	01-1500	-	-	-	30	-
20 - Cogburn Ck.	01-1600	-	-	-	203	-
21 - Twenty Mile Ck.	01-1700	-	-	-	20	-
22 - Big Silver Ck.	01-1800	-	-	-	495	-
23 - Stokke Ck.	01-2300	-	-	-	75	-
24 - Tipella Ck.	01-2500	-	-	-	63	-
25 - Douglas Ck.	01-2600	-	-	-	101	-
26 - Purcell Ck.	01-2650	-	-	-	9	-
<b>LILLOOET RIVER</b>						
27 Lillooet R.	01-0000-000-000-000-991	-	-	-	6,109	-
27a Lillooet R. (lower)	*	-	-	-	2,434	-
28 - Sloquet Ck.	01-2700	-	-	-	206	-
27b Lillooet R. (upper)	01-0000-000-000-000-992	near Pemberton	08MG005	2,160	3,675	1923-59 MC + 1960-91 R
29 - Birkenhead R.	01-4100	at Mount Currie	08MG008	596	593	1945-51 MS + 1952-71 M
30 - Poole Ck.	01-4100-070	-	-	-	29	-
31 - Green R.	01-4300	near Pemberton	08MG003	855	871	1913-30 MC + 1931-51 R
		near Rainbow	08MG004	195		1923-48 MC
32 - Pemberton Ck.	01-4400	near Pemberton	08MG025	32	35	1987-91 RC
33 - Miller Ck.	01-4500	-	-	-	74	-
34 - Ryan R.	01-4600	-	-	-	397	-
35 - Railroad Ck.	01-5000	-	-	-	30	-
36 - Sampson Ck.	01-5050	-	-	-	54	-

- dash (-) indicates that the stream has not been gauged.

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

**Table 2: Physiography and Ecoregions in the Harrison HMA.**

<i>Stream Name</i>	<i>SSIS Number</i>	<i>Total Drainage Area (km<sup>2</sup>)</i>	<i>Physiographic Region (1)</i>	<i>Ecoregions (2)</i>	<i>Ecosection (3)</i>
1 Maria Slough	00-0700	33	FL/FR	PR	SPR
2 - Hicks Ck.	00-0700-070	8	FL/FR	PR	SPR
3 Mahood Ck.	00-0740	27	FL/FR	PR	SPR
4 Ruby Ck.	00-0750	84	FL/FR	PR	SPR
<b>HARRISON RIVER</b>					
5 Harrison R.	01-0000-000-000-000-993	8,324	FR	PR	SPR/EPR
6 - Squakum Ck.	01-0100	7	FR	PR	SPR
7 - Chehalis R.	01-0400	392	FR	PR	SPR
8 - Pretty Ck.	01-0400-020	9	FR	PR	SPR
9 - Coho Ck.	01-0400-080	9	FR	PR	SPR
10 - Statu Ck.	*	112	FR	PR	SPR
11 - Morris Ck.	01-0500	52	FR	PR	SPR
12 - Weaver Ck.	01-0500-010	47	FR	PR	SPR
13 - Steelhead Ck.	01-0500-010-005	4	FR	PR	SPR
14 - Sakwi Ck.	01-0500-010-010	14	FR	PR	SPR
15 - East Ck.	01-0500-015	6	FR	PR	SPR
16 - Miami Ck.	01-0600	19	FL	PR	SPR
17 - Trout Lake Ck.	01-0700	24	FR	PR	SPR
18 Bear Ck.	*	34	FR	PR	SPR
19 - Mystery Ck.	01-1500	30	FR	PR	SPR
20 - Cogburn Ck.	01-1600	203	FR	PR	EPR
21 - Twenty Mile Ck.	01-1700	20	FR	PR	EPR
22 - Big Silver Ck.	01-1800	495	FR	PR	EPR
23 - Stokke Ck.	01-2300	75	FR	PR	EPR
24 - Tipella Ck.	01-2500	63	FR	PR	EPR
25 - Douglas Ck.	01-2600	101	FR	PR	EPR
26 - Purcell Ck.	01-2650	9	FR	PR	EPR
<b>LILLOOET RIVER</b>					
27 Lillooet R.	01-0000-000-000-000-991	6,109	PR	PR	EPR
27a Lillooet R. (lower)	*	2,434	PR	PR	EPR
28 - Sloquet Ck.	01-2700	206	PR	PR	EPR
27b Lillooet R. (upper)	01-0000-000-000-000-992	3,675	PR	PR	EPR
29 - Birkenhead R.	01-4100	593	PR	PR	EPR
30 - Poole Ck.	01-4100-070	29	PR	PR	EPR
31 - Green R.	01-4300	871	PR	PR	EPR
32 - Pemberton Ck.	01-4400	35	PR	PR	EPR
33 - Miller Ck.	01-4500	74	PR	PR	EPR
34 - Ryan R.	01-4600	397	PR	PR	EPR
35 - Railroad Ck.	01-5000	30	PR	PR	EPR
36 - Sampson Ck.	01-5050	54	PR	PR	EPR

1. Physiographic regions from Matthews (1986). FL is the Fraser Lowlands; and FR is the southern Fiord Ranges and PR the Pacific Ranges of the Coast Mountains.
2. Ecoregions from Demarchi (1993). PR is the Pacific Ranges.
3. Ecosections from Demarchi (1993). SPR is the southern Pacific Ranges; EPR, the eastern Pacific Ranges.

**Table 3: Regional Climate in the Harrison HMA.**

Climate Station	Ecosection (1)	Physiographic Region (2)	Latitude	Longitude	Elevation (m)	Precipitation (mm) (3)				Mean Annual Temperature
						Annual	May to Sept	Annual Snowfall	Greatest Daily	
<b>Pacific Ranges Ecoregion</b>										
Daisy Lake Dam	EPR	PR	49.59	123.08	381	2054.2	333.8	383	95.6	6.4
Alta Lake	EPR	PR	50.09	122.57	668	1415.4	265.2	657.4	79.8	5.7
Pemberton BCFS	EPR	PR	50.19	122.49	218	1186.9	223.9	310.5	92.2	7.2
Pemberton Meadows	EPR	PR	50.27	122.56	223	990.2	197.1	283.4	101.6	7.0
Hells Gate	EPR	PR/CM	49.47	121.27	122	1198.9	176.5	188.5	96.5	9.2
Hope A	EPR	CM	49.22	121.29	39	1715.8	326.5	192.6	142.0	9.7
Hope Kawkawa Lake	EPR	CM	49.23	121.24	152	1556.0	301.6	197.2	111.0	9.3
Allison Pass	EPR	CM	49.08	120.5	1341	1524.5	288.2	1431.5	81.3	1.8
Agassiz CDA	SPR	FR	49.15	121.46	15	1692.9	379.5	92.1	115.8	10.1

1. EPR is the Eastern Pacific Ranges and SPR the Southern Pacific Ranges Ecosections.
2. PR is the Pacific Ranges; CM, the Cascade Mountains; FR, the (southern) Fiord Ranges physiographic regions.
3. Climate data from the 1951-1980 Canadian Climate Normals.

**Table 4: Hydrologic Characteristics of the Ecoregions.**

	<i>Southern Pacific Ranges Ecoregion</i>	<i>Eastern Pacific Ranges Ecoregion</i>
<i>Mean Annual Runoff (mm)</i>	3300	1800
<i>Month with Average Maximum Discharge</i>	November	June; remains high in July
<i>Timing of annual maximum discharge</i>	October through February	late May to July; often in October & November
<i>Month with Average Minimum Discharge</i>	August	February
<i>Timing of annual minimum discharge</i>	August through October; sometimes in winter	November through April
<i>Typical Stream</i>	Chehalis River near Harrison Mills 08MG001	Green River near Pemberton 08MG003
<i>Basin Area (km<sup>2</sup>)</i>	383	855

**Table 5: Channel Stability in the Harrison HMA.**

Stream Name	SSIS Number	Channel Response					Human Modifications						
		Pattern Change	Erosion	Incision	Aggradation	Bed Material		Dyking	River Training	Encroachment	Gravel Removal	Veget. Removal	Debris Removal
						Scour	Sedimentation						
1 Maria Slough	00-0700											●	
2 - Hicks Ck.	00-0700-070												
3 Mahood Ck.	00-0740												
4 Ruby Ck.	00-0750					●					●		
<b>HARRISON RIVER</b>													
5 Harrison R.	01-0000-000-000-000-000-993											●	
6 - Squakum Ck.	01-0100				▲								
7 - Chehalis R.	01-0400	●	●		●			●		●			
8 - Pretty Ck.	01-0400-020												
9 - Coho Ck.	01-0400-080												
10 - Statu Ck.	*												
11 - Morris Ck.	01-0500												
12 - Weaver Ck.	01-0500-010		●		●			●					
13 - Steelhead C	01-0500-010-005												
14 - Sakwi Ck.	01-0500-010-010		●		●					●			
15 - East Ck.	01-0500-015												
16 - Miami Ck.	01-0600											●	
17 - Trout Lake Ck.	01-0700				●			●					
18 Bear Ck.	*												
19 - Mystery Ck.	01-1500												
20 - Cogburn Ck.	01-1600												
21 - Twenty Mile Ck.	01-1700				●						●		
22 - Big Silver Ck.	01-1800												
23 - Stokke Ck.	01-2300												
24 - Tipella Ck.	01-2500												
25 - Douglas Ck.	01-2600							●					
26 - Purcell Ck.	01-2650												
<b>LILLOOET RIVER</b>													
27 Lillooet R.	01-0000-000-000-000-000-991												
27a Lillooet R. (lower)	*												
28 - Sloquet Ck.	01-2700												
27b Lillooet R. (upper)	01-0000-000-000-000-000-992	●			●			●		●			
29 - Birkenhead R.	01-4100												
30 - Poole Ck.	01-4100-070												
31 - Green R.	01-4300												
32 - Pemberton Ck.	01-4400							●					
33 - Miller Ck.	01-4500							●					
34 - Ryan R.	01-4600				●			●	●		●		
35 - Railroad Ck.	01-5000												
36 - Sampson Ck.	01-5050												

■ " refers to upper river, ▲ " to middle river, ● " to lower river

**Table 6: Definitions of Flow Characteristics**

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

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

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

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

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

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

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

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

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

**Mean 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 7: Hydrology of Salmon Streams in the Harrison HMA**

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area					Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m3/s)					
			Oldest Pre-64 (km2)	Older 64-73 (km2)	Old 74-83 (km2)	Recent 84-93 (km2)	Proposed 94-98 (km2)	Domestic (g/day)	Irrigation (ac-ft)	Water-works (g/day)	Industrial (g/day)	Conservation (cfs)	Aug	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly		Mean 7-day Flow	
																	Aug	Sept	Summer	Winter	
Marla Slough		33	0.0	0.0	0.0	0.0	0.0	1,500	293	0	1,000	0	41	21	0	1.59	30.5	0.30	0.32	0.12	0.51
- Hicks Ck.		8	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0.39	9.9	0.07	0.08	0.03	0.12
Mahood Ck.		27	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	1.31	26.1	0.25	0.26	0.10	0.42
Ruby Ck.		84	0.0	0.0	0.0	1.3	4.4	1,000	0	0	134,537	0	7	7	7	4.06	64.4	0.77	0.81	0.31	1.29
<b>HARRISON RIVER</b>																					
Harrison R.	08MG013	8,324	27.3	87.9	186.6	262.3	66.1	284,750	2,311	5,194,900	3,112,209	115	777	614	452	481.60	1341.4	576.19	374.30	210.85	147.20
- Squakum Ck.		7	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0.35	9.0	0.07	0.07	0.03	0.11
- Chehalis R.	08MG001	392	18.9	44.3	33.7	29.0	5.2	0	0	0	20,000	65	1	1	1	36.20	347.0	8.59	10.90	5.15	10.00
- Pretty Ck.		9	0.0	0.0	0.0	0.4	0.5	0	0	0	10,000	0	1	1	1	0.42	10.5	0.08	0.08	0.03	0.13
- Coho Ck.		9	0.0	0.0	0.0	0.3	0.3	0	0	0	0	0	0	0	0	0.42	10.5	0.08	0.08	0.03	0.13
- Statu Ck.		112	4.1	9.8	18.7	12.2	1.2	0	0	0	0	0	0	0	0						
- Morris Ck.		52	0.0	0.0	0.0	0.6	0.0	101,000	0	191,400	500	40	15	15	15	2.51	43.8	0.48	0.50	0.19	0.80
- Weaver Ck.	08MG009	47	0.0	0.0	0.0	0.4	0.0	1,500	0	191,400	500	40	10	10	10	2.24	40.0	0.43	0.45	0.17	0.71
- Steelhead Ck.		4	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0.19	5.6	0.04	0.04	0.01	0.06
- Sakw Ck.		14	0.0	0.0	0.0	0.4	0.0	0	15	191,400	0	20	12	11	10	0.66	15.1	0.13	0.13	0.05	0.21
- East Ck.		6	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0.29	7.7	0.05	0.06	0.02	0.09
- Miami Ck.	08MG017	19	0.0	0.0	0.0	0.0	0.0	2,000	3	0	0	0	1	0	0	0.92	15.0	0.25	0.34	0.10	0.19
- Trout Lake Ck.		24	0.0	0.0	0.0	0.0	0.0	500	0	0	743,000	0	39	39	39	1.14	23.3	0.22	0.23	0.09	0.36
- Bear Ck.		34	0.0	0.0	5.4	4.8	0.0	0	0	0	0	0	0	0	0						
- Mystery Ck.		30	0.0	0.0	2.0	13.8	8.6	0	0	0	0	0	0	0	0	1.43	27.9	0.27	0.28	0.11	0.45
- Cogburn Ck.		203	0.0	0.0	2.0	13.8	8.6	0	0	0	0	0	0	0	0	6.15	130.0	6.22	3.77	2.04	1.23
- Twenty Mile Ck.		20	0.0	0.0	0.0	2.2	0.2	0	0	0	0	0	0	0	0	0.98	20.6	0.19	0.19	0.07	0.31
- Big Silver Ck.		495	2.2	8.7	45.5	63.6	13.1	0	0	0	0	0	0	0	0	14.98	109.2	15.16	9.19	4.97	2.99
- Stokke Ck.		75	0.0	5.3	0.0	6.3	0.0	0	0	0	0	0	0	0	0	2.26	24.1	2.29	1.39	0.75	0.45
- Tipella Ck.		63	0.0	0.0	0.0	1.6	0.0	0	0	0	0	0	0	0	0	7.4	72.2	6.77	4.72	1.83	0.84
- Douglas Ck.		101	0.0	0.0	0.7	0.7	0.8	0	0	0	0	0	0	0	0	3.06	30.7	3.10	1.88	1.02	0.61
- Purcell Ck.		9	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0.28	4.5	0.28	0.17	0.09	0.06

- Gauge numbers in Column 2 indicate that flow characteristics were calculated from those WSC records.
- Logged areas are calculated as described in Section 4 of the report.
- Total water licenses 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 licenses as described in Section 5 of the report.
- Naturalized flows are estimates of those that would occur in the absence of all upstream water extractions.

Table 7, continued

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area					Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m3/s)					
			Recent	Old	Older	Oldest	Proposed (1992-97)	Dome- stic (g/day)	Irrig- ation (ac-ft)	Water- works (g/day)	Indus- trial (g/day)	Conser- vation (cts)	Aug	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly		Mean 7-day Flow	
			(km2)	(km2)	(km2)	(km2)	(km2)	(g/day)	(ac-ft)	(g/day)	(g/day)	(cts)						Aug	Sept	Summer	Winter
<b>LILLOOET RIVER</b>																					
Lillooet R.		6,109	3.0	27.0	95.3	117.6	29.8	120,500	2,283	4,978,500	2,098,532	10	699	486	379	303.05	1358.79	534.79	309.04	114.46	53.13
Lillooet R. (lower)		2,434	2.2	9.0	41.3	40.4	3.3	102,000	137	107,000	322,381	10	47	34	28						
- Sloquet Ck.		206	1.7	0.0	2.6	0.9	0.2	0	0	0	0	0	0	0	0	24.3	186.4	22.17	15.46	5.99	2.76
Lillooet R. (upper)	08MG005	3,675	0.8	18.1	54.0	77.2	26.5	18,500	2,147	4,871,500	1776151	0	652	451	351	182.3	904.8322	321.70	185.90	68.85	31.96
- Birkenhead R.	08MG008	593	0.2	0.4	2.2	8.6	4.6	61,000	135	75,000	315,381	10	43	30	24	22.5	170.0	23.40	13.50	8.34	4.61
- Poole Ck.		29	0.0	0.0	0.0	0.2	0.3	3,000	15	0	0	0	2	1	0	0.6	6.7	0.69	0.36	0.22	0.11
- Green R.	08MG003	871	0.5	2.8	12.2	21.8	5.2	6,000	10	4,491,500	685,352	0	274	273	273	43.4	242.0	62.30	38.40	15.51	7.35
- Pemberton Ck.		35	0.0	0.0	0.0	0.8	0.0	0	0	280,000	1,076,298	0	71	71	71	2.0	21.8	2.79	1.73	0.66	0.42
- Miller Ck.		74	0.0	0.0	0.5	1.1	0.0	2,000	200	0	1,500	0	28	10	0	4.4	40.1	5.99	3.71	1.40	0.91
- Ryan R.		397	0.0	5.6	12.0	10.7	2.0	2,000	90	0	0	0	13	4	0	23.3	153.2	31.97	19.82	7.50	4.84
- Railroad Ck.		30	0.0	6.7	4.2	1.1	0.2	0	0	0	0	0	0	0	0	0.6	6.8	0.70	0.37	0.22	0.11
- Sampson Ck.		54	0.0	0.5	0.5	2.8	0.6	0	0	0	0	0	0	0	0	1.1	10.9	1.26	0.66	0.40	0.20

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

**Table 8: Storage in the Salmon Streams in the Harrison HMA.**

<i>Stream Name</i>	<i>Basin Area (mouth) (km2)</i>	<i>Total Non-Power Storage (ac-ft)</i>	<i>Total Conservation Storage (ac-ft)</i>	<i>Total Irrigation Licences (ac-ft)</i>	<i>Percent with Storage (%)</i>
Maria Slough	33	0	0	293	0
- Hicks Ck.	8	0	0	3	0
Mahood Ck.		0	0	0	0
Ruby Ck.	84	0	0	0	0
<b>HARRISON RIVER</b>					
Harrison R.	8,324	2,342	0	2,311	0
- Squakum Ck.	7	0	0	0	0
- Chehalis R.	392	0	0	0	0
- Pretty Ck.	9	0	0	0	0
- Coho Ck.	9	0	0	0	0
- Statlu Ck.	112	0	0	0	0
- Morris Ck..	52	2,162	0	0	0
- Weaver Ck.	47	2,162	0	0	0
- Steelhead Ck.	4	0	0	0	0
- Sakwi Ck.	14	2	0	0	0
- East Ck.	6	0	0	0	0
- Miami Ck.	19	0	0	3	0
- Trout Lake Ck.	24	0	0	0	0
Bear Ck.	34	0	0	0	0
- Mystery Ck.	30	0	0	0	0
- Cogburn Ck.	203	0	0	0	0
- Twenty Mile Ck.	20	0	0	0	0
- Big Silver Ck.	495	0	0	0	0
- Stokke Ck.	75	0	0	0	0
- Tipella Ck.	63	0	0	0	0
- Douglas Ck.	101	0	0	0	0
- Purcell Ck.	9	0	0	0	0
<b>LILLOOET RIVER</b>					
Lillooet R.	6,109	0	0	2,283	0
Lillooet R. (lower)	2,434	0	0	137	0
- Sloquet Ck.	206	0	0	0	0
Lillooet R. (upper)	3,675	0	0	2,147	0
- Birkenhead R.	593	0	0	135	0
- Poole Ck.	29	0	0	15	0
- Green R.	871	0	0	10	0
- Pemberton Ck.	35	0	0	0	0
- Miller Ck.	74	0	0	200	0
- Ryan R.	397	0	0	90	0
- Railroad Ck.	30	0	0	0	0
- Sampson Ck.	54	0	0	0	0

- Nonpower includes all storage for domestic, waterworks, industrial, and irrigation licences. Conservation licences are not included in the nonpower totals.
- Irrigation licences for each salmon stream are from Table 7.
- Percent with storage calculated by dividing nonpower storage by total irrigation licences for each stream

**Table 9: Sensitivity Indices -- Harrison HMA**

Stream Name	Status	SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	LOGGING		
		Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin	Index 10 Recent & Proposed
Maria Slough		34%	17%	14%	7%	6%	32%	19	0%	0%	0%
- Hicks Ck.		0%	0%	0%	0%	8%	32%	25	0%	0%	0%
Mahood Ck.		0%	0%	0%	0%	8%	32%	20	0%	0%	0%
Ruby Ck.		2%	2%	1%	1%	7%	32%	16	2%	2%	7%
<b>HARRISON RIVER</b>											
Harrison R.		0%	0%	0%	0%	44%	30%	3	3%	7%	4%
- Squakum Ck.		0%	0%	0%	0%	8%	32%	26	0%	0%	0%
- Chehalis R.		0%	0%	0%	0%	14%	28%	10	7%	32%	9%
- Pretty Ck.		2%	2%	1%	1%	7%	32%	25	5%	5%	10%
- Coho Ck.		0%	0%	0%	0%	8%	32%	25	3%	3%	7%
- Statlu Ck.		-	-	-	-	-	-	-	11%	40%	12%
- Morris Ck.		8%	8%	3%	3%	7%	31%	17	1%	1%	1%
- Weaver Ck.		6%	6%	2%	2%	7%	31%	18	1%	1%	1%
- Steelhead Ck.		0%	0%	0%	0%	8%	32%	29	0%	0%	0%
- Sakwi Ck.		24%	22%	10%	8%	6%	30%	23	3%	3%	3%
- East Ck.		0%	0%	0%	0%	8%	32%	27	0%	0%	0%
- Miami Ck.		1%	0%	0%	0%	11%	21%	16	0%	0%	0%
- Trout Lake Ck.		45%	45%	18%	17%	4%	28%	20	0%	0%	0%
- Bear Ck.		-	-	-	-	-	-	-	14%	30%	14%
- Mystery Ck.		0%	0%	0%	0%	8%	32%	20	46%	53%	75%
- Cogburn Ck.		0%	0%	0%	0%	33%	20%	21	7%	8%	11%
- Twenty Mile Ck.		0%	0%	0%	0%	8%	32%	21	11%	11%	12%
- Big Silver Ck.		0%	0%	0%	0%	33%	20%	7	13%	24%	15%
- Stokke Ck.		0%	0%	0%	0%	33%	20%	11	8%	16%	8%
- Tipella Ck.		0%	0%	0%	0%	25%	11%	10	3%	3%	3%
- Douglas Ck.		0%	0%	0%	0%	33%	20%	10	1%	1%	1%
- Purcell Ck.		0%	0%	0%	0%	33%	20%	16	0%	0%	0%

54

- Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; OR, office reserve, no licencing; PWS, possible water shortages, RNW, Refused, no water.
- Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; EIA is effective impervious area in the watershed; Basin is basin area above the mouth.
- Indices expressed as percentages except 7, which is a direct ratio.
- Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 7; values of Indices 8, 9 and 10 exceeding 20% are shaded.

**Table 9, continued**

Stream Name	Status	SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	LOGGING		
		Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 Recent/ Basin	Index 9 Total/ Basin	Index 10 Recent & Proposed
<b>LILLOOET RIVER</b>											
Lillooet R.		1%	0%	0%	0%	38%	17%	4	2%	4%	2%
Lillooet R. (lower)		-	-	-	-	-	-	-	2%	4%	2%
- Sloquet Ck.		0%	0%	0%	0%	25%	11%	8	0%	3%	1%
Lillooet R. (upper)		1%	1%	0%	0%	38%	17%	5	2%	4%	3%
- Birkenhead R.		1%	0%	0%	0%	37%	20%	8	1%	2%	2%
- Poole Ck.		1%	0%	0%	0%	37%	19%	11	1%	1%	2%
- Green R.		2%	2%	0%	1%	35%	16%	6	3%	4%	3%
- Pemberton Ck.		11%	11%	3%	4%	29%	17%	11	2%	2%	2%
- Miller Ck.		2%	1%	0%	0%	32%	21%	9	1%	2%	1%
- Ryan R.		0%	0%	0%	0%	32%	21%	7	3%	7%	3%
- Railroad Ck.		0%	0%	0%	0%	37%	19%	11	4%	40%	4%
- Sampson Ck.		0%	0%	0%	0%	37%	19%	10	5%	7%	6%

- Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; OR, office reserve, no licencing; PWS, possible water shortages, RNW, Refused, no water.
- Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; EIA is effective impervious area in the watershed; Basin is basin area above the mouth.
- Indices expressed as percentages except 7, which is a direct ratio.
- Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 7; values of Indices 8, 9 and 10 exceeding 20% are shaded.

**Table 10: Most Sensitive Streams - Harrison HMA**

Water Demand	Summer Low Flows	Winter Low Flows	Forest Harvesting
1 to 4	5	6	8 to 10
Maria Slough	Maria Slough	Streams draining to the Lillooet River	Chehalis River
Morris Creek	Ruby Creek		Statlu Creek
Weaver Creeek	Pretty Creek		Bear Creek
Sakwi Creek	Morris Creek		Mystery Creek
Trout Lake Creek	Weaver Creek		Big Silver Creek
Pemberton Creek	Sakwi Creek		Railroad Creek
	Trout Lake Creek		

FIGURES



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



Figure 2a: Salmon Streams in the Harrison HMA

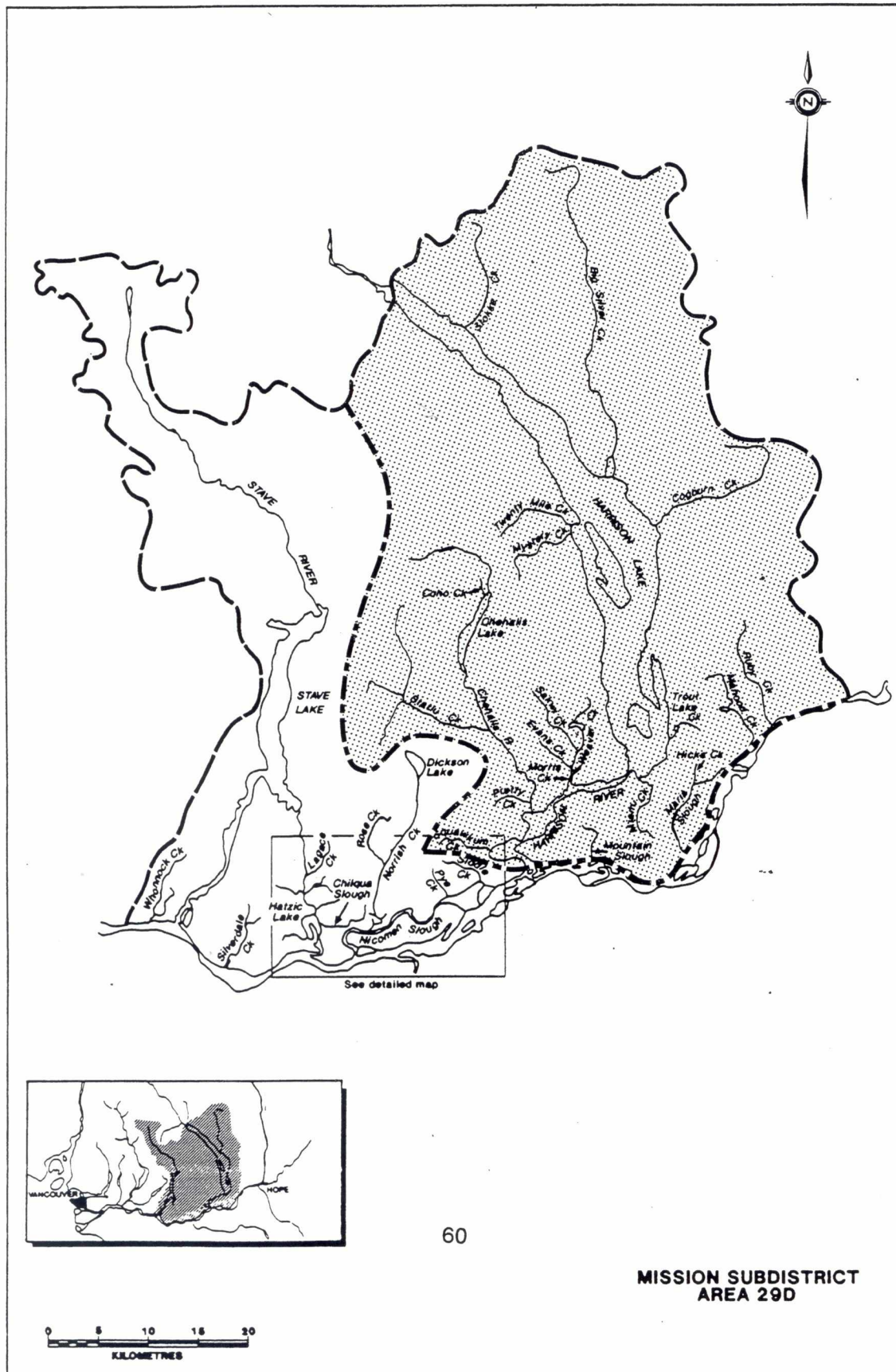
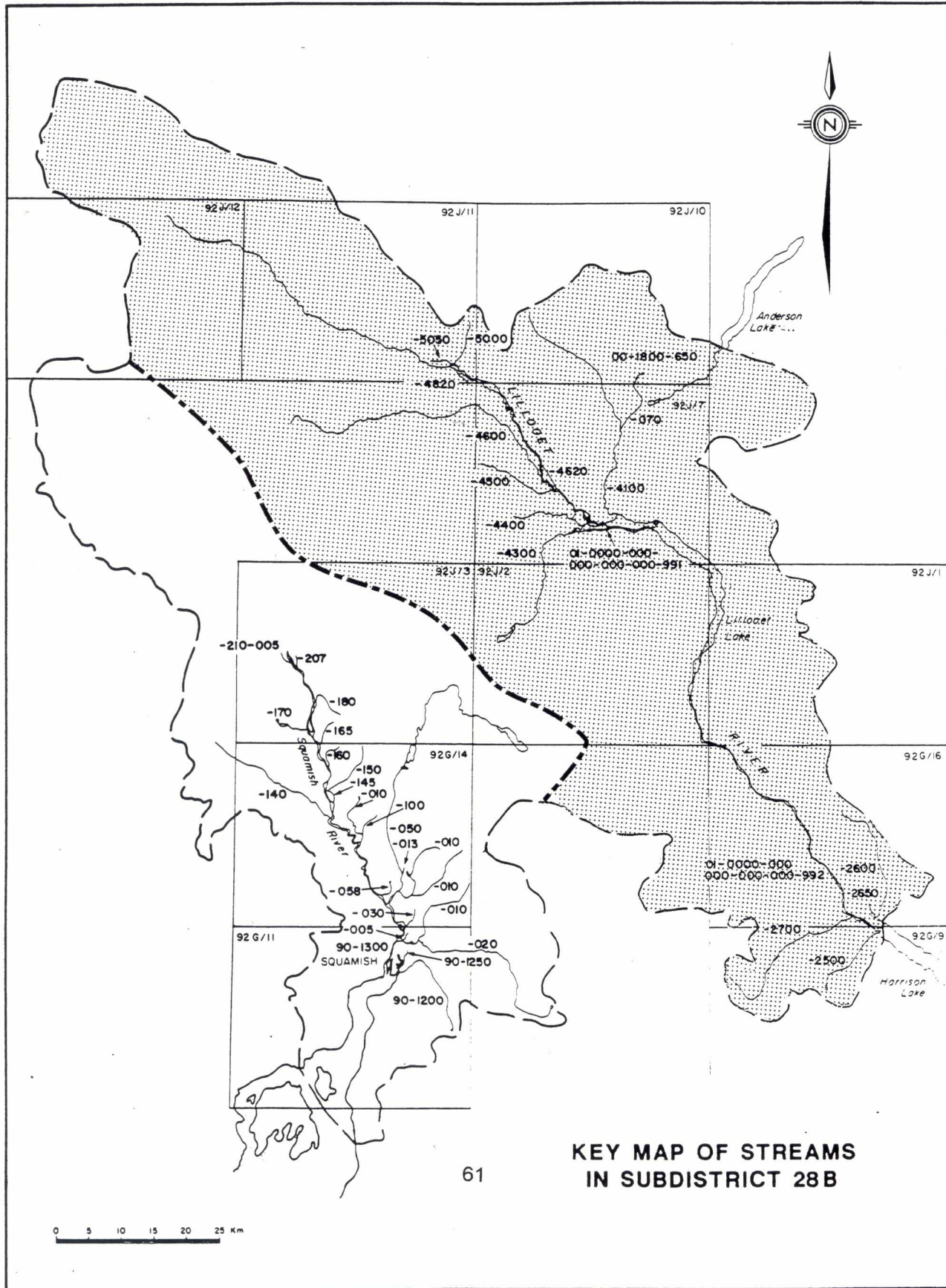
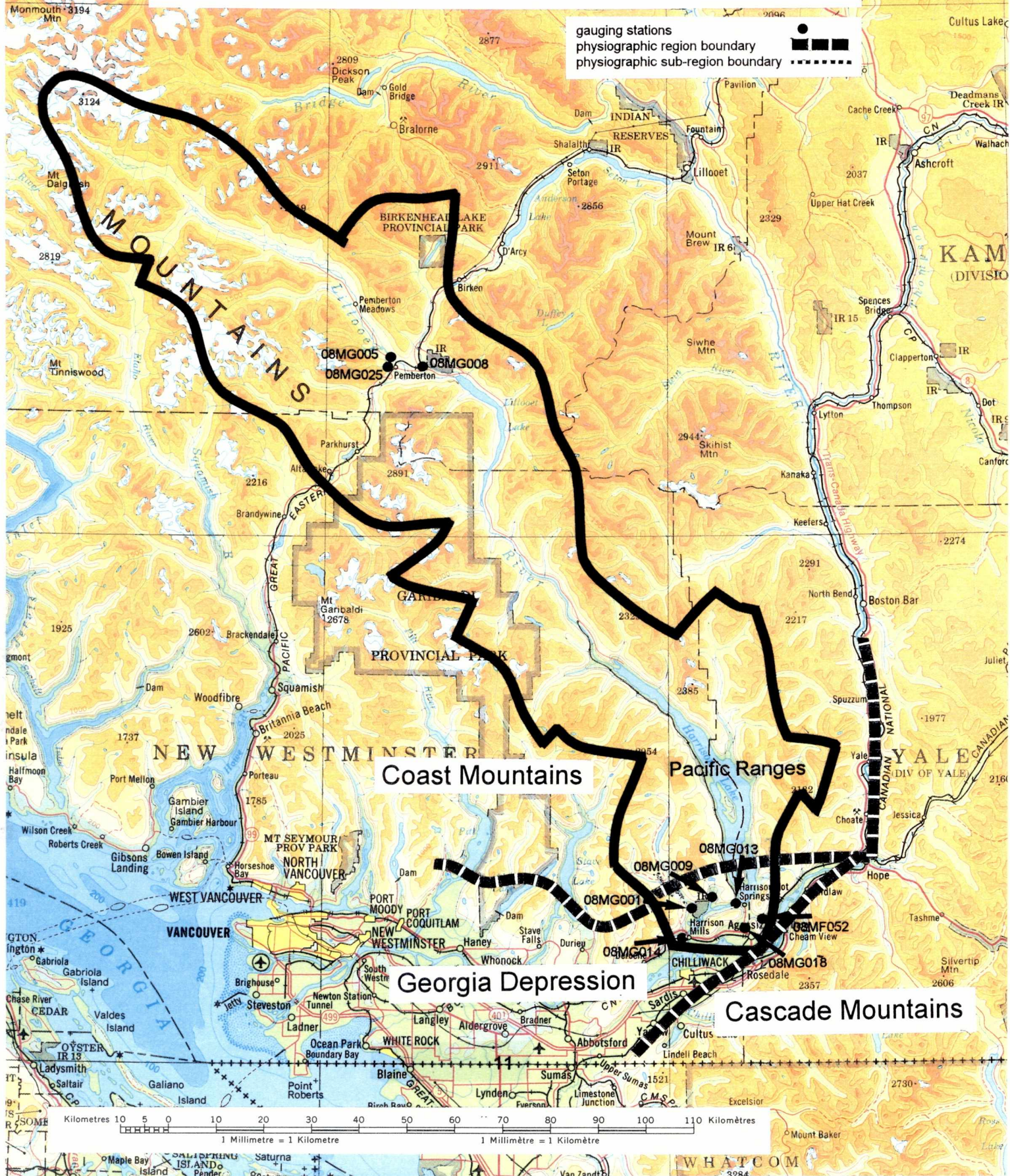


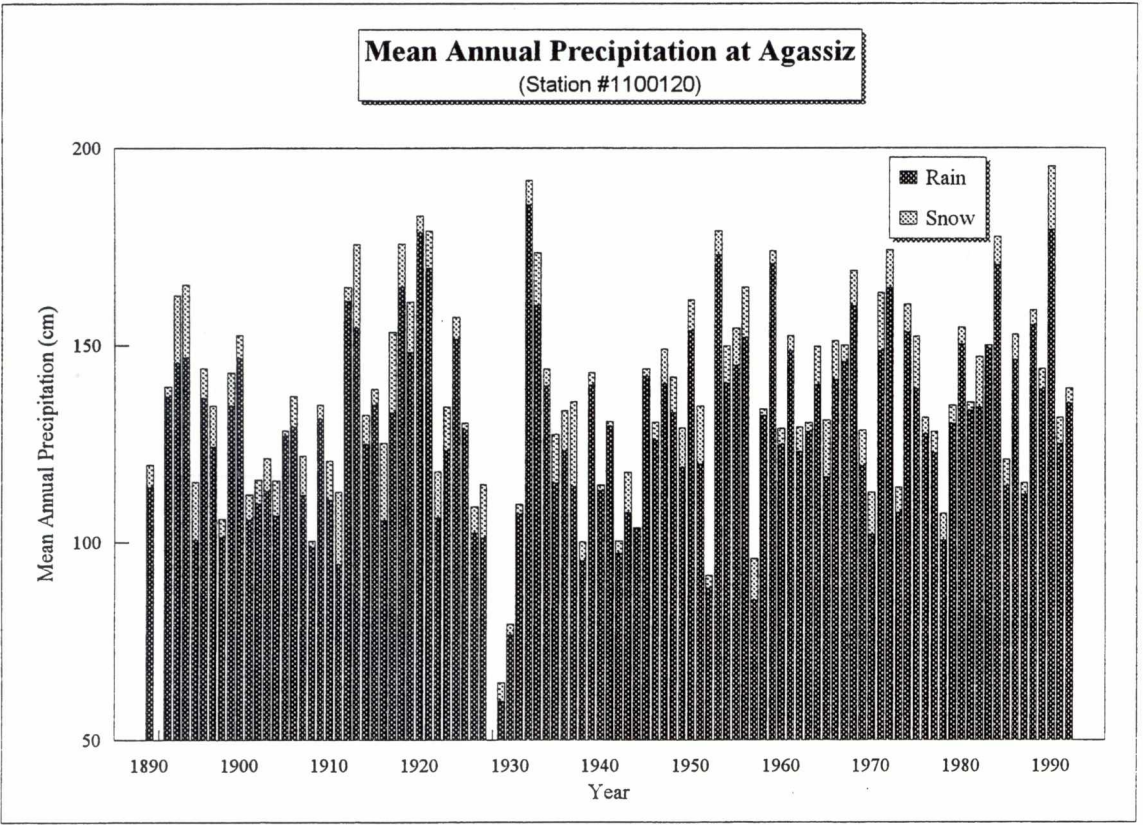
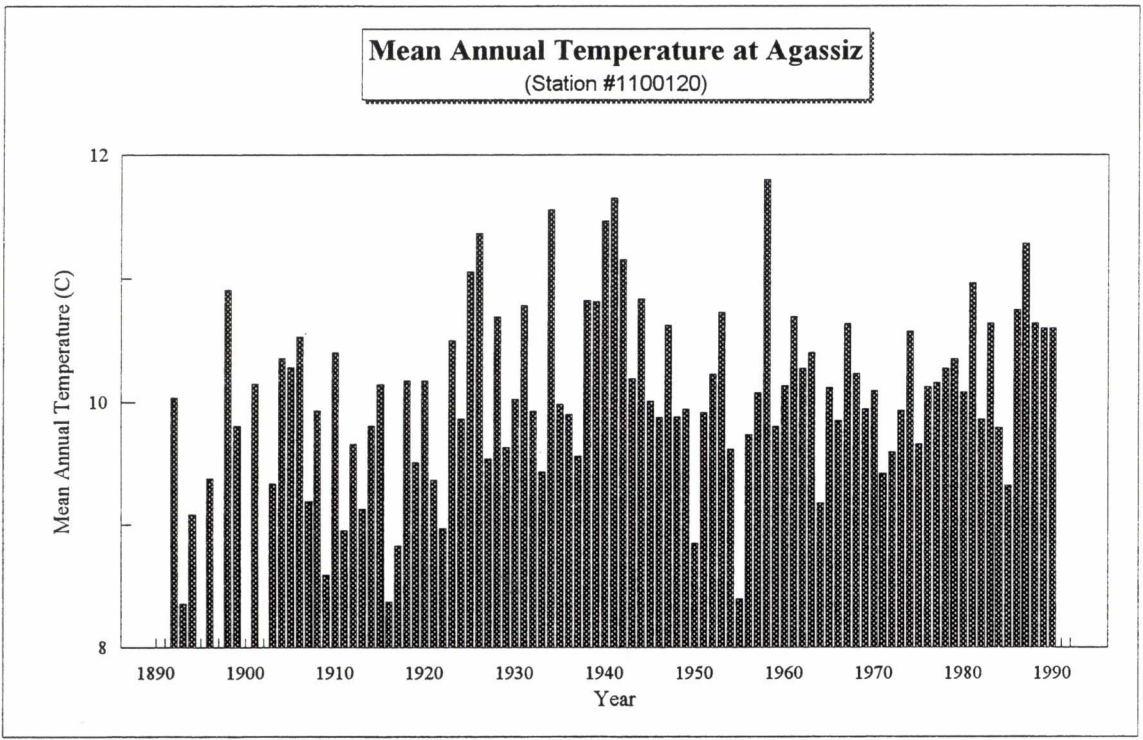
Figure 2b: Salmon Streams in the Harrison HMA



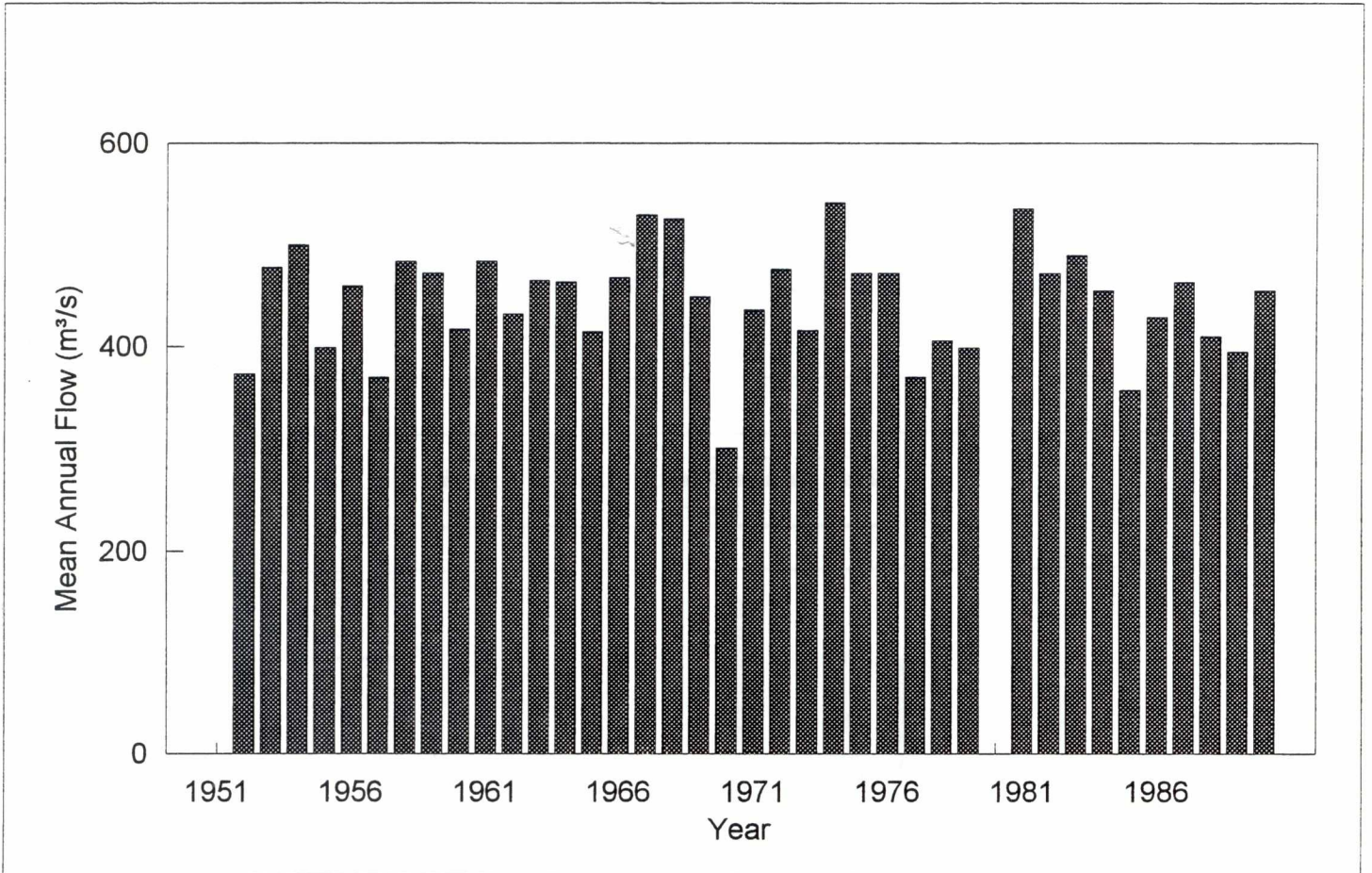
**Figure 3: Physiographic Regions and WSC Gauging Stations in the Upper Fraser HMA**



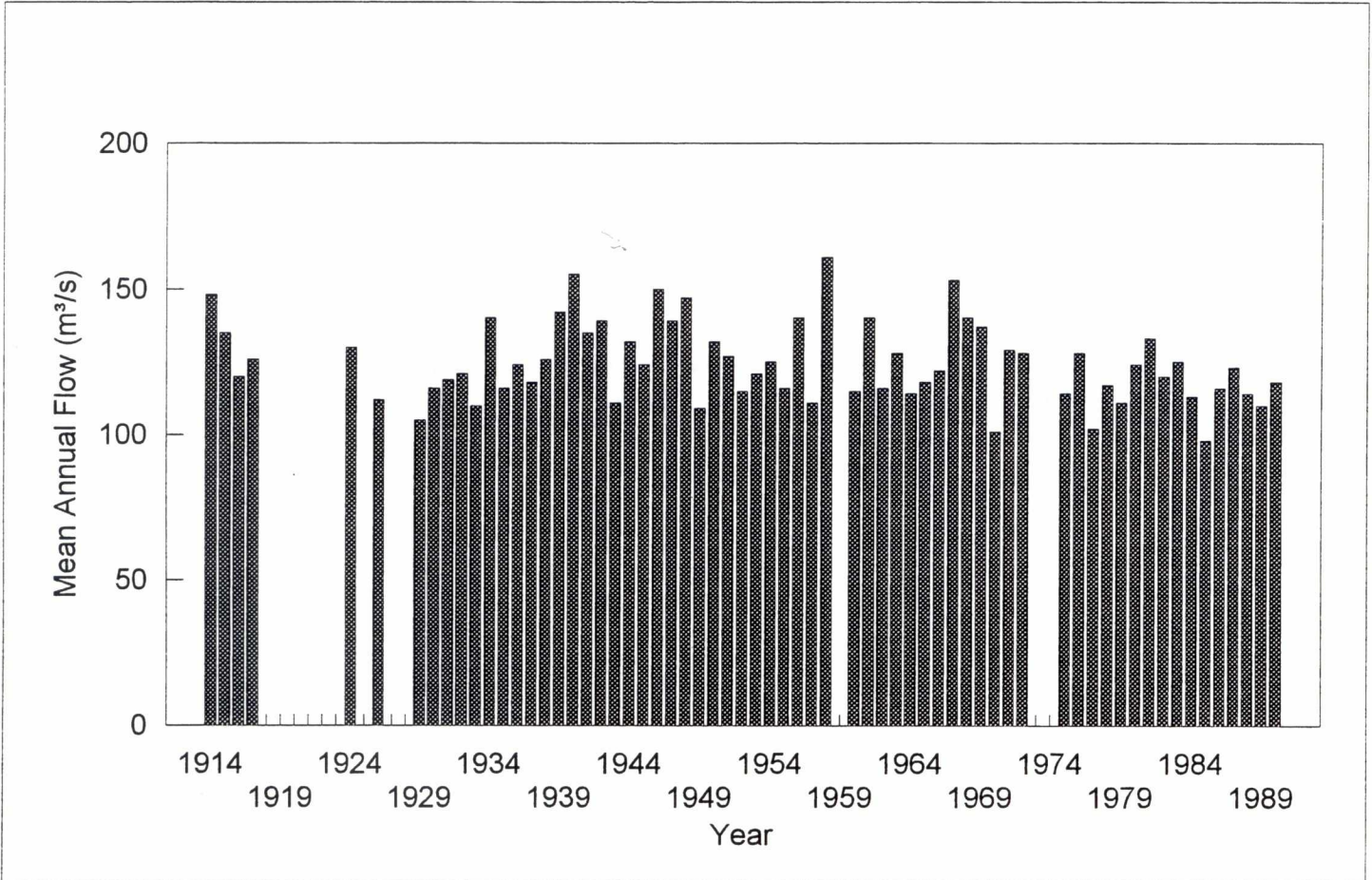
**Figure 4: Long-Term Temperature and Precipitation Trends at Agassiz**



**Figure 5a: Long-Term Variation in Discharge:  
Harrison River Near Harrison Hot Springs**

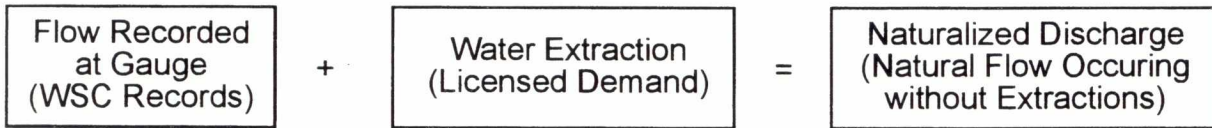


**Figure 5b: Long-Term Variation in Discharge:  
Upper Lillooet River Near Pemberton**

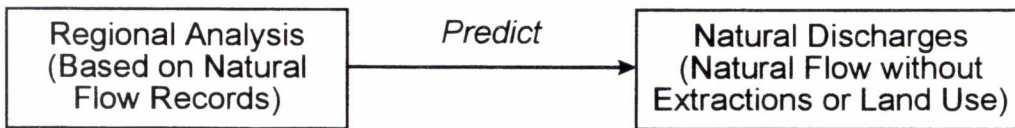


**Figure 6: Calculation of Natural and Naturalized Flows for the Salmon Streams**

*GAUGED STREAMS*



*UNGAUGED STREAMS*



**Figure 7: 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)	acre-feet
6	Land improvement	e.g. draining property, creating ponds	any
7	Mining	- hydraulic, washing coal, processing ore, placer	cubic feet/second gallons/day
<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

MEASURING STREAMFLOW AT THE MOUTHS OF UNGAUGED SALMON STREAMS

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

A few of the salmon streams have been gauged by the Water Survey of Canada at one time or another but only the Harrison, Chehalis and Lillooet Rivers met the requirements for gauged salmon streams, as they have Water Survey of Canada stations operating near their mouths and (nearly) continuous records from 1981 to 1990. Much of the HMA is ungauged and no gauges have ever operated on any of the streams between Harrison Hot Springs and Pemberton.

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

*Harrison River.* Flows at the mouth of the Harrison River were estimated by adding flow characteristics calculated at the "Chehalis River near Harrison Mills, 08MG001" gauge to those at the "Harrison River near Harrison Hot Springs, 08MG013" gauge for the period from 1981 to 1990.

*Chehalis River and Statlu Creek.* The record at the "Chehalis River near Harrison Mills, 08MG001" gauge is not complete from 1981 to 1990. Flow characteristics were calculated from the available data as there is no similar watershed with complete records over this period.

Flow characteristics were transferred to Statlu Creek based on the drainage area ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area of the ungauged stream,  $A_g$  is the drainage area of the gauged stream and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics.

*Miami Creek.* Miami Creek drains the lowland area around Agassiz and is not similar to other streams in the Harrison HMA. The "Miami Creek near Harrison Hot Springs, 08MG017" gauge was used to calculate winter 7 day low flows, mean September flows and mean annual flood. Other flow characteristics were estimated.

*Lower Harrison Tributaries.* Most of the streams near Harrison Hot Springs have small drainage areas and are steep, extending to elevations of around 1,200 to 1,500 m. Weaver Creek is the only one of these streams that has been gauged (Weaver Creek near Harrison Hot Springs, 08MG009) though records are old and incomplete. Flow characteristics are based on these records because there is no nearby gauge that may be used for adjustments.

Flow characteristics were transferred to the other lower Harrison tributaries based on the drainage area ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area of the ungauged stream,  $A_g$  is the drainage area of the gauged stream and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics. The other tributaries are: Maria Slough, and Hicks, Ruby, Pretty, Coho, Morris, Steelhead, Sakwi, East, Trout Lake, Bear, Mystery, and Twenty Mile Creeks.

*Big Silver, Stokke, Douglas and Purcell Creeks.* These creeks all drain the west side of the Lillooet Ranges and join the headwaters of the Nahatlach River. None of these creeks have been gauged. Flow characteristics calculated for the "Nahatlach River below Tachewana Creek, 08MF065" gauge were transferred to these tributaries based on the drainage area ratio  $(A_u/A_g)^n$ ;

where  $A_u$  is the drainage area of the ungauged stream,  $A_g$  is the drainage area of the gauged stream and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics.

*Sloquet and Tipella Creeks:* These two creeks drain the east side of the range between the Hamison and Stave River watersheds and join the headwaters of Stave River. Neither of these creeks has been gauged. Flow characteristics calculated for the "Stave River above Stave Lake, 08MH147" gauge were transferred to these creeks based on the ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area of the ungauged stream,  $A_g$  is the drainage area of the gauged stream, and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics.

*Birkenhead River:* The "Birkenhead River at Mount Currie, 08MG008" gauge recorded flows at the mouth of the stream from 1945 to 1971. Flow characteristics calculated from this record were adjusted to 1981 to 1990 using the "Lillooet River at Pemberton" gauge. The adjustment consisted of determining the ratio of the flow characteristic over the gauging period, and over 1981-1990, at the Lillooet River gauge and applying the ratio of the two to the older record.

*Green River:* The "Green River near Pemberton, 08MG003" gauge recorded flows near the mouth of the stream from 1914 to 1951. Flow characteristics calculated from this record were adjusted to 1981 to 1990 using the "Lillooet River at Pemberton" gauge. The adjustment consisted of determining the ratio of the flow characteristic over the gauging period, and over 1981-1990, at the Lillooet River gauge and applying the ratio of the two to the older record.

*Pemberton and Miller Creeks and Ryan River:* These three creeks all drain glacerized terrain on the south side of the Pemberton Valley. Miller and Ryan Creek have not been gauged though there are a few years of recent record on Pemberton Creek (Table 1). Rutherford Creek, which was gauged from 1925 to 1948 at the "Rutherford Creek near Pemberton, 08MG006" station also drains this same area. Flow characteristics were calculated for the Rutherford Creek gauge, adjusted to 1981 to 1990 with the Lillooet River record and then transferred to Pemberton and Miller Creeks and Ryan River. The flows were transferred with the ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area at the mouth of the ungauged stream,  $A_g$  is the drainage area at the Rutherford Creek gauge, and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics. The predictions for Pemberton Creek were checked against the available records on this creek.

*Poole, Railroad and Sampson Creeks:* These three creeks drain to the north side of the Pemberton Valley and are not gauged. The nearest similar watershed is the Gates River in the upper Seton watershed. Flow characteristics calculated for this stream (NHC 1994) were transferred to these streams. The flows were transferred with the ratio  $(A_u/A_g)^n$ ; where  $A_u$  is the drainage area at the mouth of the ungauged stream,  $A_g$  is the drainage area at the Gates Creek gauge, and  $n$  is equal to 0.8 for mean floods and 1.0 for all other flow characteristics.

**APPENDIX B**

**STREAM SUMMARIES**

## **B. STREAM SUMMARIES**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# MARIA SLOUGH

## LICENSED WATER DEMAND

Stream number 00-0700  
 Ungauged  
 Tributary to the Fraser River

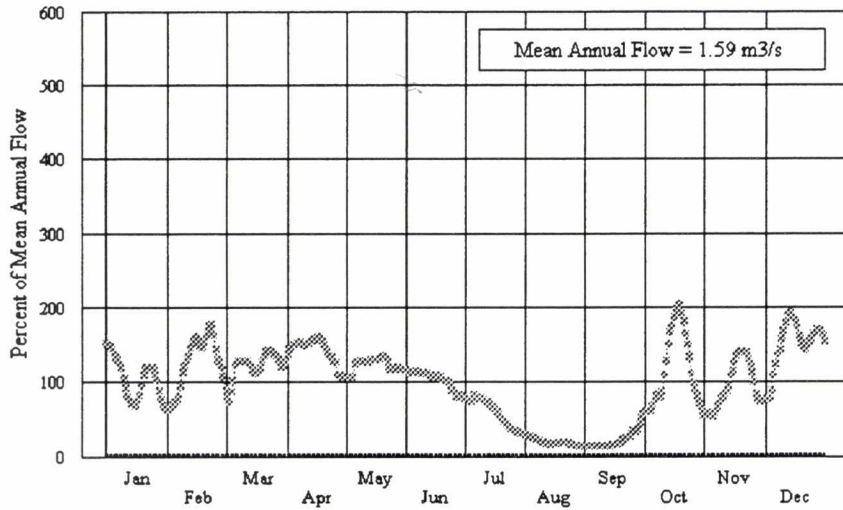
Drainage Area = 33 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,500 g/d	0.08	0.08	0.08
Irrigation	293 ac.ft.		40.49	20.92
Waterworks	0 g/d			
Industrial	1,000 g/d	0.05	0.05	0.05
Conservation	0 cfs			

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		300	320

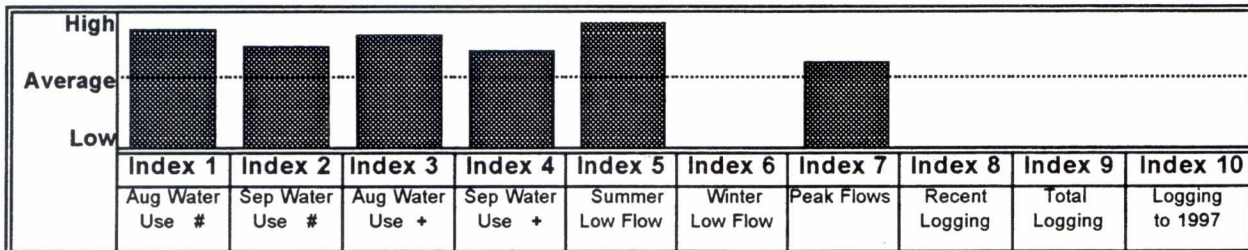
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# MARIA SLOUGH

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Although water velocities in Maria Slough are always low, groundwater upwelling from the steep slopes near the head of the slough, or through the CP railway embankment at high Fraser River flows, provides good coho habitat.*

*2. A road and powerline run along one side of the slough and riparian vegetation has been removed in some places. There is moderately heavy agricultural demand on summer flows.*

*3. The native band wishes to cross the slough at several narrow locations with a bridge and pipelines, and are planning to install small weirs to create pools and riffles as part of a golf course development. As yet there are no formal plans for these developments.*

*4. Chinook spawn at culvert outlets, where gravel accumulates. There is potential to increase the spawning area by diverting or channelizing the flow.*

# HICKS CREEK

## LICENSED WATER DEMAND

Stream number 00-0700-070

Ungauged

Tributary to Maria Slough

Drainage Area = 8 km<sup>2</sup>

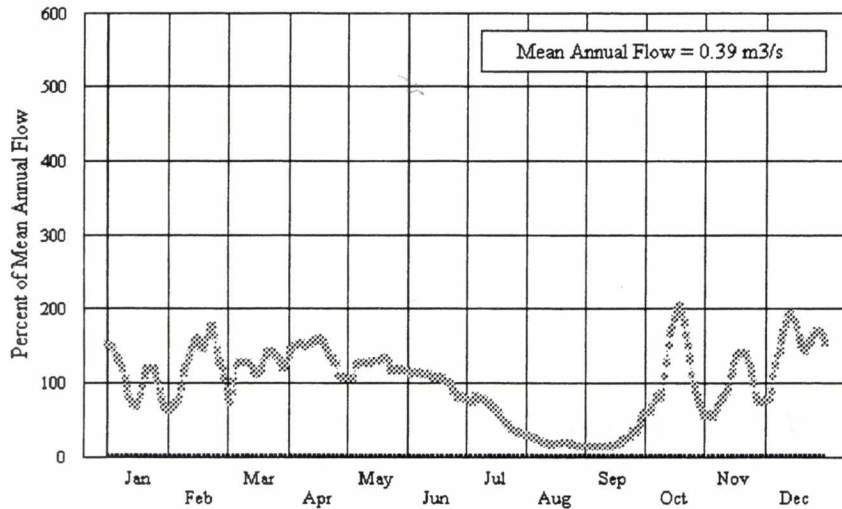
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		70	80

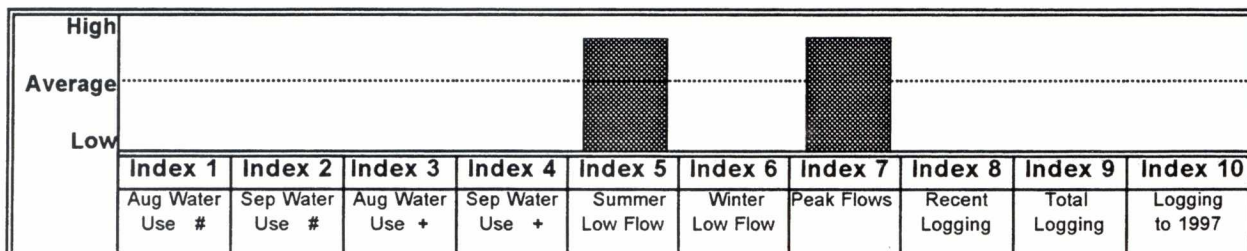
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# HICKS CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Hicks Creek flows from Hicks Lake into Maria Slough. Water removals for irrigation are quoted as a problem in the Stream Summary Catalogue but Water Rights Branch records show no licences on the creek.*

*2. The Salmon Enhancement Program constructed a groundwater spawning channel along Hicks Creek in 1985.*

# MAHOOD CREEK

## LICENSED WATER DEMAND

Stream number 00-0740  
 Ungauged  
 Tributary to the Fraser River

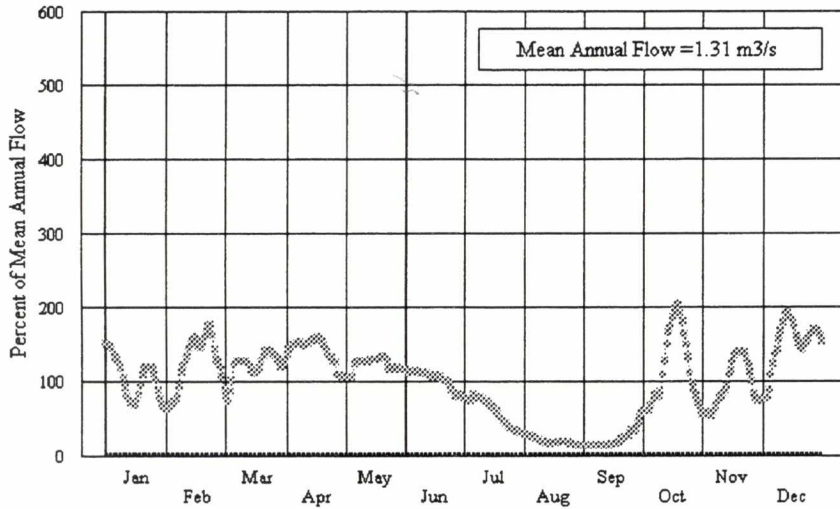
Drainage Area = 27 km<sup>2</sup>

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		250	260

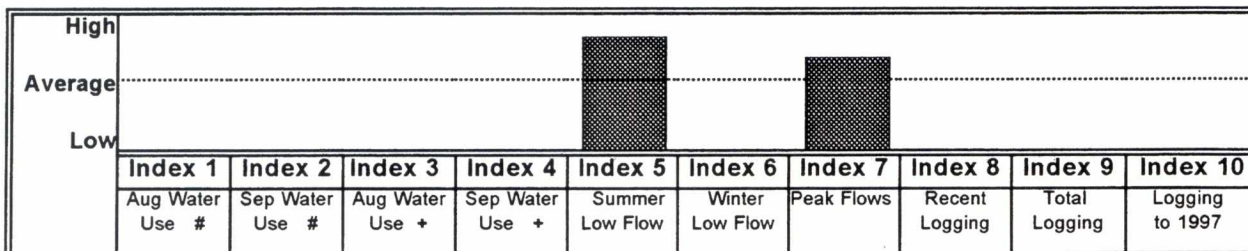
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# MAHOOD CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The Ministry of Forests silvicultural records show no harvesting on Crown Lands within the watershed but, apparently, there is some private logging. Flooding and erosion are the main problems in Mahood Creek but siltation is the main problem further downstream, in Johnson Slough.*

# RUBY CREEK

## LICENSED WATER DEMAND

Stream number 00-0750  
 Ungauged  
 Tributary to the Fraser River

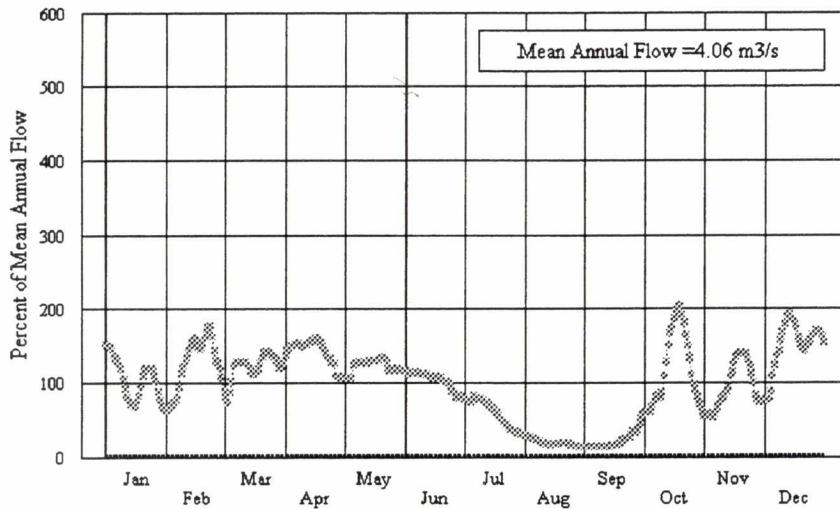
Drainage Area = 84 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,000 g/d	0.05	0.05	0.05
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	134,537 g/d	7.08	7.08	7.08
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		770	810

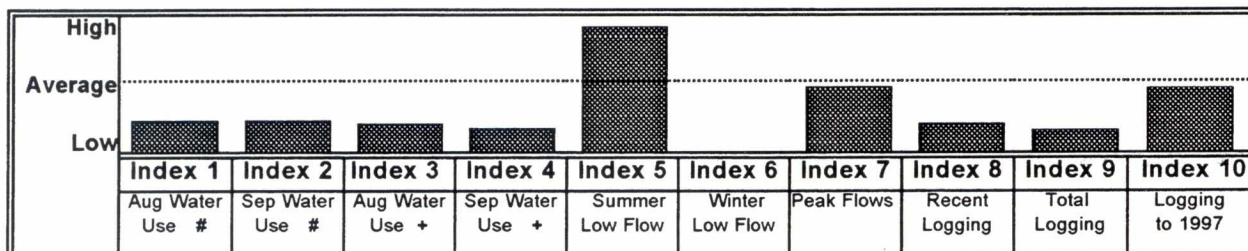
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# RUBY CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Ruby Creek is reported to have a flashy hydrograph. The Ministry of Forests silvicultural records show no logging on Crown Land prior to 1980, although the Stream Summary Catalogue identifies logging as a factor in gravel loss. About 400 hectares of logging is proposed under the current five year plan.*

*2. The Ruby Creek fan into the Fraser River has been expanding in recent years. Interest has been expressed in removing some of the gravel although the area is used for pink salmon spawning.*

# HARRISON RIVER

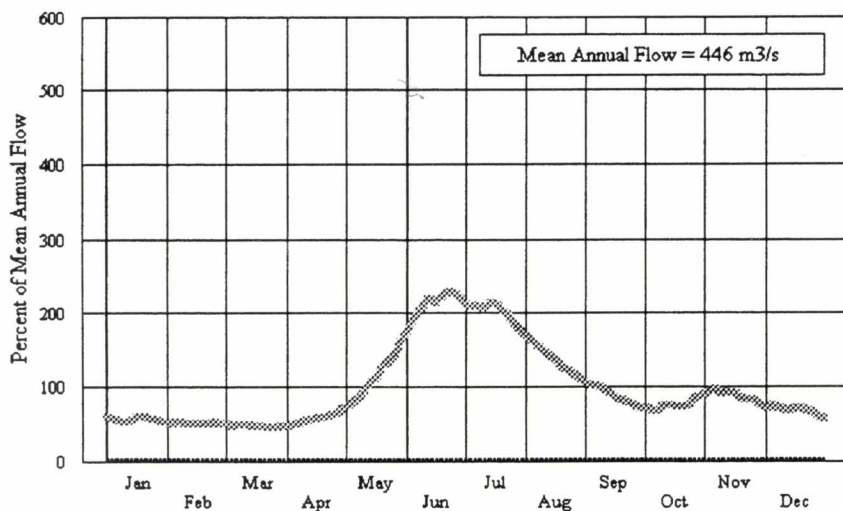
## LICENSED WATER DEMAND

Stream number 01-0000-000-000-000-000-993  
 Water Survey of Canada Station 08MG013  
 Harrison River near Harrison Hot Springs  
 Records 1951 to 1990  
 Drainage Area = 7,870 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	161,750 g/d	8.5	8.5	8.5
Irrigation	2,286 ac.ft.		316	163
Waterworks	4,993,500g/d	263	263	263
Industrial	3,018,031g/d	158.8	158.8	158.8
Conservation	10 cfs			

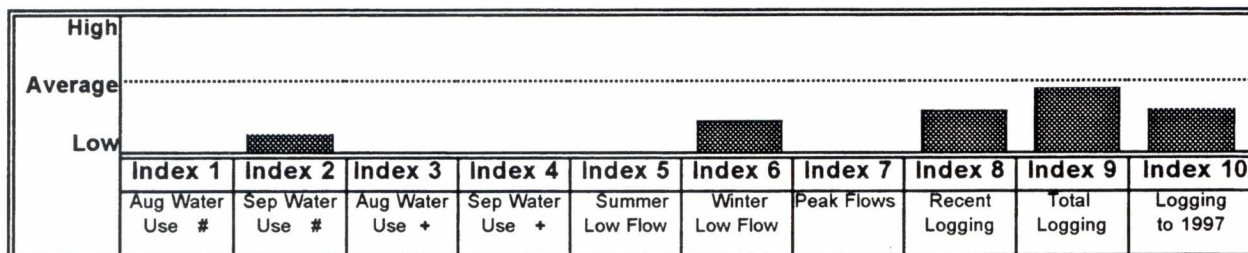
	Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>	230,000	603,000	391000

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

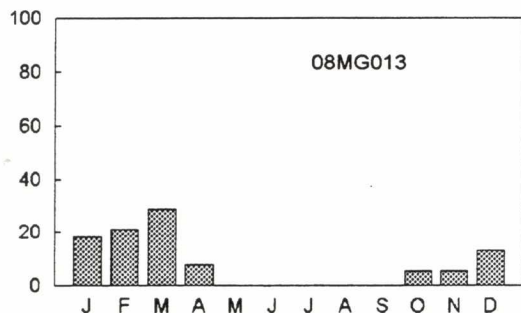
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



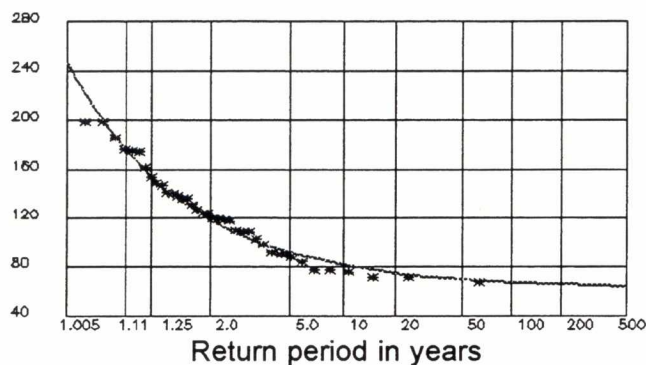
- # Water use as a proportion of the 7 day low flow
- + Water use as a proportion of the mean monthly flow for the same month

## 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>	118 m <sup>3</sup> /s	80.5 m <sup>3</sup> /s	74.1 m <sup>3</sup> /s	68.9 m <sup>3</sup> /s	66.4 m <sup>3</sup> /s
<b>Annual Flood</b>	1,260 m <sup>3</sup> /s	1,608 m <sup>3</sup> /s	1,725 m <sup>3</sup> /s	1,870 m <sup>3</sup> /s	1,965 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The Harrison River downstream of Harrison Lake is gravel bedded, straight and confined by bedrock through much of its course upstream of Chehalis Village.*
- 2. Harrison Rapids, at the Chehalis River confluence, provides an important control on water levels in the Harrison River at low flows. The lower portion of the river, which has spawning areas, has been dredged to maintain a navigation channel.*

# SQUAKUM CREEK

## LICENSED WATER DEMAND

Stream number 01-0100

Ungauged

Tributary to the Harrison River

Drainage Area = 7 km<sup>2</sup>

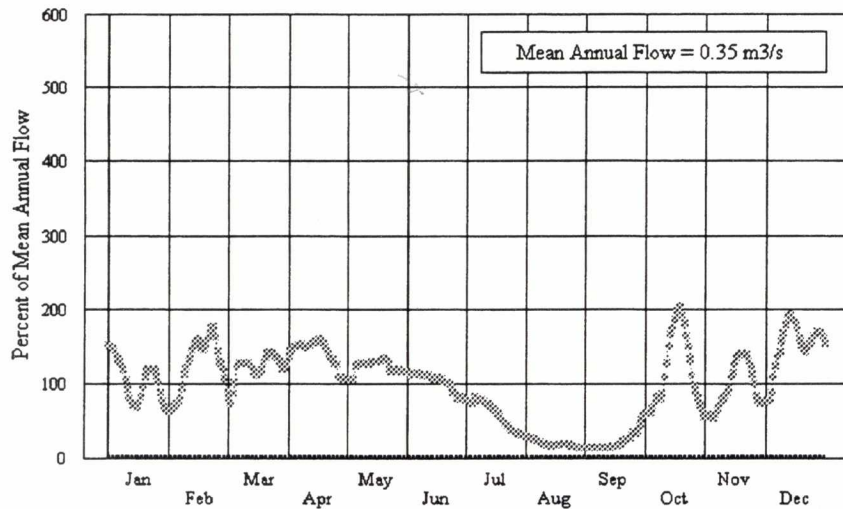
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		70	70

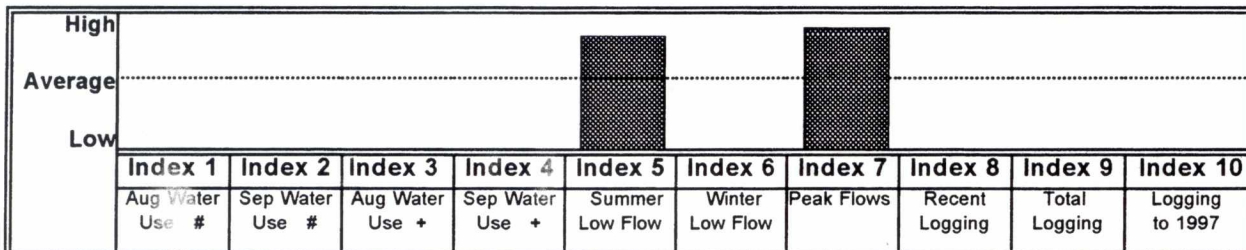
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# SQUAKUM CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Squakum Creek drains through Erroch Lake to Harrison Bay. Sewage discharge from septic fields for cottages and homes around the lake affect water quality.*

*2. The upper tributaries to Erroch Lake move large quantities of sediment and debris. The lower portions of some of these tributaries are channelized to prevent flooding.*

*3. The Stream Summary Catalogue reports critical low flows downstream of Erroch Lake.*

# CHEHALIS RIVER

## LICENSED WATER DEMAND

Stream number 01-0400

Water Survey of Canada Station 08MG001

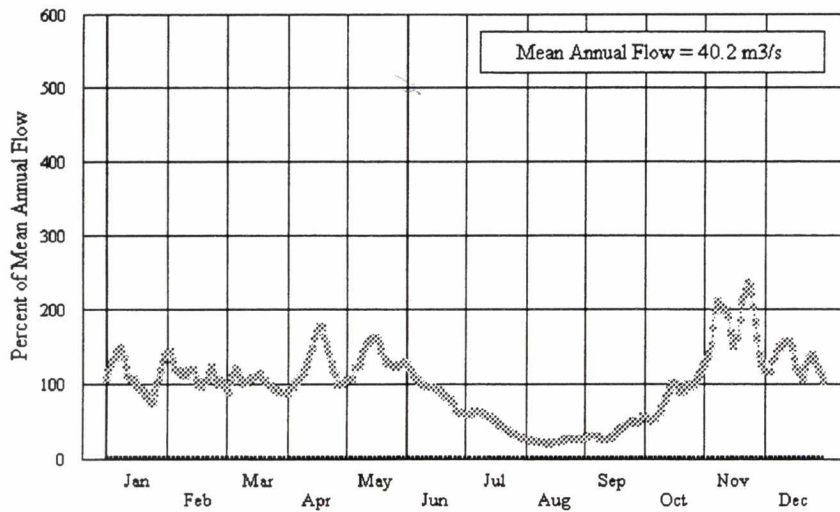
Chehalis River near Harrison Mills

Records 1911 to 1990

Drainage Area = 383 km<sup>2</sup>

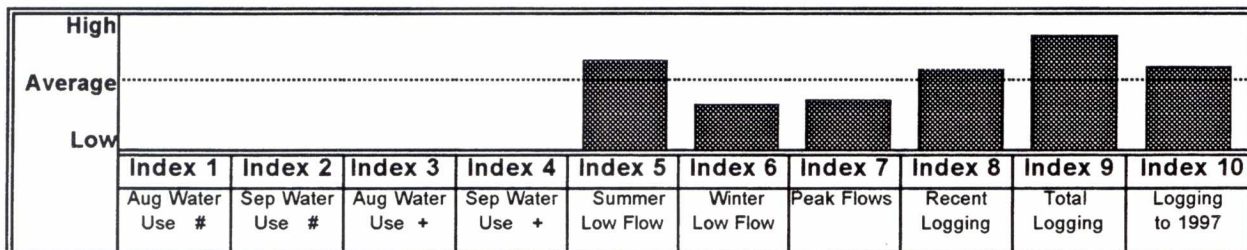
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	65 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>		<b>45,200</b>	<b>9,080</b>	<b>13,800</b>

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

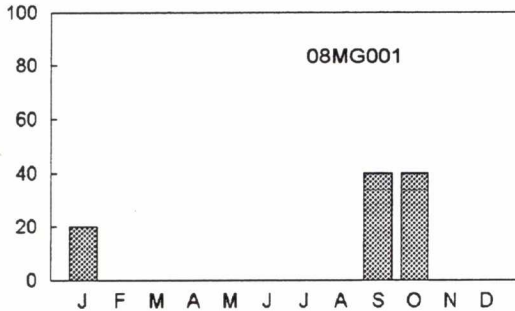


# Water use as a proportion of the 7 day low flow

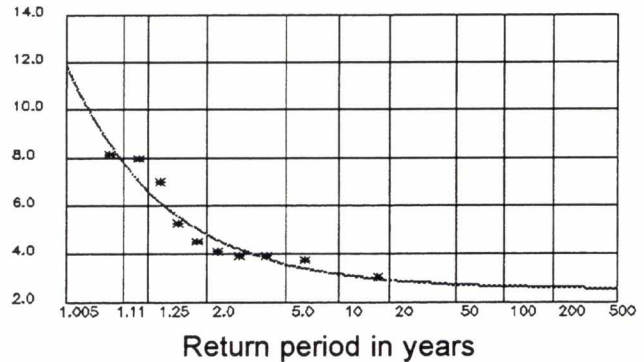
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	4.8 m <sup>3</sup> /s	3.1 m <sup>3</sup> /s	2.9 m <sup>3</sup> /s	2.7 m <sup>3</sup> /s	2.6 m <sup>3</sup> /s
<b>Annual Flood</b>	322 m <sup>3</sup> /s	604 m <sup>3</sup> /s	719 m <sup>3</sup> /s	873 m <sup>3</sup> /s	993 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The Chehalis River is laterally and vertically unstable with a history of abrupt channel changes on its fan. The river has increased its width and sinuosity since the 1940's, which is consistent with slow aggradation of the channel bed. Dykes have been built to protect various areas from flooding, including the Chehalis Hatchery.*

*2. The Department of Fisheries and Oceans regularly removes gravel in order to maintain a channel leading to the hatchery. During low flows, much of the water is lost through the thick gravels of the channel bed so that gravel removals are needed to maintain a surface flow. Upstream losses of water to Smokehouse Slough also affect low flows.*

# PRETTY CREEK

## LICENSED WATER DEMAND

Stream number 01-0400-020  
 Ungauged  
 Tributary to the Chehalis River

Drainage Area = 9 km<sup>2</sup>

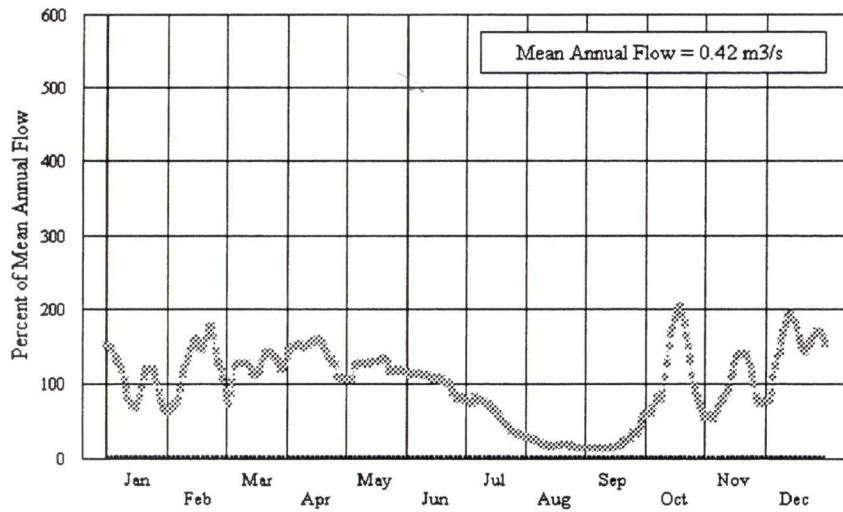
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	10,000 g/d	0.53	0.53	0.53
Conservation	0 cfs			
		Feb	Aug	Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		80	80

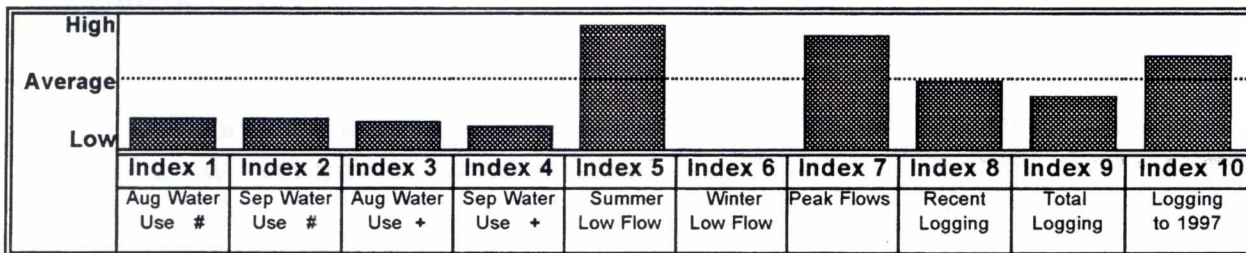
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# PRETTY CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Pretty Creek appears to be a flashy stream. It has a low summer flow index, and the annual flood flow is 25 times higher than the mean annual flow.*

# COHO CREEK

## LICENSED WATER DEMAND

Stream number 01-0400-080

Ungauged

Tributary to the Chehalis River

Drainage Area = 9 km<sup>2</sup>

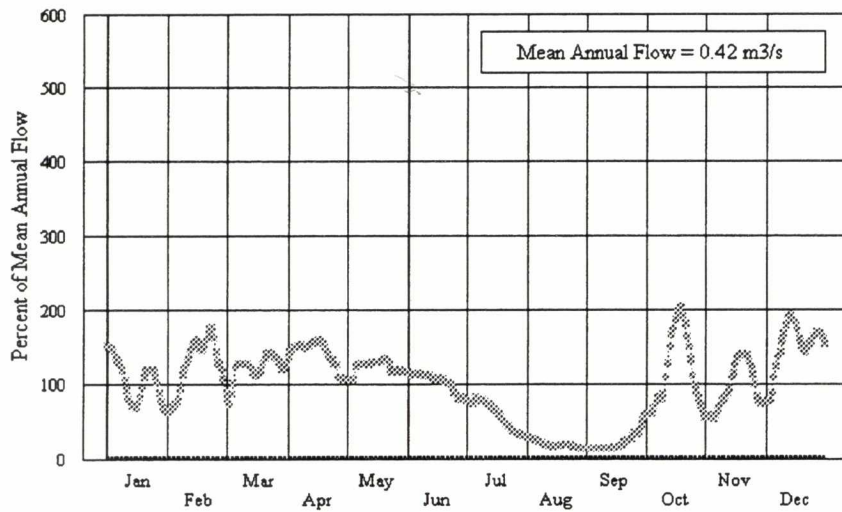
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		80	80

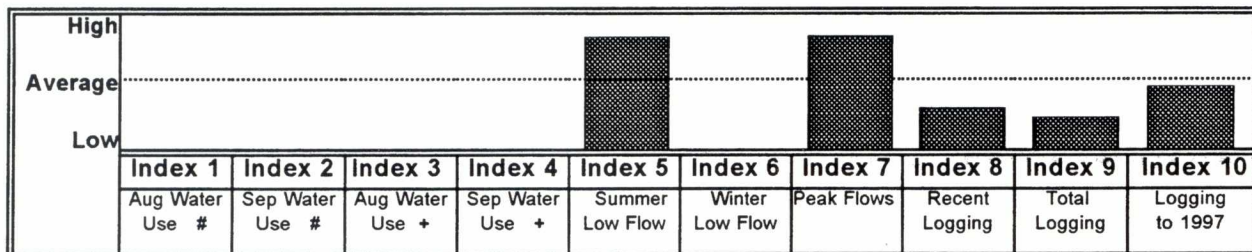
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# COHO CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Coho Creek was reportedly logged prior to 1963 but there is no record of this in the Ministry of Forests silvicultural records.*

*2. The Salmon Enhancement Program has constructed a groundwater fed channel in the upper part of the creek.*

*3. Summer flows are considered to be stable because they are groundwater derived, although the Stream Summary Catalogue reports rearing limitations due to low flows.*

# MORRIS CREEK

## LICENSED WATER DEMAND

Stream number 01-0500

Ungauged

Tributary to the Harrison River

Drainage Area = 52 km<sup>2</sup>

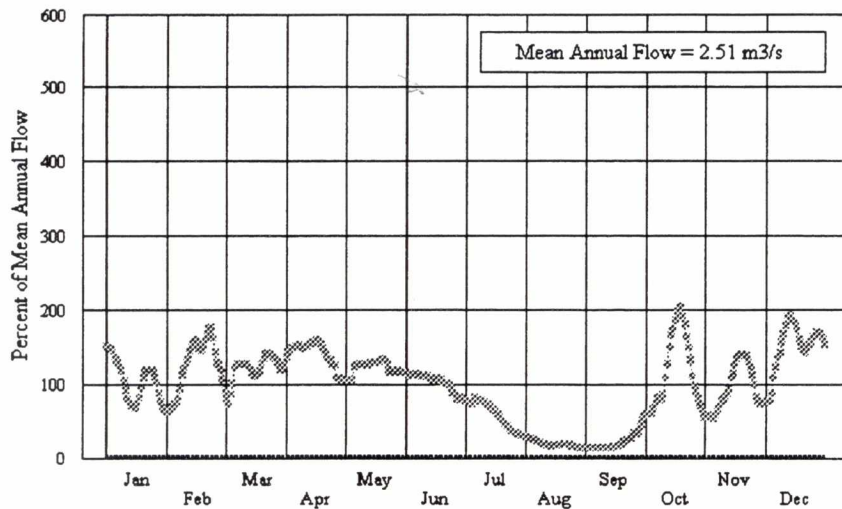
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	101,000 g/d	5.31	5.31	5.31
Irrigation	0 ac.ft.			
Waterworks	191,400 g/d	10.07	10.07	10.07
Industrial	500 g/d	0.03	0.03	0.03
Conservation	40 cfs			
		Feb	Aug	Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		480	500

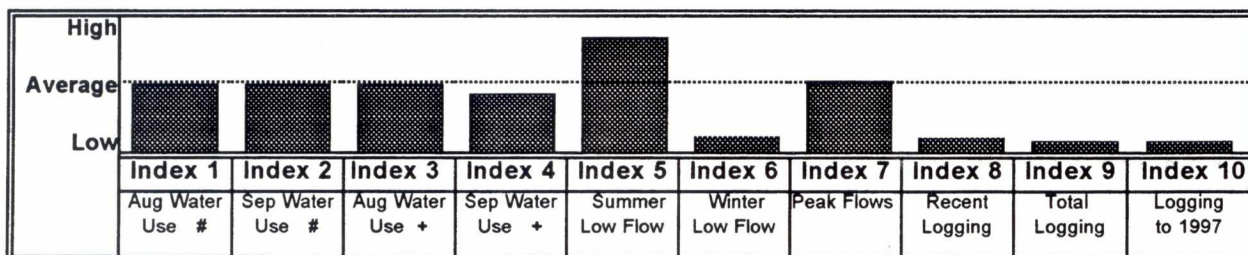
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# MORRIS CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Morris Creek is more of a slough that has been used as a log dump. Indices indicate relatively heavy water use and low summer flows.*

# WEAVER CREEK

## LICENSED WATER DEMAND

Stream number 01-0500-010

Water Survey of Canada Station 08MG009

Weaver Creek near Harrison Hot Springs

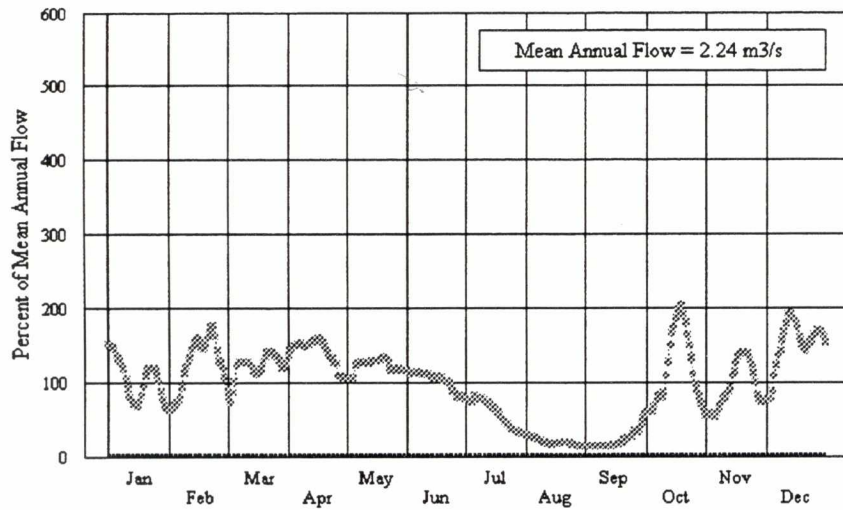
Records 1946 to 1964

Drainage Area = 42.2 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,500 g/d	0.08	0.08	0.08
Irrigation	0 ac.ft.			
Waterworks	191,400 g/d	10.1	10.1	10.1
Industrial	500 g/d	0.03	0.03	0.03
Conservation	40 cfs			

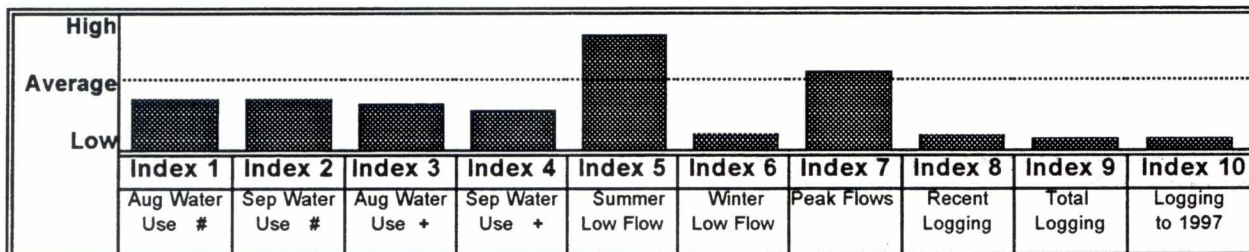
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	3,670	427	446

## 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

# WEAVER CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There has been a heavy input of gravel and logging debris into Weaver Creek from logging operations and the Hemlock Valley Ski Resort development. The creek downstream of Hudon Bridge has been dredged annually for a number of years in order to maintain access to the Weaver Creek Spawning Channel. An upstream debris basin was designed in 1988 to keep sediment from the spawning channel but it has not been built.*

*2. The spawning channel uses water stored in Weaver Lake and diverted from Sakwi Creek. The spawning channel flows tend to augment low flows in Weaver Creek when the spawning channel is operating, but Weaver Creek still has a low flow problem: apparently, it was dry during the 1952 drought.*

# STEELHEAD CREEK

## LICENSED WATER DEMAND

Stream number 01-0500-010-005

Ungauged

Tributary to Weaver Creek

Drainage Area = 4 km<sup>2</sup>

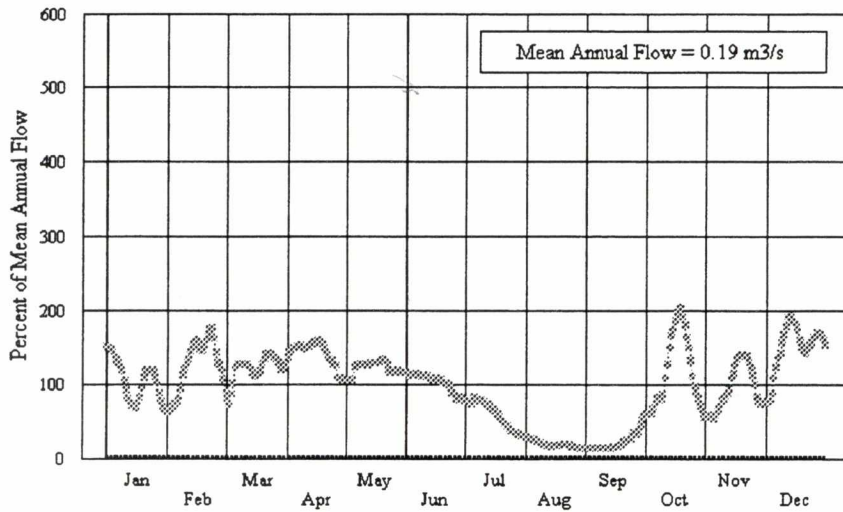
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		40	40

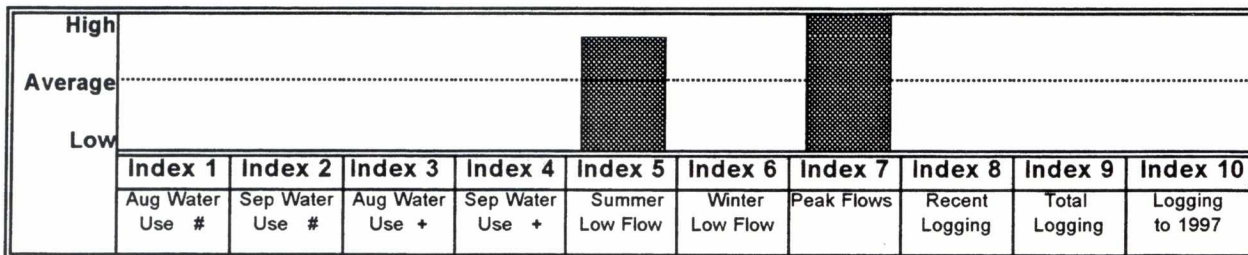
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# STEELHEAD CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is no record of logging or water licensing on Steelhead Creek. It appears to be a flashy stream with low summer low flows and a high ratio of annual flood flow to the mean annual flow.*

# SAKWI CREEK

## LICENSED WATER DEMAND

Stream number 01-0500-010-010  
 Ungauged  
 Tributary to Weaver Creek

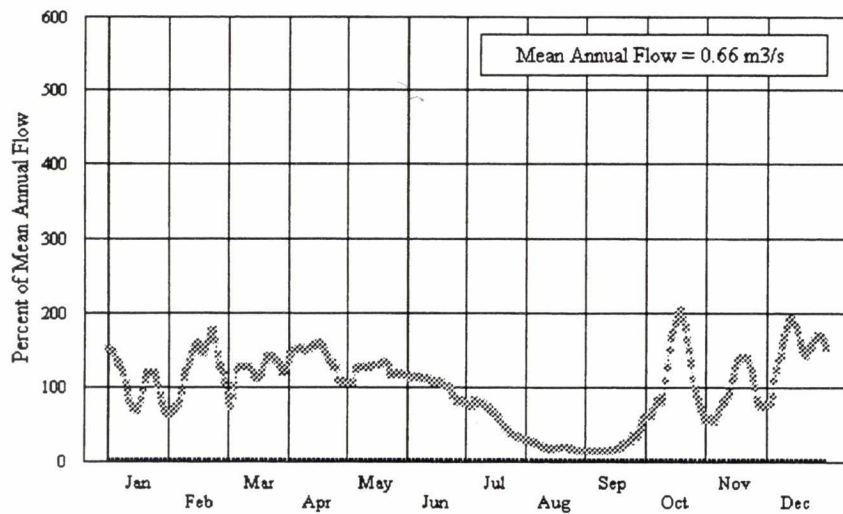
Drainage Area = 14 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	15 ac.ft.		2.07	1.07
Waterworks	191,400 g/d	10.07	10.07	10.07
Industrial	0 g/d			
Conservation	20 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		130	130

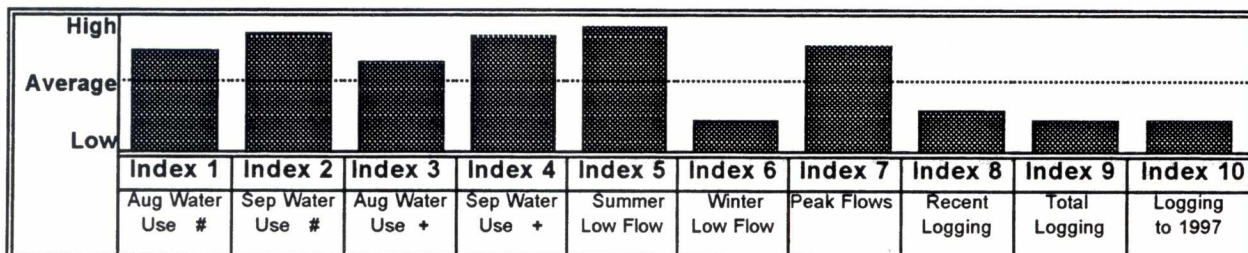
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# SAKWI CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Sakwi Creek is the main tributary of Weaver Creek, entering Weaver Creek upstream of the Weaver Creek spawning channel. Logging operations in the Sakwi Creek Watershed and the Hemlock Valley Ski Resort development have caused a heavy input of gravel and logging debris into Sakwi and Weaver Creeks.*

*2. Some of the water used by the Weaver Creek spawning channel is diverted from Sakwi Creek.*

# EAST CREEK

## LICENSED WATER DEMAND

Stream number 01-0500-015

Ungauged

Tributary to Morris Creek

Drainage Area = 6 km<sup>2</sup>

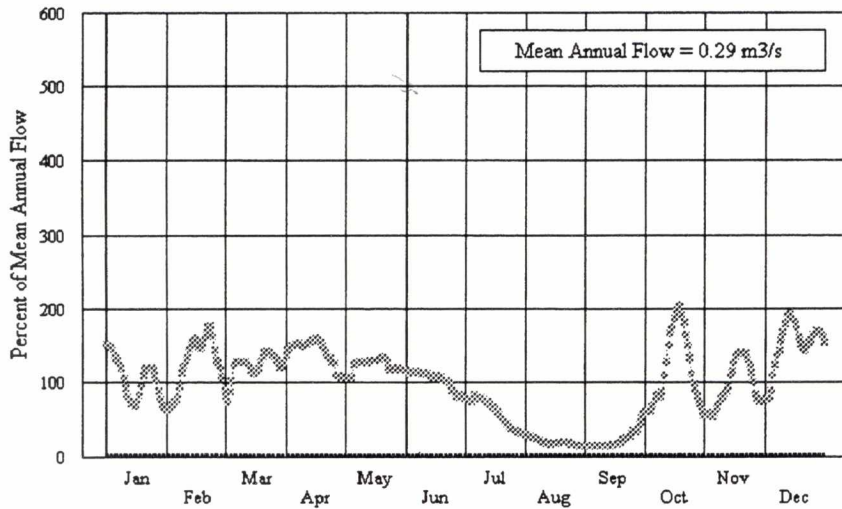
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		50	60

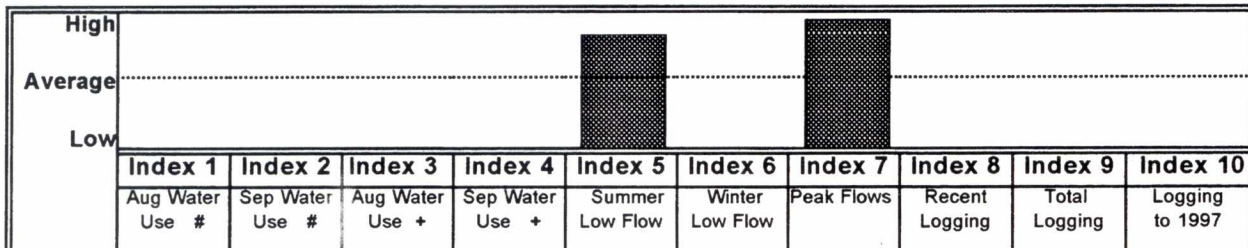
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# EAST CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. East Creek has a very small watershed of only 6 sq.km. that is not logged. The creek is flashy, with relatively severe low summer flows and high peak flows.*

# MIAMI CREEK

## LICENSED WATER DEMAND

Stream number 01-0600  
 Ungauged  
 Tributary to the Harrison River

Drainage Area = 19 km<sup>2</sup>

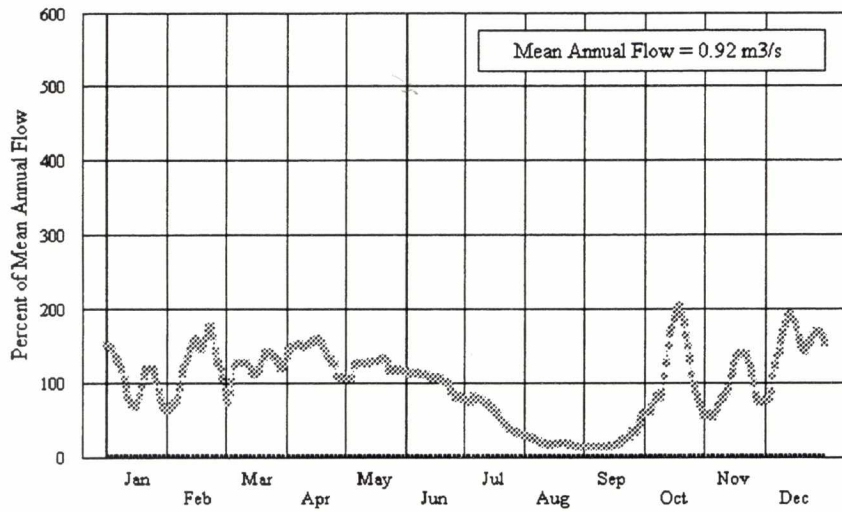
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2,000 g/d	0.10	0.10	0.10
Irrigation	3 ac.ft.		0.41	0.21
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		250	340

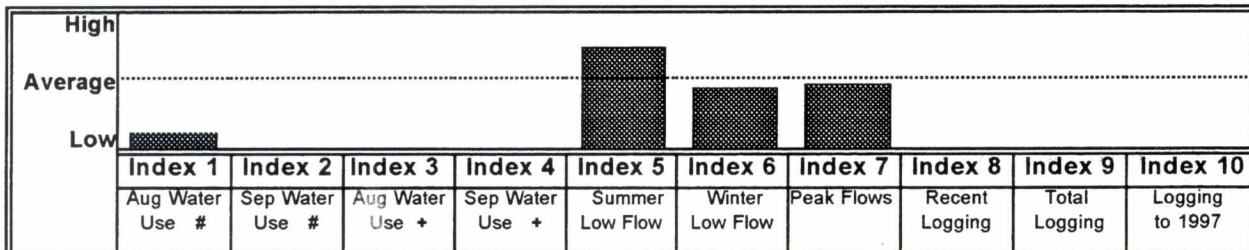
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# MIAMI CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. A new flood box on Miami Creek lowered the outlet by about one metre, allowing fish in for the first time in many years. There is a lack of riparian vegetation and the upper section, in an agricultural area, is treated as a ditch.*

*2. The Village of Harrison wishes to maintain high water levels in the lower part of the creek for water based recreation. Nutrients from agricultural activity have caused chronic weed growth; removal has been attempted by a floating mechanical cutter.*

# TROUT LAKE CREEK

## LICENSED WATER DEMAND

Stream number 01-0700  
 Ungauged  
 Tributary to the Harrison River

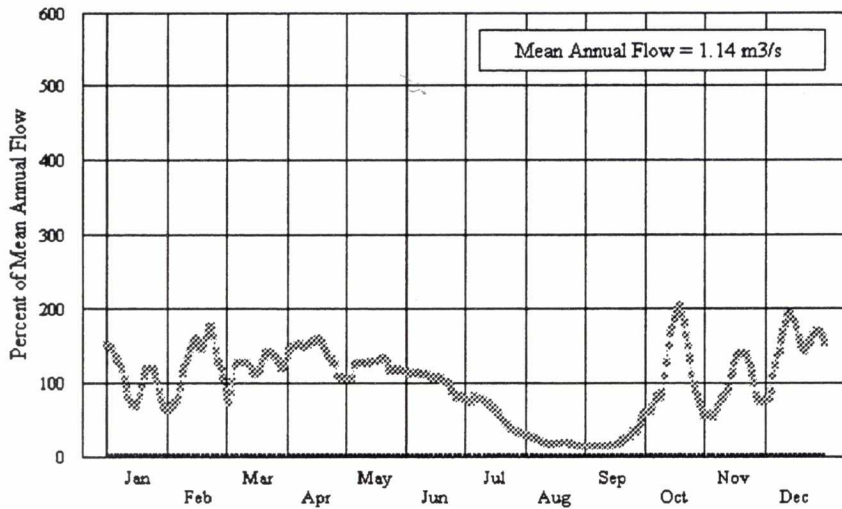
Drainage Area = 24 km<sup>2</sup>

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	743,000 g/d	39.1	39.1	39.1
Conservation	0 cfs			

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		100	70

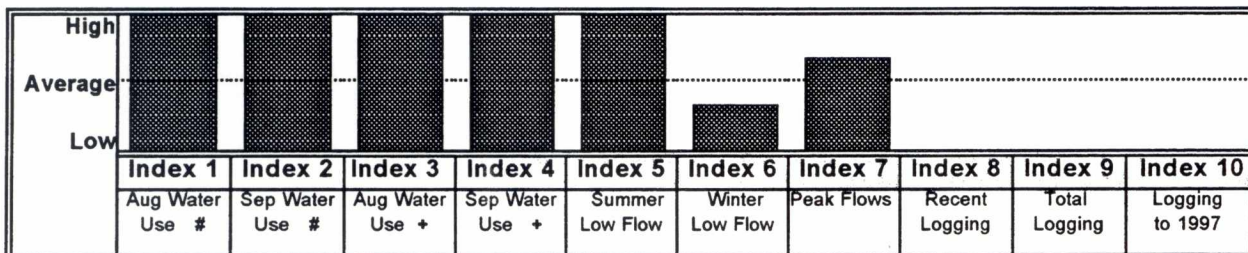
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# TROUT LAKE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Trout Lake Creek moves a large bedload; the channel is aggrading and the delta is building up. One of the upper tributaries is prone to debris flows.*
- 2. The Ministry of Transportation and Highways regularly remove gravel from beneath their bridge.*
- 3. The lower reach of Trout Lake Creek is encroached upon by a subdivision. The setbacks are insufficient; some walls have been built to floodproof residential properties.*

# MYSTERY CREEK

## LICENSED WATER DEMAND

Stream number 01-1500

Ungauged

Tributary to the Harrison River

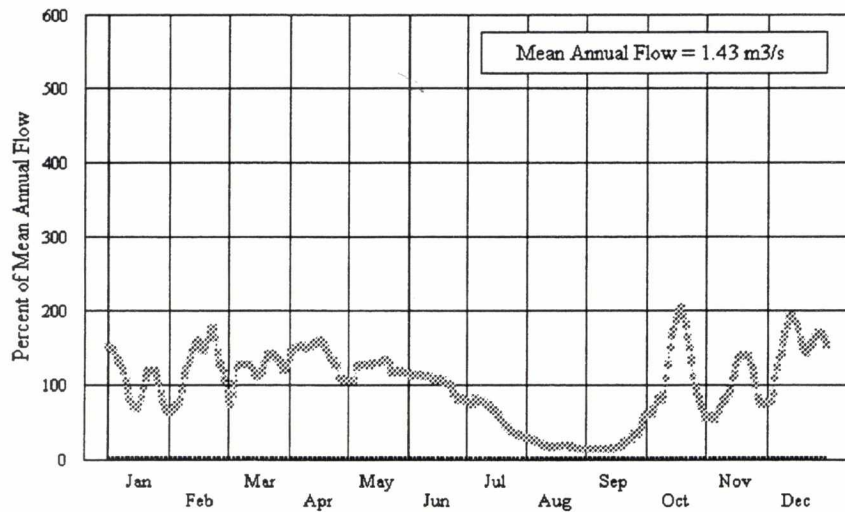
Drainage Area = 30 km<sup>2</sup>

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
		270	280

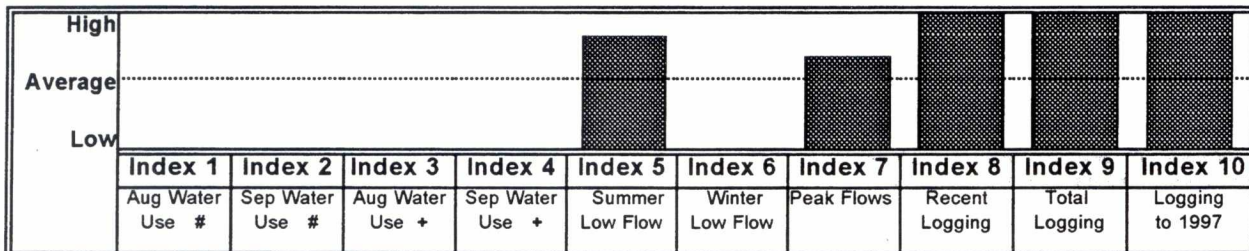
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# MYSTERY CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Mystery Creek is heavily logged. Forty-six percent of the watershed has been recently logged and 75% is proposed. Summer low flows are relatively severe.*

# COGBURN CREEK

## LICENSED WATER DEMAND

Stream number 01-1600

Ungauged

Tributary to the Harrison River

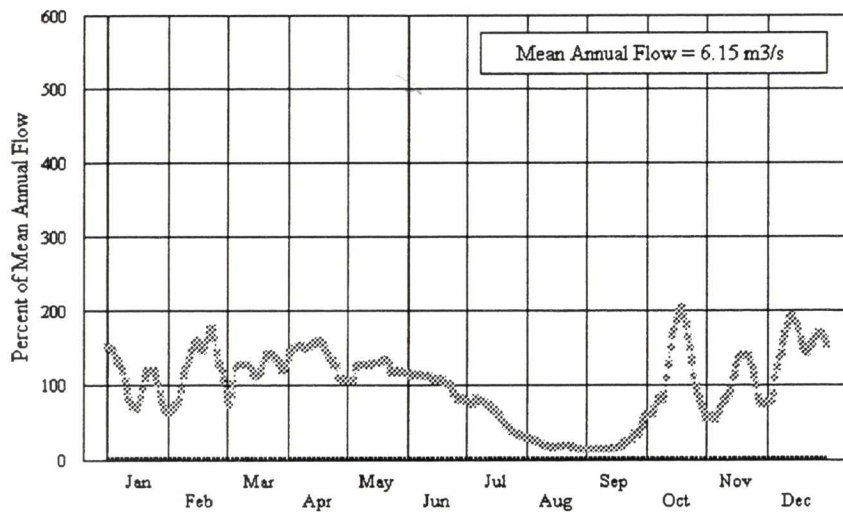
Drainage Area = 203 km<sup>2</sup>

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
		6,220	3,770

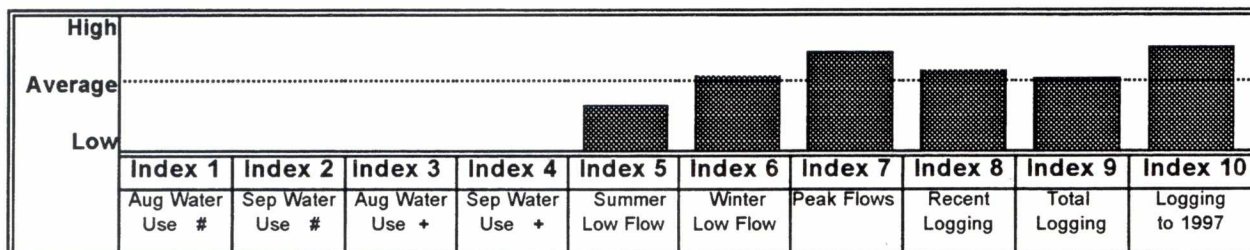
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# COGBURN CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is no water demand on Cogburn Creek but there is a moderate amount of logging, with 11% proposed.*

# TWENTY MILE CREEK

## LICENSED WATER DEMAND

Stream number 01-1700

Ungauged

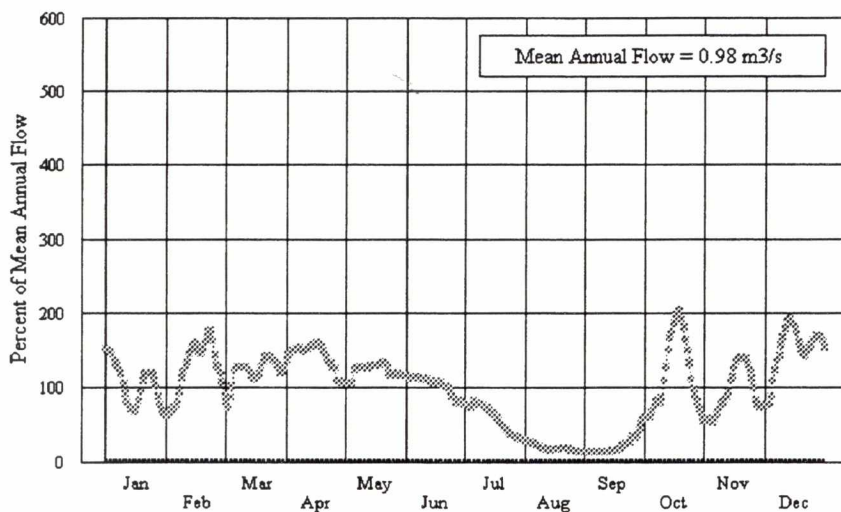
Tributary to the Harrison River

Drainage Area = 20 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>			190	190

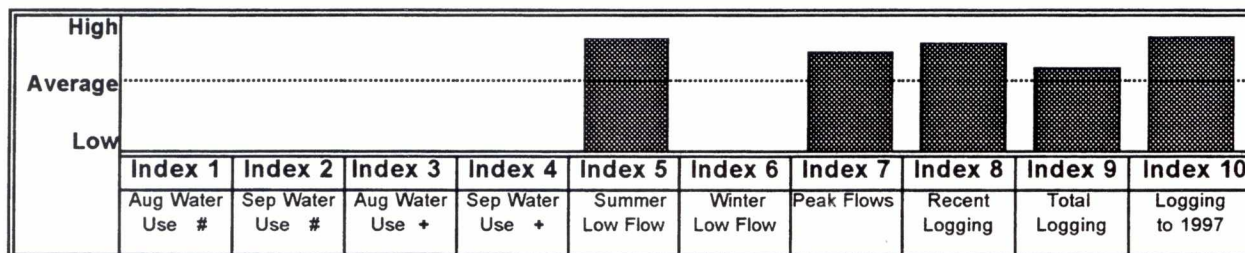
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Weaver Creek station 08MG009)



## 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

# TWENTY MILE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Twenty Mile Creek transports large quantities of coarse gravel onto its fan. The Ministry of Transportation and Highways regularly cleans debris from under their bridge.*

# BIG SILVER CREEK

## LICENSED WATER DEMAND

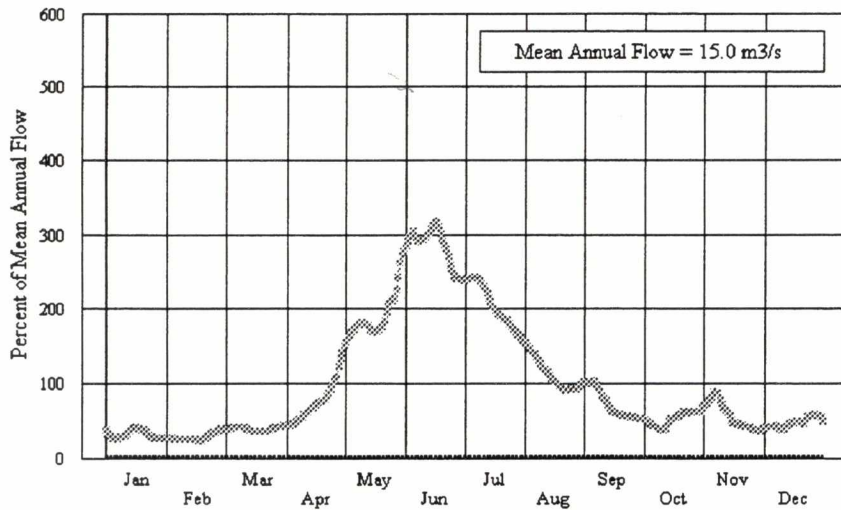
Stream number 01-1800  
 Ungauged  
 Tributary to the Harrison River

Drainage Area = 495 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>			15,160	9,190

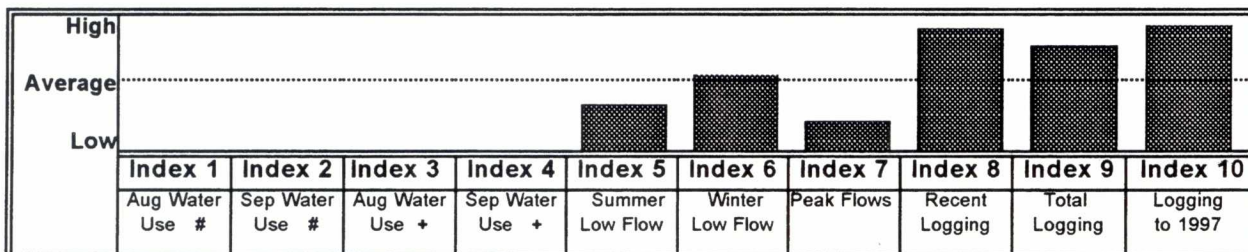
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Nahatlatch River station 08MF065)



## SENSITIVITY INDICES

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



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

# BIG SILVER CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The right channel of Big Silver Creek has been recently enhanced. The main flow was diverted from the left channel, where the substrate is very poor, to the right channel, where the substrate is good spawning gravel.*
- 2. The forest companies are wanting to extend their operations down into the lower watershed, along the main channel of Big Silver Creek, but the Department of Fisheries and Oceans is opposed.*

# STOKKE CREEK

## LICENSED WATER DEMAND

Stream number 01-2300

Ungauged

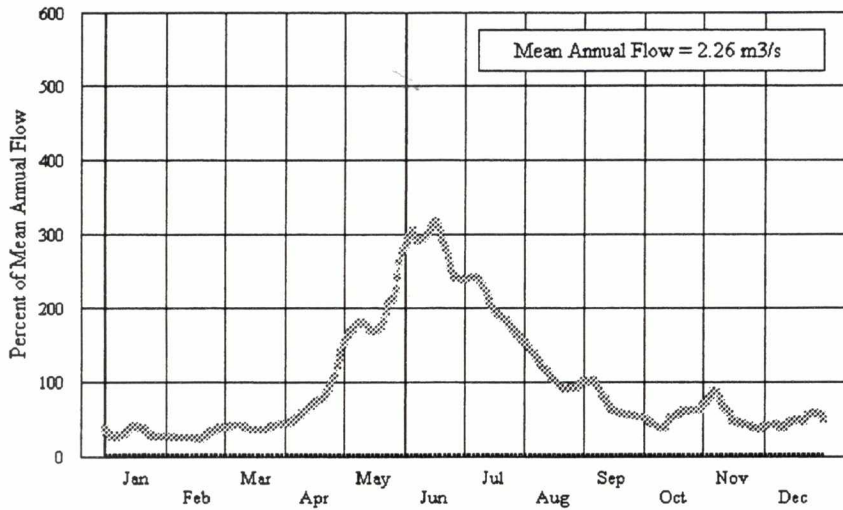
Tributary to the Harrison River

Drainage Area = 75 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			2,290	1,390

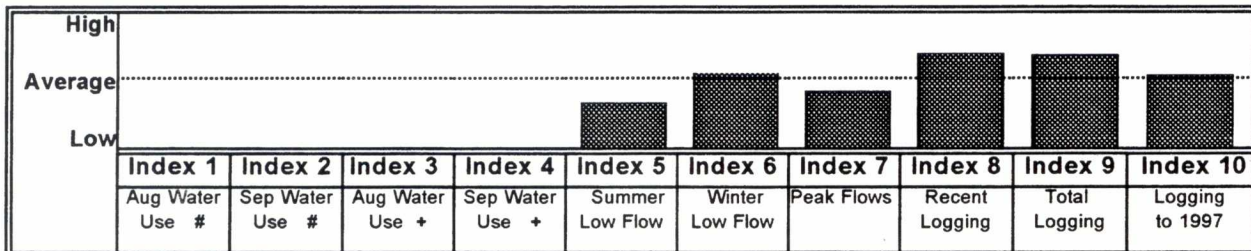
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Nahatlatch River station 08MF065)



## SENSITIVITY INDICES

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



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

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

# STOKKE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is no water demand on Stokke Creek and only moderate logging, with 8% proposed.*

# TIPELLA CREEK

## LICENSED WATER DEMAND

Stream number 01-2500

Ungauged

Tributary to the Harrison River

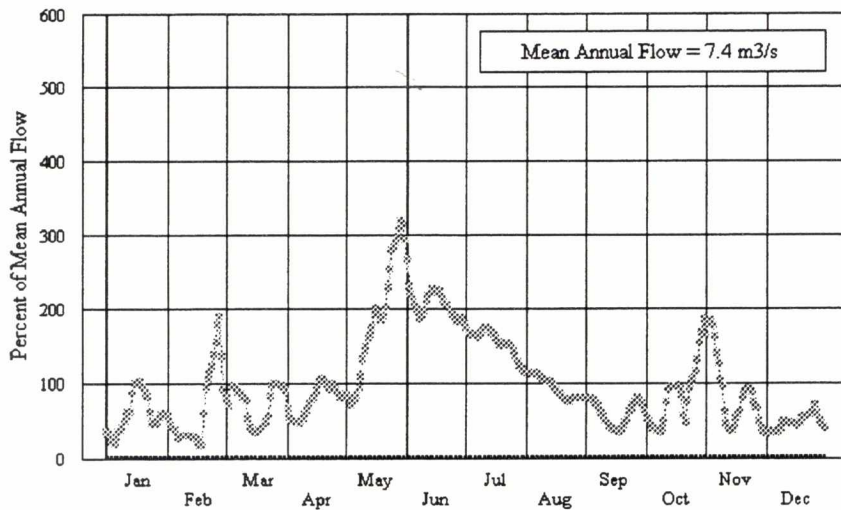
Drainage Area = 63 km<sup>2</sup>

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
		580	600

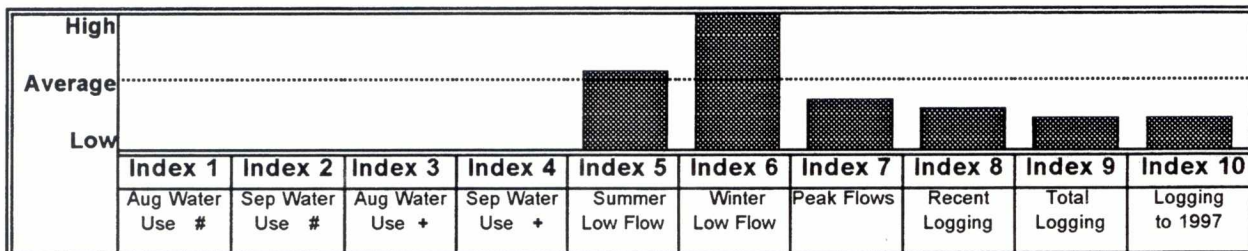
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Stave River station 08MH147)



## 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

# TIPELLA CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is no water demand and only a small amount of recent logging on Tipella Creek. Winter low flows seem to be severe.*

# DOUGLAS CREEK

## LICENSED WATER DEMAND

Stream number 01-2600

Ungauged

Tributary to the Harrison River

Drainage Area = 101 km<sup>2</sup>

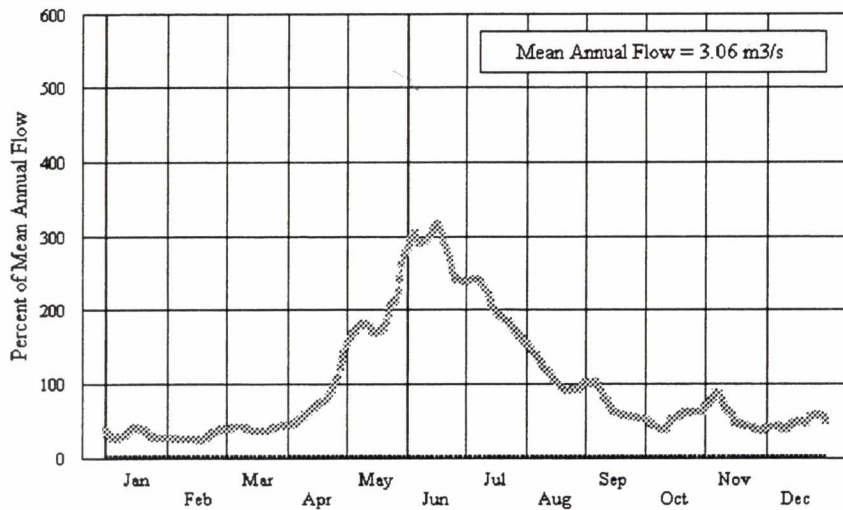
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		3,100	1,880

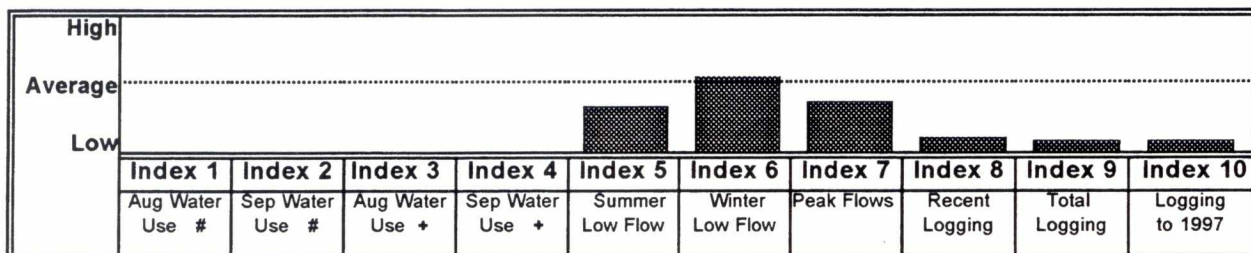
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Nahatlatch River station 08MF065)



## SENSITIVITY INDICES

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



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

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

# DOUGLAS CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The lower section of Douglas Creek has been channelized; otherwise there appears to be little development; only one percent of the watershed has been logged.*

# PURCELL CREEK

## LICENSED WATER DEMAND

Stream number 01-2650

Ungauged

Tributary to the Harrison River

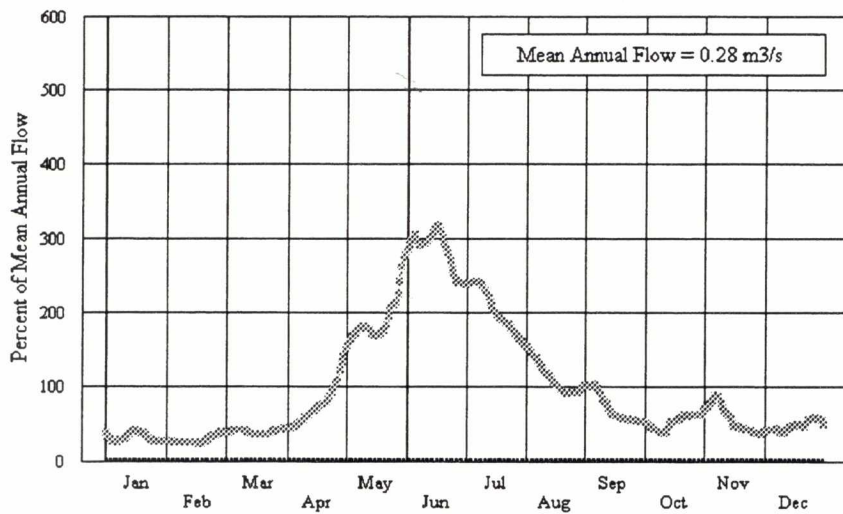
Drainage Area = 9 km<sup>2</sup>

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>		280	170

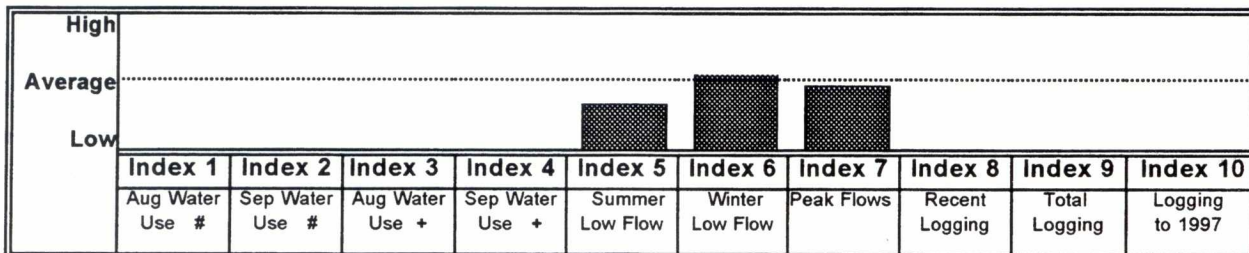
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Nahatlatch River station 08MF065)



## SENSITIVITY INDICES

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



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

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

# PURCELL CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is no water demand or logging in the small watershed, 9 sq. km., of Purcell Creek. There are also no severe hydrological problems.*

# LILLOOET RIVER

## LICENSED WATER DEMAND

Stream number

Ungauged

Tributary to the Fraser River

Drainage Area = 6,109 km<sup>2</sup>

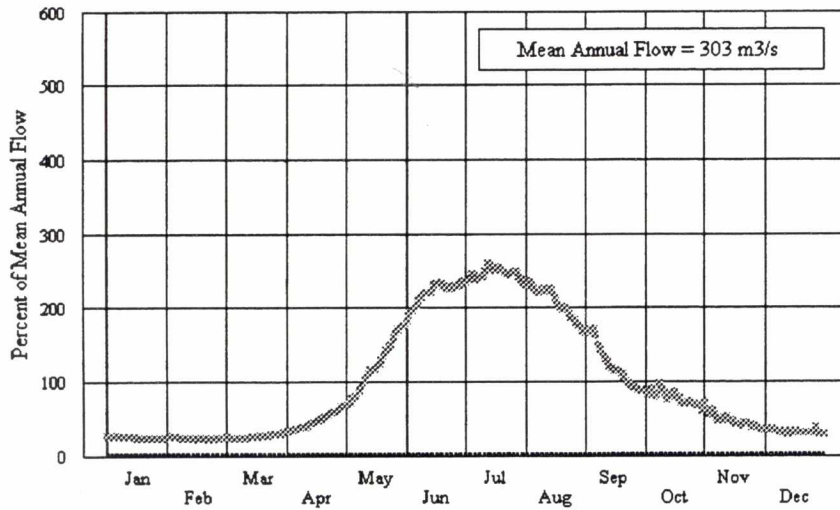
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	120,500 g/d	6.34	6.34	6.34
Irrigation	2,283 ac.ft.		315.5	108.6
Waterworks	4,978,500g/d	262.0	262.0	262.0
Industrial	2,098,532g/d	110.4	110.4	110.4
Conservation	10 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		534,790	309040

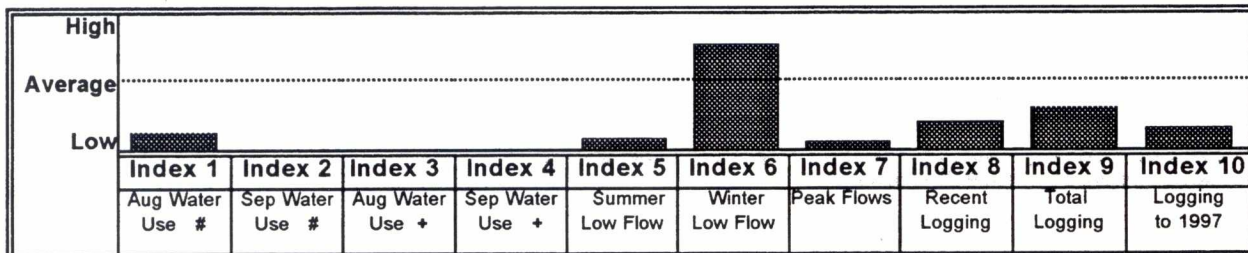
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Upper Lillooet River station 08MG005)



## 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

# LILLOOET RIVER

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The Lillooet River has been modified to reduce flood problems. Following a major flood in 1940, a program of channel straightening was undertaken. The Lillooet River above Ryan River was moved over to the left side of the valley and shortened by about 17 kilometres.*
- 2. Gravel accumulation along the Lillooet River is a problem. Public and private operations regularly remove gravel from the main river and its tributaries.*

# SLOQUET CREEK

## LICENSED WATER DEMAND

Stream number 01-2700

Ungauged

Tributary to the Lower Lillooet River

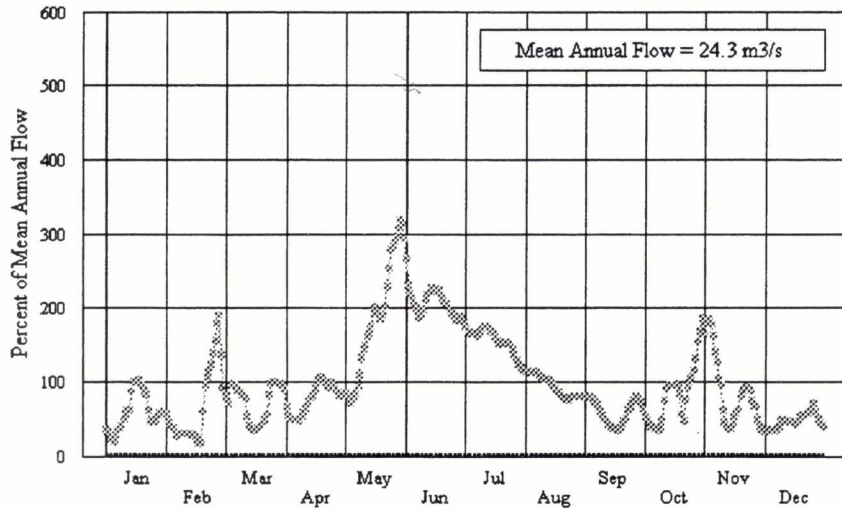
Drainage Area = 206 km<sup>2</sup>

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</b>	<b>L/S</b>		22,170	15,460

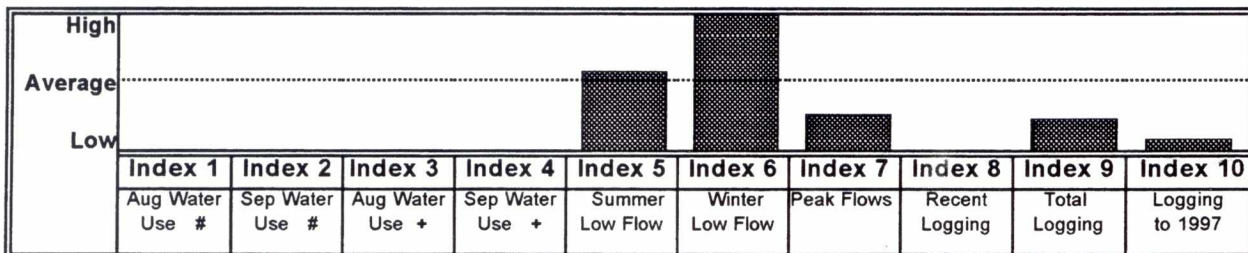
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Stave River station 08MH147)



## 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

# SLOQUET CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Although there is no water demand and very little logging, 1% proposed, on Sloquet Creek, winter low flows are considered to be severe.*

# LILLOOET RIVER

(UPPER)

Stream number 01-0000-000-000-000-992  
 Water Survey of Canada Station 08MG005  
 Lillooet River near Pemberton  
 Records 1914 to 1990  
 Drainage Area = 2,160 km<sup>2</sup>

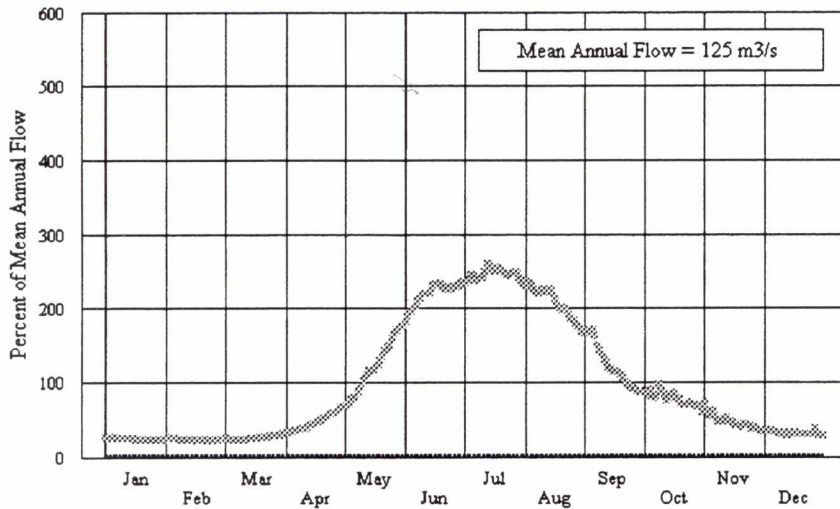
## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	12,500 g/d	0.66	0.66	0.66
Irrigation	2,003 ac.ft.		277	95
Waterworks	0 g/d			
Industrial	1,085,798g/d	57.1	57.1	57.1
Conservation	0 cfs			

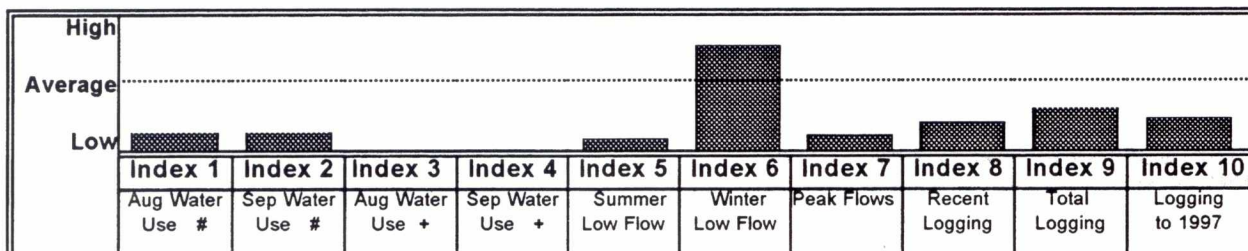
MEAN STREAM FLOW L/S	Feb	Aug	Sep
	29,700	262,000	156000

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

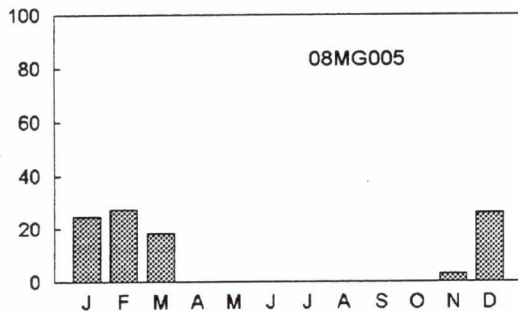
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



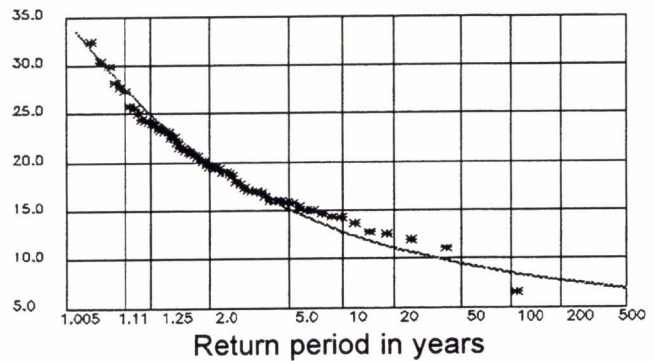
- # Water use as a proportion of the 7 day low flow
- + Water use as a proportion of the mean monthly flow for the same month

## 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>	19.9 m <sup>3</sup> /s	12.8 m <sup>3</sup> /s	11.0 m <sup>3</sup> /s	9.3 m <sup>3</sup> /s	8.4 m <sup>3</sup> /s
<b>Annual Flood</b>	505 m <sup>3</sup> /s	722 m <sup>3</sup> /s	828 m <sup>3</sup> /s	992 m <sup>3</sup> /s	1,133 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The Lillooet River has been modified to reduce flood problems. Following a major flood in 1940, a program of channel straightening was undertaken. The Lillooet River above Ryan River was moved over to the left side of the valley and shortened by about 17 kilometres.*
- 2. Gravel accumulation along the Lillooet River is a problem. Public and private operations regularly remove gravel from the main river and its tributaries.*

# BIRKENHEAD RIVER

## LICENSED WATER DEMAND

Stream number 01-4100

Water Survey of Canada Station 08MG008

Birkenhead River at Mount Currie

Records 1945 to 1971

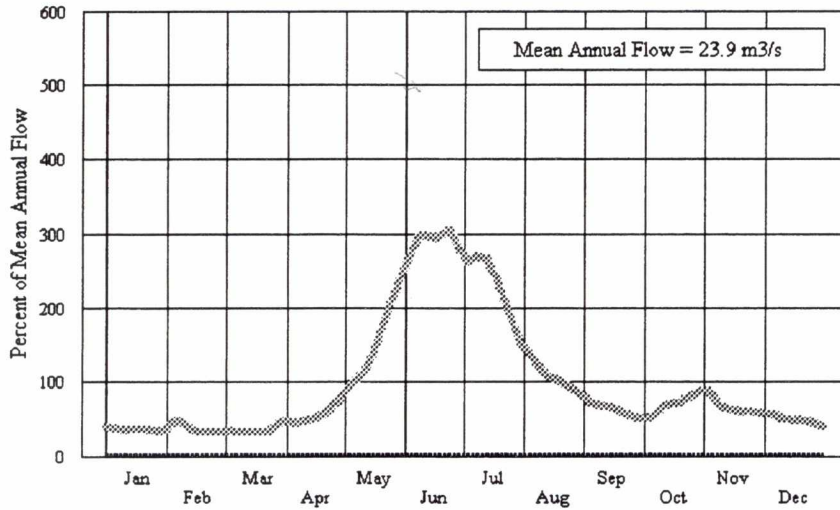
Drainage Area = 596 km<sup>2</sup>

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

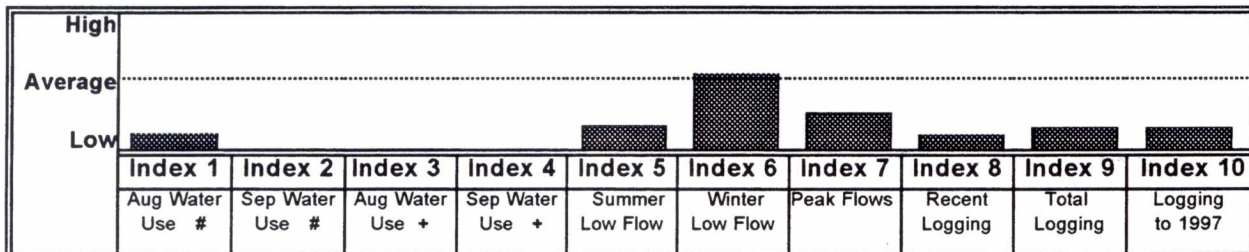
MEAN STREAM FLOW L/S	8,290	25,200	15900
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## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

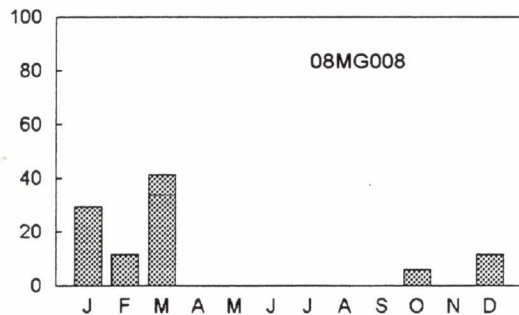


# Water use as a proportion of the 7 day low flow

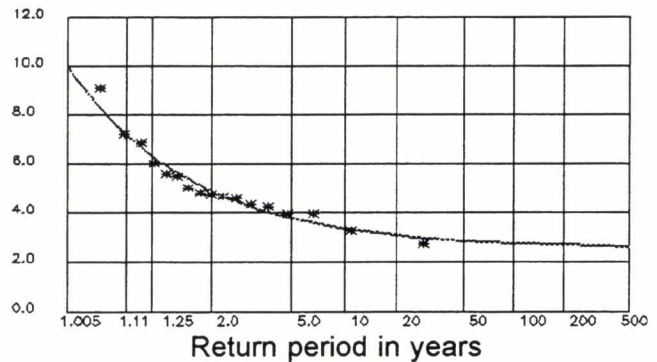
+ Water use as a proportion of the mean monthly flow for the same month

## 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>	4.88 m <sup>3</sup> /s	3.34 m <sup>3</sup> /s	3.07 m <sup>3</sup> /s	2.84 m <sup>3</sup> /s	2.74 m <sup>3</sup> /s
<b>Annual Flood</b>	107 m <sup>3</sup> /s	191 m <sup>3</sup> /s	239 m <sup>3</sup> /s	321 m <sup>3</sup> /s	400 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Although there are a number of water licences on the Birkenhead River, the water demand appears to be not a problem during the summer. Winter low flows, however, are moderately severe.*

*2. Culverts under the railway may be blocking fish access to the tributaries.*

# POOLE CREEK

## LICENSED WATER DEMAND

Stream number 01-4100-070  
 Ungauged  
 Tributary to Birkenhead River

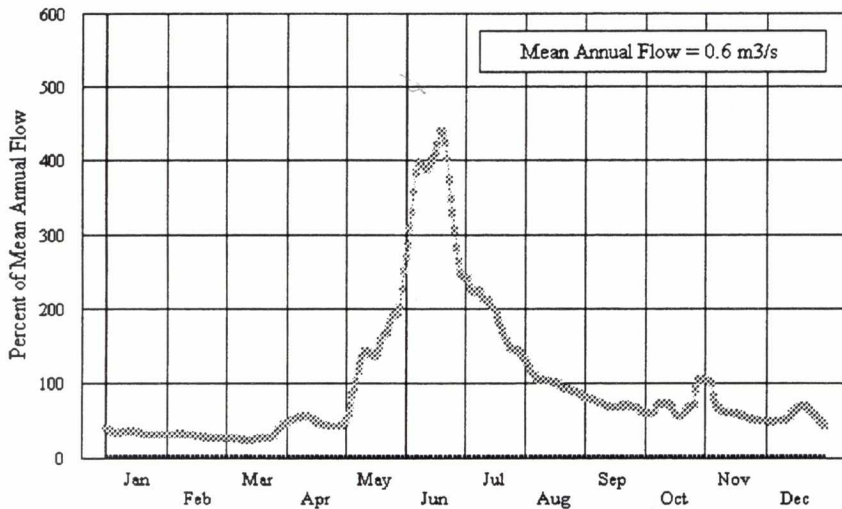
Drainage Area = 29 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	3,000 g/d	0.16	0.16	0.16
Irrigation	15 ac.ft.		1.73	0.71
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		690	360

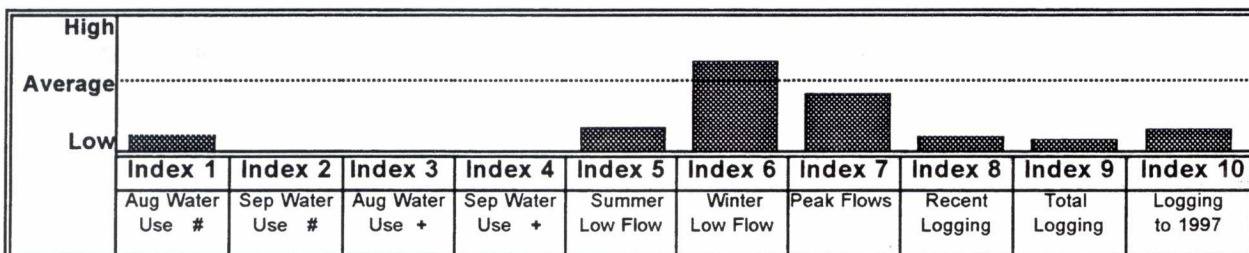
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Gates River station 08ME002)



## 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

# POOLE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is a small water demand and some logging, 2% proposed, on Poole Creek. Winter low flows are moderately severe.*

# GREEN RIVER

## LICENSED WATER DEMAND

Stream number 01-4300

Water Survey of Canada Station 08MG003

Green River near Pemberton

Records 1913 to 1951

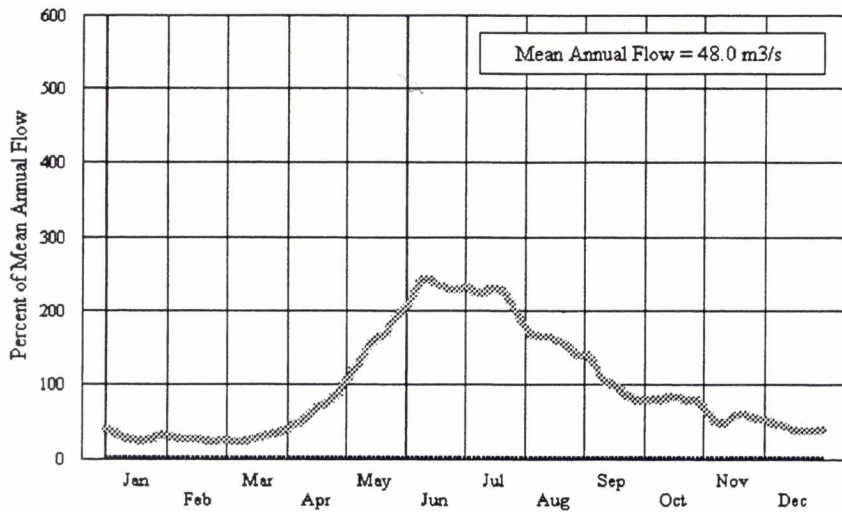
Drainage Area = 855 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	5,000 g/d	0.26	0.26	0.26
Irrigation	0 ac.ft.			
Waterworks	4,491,500g/d	236	236	236
Industrial	597,600 g/d	31.4	31.4	31.4
Conservation	0 cfs			

Feb Aug Sep

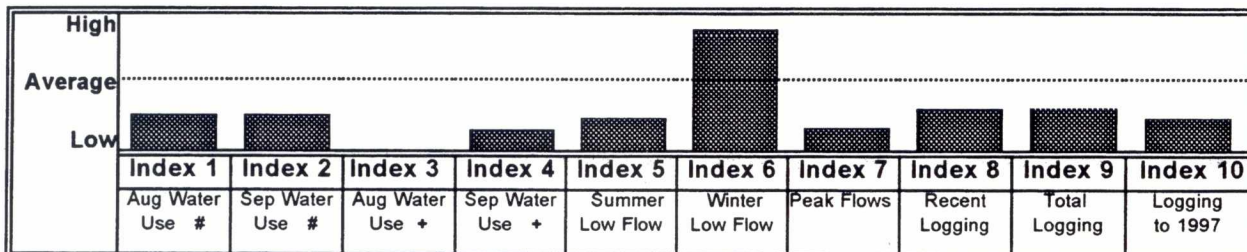
MEAN STREAM FLOW L/S	12,800	75,500	49,200
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## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

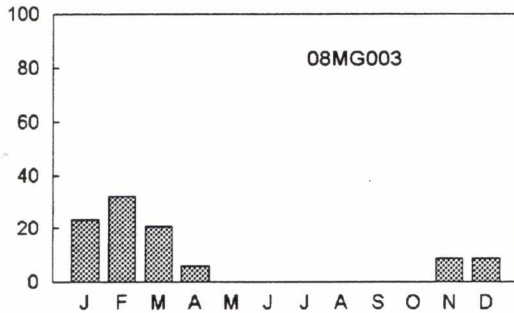


# Water use as a proportion of the 7 day low flow

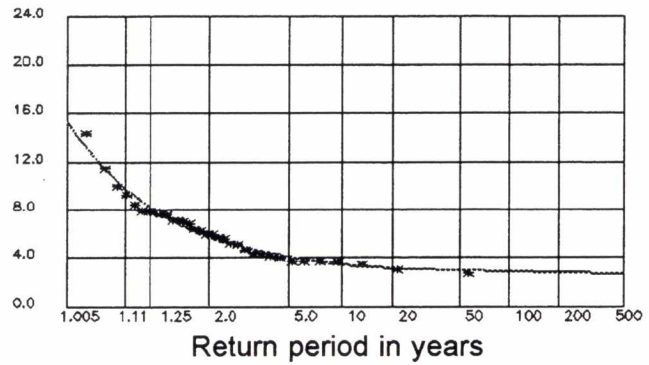
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	5.7 m <sup>3</sup> /s	3.4 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
<b>Annual Flood</b>	196 m <sup>3</sup> /s	275 m <sup>3</sup> /s	314 m <sup>3</sup> /s	375 m <sup>3</sup> /s	429 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Green River is the largest tributary to the upper Lillooet River. The lower reaches spread out into several distributary channels before joining the Lillooet River. In this region is the Balaclava golf course development and the potential for industrial and housing expansion which could affect the river.*

# PEMBERTON CREEK

## LICENSED WATER DEMAND

Stream number 01-4400

Water Survey of Canada Station 08MG025

Pemberton Creek near Pemberton

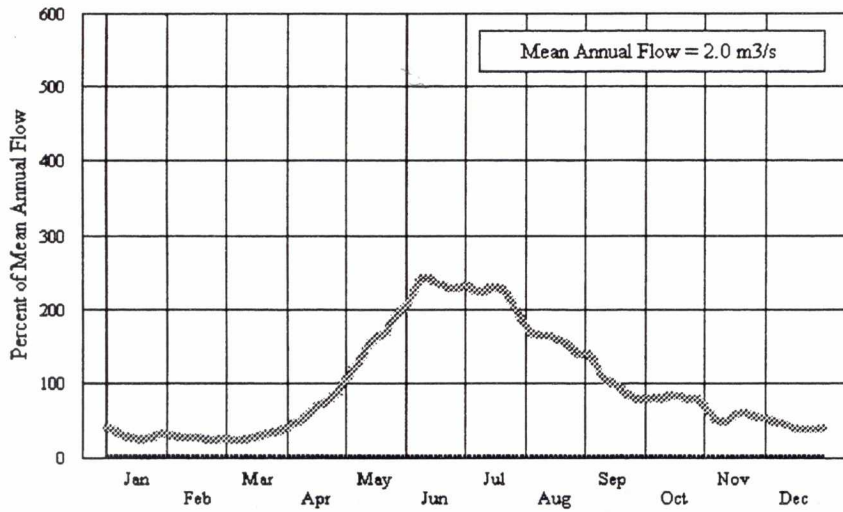
Records 1987 to 1990

Drainage Area = 31.9 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	280,000 g/d	14.7	14.7	14.7
Industrial	1,076,298g/d	56.6	56.6	56.6
Conservation	0 cfs			

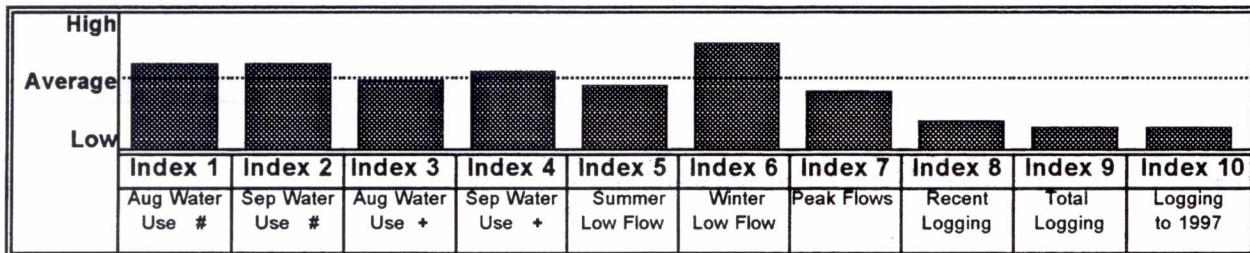
	Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>	266	2,300	1,530

## 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

# PEMBERTON CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Pemberton Creek is channelized and there is conflict between DFO and some of the land owners over flood control and erosion protection.*

# MILLER CREEK

## LICENSED WATER DEMAND

Stream number 01-4500

Ungauged

Tributary to the Upper Lillooet River

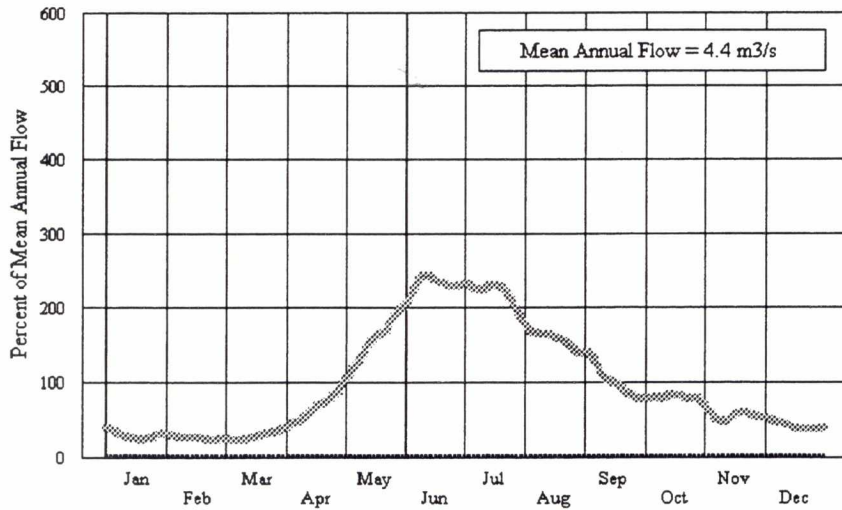
Drainage Area = 74 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2,000 g/d	0.10	0.10	0.10
Irrigation	200 ac.ft.		23.00	9.52
Waterworks	0 g/d			
Industrial	1,500 g/d	0.08	0.08	0.08
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		6,000	3,700

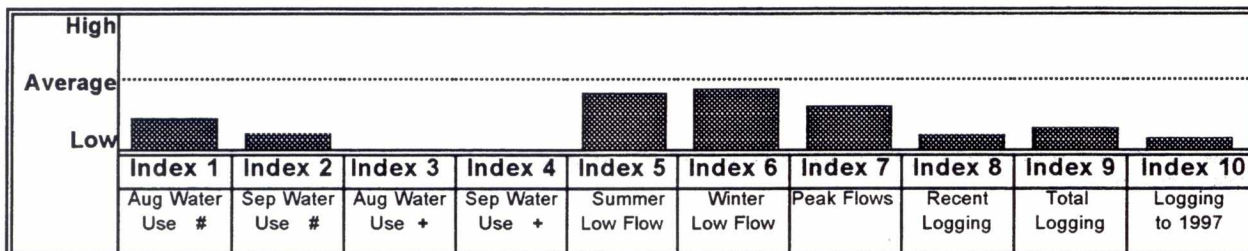
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Green River station 08MG003)



## 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

# MILLER CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Miller Creek is dyked where it crosses its fan. It is reported to be generally stable, but the dyke was overtopped during the 1984 flood.*

# RYAN RIVER

## LICENSED WATER DEMAND

Stream number 01-4600

Ungauged

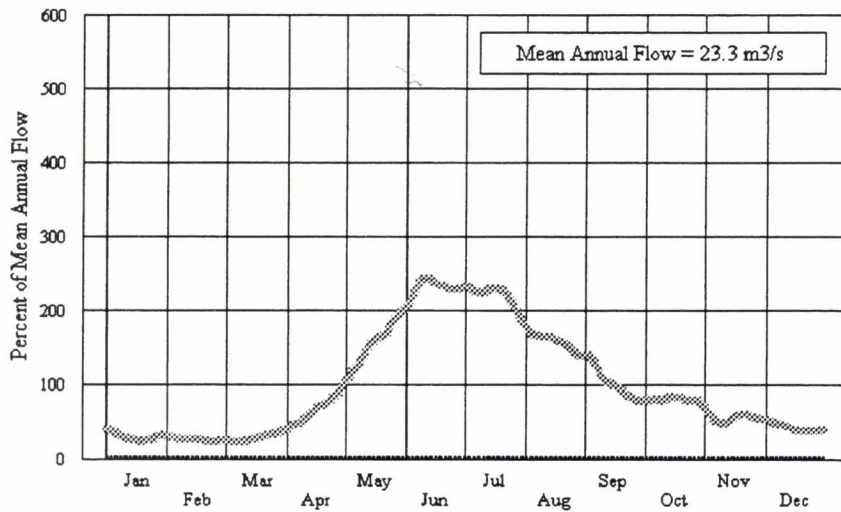
Tributary to the Upper Lillooet River

Drainage Area = 397 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2,000 g/d	0.10	0.10	0.10
Irrigation	90 ac.ft.		10.36	4.28
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
<b>MEAN STREAM FLOW L/S</b>			32,000	19,800

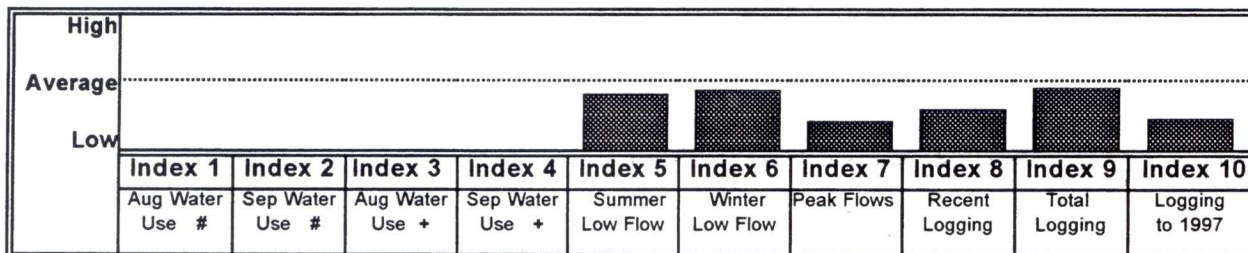
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Green River station 08MG003)



## 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

# RYAN RIVER

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The upper Ryan River carries large quantities of coarse debris which has resulted in the development of a small fan where the river enters the Pemberton Valley. In addition, two small creeks entering the Ryan River downstream of the fan are subject to debris torrents which cause flooding and changes in the course of the river.*

# RAILROAD CREEK

## LICENSED WATER DEMAND

Stream number 01-5000

Ungauged

Tributary to the Upper Lillooet River

Drainage Area = 30 km<sup>2</sup>

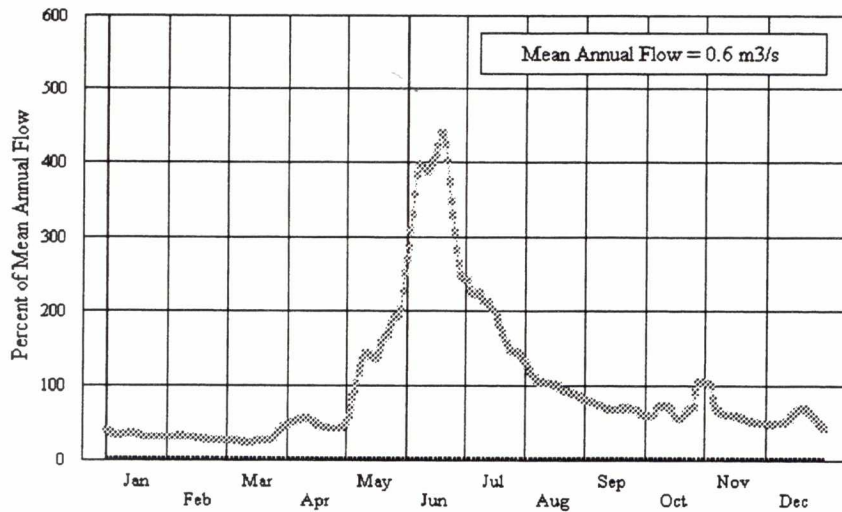
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		700	370

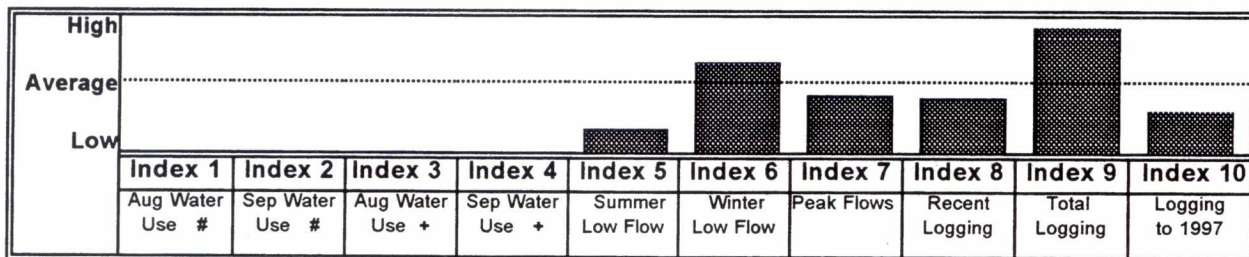
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Gates River station 08ME022)



## 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

# RAILROAD CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Forty percent of the watershed of Railroad Creek has been logged but, as some of the logging took place a number of years ago, regeneration should have reduced the clearcut equivalent area.*

# SAMPSON CREEK

## LICENSED WATER DEMAND

Stream number 01-5050

Ungauged

Tributary to the Upper Lillooet River

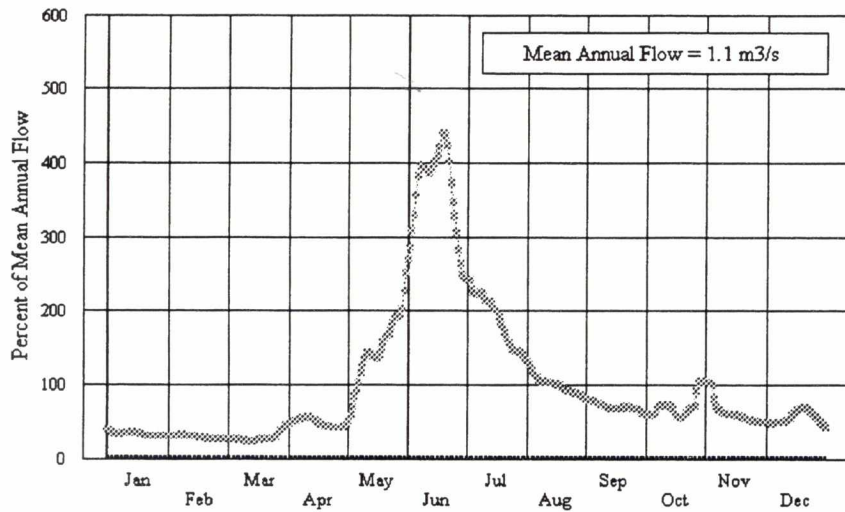
Drainage Area = 54 km<sup>2</sup>

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		1,260	660

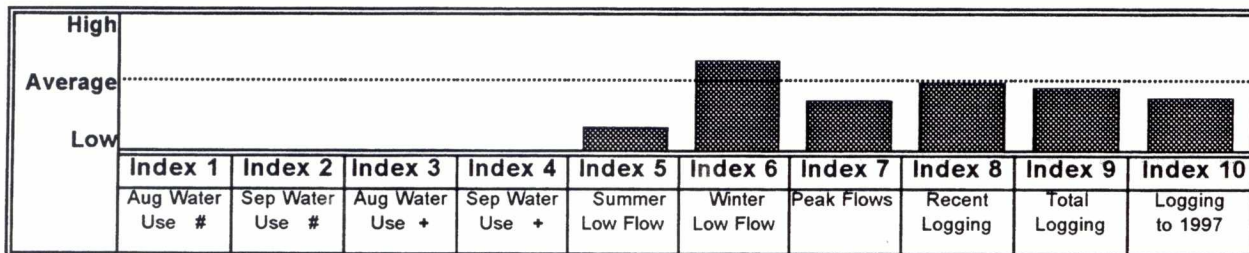
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Gates River station 08ME022)



## 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

# SAMPSON CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Winter low flows, as a percentage of mean annual flow, are relatively low compared to other streams in the Harrison Habitat Management Area.*