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

by

Kenneth M. Rood[1] and Roy E. Hamilton[2]

Fraser River Action Plan
Department of Fisheries & Oceans
555 West Hastings Street
Vancouver, B.C. V6B 5G3

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[1] Northwest Hydraulic Consultants Ltd.
#2 – 40 Gostick Place
North Vancouver, B.C. V7M 3G2

[2] Consultant
1138 Handsworth Road
North Vancouver, B.C. V7R 2A8

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 Nechako HMA which includes streams lying within the watershed of the Nechako River, which lies west of the Fraser River and joins it at Prince George (Figure 2).

An understanding of the hydrologic regime of the salmon streams is one important aspect of habitat management planning and our report describes both the regime in the salmon streams and the effect of human development on that regime. Within the Nechako HMA, agricultural, municipal and industrial extractions from surface and ground water together with 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 12 of the known and presently utilized salmon streams within the Nechako 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 the various Federal and Provincial government departments and agencies. Information available prior to 1995 has been summarized in this report. The following tasks were completed during our study:

1. Summarize and describe those aspects of the climate, physiography, surficial geology and soils that affect the hydrology of the salmon streams;

2. Describe the local hydrologic regime and prepare estimates of mean annual flows, mean annual floods, mean monthly flows and seasonal 7 day low flows for each of the salmon streams from Water Survey of Canada records, Water Management Branch records or from regional analysis for ungauged streams;

3. Use Water Rights Branch records to calculate potential licensed demand on surface waters in each of the salmon streams;

4. Review the impact of forest harvesting on hydrology and determine the portion of the watersheds of the salmon streams that are harvested;

5. Use the hydrologic, water use and land use data to calculate sensitivity indices and rank, or prioritize the various salmon streams according to water withdrawals, high flows, low flows and 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 12 salmon streams. The quality of information varied greatly from stream to stream and our method estimated flow characteristics so that streams within the study area could be compared and ranked. For a given stream, the estimated flows are not necessarily the best estimate 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

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2. THE NECHAKO HABITAT MANAGEMENT AREA

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

Climate, in combination with physiography and geology, can be used to define broad regions of similar hydrologic behaviour. As is discussed in the following sections, the salmon streams of the Nechako HMA lie within three physiographic region and also within three Ecoregions and several ecosections. The Ecoregions and physiographic regions correspond fairly well; with the Nechako Lowlands covering the same area as the Fraser Basin Ecoregion, the Nechako Plateau covering a similar area as the Fraser Plateau Ecoregion, and the Tahtsa Ranges incorporated in the Coastal Gap Ecoregion.

2.1 Physiography

The Nechako HMA is the watershed of the Nechako River (including the Chilako and Stellako Rivers) and extends west from Prince George to the Coast Mountains (Figure 3). It includes three separate physiographic regions (Matthews 1986) and the drainage basins of the salmon streams lie within one or more of these regions (Table 2). The Nechako Plateau covers the largest area in the Nechako HMA and includes most of the salmon streams. The remaining salmon streams are in the Nechako Lowlands; only the upper Nechako watershed, upstream of Kenney Dam, extends into the Tahtsa Ranges.

The Nechako Lowland extends east from Prince George to Fraser Lake and then southeast to Kenney Dam along the Nechako Valley. It is an irregularly-shaped region of low relief with elevations that are typically around 700 to 1,000 m. Major rivers that cross the Lowland, such as the Fraser and Nechako are incised well below its general level.

The Lowland is flat or gently rolling and stream channels are poorly organized, with numerous lakes and poorly drained depressions. Much of the Lowlands were covered by glacial-dammed lakes during the late retreat of the Fraser Glaciation and there are glacio-lacustrine deposits extending from Vanderhoof towards Fort Fraser, surrounding Fort St. James and surrounding Prince George (Tipper 1971). The deposits are typically compact and relatively impermeable. Most areas below 725 to 760 m were flooded, including the valleys of the Nechako, Stuart and Endako Rivers, though the sand, silt and clay deposits are not often thick enough to obscure the underlying terrain, often being less than 30 m thick (Plouffe 1991).

The Nechako HMA is mostly in the Nechako Plateau physiographic region (Holland 1976). Elevations on the Plateau exceed 900 m and are typically from 1,200 to 1,500 m. The Plateau is largely undissected, with low relief and expanses of flat or gently rolling terrain, and low hills are separated by broad, flat valleys. The Nechako Valley, where elevations are below 750 m, is deeply incised into the Plateau.

The plateau is underlain by Tertiary lava flows and pre-Tertiary sedimentary, metasedimentary, volcanic and igneous rocks. There are few exposures of local bedrock as the plateau is covered by a deep layer of glacial drift that exceeds 150 m thickness in some locations (Tipper 1963;

1971) and is often formed into drumlin-like ridges. Fraser till is the most abundant surface sediment and it typically has a clayey texture, as a result of ice over-riding unconsolidated clayey sediments (Plouffe 1991). There are few exposures of outwash gravels and sands, though esker complexes are found near Bednesti Lake and Fort St. James (Armstrong 1949) and coarse outwash sediments are found along many of the major river valleys, particularly the Endako and lower Nechako Valleys. Plouffe (1991) points out that the most recent glaciation altered the course of the Stellako and Nechako Rivers and buried alluvium marks the old courses.

Many of the surface features of the Nechako Plateau result from the Pleistocene glaciation. The most recent advance -- the Fraser Glaciation -- crossed the Plateau from west to east. Over-riding of the surface by ice sheets left drumlin-like ridges, eskers and numerous depressions. The depressions now contain lakes and swamps of various sizes which intercept upstream sediment supply.

Major and minor meltwater channels, which drained wasting ice sheets, are found over a large portion of the Nechako Plateau. Many tributaries to the Nechako and Stellako Valleys flow in old meltwater channels (Tipper 1963) and the valleys carved by the meltwater channels are much larger than the streams that presently occupy them. Many of the meltwater channels now contain lakes or swamps, resulting from glacial or post-glacial damming, which intercept sediment from upstream.

The Nechako River valley is a major meltwater channel cut deeply below the surrounding glacial and glaciolacustrine deposits, to depths ranging from 30 to 100 or so metres. The river valley received meltwater from the Ootsa and Tetachuck Lake meltwater channels and overflowed near Big Bend Creek. The lower valley is floored with glaciofluvial deposits consisting of coarse sand and gravel which have been re-worked by the modern river.

The Tahtsa Ranges are transitional between the Coast Mountains to the west and the Interior Plateaus to the east. Ridges and peaks rise to about 2,400 metres above sea level and valley bottoms are generally around 700 m. The valleys are broad, U-shaped and filled with glaciofluvial sediment (MacIntyre 1985).

Alpine glaciers and small ice-fields are common in the Tahtsa Ranges, particularly in cirque valleys surrounding the major peaks.

2.2 Surficial Geology

Cotic *et al* (1974), as part of a soil survey of the Nechako-Francois Lake area, prepared a small scale map of the surface deposits of most of the HMA. Their large scale soil maps provide detail on the genetic (parent) material for their various soil associations.

Little work has been completed on the Quaternary Geology of the northern interior of British Columbia by the Geological Survey of Canada though studies are underway (Plouffe 1991).

2.3 Climate

2.3.1 Climate and Hydrology

The Nechako HMA lies in the rainshadow of the Coast Mountains and has a modified maritime climate near the Coast Ranges changing to a typical interior climate inland, characterized by short, hot summers and long, cold winters. Precipitation is greatest in the Tahtsa Ranges of the Coast Mountains, least in the middle of the HMA near Fort Fraser and Vanderhoof, and increases towards Prince George. Climate normals for AES stations within the HMA are listed on Table 3 and hydrologic regimes are summarized on Table 4. The Tahtsa Ranges are distinct from the Fraser Basin and Nechako Plateau Ecoregions which have similar climate and hydrology.

Fraser Basin Ecoregion: Mean annual temperature is around 3°C. January is the coldest month with mean temperatures of -3°C and extreme minimum temperatures of around -50°C. July is the warmest month with mean temperatures of 15°C and extreme maximum temperatures of around 37°C.

Annual normal precipitation at Prince George ranges from 500 to 600 mm and is evenly distributed throughout the year, though March and April typically receive the least precipitation. About 40% of the total falls as snow from October through April and the greatest monthly totals generally occur in December and January. Snow accumulates through April or May and snowmelt is the main source of streamflow.

Rain falls throughout the year though it is not common in the winter months. Normal monthly totals are reasonably constant from June through September at about 45 mm and about 50 to 60% of the annual precipitation fall from May through September. These months also have high evapotranspiration demand and little of the rainfall replenishes groundwater or contributes to streamflow. Farstad and Laird (1954), based on a Thornthwaite analysis, indicate that soil moisture deficiencies typically occur by August and that the annual deficit is about 75 mm.

Floods in streams result from snowmelt in the spring and in the larger watersheds all the maximum annual flows occur in May and June. Maximum daily rainfall totals of about 55 mm have been recorded in February, July and November at the Fort St. James station. These intense rainfalls result from Pacific storms spilling over the Coast Mountains which commonly occurs in the late fall. These rainstorms may result in floods on small tributaries to the salmon streams and they increase fall flows in the larger streams. November discharges on the Chilako River average about 50% higher than those in September.

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

Nechako Plateau Ecoregion: The Nechako Plateau has lower annual precipitation and somewhat colder temperatures than the Fraser Basin Ecoregion, but otherwise has a similar climate. Lower summer precipitation produces an earlier and larger soil moisture deficiency. Deficits are typically expected by July and the annual water deficiency averages about 250 mm (Farstad and Laird 1954; Kline 1980).

With the lower (valley-bottom) precipitation and the greater soil moisture deficits, recorded annual runoff from the salmon streams in the Nechako Plateau is sometimes less than in the Fraser Basin Ecoregion, particularly in the Stellako Watershed, where annual runoff (the mean annual flow expressed as a depth over the watershed) is about 100 mm (Table 4). Small streams near Vanderhoof (e.g., Murray Creek and Clear Creek), which do not extend to high elevations and consequently do not accumulate deep snowpacks have early snowmelt peak flows and annual runoff of about 75 mm, substantially less than from larger basin. Small watersheds which extend to higher elevations, and accumulate greater quantities of snow, have greater mean annual runoff (Appendix A).

Annual maximum daily precipitation also appears to be lower in the Nechako Plateau Ecoregion though this is not expected to reduce mean annual floods, which almost always result from snowmelt.

Coastal Gap Ecoregion: The Tahtsa Lake West climate station, on the east side of the Coast Mountains, has a modified maritime climate. Precipitation totals are much higher than in the interior – about 2,000 mm compared to 500 mm – and most of the precipitation falls in the winter when Pacific Storms cross the Coast Mountains. The station is at an elevation of 853 m and about half of the annual precipitation falls as snow, though rain falls in all months. Runoff in streams accounts for most of the precipitation and totals about 1,800 mm. Substantial snowpacks develop at high elevations and the maximum winter snowpack at the Tahtsa Lake snowcourse (elevation 1,300 m) averages about 1,150 mm.

Maximum daily rainfall is greatest from September through January when up to 133 mm have been recorded. Maximum annual discharges in streams sometimes result from snowmelt but the largest discharges are in the fall and early winter and result from rain or rain on snow. Minimum annual discharges occur from December through April.

2.3.2 Temporal Variation in Climate

Long-term climate records are available at the Fort St. James (1895-1993) and Wistaria (1926-1993) climate stations (Figure 4). These records show annual and decadal fluctuations in precipitation but no long-term trend. Moore (1991) reviewed the records of these valley-bottom stations and concluded that annual precipitation had remained roughly constant but that a lower portion of the precipitation had fallen as snow since the mid-1970's. There was also an increase in temperature at these stations since the mid-1970's.

The Stuart River near Fort St. James station (08JE001) provides a record of annual streamflows extending back to 1926. The record is similar to those at the climate stations and has annual and decadal fluctuations of discharge. There is no indication of declining annual flows as might be expected with basin-wide reductions of snowfall and snow accumulation.

2.3.3 Global Warming and Climate Change

Levy (1992) discuss 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, it is generally agreed that in the Nechako

HMA that higher winter streamflows may result from an increase in winter precipitation and a decrease in the portion of this precipitation that falls as snow. The snowmelt freshet is expected to occur earlier and summer flows are expected to 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 Channel Pattern and Streamflow

Nechako River: The Nechako River crosses the HMA from east to west draining much of the Nechako Plateau. Flows in the river have been regulated by the Kenney Dam and Nechako Reservoir since 1952 in order to divert water from the basin to generate hydroelectric power at Kemano. Flows are released to the Nechako River through the Skins Lake Spillway though no consistent regime was maintained in the river for many years. The Nechako Fisheries Conservation Program now sets flows in the river for rearing, spawning and temperature management. Maximum annual discharges generally occur in July and August during releases of cooling water. The maximum discharges in the upper river are maintained at less than 283 m^3/s or less than half of the natural mean annual flood at Vanderhoof.

Water levels in the Nechako River are much lower during the early spring and summer under the regulated regime than under the natural regime. As a result of these lower levels, some tributaries are downcutting or degrading their lowermost reaches to match their profiles with water levels in the Nechako River. Sediment eroded from the tributaries is carried into the Nechako and coarse sediment is often deposited as a fan.

Upstream of the Nautley River, almost all of the flow in the Nechako River is the result of releases from the Skins Lake spillway. From the Nautley River to the Stuart River, the flow regime is altered somewhat by natural flows from the Nautley watershed. The effect of regulation on the hydrologic regime decreases downstream of the Stuart River.

The Nechako flows in an old meltwater channel that is well-incised below the level of the Nechako Plateau. The steepest portion of many of the small tributaries is where they cross from the plateau surface into the Nechako Valley. These are typically the most unstable reaches of the tributaries and provide sediment to the Nechako River. The floor of the valley is composed of glacio-fluvial sand and gravel or alluvial deposits. These coarse sediments are of variable thickness and near Diamond Island and in sections of the river upstream of Greer Creek the underlying glacio-lacustrine sediments are visible in the channel bed.

Other Salmon Streams: Many of the salmon streams have large lakes along their courses and storage alters the hydrologic regimes described on Table 3. For instance, Francois Lake stores about 1 m of water during April, May and June, which is released mostly during July, August and September. The effect of storage is to delay slightly and attenuate peak flows, which typically occur in June at the Stellako River at Glenannan (08JB002) station, and maintain water levels in the late summer and early fall so that minimum annual discharges always occur in winter. Lakes on the other salmon streams have smaller storage volumes and, consequently, less effect on hydrologic regimes.

The sediments exposed along the valleys of the salmon streams vary widely. The lowermost reaches of the Chilako River flow over glacio-fluvial sediments in an old meltwater channel though the middle sections of the river are in thick glaciolacustrine deposits which maintain high suspended sediment levels. The Stellako River flows through glacio-lacustrine and glacio-fluvial deposits and onto a contemporary delta at its junction with the Endako River. The middle reaches of the Endako River (Decker Lake to Tchesinkut River) flow through sandy glacio-deltaic deposits and these deposits are reflected in the channel bed.

2.5 Groundwater Resources

The majority of the wells on the Nechako Lowland are for domestic and livestock use. Of the 6,000 or so wells in the Lowland about 83% produce less than 1 L/s: there are far fewer wells on the Plateau but most are of low yield and used for domestic water (Atwater *et al* 1994). High capacity wells have been drilled in the Nechako Valley near Prince George and at a number of locations near Vanderhoof. Most of the aquifer underly the lacustrine sediments at depths ranging from 15 to 80 or so m. There are also productive sand and gravel deposits at depths of 25 to 50 m near Endako and Burns Lake in the Endako River valley. It is expected that extractions from these wells do not affect surface water discharges.

It is likely that low flows in many small tributaries are maintained by groundwater discharge during the late summer and early fall and that glacio-fluvial sediments and recent alluvium in valley bottoms are be important source of groundwater. However, this possibility has not been studied in detail.

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. In the Nechako HMA, lower water levels in the Nechako River have contributed to downcutting where tributaries join the main stream.

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

The typical salmon stream in the Nechako HMA starts on a rolling upland area where the channel may be steep and contained in a gully or narrow valley. Bank and valley wall erosion and channel downcutting are the most likely channel responses to disturbance in these reaches. All of the salmon streams have large lakes in their middle or lower reaches. The lakes act to intercept sediment and prevent it from entering downstream reaches and also prevent downcutting in the immediately upstream channel reaches.

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 very stable pavement.

Table 5 summarizes reported channel response to disturbance and the kinds of human modification which are discussed in Sections 7 and 8. Channel response includes pattern changes (channel avulsion or creating a new course), 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, river training (including straightening, bank protection, diversions, revetments, spurs or other structures), channel encroachment (by land filling or by narrow dykes), gravel removals (including dredging, bar scalping, and deepening of the channel), removal of riparian vegetation and removal of large organic debris. 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 Nechako HMA. Some streams have long-term gauging records at stations that continue to operate, other streams have short-term or seasonal records of moderate quality from the 1960's and 1970's, while other streams have little or no information available. The average flow characteristics in the above list, as well as other characteristics, can be reliably estimated for salmon streams with long-term discharge records. Less reliable estimates can be prepared for streams with limited records and the least reliable estimates are for streams with no records.

3.1 Reference Point for Flow Characteristics

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

The Water Survey of Canada report their data for a specific point on the stream which may be near the mouth of the stream, or a considerable distance upstream. The sites are generally selected for accessibility and for their suitability as gauging sites, rather than other criteria. When the gauging site is near the mouth of the stream we have assumed that the recorded flows also describe flows at the mouth. However, if a major tributary enters between the gauge and the mouth, or if the gauge is well upstream of the mouth, the flows recorded at the gauge were adjusted to obtain flow characteristics at the mouth either by adding measured tributaries flows or by increasing flows based on the ratio of drainage areas at the mouth and at the gauge (Appendix A).

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

3.2 Period of Record for Calculating Flow Characteristics

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

We have adopted the most recent decade, 1981-90 (inclusive), as our standard period for analysis. On natural streams In the Nechako HMA, this decade had lower mean annual discharges than were recorded in the 1950's, 1960's or 1970s and flows were well below average from 1983 through to 1989 (Figure 6).

Minimum releases from the Skins Lake Spillway to the upper Nechako River were controlled by an injunction during the early part of the 1980's and the flow regime since has been managed by the Nechako Technical Committee. Other than in July and August, when variable discharges are released for temperature control or when the Water Management Branch has requested pre-spill, monthly releases have been constant from year-to-year. Note, though, that releases from Skins Lake spillway in the 1980's were much less than in the 1960's and 1970's and much lower flows were recorded at Vanderhoof in the 1980's, than in the 1960's or 1970's, because of reduced natural inflows due to drought and reduced releases from Skins Lake spillway.

3.3 Hydrometric Data in the Nechako HMA

The Water Survey of Canada is the prime agency collecting and reporting flow data in British Columbia. Gauging stations in the Nechako 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 5 of the salmon streams have had at least one operating gauging station. However, only three salmon streams (Nechako, Stellako and Nadina Rivers) have complete gauging records from 1981 to 1990 and only on the Nechako and Stellako Rivers is the gauge near the stream mouth. It is on these streams that flow characteristics may be calculated directly from Water Survey of Canada records. These calculations are discussed in Section 3.5.

The salmon streams typically have either: 1) partial records between 1981 and 1990, 2) partial or complete records from earlier decades, such as the 1960's or 1970's, or 3) no records from the Water Survey of Canada (Table 1). Procedures for estimating flows on these streams are discussed in Section 3.6 and Appendix A.

There are also gauging stations on streams that are not within the boundaries of the study area or are not salmon streams. Where these stations provide useful information on the hydrologic characteristics of watersheds in the Nechako 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. Their miscellaneous program and their drought measurement programs (Richards 1977) were used to estimate or confirm 7 day low flows estimated for a number of the salmon streams (Appendix A).

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 the measured flow which may be reduced by water extractions.

3.5.1 Water Extractions and Flow Characteristics

For streams 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 5). We have referred to these adjusted flows as **naturalized flows** to distinguish them from measurements of the natural regime.

This approach provides a reasonable estimate of the natural flows in most of the gauged salmon streams (excluding the Nechako River) because developed storage in most watersheds consists of small, independently-operated reservoirs, because total storage is small in comparison to irrigation requirements (Table 10) 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 Nechako Reservoir is the only large storage reservoir in the Nechako HMA. Natural flows in the Nechako River have been estimated by various sources (Envirocon 1983) and were recorded at the gauge upstream of Fort Fraser (08JA001) though these were not used to calculate the flows that would occur without the reservoir. Instead, the regulated flow regime recorded from 1981 to 1990 was naturalized with the licenced extractions, as described above. The regulated regime expresses the volume of water that is available to meet various instream needs, including agricultural and other water demands, though it is recognized that natural flows in the Nechako River were once much greater than those from 1981 to 1990.

3.5.3 Annual Flow Characteristics

The historic period for the **mean annual flow** and **mean annual flood** is 1981 to 1990, inclusive (see Table 6 for definitions).

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 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 dessication 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 hygrographs, 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 hygrographs 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, 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 Nechako 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 it also increases flood discharges, through conversion of forest lands. Urbanization affects the hydrologic regime through extractions for waterworks. In the Nechako HMA, urbanization has not had a signficant effect on flood discharges in the salmon streams. Surface water extractions are discussed in detail in Section 5 "Water Licensing".

The removal of timber during conversion to agriculture or forest harvesting eliminates transpiration and the cut blocks alter the distribution of snow and often increase rates of melt. These changes in the watershed, coupled with road construction and soil modfications 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 by the stream.

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

4.1 Forest Harvesting

Maps and databases maintained by the Ministry of Forests were used to determine harvested areas in the watersheds of the salmon streams. History Record Reports lists activities in all openings (areas where forest has been removed) created prior to 1987 and continue with Small Business Forestry Enterprise Program (SBFEP) openings to 1993. Each opening is described by the region and compartment (the compartment is a large administrative unit whose boundaries follow watersheds), a location tag, date of last activity and size of the opening. The compartment for each watershed is 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 openings are listed geographically, so this procedure provides only misidentifies a few of the clearcuts.

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^2 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 1992. 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 the interior of British Columbia, snow accumulation and melt are very important to the hydrologic regime. Tree harvesting reduces the interception of snow by the canopy, reducing subsequent loss to the atmosphere, affects the distribution of snow and alters 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. Hetherington (1982), based on studies in Carnation Creek, shows increases in annual and monthly water yields.

4.2.2 Forest Harvesting and Flood Flows

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

Forest harvesting also affects flood flows generated by rain on snow, though studies have generally been conducted in the transient snow zone of the Pacific Coast and their conclusions may not be entirely transferable to the interior. Generally, greater melt rates of shallow, warm snowpacks are expected following forest harvesting because of greater transfer of convective energy from increased wind speeds and turbulence. However, a number of variables, such as antecedent snow conditions, storm characteristics and climate affect the results and few studies have demonstrated increased peak flows (Harr 1986). Beaudry (1985), based on studies in Jamieson Creek in the Seymour watershed, shows that air temperature and the presence of snow in the canopy in the forest affect the relative melt rates and runoff from clearcut and forested sites.

The 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 clearcut equivalent area (CEA) within the watershed. The CEA is calculated from the product of the total cut area and a regeneration recovery factor, which reflects the fact that there is near zero hydrologic recovery for regeneration of less than 3 m and nearly complete recovery for 9 m regeneration. Intermediate regeneration reduces the hydrologic effect of the clearcut. Maximum allowable clearcut equivalent 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, 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 Agriculture and Hydrology

Sasaki (1986) estimated that there was about 810 km^2 (200,000 acres) of farmland in the Nechako Valley in 1981, covering roughly 1.5% of the total watershed area, or about 2% of the watershed area downstream of the Kenney Dam.

Conversion of forest lands for agriculture generally has the same type of effects on the hydrologic regime as logging; it increases mean annual water yield, flood flows and summer low flows. The effects are permanent because the forest canopy does not regenerate.

In a snowmelt-dominated hydrologic regime like the Nechako Valley, agricultural clearing often does not have much effect on flood flows in the main streams. This is because the snow that accumulates in valley bottoms where agriculture is concentrated, often melts prior to the peak of the freshet and does not contribute much to the annual flood. The clearing may produce a small increase in yields but it is expected that water use and diversion for irrigation has a much more significant effect on the hydrologic regime.

4.4 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 licences on the database are ultimately approved and consequently these are included in the totals on Table 7. Summaries (by licence type) were produced for all salmon streams, as well as streams with long-term Water Survey of Canada gauging stations.

5.1 Classification of Water Licences

Figure 7 reproduces the water licence classification system used by the Water Management Branch. 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 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, including licence applications which are listed on the system.

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 Nechako 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 estimated to be about 25 cm (10 inches; Kline 1980) or 30 cm (12 inches; Sasaki 1986) in the Nechako HMA and irrigation licences are typically for 30 cm (12 inches) of water. However, the portion of the farmland which is irrigated is not known and 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 ft^3/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 ft^3/s.

Licensed amounts expressed as a volume (ac-ft) were converted to cubic decameters (dam^3), where 1 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 are assumed to be distributed as follows: May (25%), June (26%), July (33%), August (16%) and September (0%). (These percentages are from Sasaki (1986)). Note that in some years there is water use for irrigation in September. The last hay crop is usually removed in late August or early September and irrigation after the last crop is to improve soil moisture before the winter.) Monthly irrigation volumes (in dam^3) were converted to discharges (L/s) by multiplying by 10^6, and dividing by the number of seconds in the month.

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

6. SENSITIVITY INDICES FOR THE SALMON STREAMS

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

- Indices that express the level of human activity in the watersheds of the salmon. These include expressions of the proportion of the basin of the salmon streams that have been developed and the degree of utilization of water for irrigation, industrial and waterworks; and

- Indices that express the state of the particular stream and its ability to resist further change. These indices express peak flows and low flows as a ratio or percentage of the mean annual flow. Extreme values indicate stressed systems with a limited ability to withstand further hydrologic alteration.

The most useful indices for assessing habitat sensitivity would indicate the magnitude of water use during low flows in summer, compare the magnitude of low flows to mean flows, compare peak flows to mean flows and indicate the extent of 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 following table summarizes the indices:

Index	Definition	Interpretation
1	potential demand in August as a percent of the mean summer 7 day low flow	expresses the maximum portion of flow during the rearing season that is used for water demand
2	as above for September	as above
3	potential demand in August as a percent of mean August flow	expresses the typical portion of flow during the rearing season that is used for water demand
4	as above for September	as above
5	actual summer 7 day average low flow as a percent of mean annual flow	expresses the ability of the system to resist water removals; low values indicate streams with low natural 7 day low flows
6	as above for winter 7 day lows	as above
7	mean annual flood as a ratio of mean annual flow	expresses the peakiness of the stream hydrograph and the potential for scour and erosion
8	total logged area as a percent of total basin area	roughly expresses the clearcut equivalent area and indicates the extent of hydrograph changes from logging; values exceeding 20% indicate potential changes
9	recent 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 on the Nechako River results from storage, diversion for power production at Kemano, and diversion for irrigation. Water use was calculated from the licensed demand compared to flows at the Nechako River at Isle Pierre gauge (adjusted to the mouth). Implementation of the long-term regime on the Nechako River following Kemano Completion will increase the quoted percentages of flows devoted to irrigation and other uses. Note also that much of the irrigation is upstream of the Stuart River and flows recorded at the Nechako River at Vanderhoof gauge or those upstream of Fort Fraser would actually meet the irrigation demand. This is discussed further in Section 7.

Large values of Indices 1 through 4 indicate streams with great potential demand, primarily from irrigation, on summer low flows. On Table 9, those streams whose indices are the top 25% of the values are shaded.

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

6.2 Summer and Winter 7 day Low Flows

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

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

On Table 9, those streams whose indices are in the lowest 25% of the values are shaded. Most of the streams with low indices have small drainage basins and some have licensed demand while others are unaffected by diversion or storage. Typically, smaller streams have more extreme response to drought.

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. Note that the ratio of mean annual flow to drainage area is constant for those ungauged watershed whose flow characteristics were estimated by regional analysis (Appendix A). 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 Nechako 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 percentage of the total area of the watershed that has been harvested; Index 8 is the percentage of the watershed that has been recently logged (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 harvested area with little or no hydrologic recovery expected by the end of the five-year plan. The "older logging" includes cutblocks in varying stages of hydrologic recovery, ranging from those with limited or no hydrologic recovery that were recently harvested to some blocks that may be near the 9 m high regeneration which is often accepted to represent full hydrologic recovery. The percentage that have not recovered and the clearcut equivalent areas (CEA) 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) CEA to control rate-of-cut under their Watershed Assessment Procedure. This degree of clearcutting is expected to produce some changes in the hydrologic regime (Section 4.2). Index 9 is not a CEA values because it is not adjusted for hydrologic recovery of cutblocks and, as a result, may over-estimate the clearcut equivalent area of total harvesting. However, when most of the cutblocks have been harvested in recent years Index 9 may not over estimate the clearcut equivalent area by very much. Indices 8 and 10 represent clearcut equivalent areas.

We have selected total or recent harvesting covering more than 20% of the watershed, which may correspond to a CEA of up to 20%, to indicate that management concern should be raised for fish habitat. A cut of 20% represent the point where effects on the hydrologic regime often become apparent and where changes in the sediment regime of the stream may result. We have also selected a low value so that those streams where changes in the hydrologic regime may be anticipated with further cutting are identified and management options may be considered. Those streams with 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 alter downstream hydrology greatly. 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 Nechako Habitat Management Area. Maximum water demand in the salmon streams amounts to less than 10% of the summer 7 day low flows in all the salmon streams and is often expected to be less because the lowest summer flows generally occur in September when irrigation demand is expected to be near zero. Demands are greatest in the mainstream Nechako River, Endako River and Tchesinkut Creek. The Nechako River provides a particular management concern because flows in the river will be reduced if Kemano Completion proceeds, and because irrigation demand from the Nechako River and its tributaries is expected to increase.

The lowest winter and summer 7 day low flows, in relation to mean flows, occur in the upper Nadina River, Nadina and Endako Rivers. The Endako River is affected by water demand but the Nadina River has naturally low 7 day flow flows.

Several of the watersheds of the salmon streams have either a large percentage of their total area cut or a large percent cut recently. Among the larger streams, the lower Nechako River, Stellako River, Nadina River and lower Nadina River all have more than 20% of their total watershed area harvested and the Chilako watershed is close to 20% harvested. Excluding the Nadina River, these watersheds have areas converted to agriculture which also alters the natural hydrologic regime. Of the smaller watersheds, Tagetochlain (40%), Uncha (21%) and Binta (34%) Creeks have more than 20% of their basin cut. Recent logging in these watersheds apparently exceeds 20% of the basin area and further timber harvesting should be opposed in these watersheds until there is further study of hydrologic recovery and sediment issues.

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 Nechako Habitat Management Area (Section 8). We recommend further study and investigation of all the sensitive salmon streams on Table 10. Table 5 summarizes physical changes to the river channels and Appendix B also includes a summary of this information.

Nechako River: Upstream of the Nautley River, in the upper Nechako, most of the flow results from releases from the Skins Lake Spillway and there is little natural inflow. From the Nautley to the Stuart River, natural contributions to the river provide a large part of the discharge; downstream of Stuart River, the regulated releases are the smaller part of the flow. The Water

Management Branch follows these reaches when licensing. In Reach 1, no more licences are issued unless storage is provided or it is demonstrated that there is no impact on chinook salmon. There is growing agricultural demand along Reach 2; irrigation licences were issued until June 1993 but further licensing is in abeyance and there are outstanding licences dating back to 1982. Fisheries and Oceans Canada and Water Management Division are negotiating a "cap" for total extractions from this river reach. Reach 3 has adequate flows and no restriction on licensing.

Irrigation for agriculture (primarily hay growing) consumes only a small portion of the flow at the mouth of the river, with waterworks and industrial extractions in Reach 3 providing a large part of the total demand (Table 7). Most of the agricultural removals are upstream of the Stuart River near Vanderhoof where flows are lower than at the mouth. Potential demand from all sources in Reach 1 (upstream of the Nautley River) for August is about 0.027 m^3/s, or about 0.1% of the summer 7 day low flow of 33.1 m^3/s. Potential demand in Reach 2 (Nautley River to the Stuart River) in August is about 0.484 m^3/s, or about 0.8% of the summer 7 day low flow of 56.9 m^3/s (Nechako River at Vanderhoof gauge). Note that nearly all of the agricultural demand is from surface water in small tributaries, rather than from the Nechako River, and their low flows are expected to reduced to a greater extent than the main river.

Sasaki (1986) forecasts growth of the total irrigated land base along the Nechako River to be about 17,800 ha over the next 10 to 15 years. About 25% of this irrigated land would be along Reach 1 and the remainder along Reach 2. Based on a duty of 300 mm and the distribution of water use discussed in Section 5, the forecast irrigation demand would be roughly 5 to 6 times greater than the present licensed demand. The following table summarizes existing and predicted August demands, as a total and as a percentage of current summer 7 day low flows:

Reach	*Current Summer 7 Day Low Flow (m^3/s)*	*Current August Total Demand (m^3/s)*	*Forecast August Total Demand (m^3/s)*
Reach 1	33.1	0.027 (0.1%)	0.803 (2.4%)
Reach 2	56.9	0.484 (0.8%)	2.448 (4.3%)

There is an application on file for a proposed pulp mill at Vanderhoof. Water demand for this facility, which could be up to 0.2 m^3/s, would be taken from the Nechako River though process water could also be extracted from the Stuart River.

Reduction of flows in the Nechako River has resulted in some morphological changes, particularly in Reach 1, upstream of Nautley River. Reid Crowther & Partners Ltd (1987) documented encroachment of terrestrial vegetation onto bars, abandonment of secondary channels, and deposition of sediment along the Nechako River, both at tributary fans and in low-velocity depositional zones as a result of reduced sediment transport ability. The report expressed concern regarding sediment deposition in spawning areas resulting from continued sediment supply and reduced transport capacity. The Nechako Fisheries Conservation Program Technical Committee commissioned a series of reports that inventoried and prioritized sediment sources to the Nechako River for rehabilitation, evaluated secondary channels for potential improvements, mapped sand bed accumulation areas and collected base line substrate samples.

Chilako River: The Chilako River is known locally as the "Mud River" because of high turbidity and suspended sediment concentrations which seem to result from erosion of lacustrine sediments along the lower course of the river. Sediment concentrations are lower upstream of Punchaw Lake which is the upper limit of salmon migration and also lower in the tributaries. Spawning salmon are spread throughout the system with a few pairs on each patch of gravel.

The Chilako River actively meanders in its lower reaches where agriculture is concentrated. Agricultural lands are eroded by the meandering river and local farmers and B.C. Environment occasionally protect channel banks to reduce erosion rates. Erosion may have been increased by the removal of riparian vegetation.

Nearly 20% of the watershed area has been harvested and some tributary watersheds have much greater rates of cut because of salvage logging of blowdown and beetle kill. The Ministry of Forests is reviewing rate of cut in 5 tributary drainage following a request by the Department of Fisheries and Oceans. Loss of streamside vegetation as a result of timber harvesting is also a concern in the Chilako River watershed.

The Chilako watershed has sparse ranching and hay growing and the Water Management Division receives applications for irrigation licences infrequently and they expect very little increase in water demand over the next few years. Range cattle graze along most of the river and the tributaries in the upper reaches. Drift fences in the upper watershed partly control their movements but cattle cross stream banks and damage riparian habitat.

Nautley River: The Nautley River joins Fraser Lake to the Nechako River. Completion of the Kenney Dam and regulation of flows in the Nechako River, led to lowered water levels in the Nechako River during the spring freshet. This increased the elevation difference between Fraser Lake and the Nechako River and caused downcutting of the Nautley River. The local Indian Band and other residents were concerned that downcutting on the Nautley River would result in lower lake levels on Fraser Lake. To alleviate this problem, a rock weir and groynes were constructed at the lake outlet (near the bridge crossing) to prevent further downcutting and maintain the lake level regime. The river upstream of the groynes is reported to have filled with fine sediment which has little impact on habitat as the Nautley River is mainly a migration corridor.

Ormond Creek: Sockeye have not been observed in Ormond Creek since 1975 (Stream Summary Catalogue: Subdistrict #29I). The main impediments to migration are sediment deposits at the mouth, low flows and beaver dams. The lower creek flows through lacustrine sediments and, as a result, the substrate is often silty.

The Water Management Division measured low flows on this creek in 1989 and they ranged from about 0.05 to 0.10 m^3/s at Stella Road, in August. 1989 was a drought year and these flows may represent a 5 or 10-year return period 7 day low flow. The Water Management Division records no water licences on this creek and they have not received any applications for licences in the last few years.

The Carrier Sekanni Indian Band is restoring and enhancing the creek for sockeye. The bridge crossing at Stella Road was replaced with a multi-plate culvert that permits fish passage, the road was re-aligned and debris was removed from the stream. Flow control at the lake outlet and removal of sediment at the mouth are also being considered.

Stellako River: The Department of Fisheries and Oceans in Prince George reports no concerns over habitat in the reach from Francois to Fraser Lake. Land along the upper part is protected as it is part of a reserve owned by the Habitat Conservation Fund.

The Stellako and Endako Rivers join near the head of Fraser Lake. As part of Highway 16 development, the Endako River was apparently diverted to join the Stellako River at a lagoon just upstream of the mouth. The lagoon was used as log storage for Fraser Lake Sawmills. The Carrier Sekanni Indian Band would like the Endako returned to its original course.

Weed growth in the reach of the Stellako River from the lagoon to its mouth has created a problem for fish passage (Stream Summary Catalogue: Subdistrict #291).

Endako River: B.C. Environment reports that the substrate is sandy in the lower reaches of the Endako River. Gravels are provided by tributaries, particularly Shovel Creek, and the major concentration of spawning salmon is immediately downstream of this creek (Stream Summary Catalogue: Subdistrict #29I).

The Endako has summer 7 day low flows that are small in comparison to mean annual discharge but water demands are moderate. The Stream Summary Catalogue notes that DFO recommends no further licensed withdrawals in order to ensure maintenance flows.

Both the CN Rail and Highway #5 right-of-way parallel the Endako River and encroach on its floodplain but the Department of Fisheries and Oceans reports that riparian habitat has not been affected. CN Rail has proposed a grade stabilization project which will require some additional bridges.

Tchesinkut Creek: Tchesinkut Creek has a stable channel with heavy growth of willow along the banks. The channel pattern is sinuous and velocities are often low. Breaching of beaver dams at the lake outlet produces high volume releases that affect the downstream channel and riparian zone.

Nithi River: Sockeye salmon have not been reported in the river since 1983 (Stream Summary Catalogue: Subdistrict #29I). The lower reaches of the south branch of the river often de-water from late summer through the winter as a result of bed aggradation. B.C. Environment Fisheries Branch is attempting to improve low flows in this branch of the Nithi River and has measured flows in the south branch at various times. The north branch appears to have flowing water all year.

Weed growth in the lower 2 km of the river affects migration. Nithi River has a small existing water demand from industrial licences: though, the Water Management Division reports no recent licence applications.

Nithi River is considered to be a suitable candidate for restoration both through flow control and weed removal.

Nadina River: The falls at the outlet of the lake are the upper limit of salmon migration. A spawning channel at the lake outlet, which uses a deep water intake from Nadina Lake, is used by 30,000-40,000 sockeye. Gravel has also been placed along the river and the IPSFC cleaned gravels in the mid-1970's. Siltation apparently resulted from log drives along the river system.

The lower Nadina watershed has over 20% of the its area harvested. Harvesting is just beginning upstream of Nadina Lake and less than 3% of the area is cut though an additional 3% is planned to be cut over the existing 5 year plan. Timber harvesting in the Nadina River watershed is managed under a Local Resource Use Plan (LRUP) prepared by the Morice Forest District (1993). The LRUP provides management guidelines for four separate zones within the watershed. Along the Nadina River corridor, which extends to 400 m on each side of the river, management guidelines include a windfirm buffer, seeding of road right-of-ways and skid trails and erosion control plans. The buffer is intended to maintain bank stability, provide organic debris and provide shading to prevent increases in water temperature. Temperature studies conducted by Fisheries and Oceans Canada indicated that small, forested tributaries provide cool water to the mainstream of the Nadina River (Morice Forest District 1993).

8. RESULTS AND CONCLUSIONS

8.1 Effects of Development on Hydrology

Flows in the salmon streams in the Nechako HMA are greatest during snowmelt in May and June and decline over the late summer, in response to decreasing soil moisture, often reaching a minimum in August or September. Rainstorms that cross the Coast Mountains often raise discharge and water levels in October and November. Ice-cover forms in the late fall or early winter and minimum winter discharges usually occur under ice between December and March. The 1980's were a particularly dry decade in the Nechako HMA and flows were well-below their long-term averages for the years from 1983 to 1989, as a result of a long drought in the interior of British Columbia.

The salmon streams in the Nautley and Stellako watersheds have annual precipitation of around 400 to 500 mm. Evapotranspiration results in mean annual runoff of about 100 mm near Fort Fraser, increasing to 300 or 400 mm in the upper Nadina watershed as precipitation increases near the Coast Mountains. The upper Nadina River provides most of the water to the lower Stellako River. Soil moisture deficits usually occur by July and irrigation requirements are greatest during June, July, and August prior to September when flows are often least. For the smaller salmon streams (those other than the Nechako, Stellako, Endako and Chilako Rivers) 7 day summer low flows are between 0.3 and 2 m^3/s (Table 7). Minor irrigation demand can use much of these flows, particularly as extractions are at a maximum in July and August, which may coincide with the summer low flow period.

Most of the salmon streams have one or more large lakes which store snowmelt runoff and release this water through July, August and September. The lakes help to maintain flows in late summer and also release warm surface water that maintains high stream temperatures.

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 lakes on many of the streams help to reduce the effect of increased peak flows on the downstream channel and also trap sediment from the upstream watershed.

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 occur in the Nechako Valley near Vanderhoof and the Endako Valley. Agricultural activity is concentrated along the valley bottoms of the major streams though many of the licenced withdrawal points are on small tributaries to the main rivers which often record zero or very low flows in late summer, partly as a result of extractions. This is of concern to the Ministry of Environment and the Department of Fisheries and Oceans because the lower reaches of these small streams often provide habitat for downstream salmonid migrants. These small streams are not salmon spawning streams but habitat loss here may also be important.

The Ministry of Agriculture is actively encouraging expansion of irrigation of existing farmlands. Kline (1980) estimated that up to 82,000 ha of soils in the Nechako River Basin would benefit from irrigation though Sasaki (1986) thought that only about 18,000 ha would be developed in the next 10 to 15 years. The main irrigation season extends from May through August and for a water requirement of about 300 mm, the forecasted expansion greatly increases the demand on flows in Reach 1 and 2, where flows primarily result from releases from the Skins Lake Spillway. This may be further compounded if releases from the Kenney Dam are reduced following the Kemano Completion Hearings. As discussed earlier, the Department of Fisheries and Oceans and B.C. Environment have restricted further irrigation licensing upstream of the Nautley River and are working on a limit to further licensing from the Nautley River to Stuart Rivers.

B.C. Environment is issuing restricted licences that would permit further irrigation but prevent further reduction of late summer flows. The licences would permit diversion over the period to the end of June, or July 15, when flows are moderately high. This diverted water could then be stored on site for use during the period of soil moisture deficit.

The Water Management Branch does not keep records of the degree of utilization of the outstanding water licences and some licences may no longer be used. Recent increases in annual fees have led to some licences being abandoned by their holders and increases in application fees have reduced the backlog of applicants though there are a number of outstanding licence applications for the Nechako River.

Water requirements for streams other than the Nechako River are not known as neither the Water Management Branch nor the Ministry of Agriculture prepare forecasts of agricultural expansion and concomitant requirements for irrigation. However, the local Water Manager reports that very few applications for irrigation licences are received for streams other than the Nechako River.

Ground Water Use: There is little reported information on ground water use in the Nechako HMA.

Storage Developments: There are no applications before the Water Management Branch for large or medium-sized power projects in the Nechako HMA. The Water Manager is also not aware of any small hydro developments.

The Nechako Reservoir is the largest storage reservoir in the Habitat Management Area. It is owned and operated by Alcan Smelters & Chemicals Ltd and is used to divert water to Kemano for power generation which provides electricity to Kitimat. Releases from the reservoir, through the Skins Lake spillway, are the most important source of water in the Nechako River upstream of Fort Fraser. The Kemano Completion Project may further reduce releases from the reservoir.

Existing storage on most salmon streams in the Nechako HMA consists of small storage structures developed and operated by individual farmers or Ducks Unlimited. In most basins, the total developed storage only represents a small portion of the water requirements for irrigation (Table 8).

Forestry: Most cutblocks in the salmon streams were harvested since 1970 (Table 7). The lower Nechako and Nadina Rivers and Uncha, Binta and Tagetochlain Creeks have total harvested areas that exceed 20% of their watershed area. The Chilako has close to 20% of its watershed area harvested. Most other watersheds have from less than 10% to about 15% of their total area harvested, up to 1992. During our interviews, the Ministry of Environment expressed concern about specific logging-related issues -- such as road encroachments on streams, and slope failures – that affect small tributaries to the salmon streams. There was little concern about direct sediment or hydrology related forestry impacts on the larger mainstem salmon streams but concern about over-harvesting of some tributary watersheds.

B.C. Environment and the Department of Fisheries and Oceans are utilizing the Southern Interior Watershed Assessment Guidelines to examine rate-of-cut though these guidelines are not yet accepted or approved. Rate-of-cut is generally limited to 25% clearcut equivalent area and 20% in Community Watersheds. The Deparment of Fisheries and Oceans is also requesting a 30 m windfirm buffer (with selective harvest) along salmon streams and machine reserves along small streams. The Forest Practices Code, currently under final review, will also contain requirements for watershed assessments when disturbed land reaches 20% of the total area in a watershed.

The proposed cut over the next five years in the watersheds of the salmon streams ranges from 0% to a maximum of 5% of the watershed area. Those streams with large proposed cuts include Nithi River (5%) and the Lower Nechako River (4%); most other watersheds have a proposed cut of about 1%. The upper Nadina River has been little affected by forest harvesting though there has been a very large removal from the lower basin. The proposed cut over the next five years is about 3% of the watershed area. Presumably, this will be managed by the LRUP though there is some merit in maintaining the upper watershed as pristine basin, particularly since the lower area has been heavily cut.

Removal of area from the forestry land base for parks, reserves or for streamside management (riparian) zones 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: The salmon streams are mostly stable. As well, flood discharges have been low throughout the 1980's and there have been few applications for bank protection or channel improvements. Damage to stream banks most commonly results from removal of riparian vegetation by farmers or during timber harvesting or erosion sometimes results from cattle watering on stream edges. The upper Chilako River is particularly identified as suffering from loss of riparian vegetation and damage from cattle. A number of salmon streams have reportedly suffered bank and valley wall erosion that has contributed to sedimentation (Table 5). There is no systematic record of these erosion failures nor any coordinated program for remedial measures other than along the Nechako River (Rood 1991).

Channel downcutting as a result of lowered water levels in the Nechako River is one source of erosion. We expect that few streams have adjusted to the water levels that have typically occurred under the short-term regime and that a further cycle of downcutting will initiate when the long-term flow regime is imposed on the river. This issue has not been examined in detail except on the Nautley River.

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 Nechako 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 a regional low flow measurement program. On gauged streams, further analysis of additional gauging records on tributaries or the upper mainstream is warranted, where these are available.

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

1. The relationship between actual and licensed withdrawals is not known for various licence types. As well, demand varies from year-to-year, based on a number of factors. *Management of the salmon streams requires some knowledge of the annual variation of demand and we recommend regular monitoring of withdrawals to establish the demand on the most sensitive streams.*

2. Management procedures to ensure adequate instream flows for fish have not been established. *We recommend that instream flow requirements be assessed for the more sensitive salmon streams and that appropriate water management plans be developed in conjunction with other agencies (Hamilton 1992).*

8.2.2 Water Licensing and Water Use

Salmon streams in the Nechako HMA typically have low flows in August and September despite significant natural storage on many systems. A few of the streams have large potential water demands. Storage development, riparian zone management, and erosion control are important issues.

The Nechako and Endako Rivers and Tchesinkut Creek potentially have a large portion of their low flows devoted to water demand, principally for irrigation, and are under the greatest threat from existing water use. The Nechako is already managed in detail and the Endako and Stellako Rivers have an office reserve by B.C. Environment, however these reserves can be legally challenged and further licence approvals forced. *We recommend that further water withdrawals from these stream systems -- even with compensating storage -- should be opposed until actual licensed demand is established and water management options for the stream system are reviewed. Opportunities for storage development within these systems should be reviewed.*

The Nadina River has natural low summer low flows in relation to its mean annual flow. This streams is mostly unaffected by water demand and there are no outstanding licence applications. However, it is not restricted or reserved and there remains a potential for future increased water demand. *We recommend that low flows be monitored on this stream and instream flow needs assessed.* If demand increases, low flow agreements, or restrictive licensing, may be used to maintain instream flows. There are opportunities to develop storage in the basins of many of the salmon streams and these should be investigated in conjunction with biological studies. Storage may either supplement existing flows or meet future demand.

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

The Nechako Reservoir is the main storage reservoir and releases are already managed by the Nechako Conservation Program. However, other watersheds have large lakes where storage may be developed to improve low flows. DFO may participate in developing extra storage, or improving existing storage, on some salmon streams to provide additional water for release during low instream flows. In both instances, it should be ensured that some contractual relationship clearly spells out the reservoir operator's obligations.

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

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.

While it is not likely that groundwater extractions are affecting surface water discharges in the salmon streams they may affect low flows in some small tributaries. We recommend that shallow wells be inventoried and the potential reduction in streamflow from pumping from groundwater be roughly evaluated.

8.2.4 Forest Harvesting

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

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

1. It is difficult to manage the rate of cut because the Ministry of Forests does not store or present their records of openings or their proposed cut 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 of all the salmon streams should be established and the clearcut equivalent area estimated.*

2. The relationship between re-growth and hydrologic recovery is not known for the watersheds. Consequently, it is difficult to assess the effective clearcut area of watersheds with cut blocks of varying ages, and varying levels of regrowth, and the potential impact on the hydrologic regime: we recommend that further studies be undertaken. Research underway in the Stuart-Takla Fisheries/Forestry Interaction Project (Macdonald et al 1992) is examining rate of cut and cumulative impact issues.

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

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

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. *The Department of Fisheries & Oceans 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 Nechako 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 Nechako 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.*

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TABLES

Table 1: Salmon Streams in the Nechako HMA.

	Stream Name	SSIS Number	WSC Gauge Data: Gauge Name	Gauge No.	Drainage Area (km2)	Total Drainage Area (km2)	Years of Record
	NECHAKO RIVER						
1	Nechako R.	08-0000	below Cheslatta Falls	08JA017	15,600	51,900	1980-91 RC
			at Vanderhoof	08JC001	25,100		1948-85 MC: 1986-91 RC
			at Isle Pierre	08JC002	42,500		1950-91 RC
1a	Lower Nechako R.	*	-	-	-	7,729	-
1b	Upper Nechako R.	*	-	-	-	44,171	-
	CHILAKO RIVER						
2	- Chilako R.	08-0500	near Prince George	08JC005	3,390	3,578	1960-74 MC
2a	- Lower Chilako R.	*	-	-	-	1,442	-
2b	- Upper Chilako R.	*	-	-	-	2,136	-
	NAUTLEY RIVER						
3	- Nautley R.		near Fort Fraser	08JB003	6,030	6,048	1950-73 MC; 1976-91 RC
4	- Stellako R.	08-2700	at Glenannan	08JB002	3,600	3,600	1950-79 MC: 1980-91 RC
5	- Ormond Ck.	08-2700-080	-	-	-	251	-
6	- Endako R.	08-2700-140	at Endako	08JB004	1,750	2,033	1950 MS: 1951 M#
6a	- Lower Endako R.	*	-	-	-	1,018	-
6b	- Upper Endako R.	*	-	-	-	1,015	-
6c	- Tchesinkut Ck.	*	-	-	-	348	-
7	- Shovel Ck.	08-2700-140-17	-	-	-	371	-
8	- Nithi R.	08-2700-190	-	-	-	322	-
9	- Uncha Ck.	08-2700-410	-	-	-	614	-
9a	-Binta Ck.	*	-	-	-	190	
10	- Nadina R.	08-2700-990	at outlet of Nadina Lk	08JB008	399	1,093	1964-74 MS: 1975-91 RC
			near Noralee	08JB006	1,050		1950-58 RS
10a	- Lower Nadina R.	*	-	-	-	721	-
11	- Upper Nadina R.		-	-	-	372	-
12	- Tagetochlain Ck.	08-2700-990-25	-	-	-	176	-

- 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 Nechako HMA.

Stream Name	SSIS Number	Total Drainage Area (km2)	Physiographic Region (1)	Ecoregion (2)	Ecosection (3)
NECHAKO RIVER					
1 Nechako R.	08-0000	51,900	NL/NP/TR	FB/FP/CG	NEL/NAU/NEP/BUB/KIR
1a Lower Nechako R.	-	7,729			-
1b Upper Nechako R.	-	44,171			-
CHILAKO RIVER					
2 - Chilako R.	08-0500	3,578	NL/NP	FP/FB	NEL/NAU
2a - Lower Chilako R.	-	1,442	NL	FP/FB	NEL
2b - Upper Chilako R.	-	2,136	NP	FP	NEL/NAU
NAUTLEY RIVER					
3 Nautley R.	-	6,048	NP	FP/FB	BUB/NEP
4 - Stellako R.	08-2700	3,600	NP	FP	BUB/NEP
5 - Ormond Ck.	08-2700-080	251	NP	FP/FB	BUB
6 - Endako R.	08-2700-140	2,033	NP	FP	BUB
6a - Lower Endako R.	-	1,018	NP	FP	BUB
6b - Upper Endako R.	-	1,015	NP	FP	BUB
6c - Tchesinkut Ck.	-	348	NP	FP	BUB
7 - Shovel Ck.	08-2700-140-17	371	NP	FP	BUB
8 - Nithi R.	08-2700-190	322	NP	FP	BUB
9 - Uncha Ck.	08-2700-410	614	NP	FP	BUB
9a - Binta Ck.	-	190	NP	FP	BUB
10 - Nadina R.	08-2700-990	1,093	NP	FP	BUB/NEP
10a - Lower Nadina R.	-	721	NP	FP	BUB
11 - Upper Nadina R.	-	372	NP	FP	NEP
12 - Tagetochlain Ck.	08-2700-990-25	176	NP	FP	NEP

1. Physiographic Regions are from Matthews (1986). NL is the Nechako Lowlands, NP is the Nechako Plateau and TR is the Tahtsa Ranges of the Coast Mountains.
2. Ecoregions are from Demarchi (1993). FB is the Fraser Basin; FP, the Fraser Plateau; CG, the Coastal Gap Ecoregion.
3. Ecosections are from Demarchi (1993). NEL is the Nechako Lowland Ecosection; NEP is the Nechako Plateau Ecosection; NAU is the Nazko Upland Ecosection; BUB is the Bulkley Basin Ecosection; and KIR is the Kitimat Ranges Ecosection.

Table 3: Regional Climate in the Nechako HMA.

Climate Station	Ecoregion/ Ecosection	Physiographic Region	Latitude	Longitude	Elevation (m)	Precipitation (mm)				Mean Annual Temperature
						Annual	May to Sept	Annual Snowfall	Greatest Daily	
Fraser Basin Ecoregion										
Prince George A	*NEL*	*NL*	53.53	122.41	676	614.7	296.7	233.8	50	3.7
Fort St James	*NEL*	*NL*	54.27	124.15	686	476.4	213.1	195	55.9	2.8
Fort Fraser 13S	*NEL*	*NL*	53.53	124.35	701	527.9	329.4	197.8	34.8	--
Fraser Plateau Ecoregion										
Fraser Lk North Shore	*BUB*	*NP*	54.05	124.51	671	503.6	233.1	190.2	31.4	2.8
Burns Lake	*BUB*	*NP*	54.14	125.46	704	455.9	149.0	186.9	43.6	2.9
Ootsa Lk Skins Lake Spillway	*BUB*	*NP*	53.46	125.58	861	416.6	178.0	166.6	53.6	3.1
Wistaria	*BUB*	*NP*	53.49	126.13	863	430.3	188.0	188.2	39.6	2.6
Quick	*BUB*	*NP*	54.37	126.54	533	461.3	186.7	162.8	52.6	--
Coastal Gap Ecoregion										
Tahtsa Lake West	*KIR*	*TR*	53.37	127.42	863	2007.5	407.8	995.2	133.4	2.1

- NEL is the Nechako Lowland Ecosection; BUB is the Bulkley Basin Ecosection; and KIR is the Kitimat Ranges Ecosection.
- NL is the Nechako Lowland; NP is the Nechako Plateau; and TR is the Tahtsa Ranges of the Coast Mountains.

Table 4: Hydrologic Characteristics of the Ecoregions.

	Nechako Lowland Ecosection	*Nechako Plateau, Bulkley Basin & Nazko Ecosections*	*Tahtsa Ranges Ecosection*
Mean Annual Runoff (mm)	100 to 250 increases to north	100 to 400 increases to east	1800
Month with Average Maximum Discharge	May	May or June	June; remains high in July
Timing of annual maximum discharge	late April to early June	late-April to July; sometimes in Fall	late May or June; often in October and November
Month with Average Minimum Discharge	February	February or March	March
Timing of annual minimum discharge	from December through March; sometimes in late summer	from December through March; sometimes in late summer	December to April
Typical Stream	Chilako River near Prince George 08JC005	Van Tine Creek near the mouth, 08JA014	Laventie Creek near the mouth, 08JA015
Basin Area (km2)	3390	153	86.5

Table 5: Channel Stability in the Nechako HMA.

Stream Name	SSIS Number	Channel Response						Human Modifications					
						Bed Material							
		Pattern Change	Erosion	Incision	Aggradation	Scour	Sedimentation	Dyking	River Training	Encroachment	Gravel Removal	Veget. Removal	Debris Removal
NECHAKO RIVER													
1 Nechako R.	08-0000						■						
1a Lower Nechako R.	*												
1b Upper Nechako R.	*												
CHILAKO RIVER													
2 - Chilako R.	08-0500		■									■	
2a - Lower Chilako R.	*												
2b - Upper Chilako R.	*												
NAUTLEY RIVER													
3 - Nautley R.	*												
4 - Stellako R.	08-2700								●				
5 - Ormond Ck.	08-2700-080				●		●						
6 - Endako R.	08-2700-140								●				
6a - Lower Endako R.	*												
6b - Upper Endako R.	*												
6c - Tchesinkut Ck.	*		▲										
7 - Shovel Ck.	08-2700-140-170												
8 - Nithi R.	08-2700-190				▲								
9 - Uncha Ck.	08-2700-410												
9a -Binta Ck.	*												
10 - Nadina R.	08-2700-990												
10a - Lower Nadina R.	*												
11 - Upper Nadina R.													
12 -Tagetochlain Ck	08-2700-990-250												

"■" 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 the Salmon Streams in the Nechako HMA.

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Areas: Oldest (52-61) (km2)	Older (62-71) (km2)	Old (72-81) (km2)	Recent (82-91) (km2)	Proposed (1992-97) (km2)	Total Water Licenses: Domestic (g/day)	Irrigation (ac-ft)	Waterworks (g/day)	Industrial (g/day)	Conservation (cfs)	Licensed Demand (L/s): Aug	Sept	Feb	Naturalized Flows in the Salmon Streams (m3/s): Mean Annual	Mean Flood	Mean Monthly: Aug	Sept	Mean 7-day Flow: Summer	Winter
NECHAKO RIVER																					
Nechako R.	08JC002	51,900	37.3	391.6	927.3	1579.4	617.8	192,000	21,920	56,674,725	119,857,635	2,040	10940	9299	9299	244.65	561.9	448.96	220.45	144.67	97.62
- Lower Nechako R.		7,729	35.5	298.0	606.2	990.0	306.0	179,000	19,707	56,574,725	114,877,885	40	10506	9031	9031						
- Upper Nechako R.		44,171	1.7	93.6	321.1	589.4	311.8	13,000	2,214	100,000	4,979,750	2,000	434	268	268						
CHILAKO RIVER																					
Chilako R.	08JC005	3,578	22.0	101.0	245.1	290.4	141.4	7,500	1,610	0	30,000	0	123	2	2	12.30	80.2	7.76	6.86	5.35	4.91
- Lower Chilako R.		1,442	22.0	98.6	46.2	104.5	54.8	6,000	1,610	0	10,000	0									
- Upper Chilako R.		2,136	0.0	2.4	198.9	185.8	86.6	4,500	0	0	20,000	0									
NAUTLEY RIVER																					
Nautley R.	08JB003	6,048	-	-	-	-	-	101,000	3,611	1,045,000	3,209,664	40	500	229	229	21.88	76.0	24.65	15.01	12.13	6.23
- Stellako R.	08JB002	3,600	8.6	97.0	278.8	526.5	102.0	71,000	2,376	1,040,000	2,634,370	40	375	197	197	15.75	47.7	20.98	12.75	6.78	4.48
- Ormond Ck.		251	0.0	3.4	4.4	2.3	0.0	0	0	0	0	0	0	0	0	1.10	5.3	0.93	0.58	0.43	0.33
- Endako R.		2,033	1.6	13.8	75.0	80.5	22.3	30,000	1,235	5,000	575,294	0	125	32	32	6.13	43.1	2.67	1.83	1.43	1.33
- Lower Endako R.		1,018	1.2	5.3	43.2	38.1	9.8	16,000	802	5,000	277,075	0									
- Upper Endako R.		1,015	0.5	8.6	31.7	42.5	12.6	14,000	433	0	298,219	0									
- Tchesinkut Ck.		348	1.2	0.5	9.4	29.6	3.8	9,500	325	0	276,075	0	39	15	15						
- Shovel Ck.		371	0.0	0.0	24.7	5.5	2.7	0	0	0	0	0	0	0	0	1.62	7.8	1.37	0.85	0.63	0.48
- Nithi R.		322	0.7	13.3	12.5	21.9	15.3	0	0	0	674,106	0	35	35	35	1.41	6.8	1.19	0.74	0.55	0.42
- Uncha Ck.		614	2.1	10.8	30.9	87.0	13.0	12,000	315	4,000	9,500	0	25	1	1	2.68	13.0	2.27	1.41	1.04	0.80
-Binta Ck.		190	0.0	5.0	23.0	41.8	4.3	0		0	0	0									
- Nadina R.		1,093	0.4	12.9	63.2	177.7	14.9	1,500	0	0	0	40	0	0	0	8.27	83.8	5.92	3.63	2.04	1.62
- Lower Nadina R.		721	0.4	12.9	62.9	166.7	1.8	1,500	0	0	0	0									
- Upper Nadina R.	08JB008	372	0.0	0.0	0.3	11.0	13.1	0	0	0	0	40	0	0	0	5.24	41.4	3.44	2.06	1.08	0.73
- Tagetochlain Ck.		176	0.0	9.0	8.0	53.1	1.8	0	0	0	0	0	0	0	0	0.77	3.7	0.65	0.40	0.30	0.23

- Gauge numbers in Column 2 indicate that flow characteristics were calculated from those Water Survey of Canada 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 of the Nechako HMA.

Stream Name	*Basin Area (mouth) (km2)*	*Total Non-Power Storage (ac-ft)*	*Total Conservation Storage (ac-ft)*	*Total Irrigation Licences (ac-ft)*	*Percent with Storage (%)*
NECHAKO RIVER					
Nechako R.	51,900	2,948	48,493	21,920	13%
Lower Nechako R.	7,729	2,813	43,368	19,706	14%
Upper Nechako R.	44,171	135	5,125	2,214	6%
CHILAKO RIVER					
- Chilako R.	3,578	472	1,915	1,610	29%
- Lower Chilako R.	1,442	472	1,104	1,610	29%
- Upper Chilako R.	2,136	0	811	0	0%
NAUTLEY RIVER					
-Nautley R.	6,048	356	23,201	3,611	10%
- Stellako R.	3,600	312	38,171	2,376	13%
- Ormond Ck.	251	0	0	0	0%
- Endako R.	2,033	45	1,030	1,235	4%
- Lower Endako R.	1,018	2	998	802	0%
- Upper Endako R.	1,015	43	32	433	10%
- Tchesinkut Ck.	348	2	0	325	1%
- Shovel Ck.	371	0	0	0	0%
- Nithi R.	322	0	0	0	0%
- Uncha Ck.	614	10	0	315	3%
- Binta Ck.	190	0	0	0	0%
- Nadina R.	1,093	0	16,000	0	0%
- Lower Nadina R.	721	0	0	0	0%
- Upper Nadina R.	372	0	16,000	0	0%
- Tagetochlain Ck.	176	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.
-Conservation storage includes the 16,000 acre-feet storage on Nadina Lake.

Table 9: Sensitivity Indices -- Nechako HMA.

Stream Name	Status	SUMMER WATER USE Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	LOW FLOWS Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	PEAK FLOWS Index 7 Q2/ QAA	LOGGING Index 8 Total/ Basin	Index 9 Recent/ Basin	Index 10 Recent & Proposed
NECHAKO RIVER											
Nechako R.	OR	8%	6%	2%	4%	55%	36%	2	6%	3%	4%
Lower Nechako R.	OR								25%	13%	17%
Upper Nechako R.	OR								2%	1%	2%
CHILAKO RIVER											
Chilako R.		2%	0%	2%	0%	43%	40%	7	18%	8%	12%
Lower Chilako R.									19%	7%	11%
Upper Chilako R.									18%	9%	13%
NAUTLEY RIVER											
Nautley R	FR & OR	4%	2%	2%	2%	54%	27%	3	-	-	-
- Stellako R.		6%	3%	2%	2%	42%	27%	3	25%	15%	17%
- Ormond Ck.		0%	0%	0%	0%	39%	30%	5	4%	1%	1%
- Endako R.		9%	2%	5%	2%	23%	21%	7	8%	4%	5%
- Lower Endako R.									9%	4%	5%
- Upper Endako R.									8%	4%	5%
- Tchesinkut Ck.									12%	9%	10%
- Shovel Ck.		0%	0%	0%	0%	39%	30%	5	8%	1%	2%
- Nithi R.		6%	6%	3%	5%	36%	27%	5	15%	7%	12%
- Uncha Ck.		2%	0%	1%	0%	39%	30%	5	21%	14%	16%
-Binta Ck.									37%	22%	24%
- Nadina R.		0%	0%	0%	0%	25%	20%	10	23%	16%	18%
- Lower Nadina R.									34%	23%	23%
- Upper Nadina R.		0%	0%	0%	0%	21%	14%	8	3%	3%	6%
- Tagetochlain Ck.		0%	0%	0%	0%	39%	30%	5	40%	30%	31%

-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 and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Total is total logging; Recent is recent logging Proposed is proposed cut (1992-1997); Basin is basin area above the mouth.

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

Table 10: Most Sensitive Streams -- Nechako HMA

Water Demand	*Summer Low Flows*	*Winter Low Flows*	*Forest Harvesting*
1 to 4	*5*	*6*	*8 to 10*
Nechako R	Endako R.	Endako R	Lower Nechako
Endako R	Nadina R.	Nadina R.	Stellako R
Nithi R	Upper Nadina R	Upper Nadina R	Uncha Ck
			Binta Ck
			Nadina R
			Lower Nadina R
			Tagetochlain Ck

FIGURES

Figure 1: Fraser River Habitat Management Areas

Figure 2: Salmon Streams in the Nechako HMA

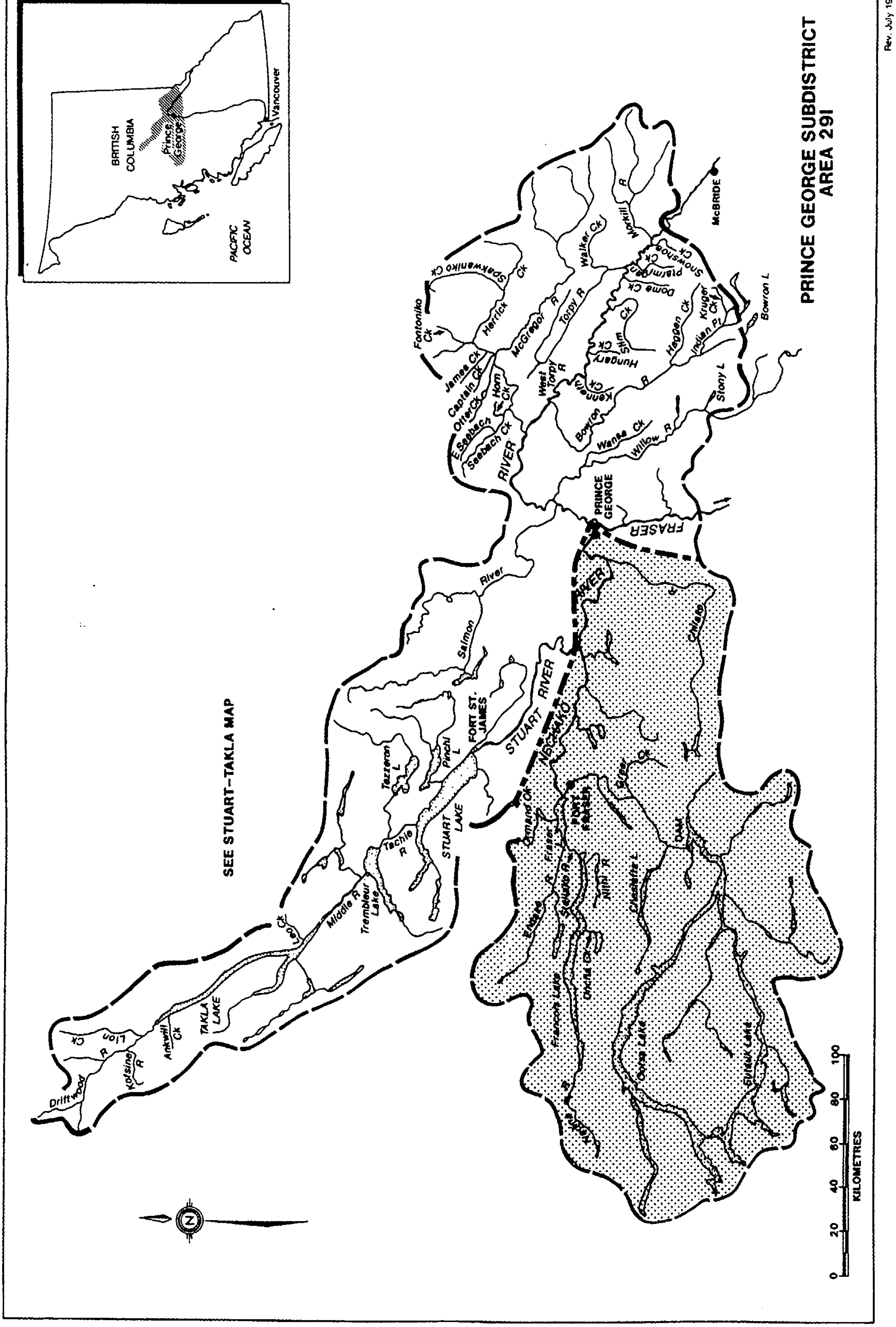
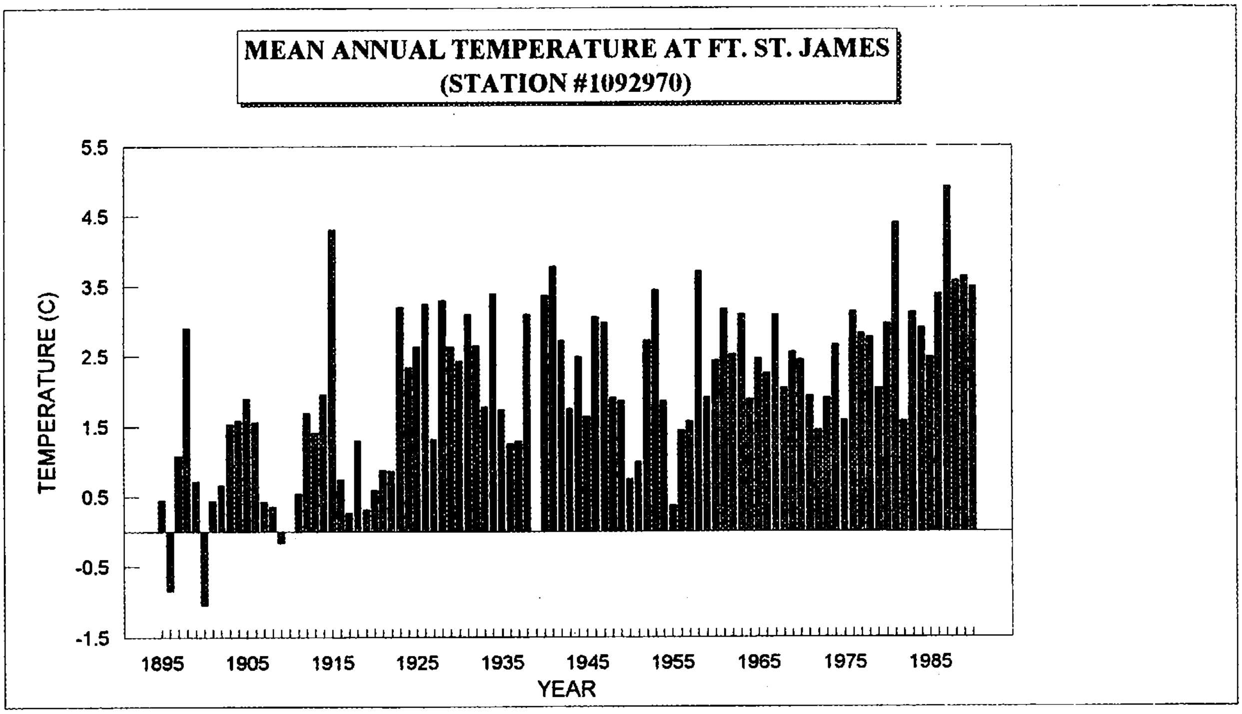


Figure 4: Long-Term Precipitation and Temperature Trends at Fort St. James



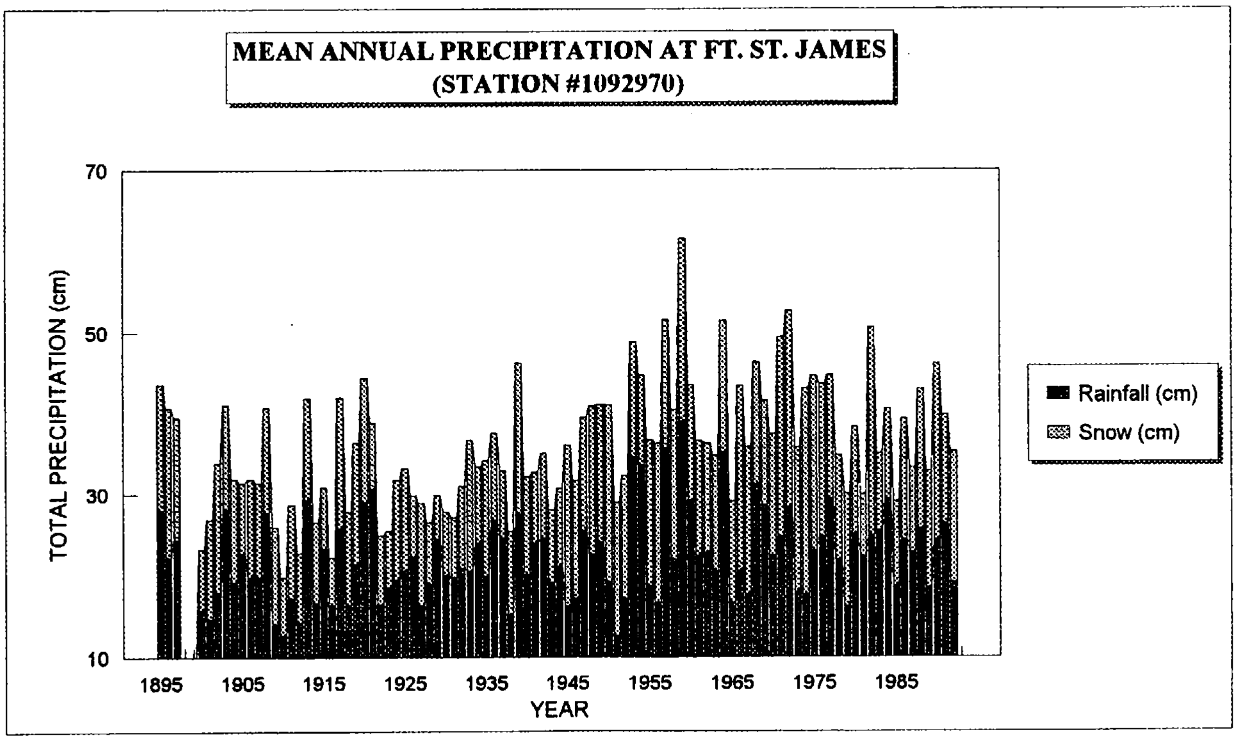


Figure 5: Calculation of Natural and Naturalized Flows for the Salmon Streams

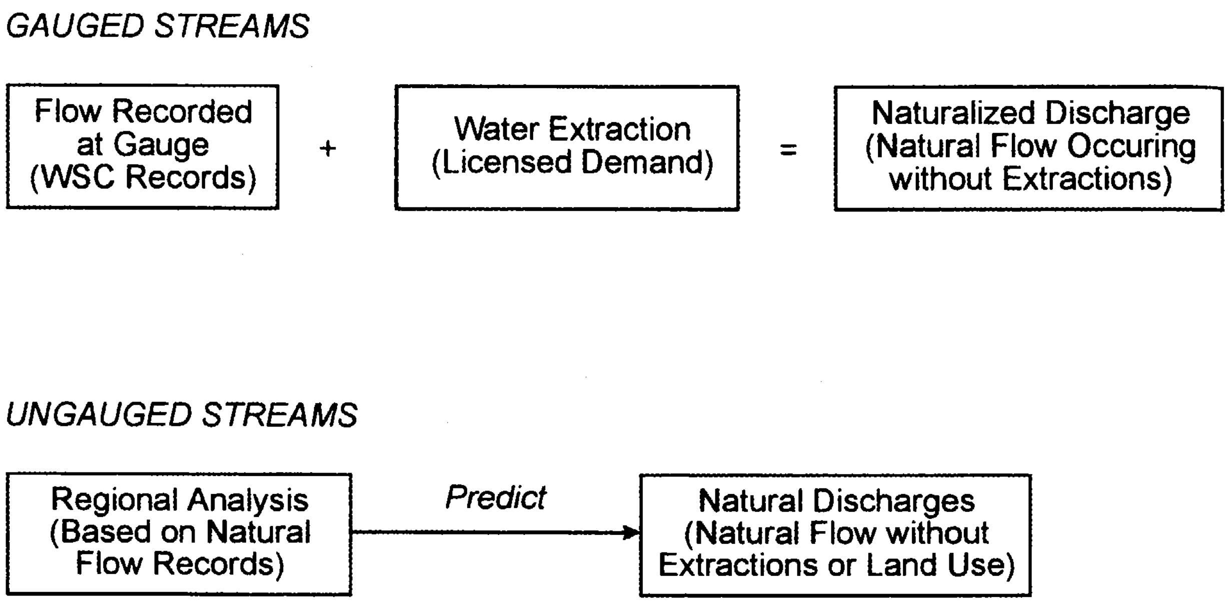


Figure 6: Long-Term Variation in Discharge: Stellako River at Glenannen

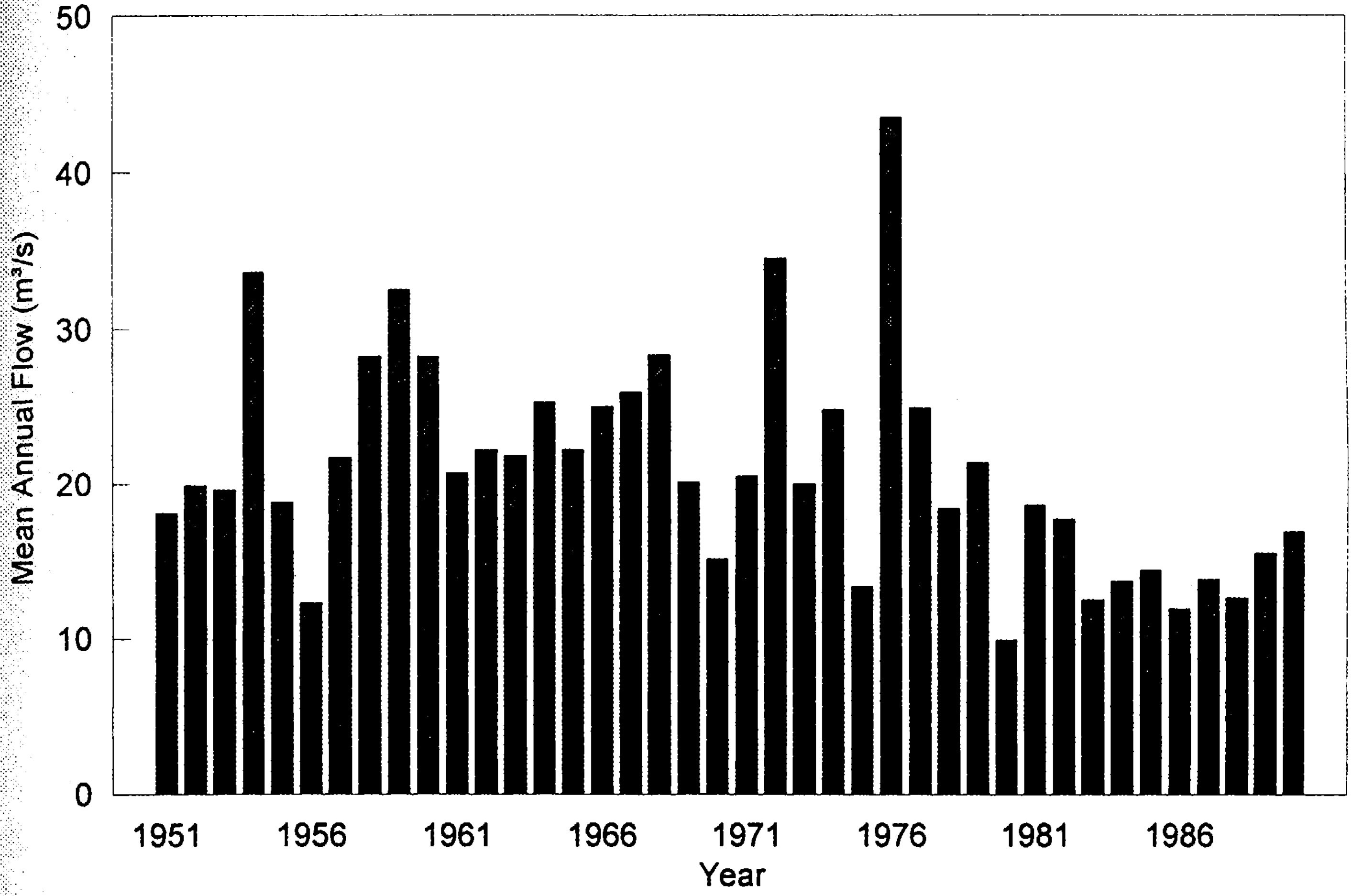


Figure 7: Classification of British Columbia Water Licences

No.	USE CLASS	DESCRIPTION (uses included)	UNITS
	CONSUMPTIVE:		
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
	NON-CONSUMPTIVE:		
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

ESTIMATING FLOWS AT THE MOUTH OF UNGAUGED SALMON STREAMS

A. ESTIMATING FLOWS AT THE MOUTH OF UNGAUGED SALMON STREAMS

Many of the salmon streams have either been gauged by the Water Survey of Canada or have miscellaneous measurements by the Water Management Branch. The Nechako, Nautley and Stellako Rivers met the requirements for a gauged salmon stream, as they have Water Survey of Canada stations operating near their mouths and continuous records from 1981 to 1990.

The hydrologic characteristics of the other salmon streams were estimated by regional regression analysis or, to a lesser extent, by transfer and adjustment of flow records from upstream gauges or gauges on other streams, use of older gauging records, or miscellaneous measurements. Table A1 summarizes the procedures used for calculations on each salmon stream, which are described in detail in the following sections.

A.1 Regional Hydrologic Analysis

Regional hydrologic analysis was the most common method for estimating flows (Table A1). This procedure predicts the flow characteristics of ungauged watersheds from relationships between flow characteristics and climate or physiography that were developed for watersheds with gauging stations. The simplest and best relationships occur within regions, such as the Nechako Plateau and Nechako Lowland that are reasonably homogeneous with respect to flow-generating mechanisms, climate and physiography.

A.1.1 Criteria for Selecting Gauging Records

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

1. All stations should have a complete or nearly complete record of flows during a common base period. In this report our base period is 1981 to 1990, inclusive;

2. The length of the base period should be at least 10 years, though some compromise is necessary between long base periods and the number of stations available for inclusion in the analysis;

3. Typically, drainage areas at the gauging sites should exceed 100 km^2 and be less than several thousand km^2. The lower limit avoids local anomalies, the upper limit avoids artificially high correlations induced by including large drainage areas that encompass most of the region. Most of the basins that require flow predictions are between 200 and 1,000 km^2;

4. The records should all be reasonably independent. Where there are multiple records on one stream, only one record should be used or the records should be subtracted to produce flow estimates for the independent portions of the total basin area; and

5. There should be no upstream regulation, water use, or diversion out of the basin.

The above list is ideal; the following section discusses relaxing these criteria to provide sufficient stations for an adequate statistical analysis.

A.1.2 Water Survey of Canada Records

Table A2 lists the Water Survey of Canada stations on the Nechako Plateau or Lowland, or nearby, that were used for analysis. There are twelve stations within these ecoregions but two stations have higher runoff than the others (MacIvor Creek and Nadina River) and were eliminated from further analysis.

Most of the stations have complete records during the 1980's, but it was necessary to adjust records on Wright and Richfield Creeks to the 1981-1990 period using records on the Salmon River. The adjustment consisted of determining the ratio of the flow characteristics over the gauging period, and over 1981-1990, at the long-term gauges. These ratios were then applied to the flow characteristics calculated from the older record. Table A2 indicates the period of record used for the adjustment at the older gauges.

Water is extracted from some streams upstream of their gauges. Flows were adjusted following the procedures outlined in Chapter 2 of the report, utilizing summaries of water licences obtained from the Water Management Branch. Table A2 reports the adjusted data.

Not all the records in Table A2 are independent but gauging areas at the stations in the same watersheds are sufficiently different to require no adjustment.

A.1.3 Climate and Physiographic Data

There is only a small variability of climate within the Nechako Lowland and Plateau but basin elevation and lake areas vary, which affect low flows. Drainage area, maximum elevation, the portion of the basin over 1,000 m, and the area of lakes in the watershed were selected to correlate with the hydrologic characteristics at the gauging stations. Basin area was strongly correlated with all characteristics and lake area was correlated with mean annual flow, mean September flow and the summer and winter 7 day low flows. Multiple-variable regression equations based on these two characteristics had high correlation coefficients but the predicted flows were not always logical. The multi-variate equations predicted higher September than August flows which does not agree with observations on gauged streams in the region. As a result, the area of lakes was dropped from the analysis, though it may be important in individual watersheds, and regression equations were based on drainage area.

A.1.4 Regression Analysis

Procedures: The procedures used in predicting flows on the ungauged salmon streams were:

1. Bi-variate correlation between drainage area and the chosen flow characteristic were calculated for both logarithmic transformed and non-transformed data.

2. The relationship with the highest r^2 and the lowest standard error, for each flow characteristic, was established.

3. The selected relationship was used to predict flow characteristics at ungauged salmon streams.

Mean Annual Flows and Mean Annual Floods: Basin area was significantly correlated with both mean annual flow and mean annual flood. Correlations were stronger with non-transformed variables. The regression equations were constrained to pass through zero. The constants and coefficients for the linear regression equations, relating mean annual flow and mean annual flood to basin area are shown in the following table:

Variable	Constant	Coefficent	r^2	SE_y	N
Mean Flow	0.0	0.0044	0.92	2.55	10
Mean Flood	0.0	0.021	0.46	37.5	10

The coefficient of the mean annual flow equation is equivalent to an annual runoff of 139 mm. Because the equations were constrained to pass through zero, the ratio of the mean flood to mean flow is constant for all watersheds, where these values are estimated by the regression equations. The constant value is 0.021/0.0044, or 5.

Mean Monthly Flows: Basin area was significantly correlated with both August and September mean monthly flows. Correlations were stronger with non-transformed variables. The regression equations are constrained to pass through zero. The constants and coefficients for the linear regresssion equations, relating mean August and September flows to basin area are summarized in the following table.

Month	Constant	Coefficient	r^2	SE_y	N
August	0	0.0037	0.78	4.39	10
Sept	0	0.0023	0.82	2.43	10

Seven Day Low Flows: Basin area was significantly correlated with both summer and winter 7 day low flows. Correlations were stronger with non-transformed variables. The regression equations are constrained to pass through zero. The constants and coefficients for the linear regresssion equations, relating mean summer and winter 7 day low flows to basin area are summarized in the following table.

Flow	Constant	Coefficient	r^2	SE_y	N
Summer	0	0.0017	0.84	1.67	10
Winter	0	0.0013	0.90	0.93	10

Using these two equations means that the the ungauged watersheds will have their annual minimum flows during winter. This is appropriate for watersheds with large lakes which is true for most of the ungauged salmon streams.

A.1.5 Predicting Flow Characteristics in Ungauged Salmon Streams

The equations from the above section were used to predict mean annual flows, mean annual floods, mean monthly and mean 7 day low flows for some of the ungauged salmon streams (Table A1). Predicted flows for salmon streams, which have no gauging records, are calculated from the regression equations and reported in Table 7. For those salmon streams with short-term records collected by the Water Survey of Canada or miscellaneous low flow measurements by the Water Management Branch, the measurements were sometime used instead of the regression estimates. Procedures used for the individual streams are discussed below.

A.2 Estimates from Older or Incomplete Gauging Records

Older or incomplete gauging records were used to estimate flows at the mouth of the following salmon streams:

Chilako River: The "Chikako River near Prince George, 08JC005" gauge operated near its mouth from 1960 to 1974. Mean annual flow, mean annual flood, mean monthly discharges and mean 7 day low flows were calculated from these records. The calculated characteristics were adjusted to the 1981-1990 period with the "Baker Creek at Quesnel, 08KE016" record, as discussed in Section A.1.2. The records at the gauge were assumed to reflect flows at the mouth.

A.3 Transfers from Upstream or Nearby Gauges

Flows were estimated at the following gauging stations by transfer from an upstream gauge or from a gauge on a nearby similar stream:

Nechako River: The flows recorded at the "Nechako River at Isle Pierre, 08JC002" gauge, which has operated from 1950 through 1993, were used to calculate flow characteristics for 1981 to 1990. The flows were adjusted to the mouth by adding Chilako River flows multiplied by 2.4 to reflect inflows from the total drainage area to the mouth.

Endako River: Flows in the Endako River calculated by subtracting measured discharge at the "Stellako River near Glenannen, 08JB002" from those at the "Nautley River near Fort Fraser, 08JB003", gauge and correcting the difference for mean changes in storage on Fraser Lake, adjusted for losses to lake evaporation. The evaporation adjustments are uncertain and the differences were reduced by 1 m^3/s in August and 0.5 m^3/s in September. Mean 7 day low flows in the summer were set as a percentage of the calculated September flow. Mean 7 day winter flows were calculated from the difference at the two gauges adjusted by the average storage contribution from Fraser Lake.

Nadina River: Flow characteristics were calculated for 1981 to 1990 at the "Nadina River at the outlet of Nadina Lake, 08JB008" gauge. This gauge records flow from 399 km^2 (38% of the total area) of the watershed, and includes inflows from the higher elevations in Tahtsa Ranges. As a result, the upper Nadina has much higher mean annual runoff than the lower part of the basin.

Flows at the mouth were estimated by adding discharges predicted from the regression equations for the lower 650 km^2 of the watershed to the recorded flows at the gauge at Nadina Lake. These flows were then compared with the seasonal records from 1950 to 1958 at the "Nadina River near Noralee, 08JC006" gauge to ensure that this approach predicted reasonable flows.

A.4 Miscellaneous Measurements

Miscellaneous flow measurements were collected on Ormond Creek in 1989 which was a relatively low flow year. Regression equations were used to estimate flows in preference to the miscellaneous measurements though the minimum flow of 52 L/s on August 18, 1989 may indicate the magnitude of summer low flows during a long, dry period.

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

	Stream Name	WSC Gauging Records		WMB Miscellaneous Measurements	Drainage Area (km2)	Mean Annual Flow	Mean Annual Flood	Monthly Discharges		7 Day Low Flows	
		Gauge Name	Drainage Area (km2)					Mean August	Mean September	Mean Summer	Mean Winter
	NECHAKO RIVER										
1	Nechako River	at Isle Pierre	42500		51,900	transfer	transfer	transfer	transfer	transfer	transfer
	CHILAKO RIVER										
2	- Chilako R.	near Prince George	3390		3,578	transfer	transfer	transfer	transfer	transfer	transfer
	NAUTLEY RIVER										
3	Nautley River	near Fort Fraser	6048		6,048	gauge	gauge	gauge	gauge	gauge	gauge
4	- Stellako R.	at Glenannen	3600		3,600	gauge	gauge	gauge	gauge	gauge	gauge
5	- Ormond Ck.	-		1989	251	regr.	regr.	regr.	regr.	regr.	regr.
6	- Endako R.	at Endako	1750		2,033	subtr.	subtr.	subtr.	subtr.	subtr.	subtr.
7	- Tchesinkut Ck.	-			348	regr.	regr.	regr.	regr.	regr.	regr.
8	- Shovel Ck.	-			371	regr.	regr.	regr.	regr.	regr.	regr.
9	- Nithi R.	-			322	regr.	regr.	regr.	regr.	regr.	regr.
10	- Uncha Ck.	-			614	regr.	regr.	regr.	regr.	regr.	regr.
11	- Nadina R.	near Noralee	1050		1,093	transfer	transfer	transfer	transfer	transfer	transfer
12	- Tagetochlain Ck.	-			176	regr.	regr.	regr.	regr.	regr.	regr.

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

Table A2: Physiographic and Streamflow Data

Gauging Station	Gauge Number	Period for Flow Calculations	Drainage Area (km2)	Area of Lakes (km2)	Maximum Elevation (m)	Area over 3500 feet (%)	Flow Characteristics (m3/s) Mean Flow	Mean Runoff (mm)	Mean Flood	Mean August	Mean September	Mean Summer 7 Day Low	Mean Winter 7 Day Low
Stellako River at Glenannen	08JB002	1981-1990	3600	370	2124	0.26	15.75	138	47.7	21.08	13.03	7.06	4.48
Van Tine Creek near the mouth	08JA014	1981-1990	153	1.25	1739	0.90	0.75	154	9.3	0.29	0.36	0.12	0.06
Nautley River near Fort Fraser	08JB003	1981-1990	6030	460	2124	0.34	21.88	114	76.0	24.80	15.43	12.55	6.23
Buck Creek at the mouth	08EE013	1981-1990	580	2	1563	0.56	3.97	216	41.0	0.82	0.48	0.29	0.30
Muskeg River north of Joanne Lk	08KC003	1981-1990	303	5	1000	0.00	1.91	198	17.0	0.44	0.45	0.32	0.55
Salmon River near Prince George	08KC001	1981-1990	4300	90	1527	0.05	24.34	179	176.1	5.79	4.71	3.10	7.80
Tsilcoh River near the mouth	08JE004	1981-1990	414	0.1	1000	0.01	2.14	163	26.1	0.35	0.38	0.23	0.58
Kazchek Creek near the mouth	08JE005	1981-1990	881	70	1600	0.35	5.99	214	34.1	2.85	1.44	0.87	1.30
Wright Creek at the mouth	08KC002	1965-1974	181	5	900	0.00	0.90	157	15.1	0.02	0.06	0.002	0.08
Richfield Creek near Topley	08EE009	1965-1974	173	3	1646	0.42	0.98	178	10.2	0.25	0.31	0.12	0.06
MacIvor Creek near the mouth	08JA016	1981-1990	53.4	0.1	2254	1.00	0.894	528	6.6	0.94	0.58	0.42	0.06
Nadina River at outlet of Nadina Lk	08JB008	1981-1990	399	20	2124	0.77	5.24	414	41.4	3.44	2.06	1.08	0.73

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 streams in the HMA. 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^3/s, for return periods up to about 100 years. Note that the confidence in the estimated flow at a given return period depends on the length of record available at the gauging station. For streams with only a few years of record (as shown by the number of data points) the curve is an approximation. Also note that estimates beyond about 50 years are only approximate even when there is ten or twenty years of record. No distribution is produced for the ungauged streams.

Annual 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.

NECHAKO RIVER

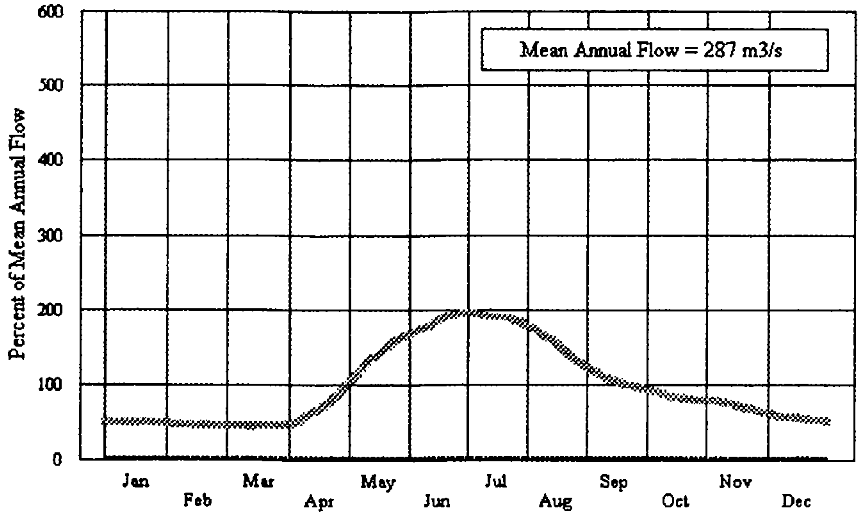
LICENSED WATER DEMAND

Stream number 08-0000
Water Survey of Canada Station 08JC002
Nechako River at Isle Pierre
Records 1950 to 1990
Drainage Area = 42,500 km²

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	179,500 g/d	9.4	9.4	9.4
Irrigation	20,160 ac.ft.	0	1,486	0
Waterworks	2,435,000g/d	128	128	128
Industrial	9,173,088g/d	483	483	483
Conservation	2,040 cfs			

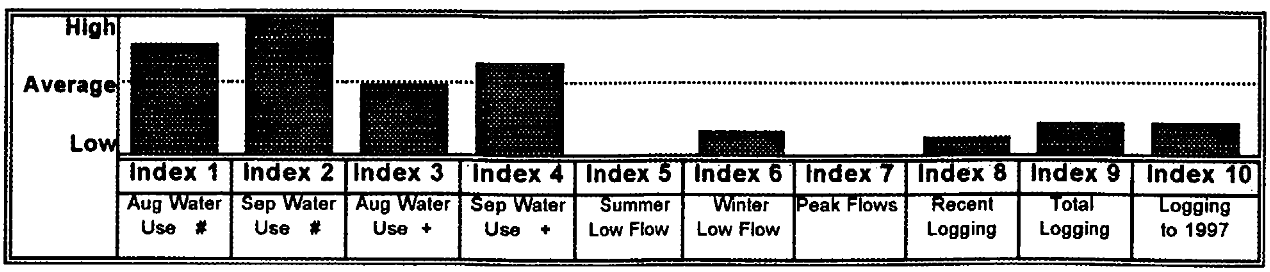
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	135,000	439,000	304000

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

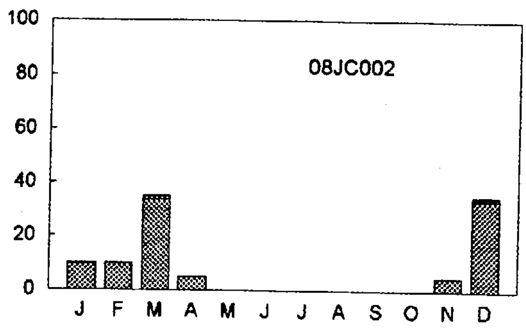
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



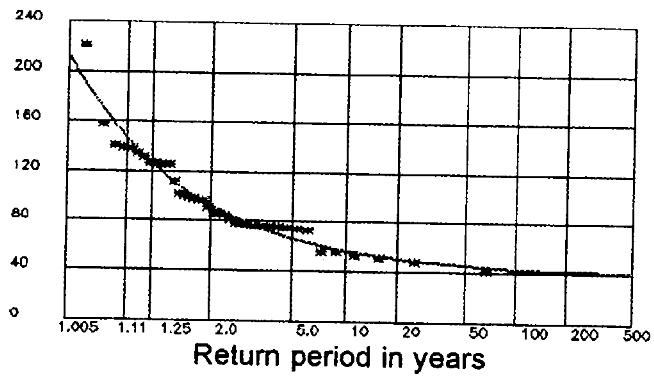
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

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



7 Day Low Flow Frequency Curve (Flow in m³/s)



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	91.9 m^3/s	56.0 m^3/s	49.8 m^3/s	44.8 m^3/s	42.4 m^3/s
Annual Flood	617 m^3/s	939 m^3 /s	1050 m^3/s	1180 m^3/s	1270 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. The Nechako river has been divided into three reaches by the Water Management Branch:

REACH 1 - Above Nautley River. Most of the flow results from releases from the Skins Lake Spillway. No new licences issued unless storage provided or it is demonstrated there is no impact on chinook. Potential water demand (existing licences) for August is 0.1% of the summer 7 day low flow of 33.1 m3/s. Future demand may be about 2.4%.

REACH 2 - Nautley River to Stuart River. Natural runoff provides a large proportion of the flow. Irrigation demand is increasing but further licensing is in abeyance. Water Management Branch and DFO are presently negotiating a "cap" for total extractions. Potential water demand (existing licences) for August is 0.8% of the summer 7 day low flow of 56.9 m3/s. Future demand may be about 4.3%.

REACH 3 - Below Stuart River - Adequate flows. No restriction on licensing.

2. Reduction of flows has resulted in some morphological changes, particularly in Reach 1 where sediment deposition in spawning areas is a continuing threat. The Nechako Fisheries Conservation Program Technical committee commissioned a series of reports which detail the morphological changes.

CHILAKO RIVER

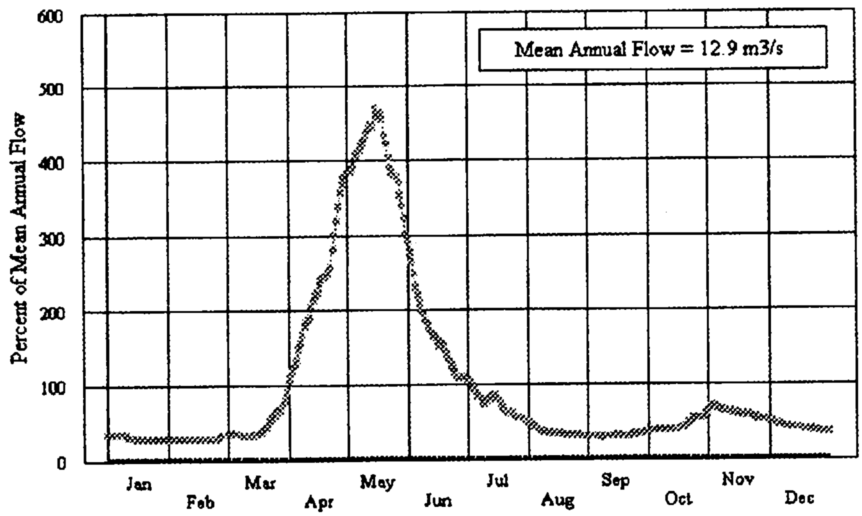
Stream number 08-0500
Water Survey of Canada Station 08JC005
Chilako River near Prince George
Records 1960 to 1974
Drainage Area = 3,390 km^2

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	7,500 g/d	0.39	0.39	0.39
Irrigation	1,610 ac.ft.	0	118	0
Waterworks	0 g/d			
Industrial	30,000 g/d	1.59	1.59	1.59
Conservation	0 cfs			

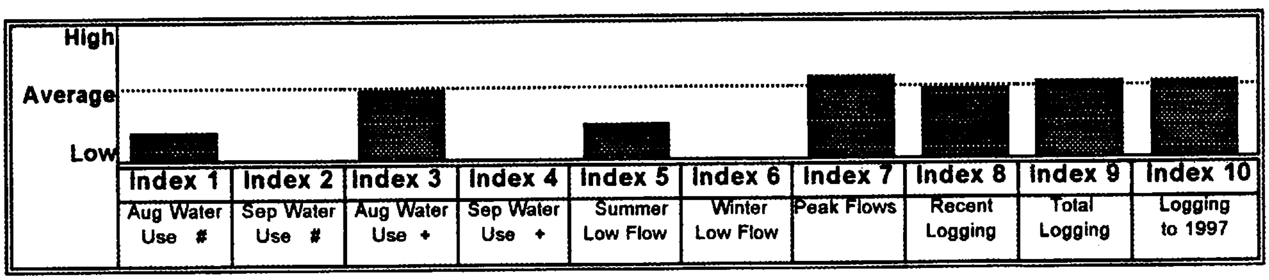
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	3,630	5,990	4,820

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

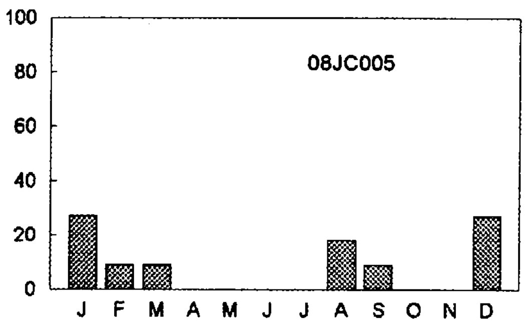
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



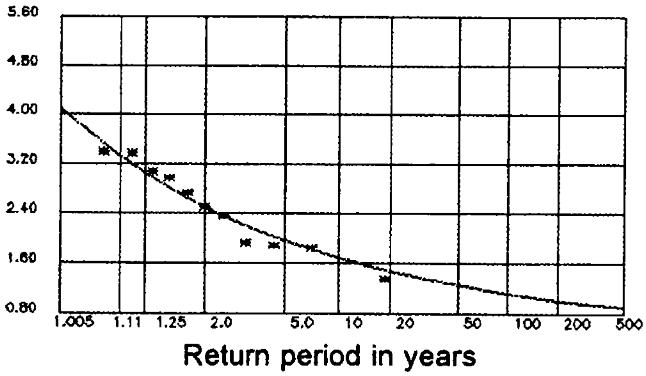
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

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



7 Day Low Flow Frequency Curve (Flow in m³/s)



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	2.51 m^3/s	1.67 m^3/s	1.46 m^3/s	1.24 m^3/s	m^3/s
Annual Flood	73 m^3/s	125 m^3/s	151 m^3/s	191 m^3/s	226 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. Nearly 20% of the Chilako Watershed has been logged; some tributaries have greater percentages logged. The Ministry of Forests has started a review of the rate of cut in five tributary drainages following a request by the Department of Fisheries and Oceans.

2. The lower mainstem is highly turbid from erosion of lacustrine deposits. Loss of streamside vegetation from farming and logging aggravates the erosion process.

3. Although fences partly control their movements, range cattle damage the riparian habitat in many locations in the watershed.

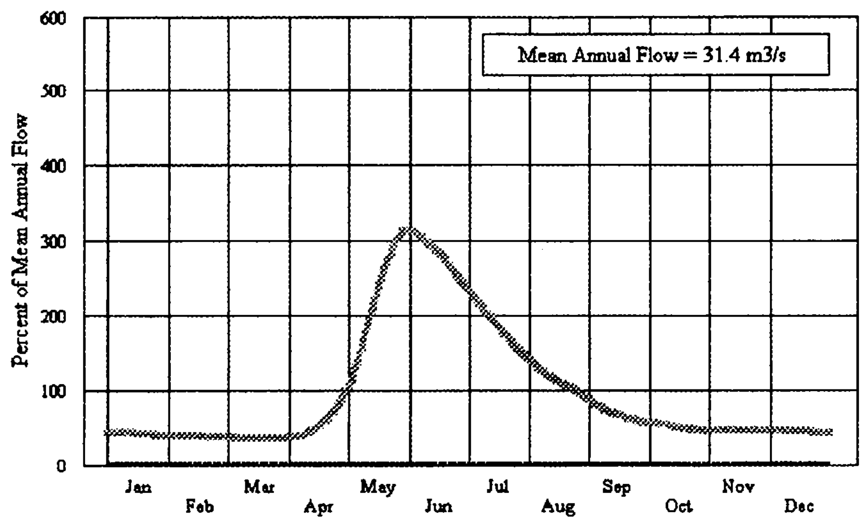
NAUTLEY RIVER

LICENSED WATER DEMAND

Stream number
Water Survey of Canada Station 08JB003
Nautley River near Fort Fraser
Records 1950 to 1990
Drainage Area = 6,030 km^2

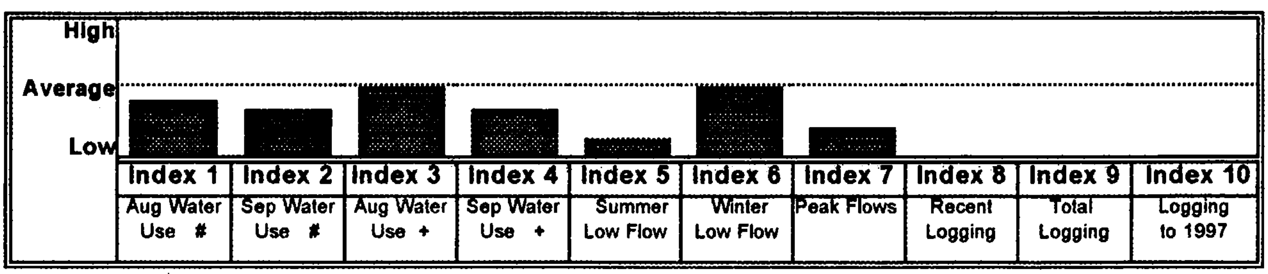
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	101,000 g/d	5.3	5.3	5.3
Irrigation	3,610 ac.ft.	0	266	0
Waterworks	1,025,000g/d	54	54	54
Industrial	3,209,664g/d	169	169	169
Conservation	40 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S		12,400	35,200	21,300

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

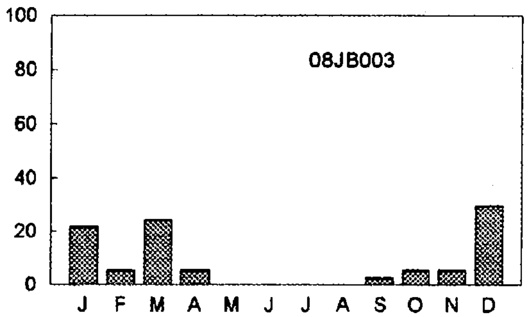
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



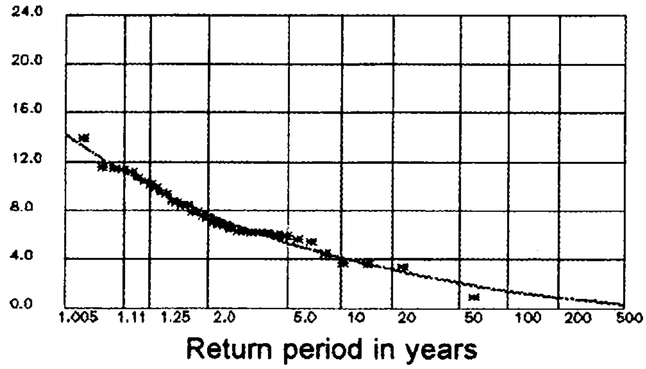
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

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



7 Day Low Flow Frequency Curve
(Flow in m^3/s)



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	7.72 m^3/s	4.06 m^3/s	3.06 m^3/s	2.02 m^3/s	1.38 m^3/s
Annual Flood	100 m^3/s	169 m^3/s	196 m^3/s	232 m^3/s	260 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. Construction of the Kenney Dam has resulted in reduced water levels in the Nechako River during spring freshets. The resultant elevation difference between Fraser Lake and the mouth of the Nautley River caused downcutting of the Nautley River channel. A rock weir and groynes were constructed to prevent the downcutting. The river upstream of the weir is reported to have filled with fine sediment but this is considered to have little impact on fish because the Nautley is primarily a migration corridor.

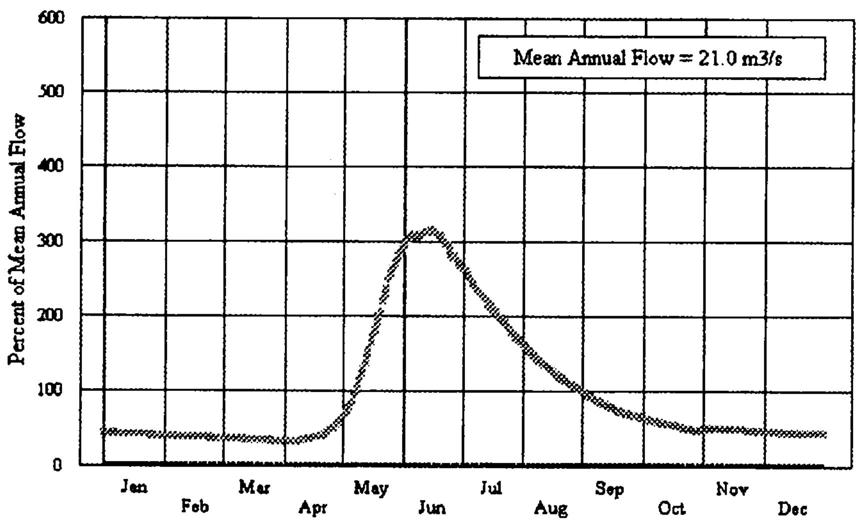
STELLAKO RIVER

Stream number 08-2700
Water Survey of Canada Station 08JB002
Stellako River at Glenannan
Records 1929 to 1990
Drainage Area = 3,600 km²

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	64,500 g/d	3.40	3.40	3.40
Irrigation	2,376 ac.ft.	0	175	0
Waterworks	4,000 g/d	0.21	0.21	0.21
Industrial	2,625,870g/d	138	138	138
Conservation	40 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S		7,950	26,100	16,200

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

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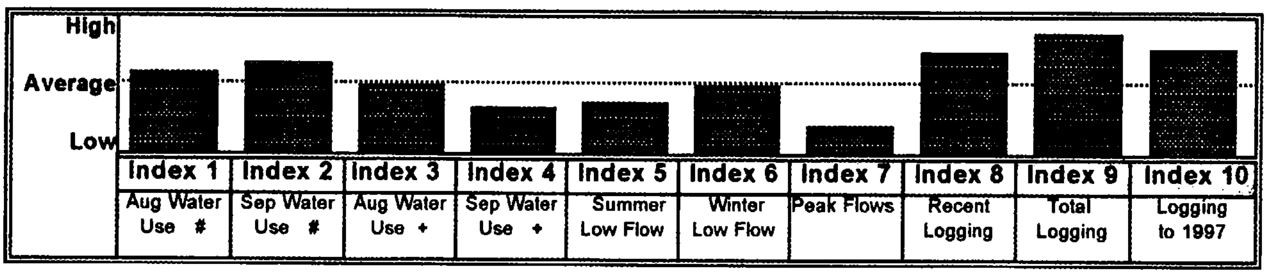
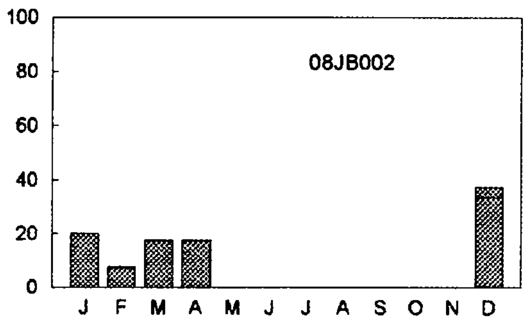


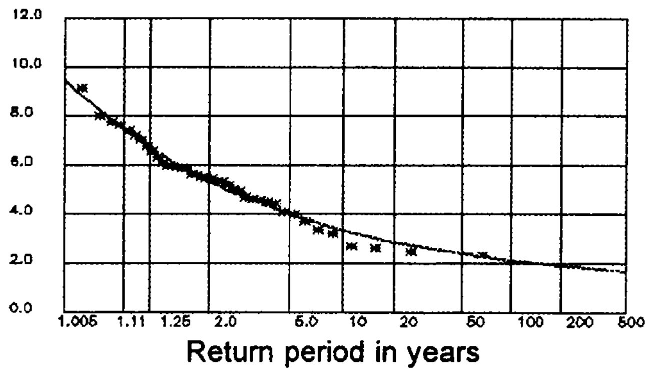
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

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



7 Day Low Flow Frequency Curve (Flow in m^3/s)



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	5.34 m^3/s	3.35 m^3/s	2.86 m^3/s	2.37 m^3/s	2.10 m^3/s
Annual Flood	63.5 m^3/s	115 m^3/s	135 m^3/s	164 m^3/s	186 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. The Endako River was apparently diverted during Highway 16 development into the Stellako River at a lagoon just upstream of the mouth. Weed growth below the lagoon is a problem for fish passage. The Carrier Sekanni Indian Band would like the Endako returned to its original course.

2. The upper part of the Stellako River is protected by a reserve owned by the Habitat Conservation Fund.

ORMOND CREEK

LICENSED WATER DEMAND

Stream number 08-2700-080
Ungauged
Tributary to Stellako River

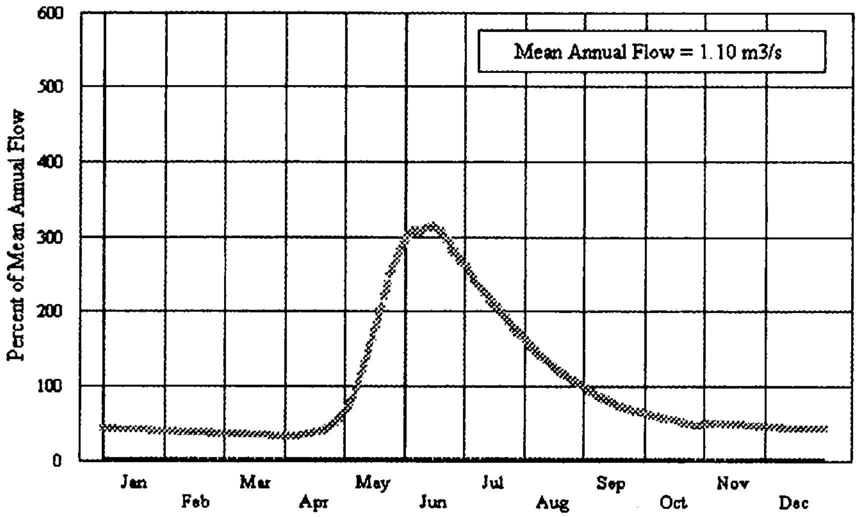
Drainage Area = 251 km²

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		900	570

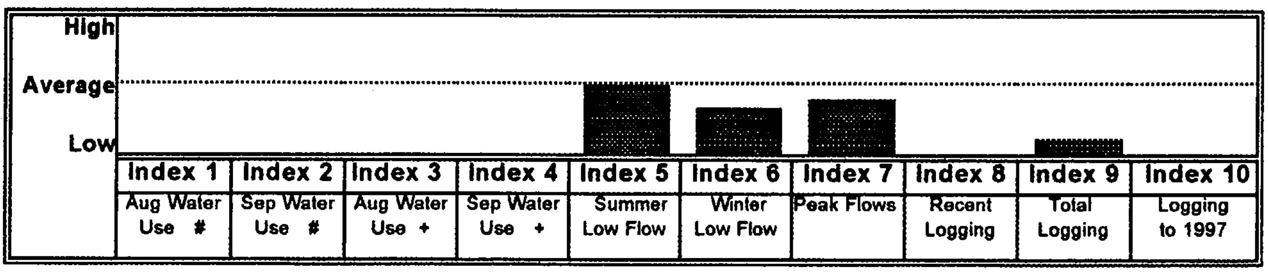
MEAN ANNUAL HYDROGRAPH

(Estimated, using Stellako River station 08JB002)



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

ORMOND CREEK

SUMMARY NOTES AND RECOMMENDATIONS

1. Ormond Creek is often silty because it flows through lacustrine sediments. Main obstacles to migration are sediment deposits at the mouth, low flows, and beaver dams.

2. The Carrier Sekanni Indian Band is working at restoring and enhancing the creek. The bridge crossing was replaced with a culvert that permits fish passage, the road was realigned and debris was removed from the stream. Flow control at the lake outlet and removal of sediment at the mouth are also being considered.

ENDAKO RIVER

LICENSED WATER DEMAND

Stream number 08-2700-140
Ungauged
Tributary to Stellako River

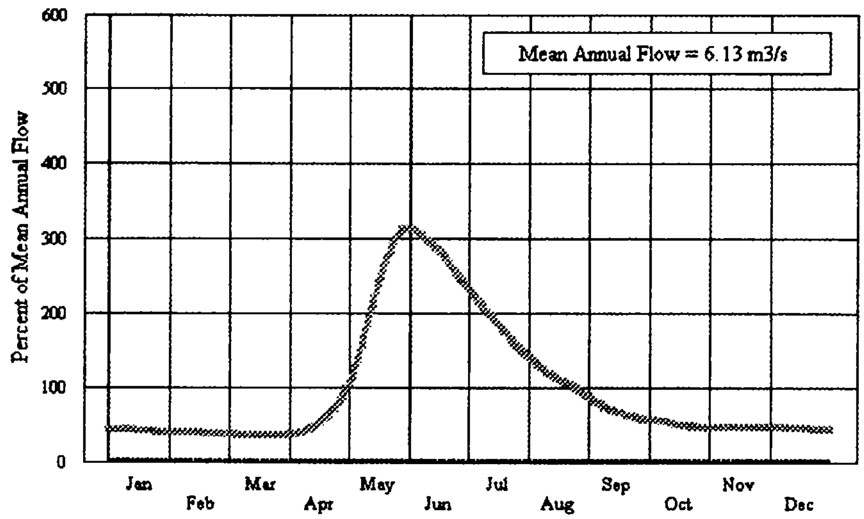
Drainage Area = 2,033 km²

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	30,000 g/d	1.58	1.58	1.58
Irrigation	1,235 ac.ft.	0	91	0
Waterworks	5,000 g/d	0.26	0.26	0.26
Industrial	575,294 g/d	30.3	30.3	30.3
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		3,730	2,410

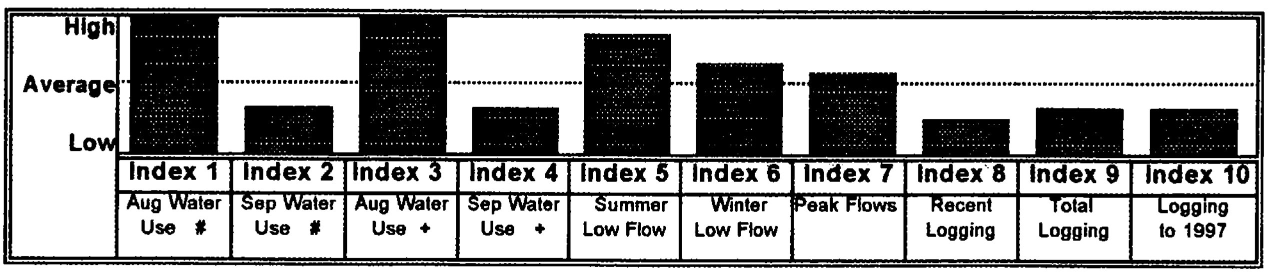
MEAN ANNUAL HYDROGRAPH

(Estimated, using Nautley River station 08JB003)



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

ENDAKO RIVER

SUMMARY NOTES AND RECOMMENDATIONS

1. Both CN Rail and Highway #5 run parallel to the Endako River , encroaching on its floodplain, but DFO reports that riparian habitat has not been affected.

2. The Ministry of Environment reports that substrate is sandy in the lower reaches of the river. Gravels are provided by tributaries. The major concentration of spawning salmon is immediately downstream of Shovel Creek.

3. The Stream Summary Catalogue recommends no further water licences because of low summer flows.

SHOVEL CREEK

LICENSED WATER DEMAND

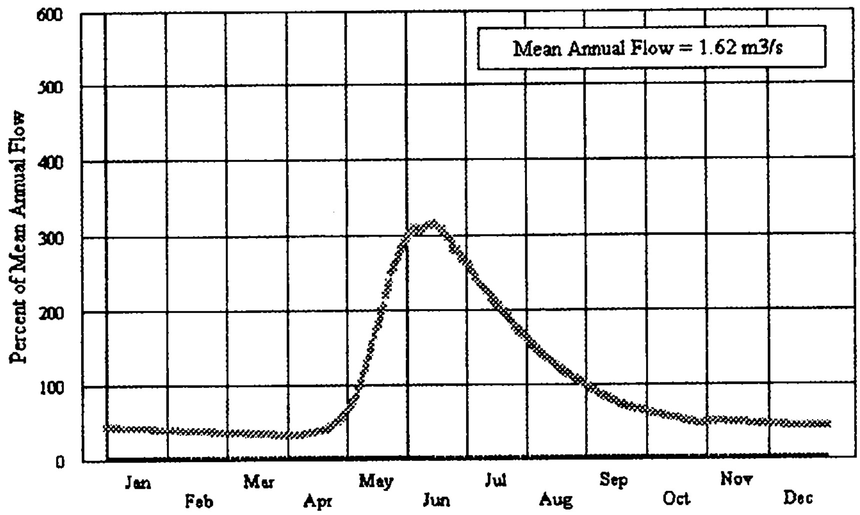
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S			1,330	840

Stream number 08-2700-140-170
Ungauged
Tributary to Upper Endako River

Drainage Area = 371 km²

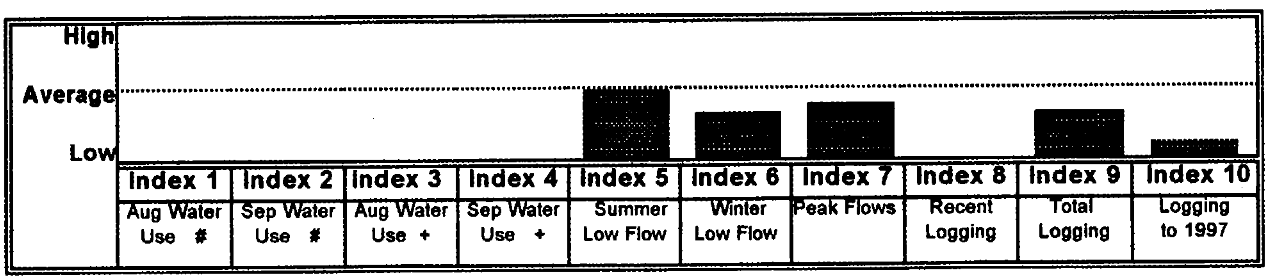
MEAN ANNUAL HYDROGRAPH

(Estimated, using Stellako River station 08JB002)



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

SHOVEL CREEK

SUMMARY NOTES AND RECOMMENDATIONS

1. Shovel Creek is an important source of gravel recruitment for Endako River spawning areas.

NITHI RIVER

Stream number 08-2700-190
Ungauged
Tributary to Stellako River

Drainage Area = 322 km²

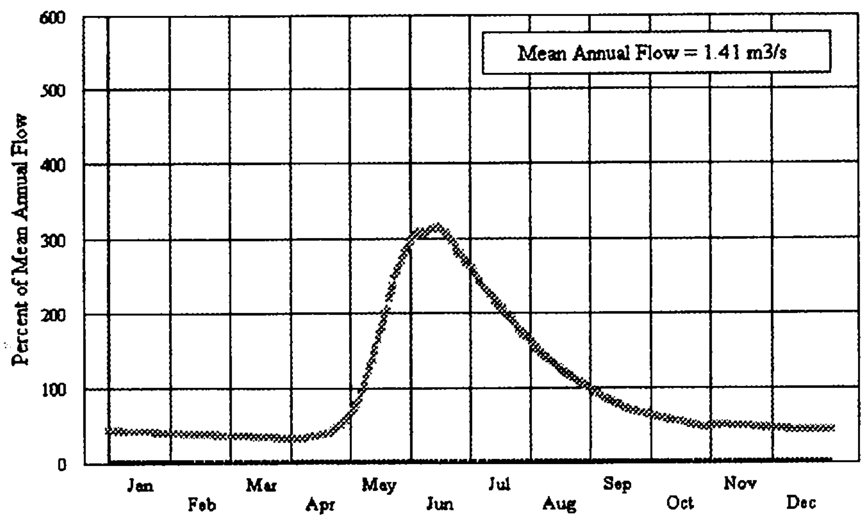
LICENSED WATER DEMAND

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	674,106 g/d	35.5	35.5	35.5
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		1,150	730

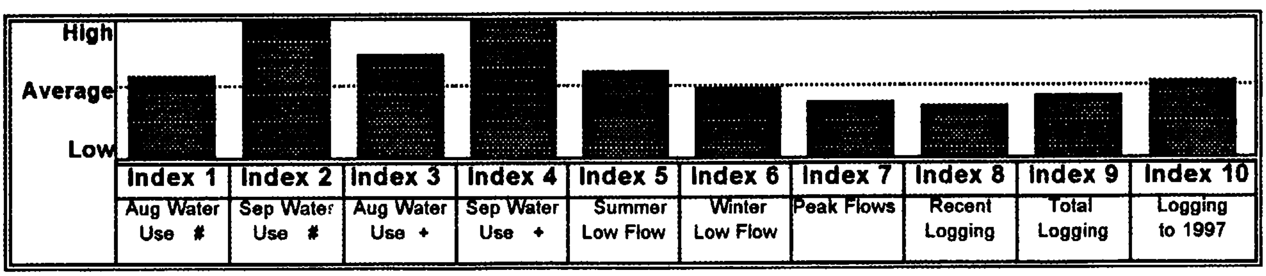
MEAN ANNUAL HYDROGRAPH

(Estimated, using Stellako River station 08JB002)



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

NITHI RIVER

SUMMARY NOTES AND RECOMMENDATIONS

1. The lower reaches of the south branch of Nithi River often dewater in late summer and winter as a result of bed aggradation. The Ministry of Environment is attempting to improve the flows. The north branch appears to have flowing water all year.

2. Nithi River is considered to be a suitable candidate for restoration by flow control and weed removal; weed growth in the lower river affects salmon migration.

UNCHA CREEK

Stream number 08-2700-410
Ungauged
Tributary to Stellako River

Drainage Area = 614 km²

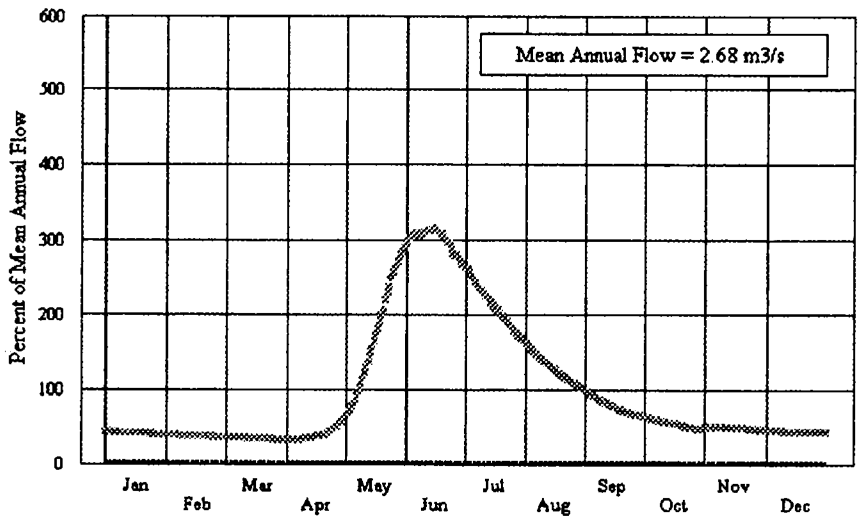
LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	12,000 g/d	0.63	0.63	0.63
Irrigation	315 ac.ft.	0	23.2	0
Waterworks	4,000 g/d	0.21	0.21	0.21
Industrial	9,500 g/d	0.5	0.5	0.5
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		2,200	1,390

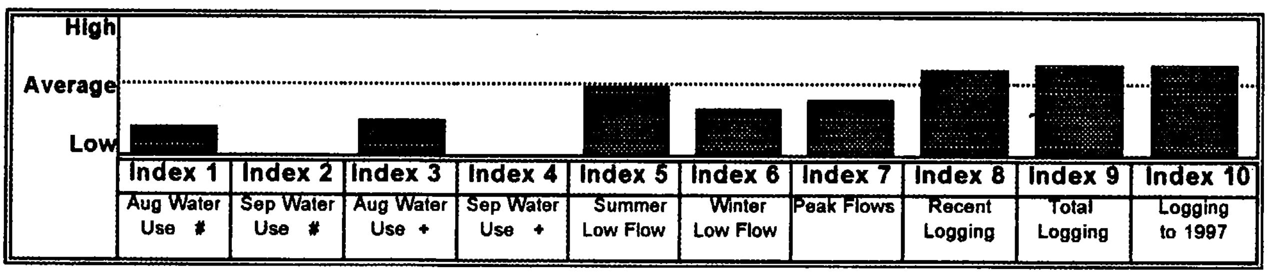
MEAN ANNUAL HYDROGRAPH

(Estimated, using Stellako River station 08JB002)



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

UNCHA CREEK

SUMMARY NOTES AND RECOMMENDATIONS

1. Uncha Creek has 21 % of its basin area logged. Further logging should be opposed until hydrologic recovery and sedimentation studies have been made.

NADINA RIVER

Stream number 08-2700-990

Nadina River, flowing intoFrancois Lake

Drainage Area = 1,093 km²

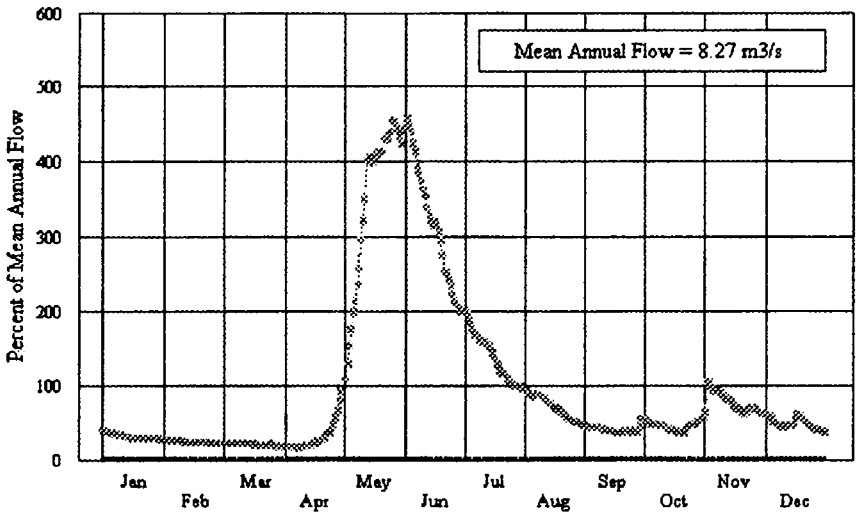
LICENSED WATER DEMAND

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	0g/d			
Industrial	0g/d			
Conservation	40 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S	1,280	3,880	2,230

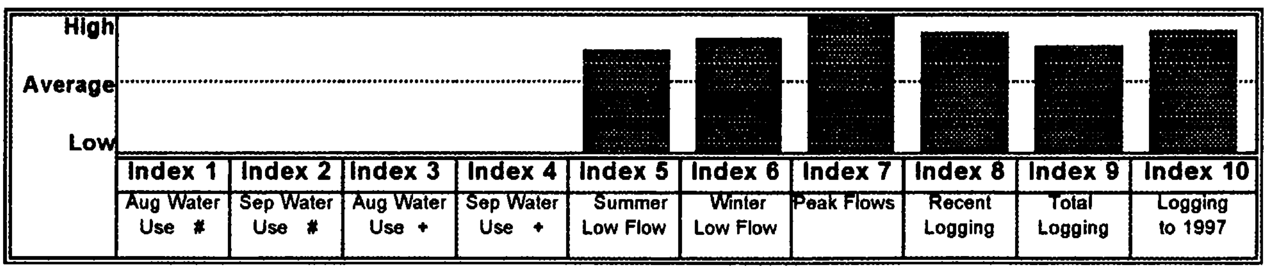
MEAN ANNUAL HYDROGRAPH

(Estimated, using Upper Nadina station 08JB008)



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

NADINA RIVER

SUMMARY NOTES AND RECOMMENDATIONS

1. The lower Nadina watershed has over 20% of its area logged. Logging is managed under a Local Resource Use Plan. Along the Nadina River corridor, 400 m. each side of the river, guidelines include: a windfirm buffer to maintain bank stability, provide organic debris, and provide shade to reduce water temperature; seeding of road right-of-ways and skid trails; and erosion control.

2. Temperature studies by DFO indicated that small, forested tributaries provide cool water to the mainstem Nadina.

3. Natural summer low flows are relatively low compared to other streams, and although there are no outstanding water licence applications, we recommend that low flows be monitored and instream flow needs assessed.

NADINA RIVER
(UPPER)

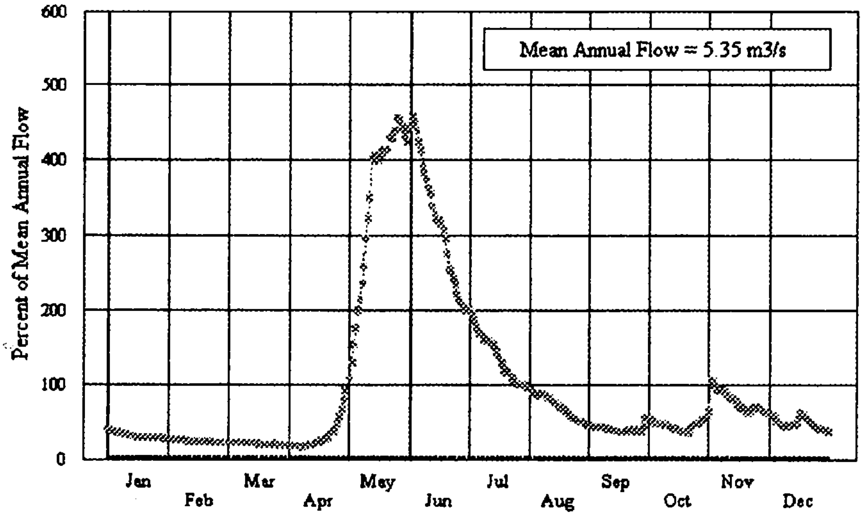
Stream number 08-2700-990
Water Survey of Canada Station 08JB008
Nadina River at outlet of Nadina Lake
Records 1964 to 1990
Drainage Area = 399 km^2

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0g/d			
Industrial	0g/d			
Conservation	40 cfs			

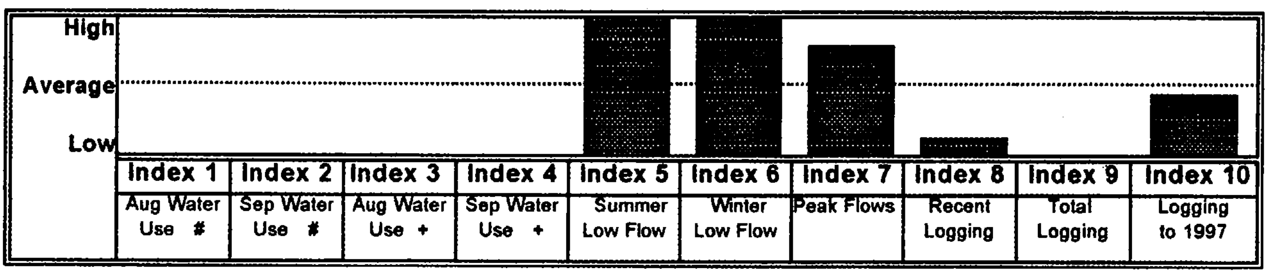
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	1,280	3,880	2,230

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

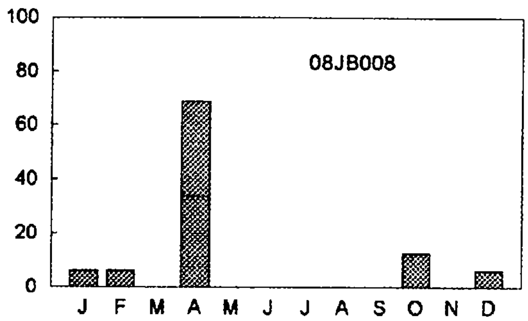
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



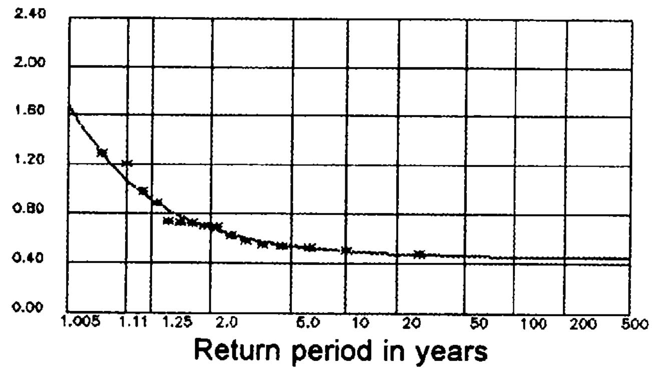
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

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



7 Day Low Flow Frequency Curve (Flow in m³/s)



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	0.67 m^3/s	0.49 m^3/s	0.47 m^3/s	0.46 m^3/s	m^3/s
Annual Flood	33.5 m^3/s	59.3 m^3/s	71.4 m^3/s	89.1 m^3/s	104 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. The lower Nadina watershed has over 20% of its area logged. Logging is managed under a Local Resource Use Plan. Along the Nadina River corridor, 400 m. each side of the river, guidelines include: a windfirm buffer to maintain bank stability, provide organic debris, and provide shade to reduce water temperature; seeding of road right-of-ways and skid trails; and erosion control.

2. Temperature studies by DFO indicated that small, forested tributaries provide cool water to the mainstem Nadina.

3. Natural summer low flows are relatively low compared to other streams, and although there are no outstanding water licence applications, we recommend that low flows be monitored and instream flow needs assessed.

TAGETOCHLAIN CR.

LICENSED WATER DEMAND

Stream number 08-2700-990-250
Ungauged
Tributary to Upper Nadina River

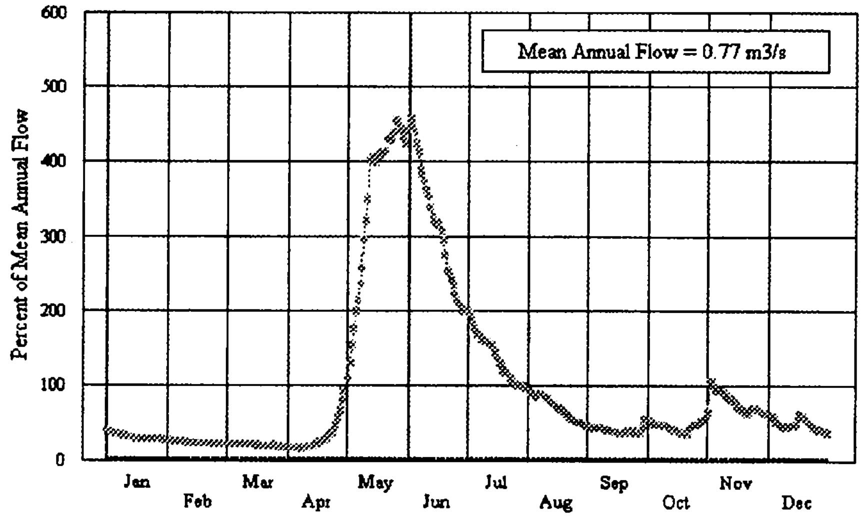
Drainage Area = 176 km²

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		630	400

MEAN ANNUAL HYDROGRAPH

(Estimated, using Upper Nadina station 08JB008)



SENSITIVITY INDICES

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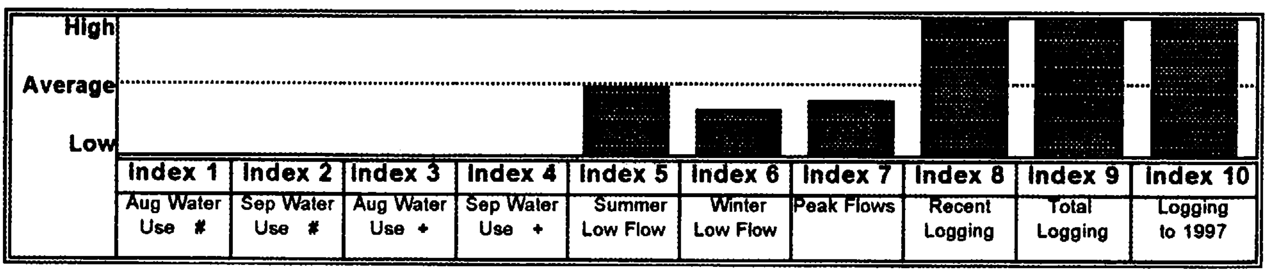

\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

TAGETOCHLAIN CREEK

SUMMARY NOTES AND RECOMMENDATIONS

1. Tagetochlain Creek has 40 % of its basin area logged. Further logging should be opposed until hydrologic recovery and sedimentation studies have been made.