HYDROLOGY AND WATER USE FOR SALMON STREAMS IN THE SETON/BRIDGE HABITAT MANAGEMENT AREA, BRITISH COLUMBIA

Prepared for:

Fraser River Action Plan

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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 Seton/Bridge HMA which includes streams draining to the Fraser River near Lillooet that lie within the watersheds of the Seton or Bridge Rivers (Figure 2). Both major rivers are developed for hydroelectric power by B.C. Hydro though many tributaries have natural flows.

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 Seton/Bridge HMA, regulation, diversion and release of flows by hydroelectric facilities, agricultural, municipal and industrial extractions from surface water and forest harvesting impacts on floods and low flows are the main hydrologic issues.

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

1.2 Scope of the Study

Our study examines 6 known and presently utilized salmon streams within the Seton/Bridge HMA of the total of 9 that are listed in SSIS (the Federal/Provincial Stream Information Summary System; Table 1). Tyaughton, Williams and Fergusson Creeks are upstream of Terzaghi Dam, which prevents upstream migration by anadromous salmon, as a result, they are not analyzed in this report. 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.

Figure 1: Fraser River Habitat Management Areas

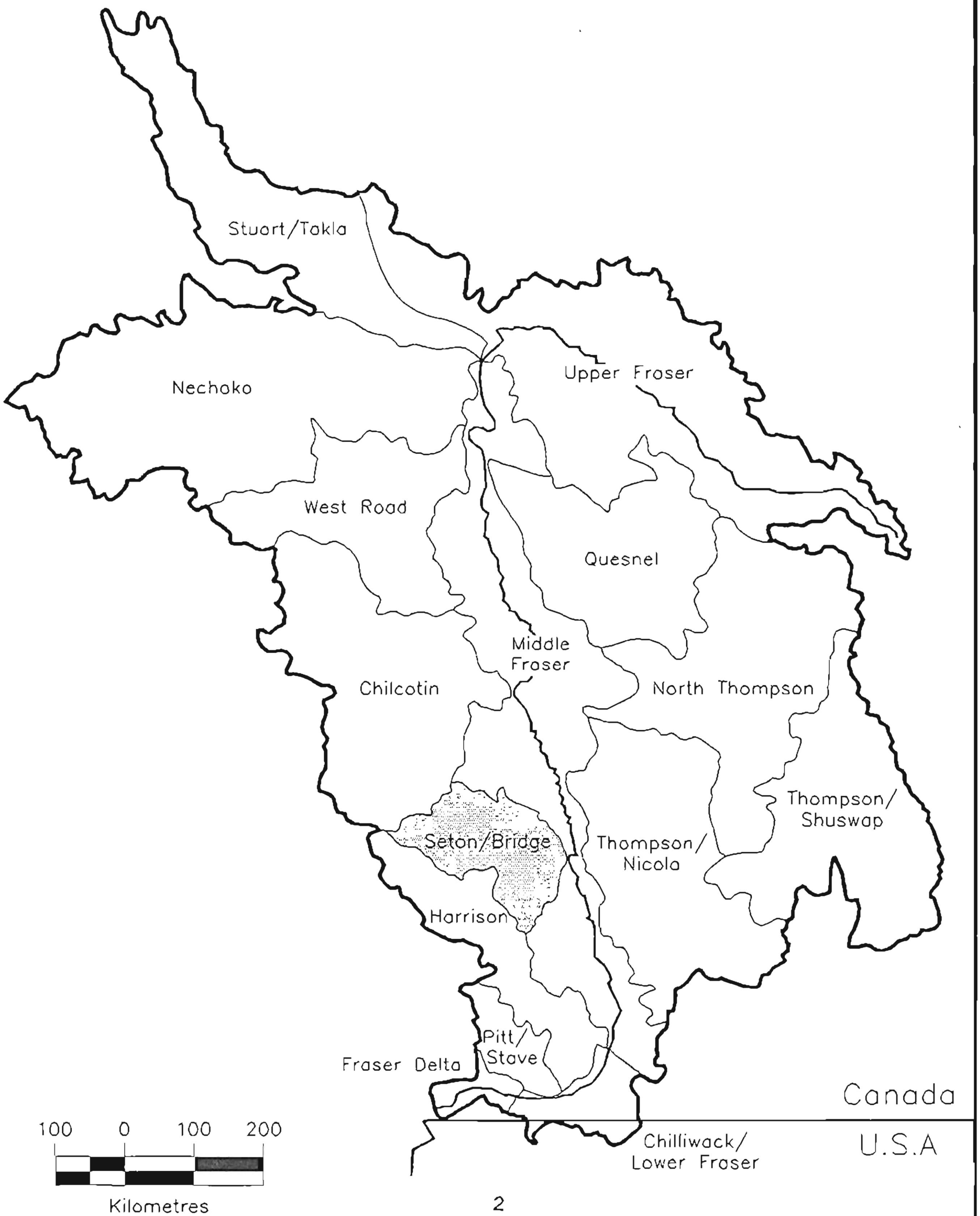

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Figure 2: Salmon Streams in the Seton/Bridge HMA (from Fisheries & Oceans Canada)

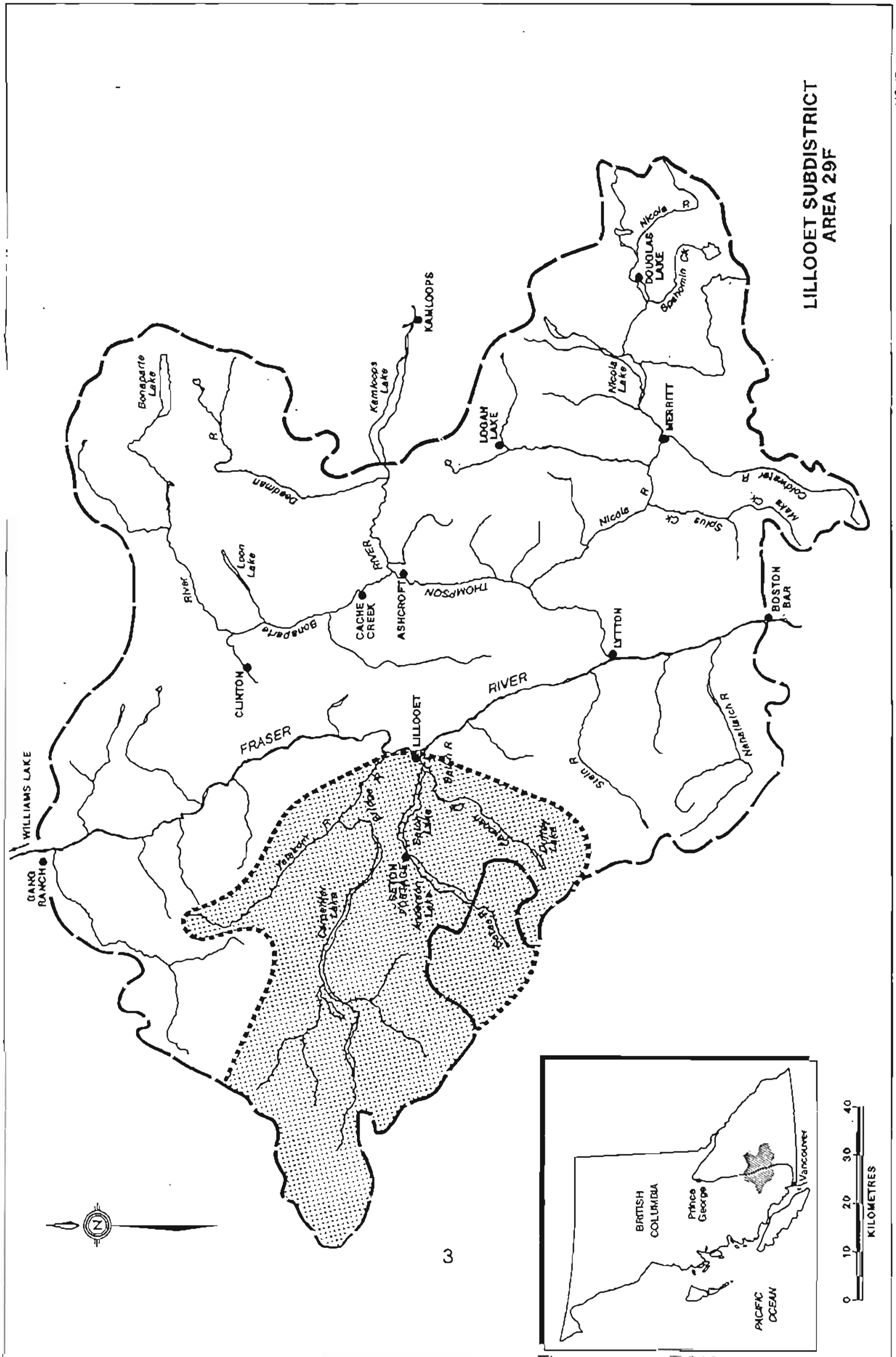


Table 1: Salmon Streams in the Seton/Bridge HMA.

	Stream Name	SSIS Number	WSC Gauge Data: Gauge Name	Gauge No.	Drainage Area (km2)	Total Drainage Area (km2)	Years of Record
	SETON RIVER						
1	Seton R.	00-1800-000-000-000-000-992	near Lillooet	08ME003	1,040	1,920	1950-91 RC
			below Cayoosh Ck.	08ME018	1,680		1950-51 RS + 1952-53 RC
2	- Cayoosh Ck.	00-1800-050	near Lillooet	08ME002	878	880	1955-91 RC
3	- Portage R.	00-1800-000-000-000-000-991	near Seton Lake P.O.	08ME015	728	818	1949-55 MC
3a	- Whitecap Ck.	*					
4	- Gates R.	00-1800-650	below Halmore Ck.	08ME022	328	343	1965-68 MC
	BRIDGE RIVER						
5	Bridge R.	00-1900	near Shalalth	08ME001	3,650	4,637	1913-48 RC
			at LaJoie Falls	08ME004	956		1924-48 RC
			near Gold Bridge	08ME005	1,650		1924-41 MC
			below Tyaughton Ck.	08ME014	3,100		1929-41 RC
			below Bridge Glacier	08ME023	-		1978-91 RC
6	- Yalakom R.	00-1900-150	above Ore Ck.	08ME025	575	676	1983-91 RC
6a	- Lower Yalakom R.	*					
6b	- Upper Yalakom R.	*					
7	- Tyaughton Ck.	00-1900-610	near Bridge River	08ME007	759	757	1924-27 MC; 28-41 M#
8	- Williams Ck.	00-1900-620	-	-	-	10	-
9	- Fergusson Ck.	00-1900-710	-	-	-	30	-

- dash (-) indicates that the the stream has no gauging records.
- asterisk (*) indicates that the watershed is not a SISS stream and is included only for logged area analysis

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 priorize the various salmon streams according to water withdrawals, high flows, low flows and forest harvesting.

6. Summarize the main issues for the salmon streams and discuss technical or management alternatives based on interviews and discussions with government personnel.

The main task was calculating flow characteristics for the 6 salmon streams. The quality of information varied greatly from stream to stream; our method estimated flow characteristics so that streams within the study area could be compared and ranked. The estimated flows are not necessarily the best estimate for any individual stream and should not be used for design of structures or evaluation of projects without further, detailed study of that particular stream.

1.3 Organization of the Report

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

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

1.4 Acknowledgements

Funding for this study was provided by the federal Department of Fisheries and Oceans through the Fraser River Action Plan, a federal Green Plan Initiative. A number of individuals provided an overall perspective on land and water use and hydrology, as well as information on the salmon streams. We would like to thank Paul Doyle, Ian McGregor and Ron Smith of the Kamloops Office of the Ministry of Environment, Lands and Parks; and Gordon Kosakoski and John Patterson of the Department of Fisheries and Oceans.

2. THE SETON/BRIDGE 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 Seton/Bridge HMA lie within two physiographic regions and also within two ecoregions and three ecosections. The ecoregions and physiographic regions do not correspond well. The following sections describe the climate of the HMA for each ecoregions.

2.1 Physiography

The Seton/Bridge HMA includes the watersheds of the Seton and Bridge Rivers and extends westward from Lillooet on the Fraser River to the crest of the Coast Mountains (Figure 3). The total area of the HMA is about 6,500 km^2. The drainage basins of the larger salmon streams often include more than one physiographic region and more than one ecoregion (Table 2). On the other hand, many of the smaller salmon streams lie within only one physiographic region and ecoregion.

Chilcotin Ranges: The Chilcotin Ranges are an eastern subdivision of the Coast Mountains composed largely of sedimentary and volcanic rocks within the HMA. The Yalakom River, which flows along the Yalakom Fault (part of the Fraser Fault System that extends into Washington) separates the Camelsfoot and Chilcotin Ranges. The highest peaks in the Chilcotin Ranges are about 2,800 m in the upper Yalakom. Higher peaks, such as Big Dog Mountain and Shulaps Peak are serrate in form; lower peaks were rounded by glaciation. Ice reached maximum elevations of about 2,400 m during the most recent advance.

Pacific Ranges: The Pacific Ranges of the Coast Mountains are formed in granitic stocks and extend southeastward from Bella Coola to the Fraser Valley. In the vicinity of the Bridge River there are a number of peaks of around 3,300 m elevation. Many of these have an alpine appearance as they projected above the Cordilleran ice sheet which reached elevations of about 2,500 m, while lower peaks were rounded by glacial erosion. Extensive ice-fields remain along the crest of the

Figure 3: Physiographic Regions and WSC Gauging Stations in the Seton/Bridge HMA

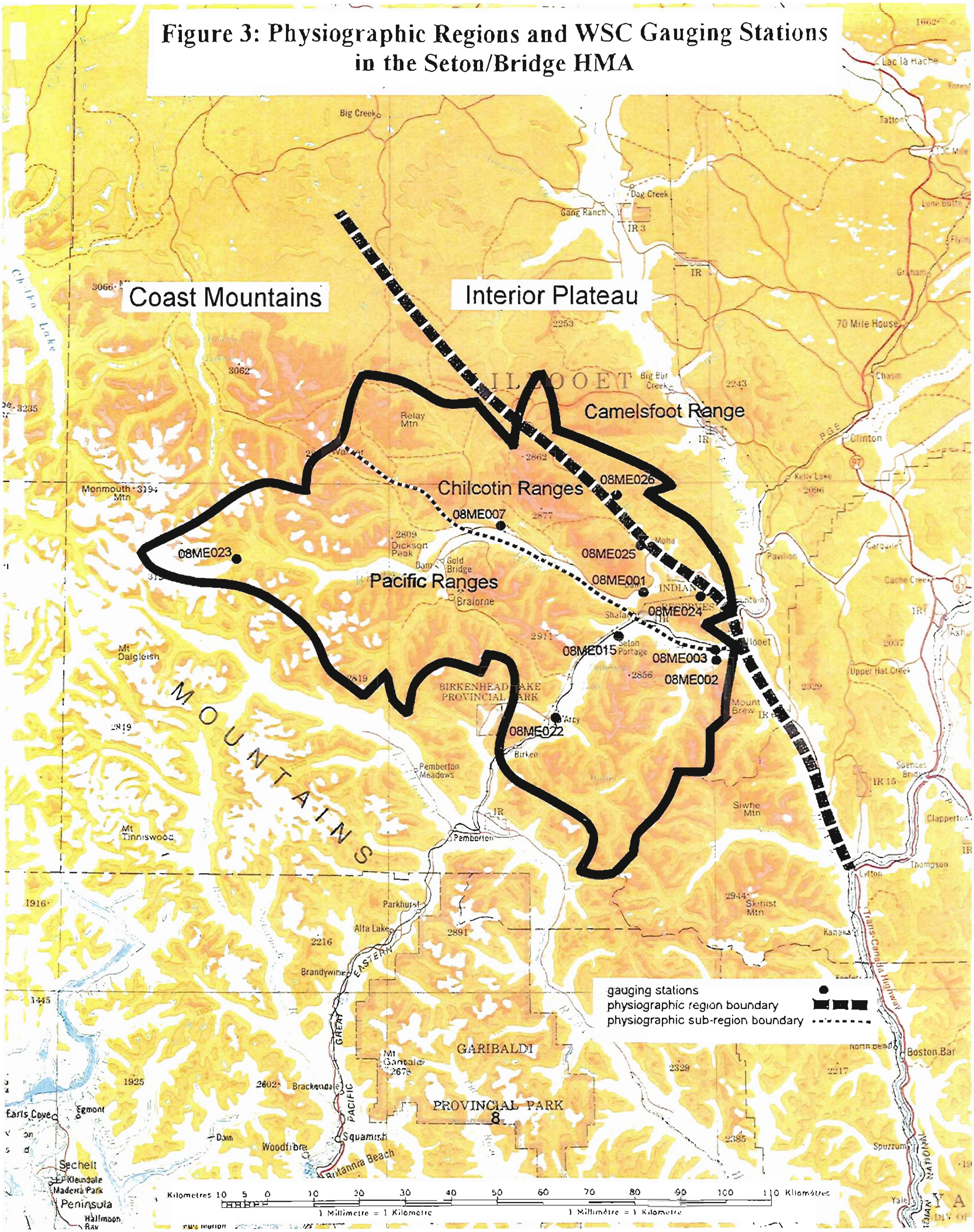


Table 2: Physiography and Ecoregions in the Seton/Bridge HMA.

	Stream Name	SSIS Number	Total Drainage Area (km2)	Physiographic Region (1)	Ecoregions (2)	Ecosections (3)
	SETON RIVER					
1	Seton R.	00-1800-000-000-000-000-992	1,920	PR	ITR	SCR/LPR
2	- Cayoosh Ck.	00-1800-050	880	PR	ITR	SCR/LPR
3	- Portage R.	00-1800-000-000-000-000-991	818	PR	ITR	LPR
3a	- Whitecap Ck	•		PR	ITR	LPR
4	- Gates R.	00-1800-650	343	PR	ITR	LPR
	BRIDGE RIVER					
5	Bridge R.	00-1900	4,637	PR/CR	ITR/CR	SCR/CCR
6	- Yalakom R.	00-1900-150	676	PR/CR	ITR/CR	SCR/CCR
6a	- Lower Yalakom R.	•	356	PR/CR	ITR	SCR
6b	- Upper Yalakom R.	•	321	PR/CR	ITR/CR	SCR/CCR
7	- Tyaughton Ck.	00-1900-610	757	PR/CR	ITR/CR	SCR/CCR
8	- Williams Ck.	00-1900-650	10	PR	ITR	SCR
9	- Fergusson Ck.	00-1900-710	30	PR	ITR	SCR

1. Physiographic regions from Matthews (1986). PR is the Pacific Ranges and CR, the Chilcotin Ranges, of the Coast Mountains.
2. Ecoregions from Demarchi (1993). ITR are the Interior Transition Ranges and CR are the Chilcotin Ranges.
3. Ecosections from Demarchi (1993). LPR are the Leeward Pacific Ranges, SCR, the Southern Chilcotin Ranges and CCR, the Central Chilcotin Ranges.

Pacific Ranges and the Bridge glacier in the upper Bridge watershed covers about 140 km^2. Snow avalanches, debris slides and debris flows are important sources of debris to tributary streams within the Pacific Ranges. Many of the larger streams have a braided pattern, particularly downstream of glaciers, where they receive large quantities of coarse sediment. In the Bridge River, this glacial debris is deposited in a large delta at the head of Downton Lake.

The lower Bridge River had a very complicated pattern of erosion and deposition following the most recent glacial advance (B.C. Hydro 1986). Following inundation by the Cordilleran and Interior ice sheets, the Bridge River was occupied by valley glaciers extending from the upper Bridge River and from the Yalakom Valley. As the Bridge lobe retreated, a temporary glacial lake formed and glaciolacustrine silts and clays, which are now exposed in the valley walls of the Bridge River were deposited. There was a complex series of retreats and advances that lead to thick deposits of glacial sediments through which the Bridge River later eroded. There are still thick deposits in the valley bottom in places: the Terzaghi Dam is underlain by 150 m of sediment, including an upper alluvium, a 25 m thick layer of glaciolacustrine silt and clay, and a 100 m thick layer of gravel and sand. This lower layer is a groundwater aquifer.

The Bridge River is contained in a narrow valley downstream of Terzaghi Dam, partly cut in bedrock but often incised into glacio-lacustrine and glacio-fluvial deposits. Ravelling of unconsolidated sediments on steep, high banks that are undercut by the Bridge River and failures in small tributary gullies are important sources of sediment.

2.2 Surficial Geology

There has been very little work on the Quaternary Geology of the Seton/Bridge region by the Geological Survey of Canada or the B.C. Department of Mines. Most studies of surficial geology were completed as part of power developments and are very detailed in the vicinity of dams and powerhouses but have limited coverage of the overall basin.

2.3 Climate

The Seton/Bridge HMA lies within the Cordilleran climate region and is affected by both continental and modified maritime conditions. In the winter, Pacific storms cross the Coast Mountains transporting maritime moisture into the upper watershed which produces thick snowpacks and occasional intense fall rainstorms.

The Seton/Bridge HMA lies within the Cordilleran climate region and is affected by both continental and modified maritime conditions. In the summer, cold low pressure systems entering from the west interact with warm continental air producing very intense but short duration, rainstorms (B.C. Hydro 1986).

There is a considerable variation of precipitation from west to east. In the upper watershed near the Coast Mountains there are thick forests and large icefields and annual precipitation may be around 2,000 mm. Lillooet, in the eastern end of the HMA, lies within the dry Interior and has annual precipitation of 300 to 400 mm (Table 3).

Table 4 describes the hydrologic regions associated with the various ecosections. Examination of Tables 3 and 4 (and regional hydrology studies: Rood 1988) suggests that are two distinct hydrologic regions in the HMA: an eastern "dry" ecoregion including most of the Chilcotin Ranges (specifically, the Central Chilcotin Ranges and part of the Southern Chilcotin Ranges ecosections) and a western "wet" ecoregion including most of the Interior Transition Ranges (specifically, the Leeward Pacific Ranges and part of the Southern Chilcotin Ranges ecosections). These are discussed below:

2.3.1 Climate of the Ecoregions

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

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

Table 3: Regional Climate in the Seton/Bridge HMA.

Climate Station	Ecosection (1)	Physiographic Region (2)	Latitude	Longitude	Elevation (m)	Precipitation (mm) (3) Annual	May to Sept	Annual Snowfall	Greatest Daily	Mean Annual Temperature
Interior Transition Ranges Ecoregion										
Lillooet Seton BCHPA	*SCR*	*PR*	50.40	121.55	198	286.5	93.6	48	29.5	8.7
Lillooet	*SCR*	*PR*	50.42	121.56	290	391.4	139.7	73.2	114.3	-
Lillooet Cedar Falls	*SCR*	*PR*	50.36	121.52	555	405.0	127.6	118.5	51.1	-
Lillooet Russell St	*SCR*	*PR*	50.42	121.56	244	341.5	118.7	81.4	47.2	-
Shalath	*SCR*	*PR*	50.44	122.13	244	514.2	118.3	110.5	55.1	9.6
Bralorne	*SCR*	*PR*	50.47	122.49	1015	636.3	156.6	271.3	55.9	4.1
Leeward Pacific Ranges Ecoregion										
Pemberton BCFS	*EPR/LPR*	*PR*	50.19	122.49	218	1186.9	223.9	310.5	92.2	7.2
Pemberton Meadows	*EPR/LPR*	*PR*	20.27	122.56	223	990.2	197.1	283.4	101.6	7.0

1. SCR is the Southern Chilcotin Ranges, EPR is the Eastern Pacific Ranges and LPR is the Leeward Pacific Ranges Ecosection.
2. PR is the Pacific Ranges physiographic region.
3. Climate data from the 1951-1980 Canadian Climate Normals.

Table 4: Hydrologic Characteristics of the Ecoregions.

	Leeward Pacific Ranges Ecosection	*Southern Chilcotin Ranges Ecosection*	*Central Chilcotin Ranges Ecosection*
Mean Annual Runoff (mm)	700	1500	225
Month with Average Maximum Discharge	June	July	June; remains high in July
Timing of annual maximum discharge	May and June; sometimes in October	June and July; sometimes August or early Fall	late May to July
Month with Average Minimum Discharge	February	February	February and March
Timing of annual minimum discharge	December through March	November through February	November through February
Typical Stream	Gates Creek below Haylmore Ck 08ME022	Bridge River at Lajoie Falls 08ME004	Yalakom River above Ore Creek 08ME025
Basin Area (km2)	326	956	575

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

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

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

Interior Transition Ranges: The Pemberton climate stations (which lie to the west of the Pacific Leeward Ranges) seem most representative of the Interior Transition Ranges. Mean annual temperatures at these valley-bottom stations are similar to Lillooet. Winter temperatures are slightly warmer than Lillooet and summer temperatures are cooler. Annual normal precipitation is around 1,100 mm, with about 25% of the total falling as snow. The portion falling as snow increases substantially with elevation, as does total precipitation, and snowcourses in the upper Bridge and Seton watersheds (McGillivray Pass and Green Mountain) have normal maximum water equivalents of around 700 mm.

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

The annual flood results from snowmelt and about 64% of the annual runoff in the Upper Bridge River is recorded from May through July (B.C. Hydro 1986). Melting of snow and ice on the Bridge and other Glaciers helps to maintain discharges in the late summer, particularly in August.

Rainstorms that cross the Coast Mountains occasionally produce large floods between August and October; the flood of record to Downton Reservoir occurred in October 1984.

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

2.3.2 Temporal Variation in Climate

Short-term climate records are available at a number of stations in Lillooet. Records lengths are too short to indicate trends in climate. Moore (1991) reviewed records at stations north and south of the Seton/Bridge HMA and concluded that annual precipitation had remained roughly constant but that a lower portion of the precipitation had fallen as snow since the mid-1970's. There was also an increase in temperature at these stations since the mid-1970's. There has been no comparable analysis of snow fall and accumulation at higher elevations in the Seton/Bridge HMA but snow course data at McGillivray Pass (1800 m) and Green Mountain (1,710 m) shows below-normal accumulation throughout most of the late 1970's and 1980's (Ministry of Environment 1992).

2.2.3 Global Warming and Climate Change

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

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

2.4 Groundwater Resources

Atwater et al (1994) discuss the groundwater resources of the Fraser Plateau. Most wells on the plateau are of low yield (less than 1 L/s) and supply water for households or stock watering. High production wells (greater than 7 L/s) are found near Lillooet, at depth in sand and gravel deposits, and north of Lillooet in bedrock. There are no specific studies of groundwater resources in the Seton/Bridge HMA.

It is expected that groundwater reservoirs (or aquifers) recharge during fall rains and spring snowmelt when vegetation is dormant and evapotranspiration is at a minimum. Groundwater reservoirs discharge during the summer when inflows to the reservoir are small because precipitation is at a minimum and evapotranspiration consumes much of the rainfall. It is likely that low flows in some small tributaries are maintained by groundwater discharge during the late summer and early fall and that glacio-fluvial deposits, particularly those in the bottom of major valleys, may be important source of groundwater. However, this possibility has not been studied in detail.

2.5 Stream Pattern and Hydrology

Both the Seton and Bridge Rivers are regulated by B.C. Hydro. There are two dams on the Bridge River: Lajoie Dam, which is upstream of the Hurley River, stores inflow from the upper watershed and generates power from the outflow. Terzaghi Dam is downstream of Lajoie Dam, about 40 km upstream of Lillooet. This dam, and its reservoir Carpenter Lake, are used to store water which is diverted via two tunnels to a generating station at Shalath on Seton Lake. Except in times of flood, water in Carpenter Lake is diverted to Shalath and releases from the overflow spillway or the gaited spillway are infrequent. As a result, riparian vegetation has narrowed the channel and sediments have deposited along its margins.

There have only been nine spills since the dam filled in 1961, on average once every 3 years. The largest spill occurred in August and September 1991, as a result of a severe rainstorm occurring when Carpenter Lake was near full pool level. The 1991 spill mobilized large quantities of sediment, eroded riparian vegetation and damaged fish habitat. Water diverted to Seton Lake either passes over the dam into the Seton River or passes through the Seton Generating Facility and into the Fraser River. Water from Cayoosh Creek is also diverted into Seton Lake and utilized in the spawning channel along Seton River.

There is limited storage on Seton Lake; consequently, floods on Gates River and Portage River create spill over the dam into the Seton River.

2.6 Stream Stability

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

The stream response to these external factors 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 Seton/Bridge HMA starts in a steep upland area where the channel may be steep and contained in a gully or narrow valley. Sediment is provided to the channel by snow avalanches, debris slides and flows from valley walls, glacial erosion, and stream erosion of valley walls and channel banks. Channel widening and downcutting are the most likely channel responses to disturbance though in bedrock floored canyons channel adjustment is limited.

The larger rivers are generally unconfined in their lower reaches as they often flow in a broad valley or on their fan. Many of the salmon streams meander in these reaches and bank erosion and channel instability are common, particularly where there is a supply of coarse debris from upstream reaches. Channel reaches immediately downstream of lakes are often very stable because floods are regulated by lake storage, there is no supply of sediment, and the bed material is winnowed to a stable pavement. Table 5 summarizes reported channel response to disturbance and the kinds of human modification 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

Table 5: Channel Stability in the Seton/Bridge HMA.

	Stream Name	SSIS Number	Channel Response				Bed Material		Human Modifications					
			Pattern Change	Erosion	Incision	Aggrad-ation	Scour	Sediment-tation	Dyking	River Training	Encroach-ment	Gravel Removal	Vegel Removal	Debris Removal
	SETON RIVER													
1	Seton R.	00-1800			●	●	●							
2	- Cayoosh Ck.	00-1800-050												
3	- Portage Ck.	00-1800		●		●								
3a	- Whitecap Ck.	*							●	●				
4	- Gates R.	00-1800-650							●	●				●
	BRIDGE RIVER													
5	Bridge River	00-1900		●				●					●	
6	- Yalakom R.	00-1900-150												
6a	- Lower Yalakom R.	*												
6b	- Upper Yalakom R.	*												
7	- Tyaughton Ck.	00-1900-610												
8	- Williams Ck.	00-1900-620												
9	- Fergusson Ck.	00-1900-710												

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

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), removalof 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 Seton/Bridge HMA. Some streams have long-term gauging records at stations that continue to operate, while other streams have short-term or seasonal records of moderate quality from the 1950's, 1960's and 1970's. 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.

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 lowest average flow for 7 consecutive days between November 1 and April 30.

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

3.1 Reference Point for Flow Characteristics

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

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

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

3.2 Period of Record for Calculating Flow Characteristics

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

We have adopted the most recent decade, 1981-90 (inclusive), as our standard period for analysis. In the Seton/Bridge HMA, this decade has lower mean annual discharges than were recorded in the 1950's, 1960's or 1970's. On Seton River, Bridge River and Cayoosh Creek the calculated regimes reflect upstream regulation.

3.3 Hydrometric Data in the Seton/Bridge HMA

The Water Survey of Canada is the prime agency collecting and reporting flow data in British Columbia. Gauging stations in the Seton/Bridge 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 all of the salmon streams have had at least one operating gauging station though some operated prior to construction of hydroelectric facilities. However, only three salmon streams (Seton River, Cayoosh Creek, and Yalakom River) have complete gauging records from 1981 to 1990 and stations 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 other salmon streams typically have either: 1) partial or complete records from earlier decades, such as the 1960's or 1970's, or 2) no records from the Water Survey of Canada that describe the regulated flow regime (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 Seton/Bridge HMA they are used in estimating flow characteristics (Appendix A).

3.4 Other Sources of Hydrometric Data

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

3.5 Gauged Salmon Streams

The gauged salmon streams are those where flow characteristics can be calculated directly from Water Survey of Canada records. (Data for gauged salmon streams are shown shaded 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 extraction -- are best-suited for the sensitivity indices so that licensed extractions can be expressed as a percentage of the total available flow, rather than the measured flow. In the Seton/Bridge HMA, regulated releases are treated as natural flows for the purpose of calculating water utilization.

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 each stream by adding potential water extractions, as calculated from summaries of water licences, to the flow recorded at the gauge (Figure 4). We have referred to these adjusted flows as **naturalized flows** to distinguish them from measurements of the natural regime.

In the Seton/Bridge HMA regulated releases have been treated as natural flows and adjusted by adding water extractions. The naturalized flows then represent the 1981 to 1990 release regime from the various reservoirs and diversion structures and also represent the regime that is currently available for salmon habitat.

3.5.2 Storage and Flow Characteristics

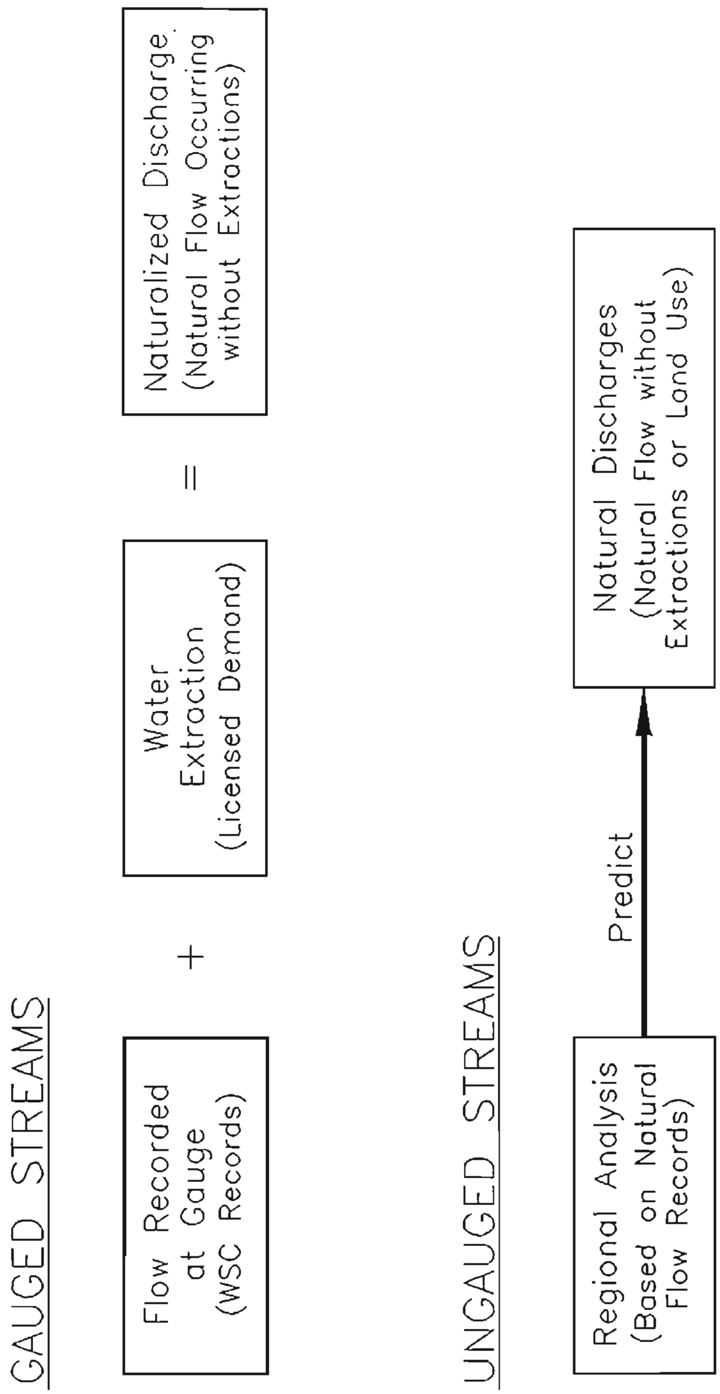
Downton Lake and Carpenter Lake on the Bridge River are storage reservoirs operated by B.C. Hydro as is Seton Lake on the Seton River. Water is diverted from Cayoosh Creek and Bridge River into Seton Lake. There is no developed non-power storage, except on Cayoosh Creek, where 9,000 ac-ft are licensed.

Table 7: Hydrology of the Salmon Streams In the Seton/Bridge HMA.

Stream Name	WSC Gauge No.	Basin Area (mouth) (km2)	Logged Area					Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m3/s)					
			Oldest pre 63 (km2)	Older 63-72 (km2)	Old 73-82 (km2)	Recent 83-92 (km2)	Proposed (1993-98) (km2)	Domestic (g/day)	Irrigation (ac-ft)	Waterworks (g/day)	Industrial (g/day)	Conservation (cfs)	Avg	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly Aug	Mean Monthly Sept	Mean 7-day Flow Summer	Mean 7-day Flow Winter
SETON RIVER																					
Seton R.	08ME003	1,920	3.1	19.1	33.1	62.8	22.0	1,602,500	2,042	2,108,500	5,000	310	434	291	196	28.50	150.0	34.64	22.78	12.95	8.68
- Cayoosh Ck.	08ME002	878	0.0	8.8	26.9	43.6	15.5	5,500	14	0	0	200	2	1	0	14.10	100.4	4.94	1.38	0.87	0.99
- Portage R.	08ME015	728	0.0	3.6	3.3	12.8	0.0	78,500	1,536	56,000	5,000	60	183	75	3	17.50	73.7	25.70	12.60	6.06	3.80
- Whitecap Ck.		75	0.0	1.7	0.3	4.0	0.0	-	-	-	-	-	-	-	-						
- Gates R.	08ME022	326	0.0	0.0	0.4	5.6	4.0	35,500	787.8	17000	2000	40	93	38	1	6.49	45.9	7.62	3.98	2.62	1.82
BRIDGE RIVER																					
Bridge River		4,637	15.7	15.7	61.7	190.6	82.8	81,000	2,307	191,000	379,419	661	304	142	34	6.02	30.80	9.17	5.73	3.21	1.58
- Yalakom R.	08ME025	676	11.7	3.7	6.1	16.1	32.2	3,500	421	0	0	0	49	20	0	4.11	22.7	6.23	3.90	2.18	1.08
- Lower Yalakom R.		356	7.3	1.1	6.1	14.5	10.0	-	-	-	-	-	-	-	-						
- Upper Yalakom R.		321	4.4	2.5	0.0	1.6	22.2	-	-	-	-	-	-	-	-						
- Tyaughton Ck.		757	0.7	1.1	5.4	65.6	10.2	-	-	-	-	-	-	-	-						
- Williams Ck.		10	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-	-	-	-						
- Fergusson Ck.		30	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-	-	-	-						

- 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.

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



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3.5.3 Annual Flow Characteristics

The historic period for the **mean annual flow** is 1981 to 1990, inclusive (see Table 6 for definitions). The historic period for the **mean annual flood** is 1981 to 1990, inclusive. No adjustments were made for the effect of regulation (Section 3.5.1).

3.5.4 Seasonal Flow Characteristics

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

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

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

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

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

3.6 Gauging Records on the Stream Summary Sheets

The flows recorded at gauging stations on the salmon streams are of interest for more than establishing average flow characteristics at their mouths. The gauging records permit calculation of detailed flow characteristics such as mean annual 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 natural 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 Seton/Bridge 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 Seton/Bridge HMA, urbanization has not had a significant 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 forest harvesting eliminates transpiration and the cut blocks alter the distribution of snow and may often increase rates of melt. These changes in the watershed, coupled with road construction and soil changes during logging tend to increase water yield (mean annual flow), mean annual floods and summer base flows.

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

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

4.1 Forest Harvesting

Maps and databases maintained by the Ministry of Forests were used to determine harvested areas in the watersheds of the salmon streams. History Record Reports lists activities in all openings (areas where forest 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 skidded 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 (Bosh 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 equivalent clearcut area (ECA) within the watershed. The ECA is calculated from the product of the total cut area and a regeneration recovery factor, which reflects the fact that there is near zero hydrologic recovery for regeneration of less than 3 m and nearly complete recovery for 9 m regeneration. Intermediate regeneration reduces the hydrologic effect of the clearcut. Maximum allowable equivalent clearcut areas will vary with basin type and the history of past disturbance, but may range from 20% to 35%.

4.2.3 Forest Harvesting and Sedimentation

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

The relative importance of various erosion processes, and the various forestry activities, to the total sediment budget of a disturbed watershed depend on the precipitation regime, character of the watershed, soils, and logging practices. Details may only be resolved after on-site 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

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 in most of the Lillooet area, 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. 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 5 reproduces the water licence classification system used by the Water Management Branch. Water licences are classified into consumptive and non-consumptive uses and further classified by the type of user. Computer-generated summaries, obtained from the Water Rights Branch, Victoria, utilize the main classification on Figure 5, as well as providing more detail on the type of user, producing a total of 73 sub-categories (including non-consumptive uses).

5.1.1 Consumptive Licences

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

5.1.2 Non-Consumptive Licences

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

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

Figure 5: 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

Table 8: Storage in the Salmon Streams of the Seton/Bridge 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 (%)*
SETON RIVER					
Seton R.	1,920	0	0	2,042	0
- Cayoosh Ck.	878	0	0	14	0
- Portage R.	728	0	0	1,536	0
- Whitecap Ck.	75	-	-	-	-
- Gates R.	326	0	0	787.8	0
		0	0		
BRIDGE RIVER					
Bridge River	4,637	0	40,000	2,808	0
- Yalakom R.	676	0	0	421	0
- Lower Yalakom R.	356	-	-	-	-
- Upper Yalakom R.	321	-	-	-	-
- Tyaughton Ck.	757	-	-	-	-
- Williams Ck.	10	-	-	-	-
- Fergusson Ck.	30	-	-	-	-
TOTAL		0	40,000	4,850	0

- Nonpower includes all storage for domestic, waterworks, industrial, and irrigation licences. Conservation licences are not included in the nonpower totals.
- There is 9,000 ac-ft of "non-power" storage in Cayoosh Ck. Assumed used for power.
- 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.

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 Seton/Bridge HMA are insignificant when compared to irrigation use or to streamflow.

5.2.2 Irrigation Licences

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

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

Actual irrigation demand can be estimated from the area of irrigated land and a calculated or estimated water duty. The duty -- the water needed for the irrigation season expressed as a depth -- is not known for the Seton/Bridge HMA, and irrigation licences are for 30 cm (12 inches) to 90 cm (36 inches) of water. As well, 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, 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 licences, to gallons/day for waterworks and domestic licences and ft^3/s for conservation licences. Licensed amounts expressed as a discharge were converted to litres per second (L/s) using appropriate conversion factors: 1 L/s is equivalent (approximately) to 19,000 imperial gallons/day; 1 L/s is equivalent (approximately) to .035 ft^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 (15%), June (15%), July (30%), August (30%) and September (10%). (The breakdown of irrigation use was provided by the Abbotsford Office of the Ministry of Agriculture, Fisheries and Food.) These percentages represent the average distribution of water and may not be appropriate in any particular year, as a result of weather and cropping practices. Monthly irrigation volumes (in dam^3) were converted to discharges (L/s) by multiplying by 10^6, and dividing by the number of seconds in the month.

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

6. SENSITIVITY INDICES FOR THE SALMON STREAMS

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

- Indices that express the level of human activity in the watersheds of the salmon streams. These include expressions of the proportions of their watersheds that have been logged 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	recent logged area as a percent of total basin area	roughly expresses the equivalent clearcut area and indicates the extent of hydrograph changes from logging; values exceeding 20% indicate potential changes
9	total logged area as a percent of total basin area	as above
10	recent and proposed logging as a percent of total basin area	as above

6.1 Summer Water Demand

Indices 1, 2, 3 and 4 express potential demand in August and September as percentages of various measures of low flow and indicate the total portion of the natural low flows devoted to irrigation and other water uses. Indices 1 and 2 compare potential water demand to mean 7 day summer low flows, which typically occur in August or September. The 7 day low flows used in calculating the indices are "naturalized"; that is, they are estimates of the natural low flow or the typical low flow

Table 9: Sensitivity Indices -- Seton/Bridge 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 Recent/ Basin	Index 9 Total/ Basin	Index 10 Recent & Proposed
SETON RIVER											
Seton R.		3%	2%	1%	1%	44%	30%	5	3%	6%	4%
- Cayoosh Ck.		0%	0%	0%	0%	6%	7%	7	5%	9%	7%
- Portage R.		3%	1%	1%	1%	34%	22%	4	2%	3%	2%
- Whitecap Ck									5%	8%	5%
- Gates R.		4%	1%	1%	1%	40%	28%	7	2%	2%	3%
BRIDGE RIVER											
Bridge River		9%	4%	3%	2%	51%	26%	5	4%	6%	6%
- Yalakom R.		2%	1%	1%	1%	53%	26%	6	2%	6%	7%
- Lower Yalakom R.									4%	8%	7%
- Upper Yalakom R.									1%	3%	7%
- Tyaughton Ck.									9%	10%	10%
- Williams Ck.									0%	0%	0%
- Fergusson Ck.									0%	0%	0%

-Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; OR, office reserve, no licencing; PWS, possible water shortages, RNW, Refused, no water.
- Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and mean Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; Total is total logged area; Recent Is recent logging; Proposed is proposed cut (1993-1998). Basin is basin area above the mouth.
-Indices expressed as percentages except 7, which is a direct ratio.
-Shading indicates salmon streams with most extreme values for the various indices. Values of Indices 8, 9 and 10 exceeding 20% are shaded.

released from a dam or diversion, and, consequently, the indices indicate the percentage of the available 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 comparepotential demand in August and September to *average* flows in these months and are a measure of the typical portion of flows devoted to irrigation during the late summer.

Demand on the Seton/Bridge River results from diversion for irrigation, industry and waterworks. Large values of Indices 1 through 4 indicate streams with great potential demand on summer low flows. Most salmon streams have no water demands and on Table 9 only the Bridge River is shaded, where maximum demand is 9% of summer low flows.

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

6.2 Summer and Winter 7 day Low Flows

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

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

On Table 9, only Cayoosh Creek, whose summer and winter 7 day flows are low relative to mean flow, is shaded.

6.3 Peak Flows

Index 7 compares the mean annual flood to mean annual flow, expressing the mean annual flood as a ratio of the mean annual flow. Higher values of the index indicate streams with a greater range or variability of flow. Higher values of the index may also indicate, potentially, lower channel stability, though channel slope and bed materials are also very important. Typically, the ratio of mean annual flood to drainage area increases with decreasing drainage area. This occurs because smaller basins are often completely covered by individual storms, whereas not all of the larger basins are exposed and, as a result, have lower mean annual floods per unit area. The ratios on Table 9 are typically between 4 and 7 and we have not shaded any of the streams on Table 9.

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

6.4 Logging

Indices 8, 9 and 10 express the area of logging as a percentage of total basin area. Index 8 is the percentage of the watershed that has been recently logged (less than 10 years old based on silvicultural records); Index 9 is the percentage of total logging (all cutblocks including those blocks with some hydrologic recovery). Index 10 expresses the area of recent and proposed logging as a percentage of total basin area and reflects the area of clearcut with little or no hydrologic recovery expected by the end of the five-year plan. The "older logging" includes cutblocks in varying stages of hydrologic recovery, ranging from those with limited or no hydrologic recovery that were recently harvested to some blocks that may be near 7 m green-up which is accepted to represent full hydrologic recovery. The percentage that have not recovered and the equivalent clearcut areas (ECA) of the older logged areas are not known.

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

We have selected recent harvesting covering more than 20% of the watershed, which may correspond to a ECA of up to 20%, to indicate that management concern should be raised for fish habitat. A cut of 20% represent the point where effects on the hydrologic regime often become apparent and where changes in the sediment regime of the stream may result. We have also selected a low value so that those streams where changes in the hydrologic regime may be anticipated with further cutting are identified and management options may be considered. Those streams with recent, total or recent and proposed logging greater than 20% of the basin area 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. If the forested area is only a small portion of the basin area, clearing a large percentage of the forest will have an undetectable influence on the hydrologic regime. Also, the Ministry of Forests uses total basin area in calculating these indices and we have followed their practice.

7. DISCUSSION OF THE SALMON STREAMS

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 Sensitive Streams

The most sensitive salmon streams in the Seton/Bridge Habitat Management Area are shaded on Table 9. Maximum water demand in nearly all the salmon streams amounts to less than 5% of the summer 7 day low flows in most the salmon streams and only exceeds this value in the Bridge River downstream of Terzaghi Dam.

Summer 7 day low flows are reasonably high, exceeding 35% of mean flows, on all the salmon streams, except Cayoosh Creek, as a result of late snowmelt and summer rainfall that maintain flows. On Cayoosh Creek, both summer and winter 7 day low flows are less than 10% of mean flows, likely as a result of upstream diversion and power production. Winter 7 day low flows are typically about one-half of the summer 7 day low flows and occur under-ice in all the natural streams.

The maximum total cut in the watersheds of the salmon streams does not exceed 10% of basin area. Proposed cuts over the next 5-year plan are mostly around one or two percent, except in the upper Yalakom, where the proposed cut amounts to 6% of watershed area.

7.2 Discussion by Stream

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

Seton River: During upstream migration, the percent of Cayoosh water passing through the fishway is maintained at a low percentage of total flow. Fisheries and Oceans Canada manages the flows by letter to B.C. Hydro, who monitors fish passage. Apparently there were passage problems in 1993. B.C. Hydro has been studying suitable fish screens for the upper end of their power canal.

The fan/delta of the Seton River is growing out into the Fraser River and pushing it against its far bank, causing some erosion. The fan grew following the 1991 spills into the Seton River: some of the sediment is from Cayoosh Creek but a large part of it is from bank erosion and, possibly, bed degradation along Seton River. The Seton River seemed to widen appreciably following the 1991 flood.

There are two diversion points on the Seton River. Ainsworth Lumber extracts water for fire prevention (sprinkling to keep logs in their storage area wet). They have had aggradation problems at their intake and are planning to re-construct it. The Town of Lillooet has an infiltration gallery downstream of the Highway Bridge from which they pump water to help fill their reservoirs. Most of their water is currently obtained from Town or Dickey Creeks; however, these creeks are water-short and Lillooet would like to upgrade their intakes and remove more water from the Seton River.

Cayoosh Creek: There is a small powerhouse immediately upstream of the diversion tunnel leading to Seton Lake. As Cayoosh Creek is very mobile near the tailrace the operators have re-constructed their outlet to Cayoosh Creek and completed some remedial work on the opposite downstream bank. There is an application for placer mining which would incorporate a second small hydro project further upstream. As proposed, this project would divert flow from the main creek, drying up about 1 kilometre of streambed.

Portage River: In 1991, there were a number of debris flows and slides on the north side of Anderson and Seton Lakes. Whitecap Creek, which joins Portage River from the north, experienced some major failures and deposited large quantities of coarse cobbles on its fan and in the main river. Whitecap Creek has been a persistent problem: B.C. Rail, which crosses its fan, previously diverted the creek and private landowners have also attempted to halt bank erosion.

There is a revetment on the bank of Portage River directly opposite Whitecap Creek. Portage River is narrowed at this point, by the Whitecap Creek fan, and the embankment is failing and falling into the stream. The Department of Fisheries and Oceans is concerned that logging in the Whitecap Creek watershed is aggravating the sediment supply.

Gates River: There have been several years of above-average annual floods on Gates River and landowners have been repairing damage to stream banks and removing log jams in the river.

Bridge River: There are two or three placer miners operating along the Bridge River. The miners often operate within the old river channel, on bar surfaces, but outside of the typical wetted perimeter of the diminished channel. The 1991 and 1992 spills from Terzaghi Dam washed out some of these operations.

The 1991 and 1992 spills also washed out part of the road. Emergency rip rap dumps were used to preserve the road in 1991 and to a much lesser extent in 1992. These spills also eroded riparian vegetation which had colonized bars along the Bridge River that were no longer regularly flooded, eroded spawning gravels, and deposited sediment along the river.

The Bridge River is productive upstream of the Yalakom River but there are problems with low flows as water is derived from springs, groundwater inflows, and small tributaries. Little is known of the Bridge downstream of the Yalakom River. D.B. Lister and Associates Ltd tried to examine this reach of river but could not get permission to enter the reserve.

After the 1991 spill, B.C. Hydro built gravel platforms in the Bridge River, excavating the bed and installing spawning gravels. Apparently, these platforms have worked well, although they were affected by the 1992 spill.

The main fishery concerns on this system are: the frequency and magnitude of spills from the Terzaghi Dam, and the lack of adequate minimum flow releases from the Terzaghi Dam. Instream complexing has been suggested as a means for developing more habitat.

Yalakom River: The Yalakom has consistent flows over much of the summer and seldom experiences the late summer and fall floods that occur on the Bridge and Seton Rivers. The Salmon Enhancement Program tried to remove a barrier to upstream migration by blasting but the removal may not have been effective. Sockeye and chinook salmon were planted in the upper river as far back as the 1960's with doubtful success. B.C. Environment and Fisheries and Oceans Canada are planning a biological assessment of the system in 1994.

8. RESULTS AND CONCLUSIONS

8.1 Effects of Development on Hydrology

In the Seton/Bridge HMA, flows in the salmon streams are greatest during snowmelt in May and June and remain reasonably high over the late summer, in both natural and regulated streams. Rainstorms often raise discharge and water levels in August, September or October. Ice-cover forms in the late fall or early winter and minimum winter discharges usually occur under ice between December and March. Winter low flows are typically about one-half of those occurring in the summer. The 1980's were a dry decade in the Seton/Bridge HMA and flows were well-below their long-term averages for the years from 1983 to 1989. This appears to have resulted from reduced winter snow accumulation rather than reduced annual precipitation. Diversion for irrigation or waterworks affect some streams but there is limited agriculture and less than 10% of low flows are diverted in any of the streams. The greatest portion of low flows are diverted from the Bridge River which has limited inflows from springs, groundwater and small tributaries.

Forest harvesting is the main human activity that affects peak discharges though less than 10% of the watershed area of the salmon streams has been harvested. Forest harvesting on unstable soils may also increase suspended sediment concentrations and coarse debris supply which affects downstream habitat.

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

Surface Water Use: The major surface water extractions for irrigation are from Gates River, Portage River and the lower Bridge River. Extractions, as a percentage of summer flows, are greatest from the lower Bridge River, where upstream regulation has severely reduced the flows. There are water licences on many of the small tributaries to the Bridge River. Licensees have complained that forest harvesting has affected the quantity of water available for diversion.

The Water Management Branch does not keep records of the degree of utilization of the outstanding water licences and some licences may no longer be used. Recent increases in annual fees have lead to some licences being abandoned by their holders and increases in application fees have reduced the backlog of applicants. Revision of the Water Act may result in further fee increases which would further reduce the number of application and lead to additional abandonment of under-utilized licences.

Future water demand for irrigation in Seton/Bridge HMA is not known as neither the Water Management Branch nor the Ministry of Agriculture, Fisheries and Food prepare forecasts of agricultural expansion and concomitant requirements for irrigation. However, the local Water Manager reports that there are no applications for irrigation licences and none are anticipated in this District.

Ground Water Use: Little is known of ground water use in the Seton/Bridge HMA though it is not expected to affect surface flow in the salmon streams.

Storage Developments: There are no applications before the Water Management Branch for large or medium-sized power projects in the Seton/Bridge HMA. Developers have planned for a small hydro projects on upper Cayoosh Creek.

There is no existing non-power storage on salmon streams in the Seton/Bridge HMA and none is planned.

Forestry: All the salmon streams have less than 10% of their watersheds harvested, and only minor changes to hydrologic regimes are expected. Most cutblocks in the salmon streams were harvested since 1973 (Table 7). Water licencees on small tributaries to the Bridge River have complained to the Water Managment Division that logging has altered flows in their streams.

The proposed cut over the next five-year plan in the watersheds of most salmon streams is between 0% and 3% of total basin area. The Yalakom River is the only exception: here, the proposed cut in the upper watershed amounts to around 6% of the watershed area. We recommend that the proposed harvest be well-distributed over the watershed and that harvesting be monitored, particularly regarding sediment contributions to streams.

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 soil stability and sedimentation in the salmon streams.

Placer Mining: There is minor activity on Bridge River and Cayoosh Creek and these streams have been historically mined for a number of years. The current level of activity is not affecting the salmon streams.

Flooding, Erosion and Sedimentation: Some of the salmon streams are unstable, such as the Seton River and Portage River. High flows in the Seton River appear to be removing gravels which are not replenished. With continued high flows, channel downcutting and coarsening of bed material may be expected. Instability in Portage River results from an oversupply of coarse debris from Whitecap Creek. Deposition of this material forces Portage River against its south bank and is eroding the revetment placed there.

Erosion and sedimentation along the Bridge River are a result of unusual spills from Terzaghi Dam. Reducing the magnitude and frequency of spills is key to maintaining this river as a productive system.

There is no systematic record of streambank stability problems nor any coordinated program for remedial measures in the salmon streams.

8.2 Technical and Management Recommendations

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

8.2.1 Estimation of Flows and Demands in the Salmon Streams

Flows for the salmon streams were estimated from complete gauging records, partial gauging records, transfer from nearby stations or regional analysis. As discussed, 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, such as Lower Bridge River, 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. On gauged streams, further analysis of additional gauging records on tributaries or the upper mainstem is warranted, where these are available.

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

1. The relationship between actual and licensed withdrawals is not known for various licence types. As well, demand varies from year-to-year, because of 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

The lower Bridge River is the only salmon stream with a moderate water demand. *We recommend that further water withdrawals from this stream, and its tributaries, be monitored and opportunities for storage development within small tributaries to the main river be reviewed.*

There are options for improving flows and fish habitat in the lower Bridge River by altering the operation of the Terzaghi Dam. The magnitude and frequency of spills from the reservoir can be reduced by maintaining sufficient freeboard to store flood inflows from summer rainstorms. A constant flow release from the Terzaghi Dam would greatly improve fish habitat. B.C. Hydro is examining these issues.

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 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 reduction in streamflow from pumping from groundwater be evaluated.

8.2.4 Forest Harvesting

A number of the salmon streams have insignificant or zero licensed demand and are not likely to experience increased agricultural or water supply demand in the near-future. In these streams, logging is the main land use with the potential to alter the hydrologic or sediment regimes or alter channel morphology. It is generally felt that the hydrologic regime may be preserved or managed by controlling the rate of clearcutting which affects 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 cause deterioration of spawning gravel quality. Such problems must be investigated on a site by site basis and managed by following road construction and harvest prescription guidelines provided by the responsible agencies.

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

1. It is difficult to manage the rate of cut because the Ministry of Forests does not present their existing and proposed cut data by watershed. *We recommend that DFO arrange with the Ministry of Forests to have the proposed cut on five-year plans sorted by watershed. Total previous and proposed cut within the watersheds should be established.*

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

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

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

8.2.5 Placer Mining

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

8.2.6 Sedimentation and Sediment Sources

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

Ultimately, the erosion events should be mapped or incorporated into a GIS database for display with respect to habitat along the streams along with anecdotal information on the history of erosion, flooding, sedimentation and channel changes in the salmon streams in the Seton/Bridge 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 Seton/Bridge 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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A. ESTIMATING FLOWS AT THE MOUTH OF UNGAUGED SALMON STREAMS

All of the salmon streams have been gauged by the Water Survey of Canada at one time or another and the Seton River, Cayoosh Creek, and Yalakom River meet the requirements for gauged salmon streams, as they have Water Survey of Canada stations operating near their mouths and (nearly) continuous records from 1981 to 1990. Records from Cayoosh Creek and Seton River measure the regime near the mouths of these creeks, as affected by storage and upstream diversion for power generation.

The hydrologic characteristics of the other salmon streams were estimated by adjusting and transferring Water Survey of Canada gauging records to the mouth of the stream. The following sections describe the procedures used to estimate flows at the mouth of each of the salmon streams. (No estimates have been prepared for Tyaughton, Williams or Fergusson Creeks as Terzaghi Dam prevents access to these streams by anadromous salmon.)

Seton River: Flows at the mouth were estimated by adding flows recorded at the "Seton River near Lillooet, 08ME003" gauge and the "Cayoosh Creek near Lillooet, 08ME002" gauge.

Portage Creek: The "Portage Creek near Seton Lake P.O., 08ME015" recorded flows near the mouth of Portage Creek from 1949 to 1955. Mean annual flow, mean annual flood, mean monthly discharges and mean 7 day low flows were calculated from these records. The calculated characteristics were adjusted to the 1981 to 1990 perid with the "Lillooet River near Pemberton, 08MG005" gauge. The adjustment consisted of determining the ratio of the flow characteristics over the gauging period, and over 1981-1990, at the long-term gauge. These ratios were then applied to the flow characteristics calculated from the older record.

Gates River: The "Gates River below Haylmore Creek, 08ME022" gauge recorded flows near the mouth of Gates River from 1965 to 1968. Mean annual flow, mean annual flood, mean monthly discharges and mean 7 day low flows were calculated from these records. The calculated characteristics were adjusted to the 1981 to 1990 perid with the "Lillooet River near Pemberton, 08MG005" gauge. The adjustment consisted of determining the ratio of the flow characteristics over the gauging period, and over 1981-1990, at the long-term gauge. These ratios were then applied to the flow characteristics calculated from the older record.

Bridge River: Releases from the Terzaghi Dam are infrequent (Section 2.5) and flows at the mouth of Bridge River are from the 990 km^2 watershed downstream of the dam. The gauge on the Yalakom River measures inflows from 575 km^2 of this area. There are few gauges on other tributaries to the lower Bridge River. However, Moon Creek, a small tributary, has unit monthly flows that are very close to those from the Yalakom. On this basis, flow characteristics at the mouth of the Bridge were estimated from the ratio $(A_m/A_g)^n$; where A_m is the drainage area between Terzaghi Dam and at the mouth of Bridge River, A_g is the drainage area at the Yalakom River gauge and n is equal to 0.8 for mean floods and 1.0 for all other flow characteristics.

Yalakom River: The "Yalakom River above Ore Creek, 08ME025" gauge measures flows from 85% of the watershed and flows were measured from 1983 to 1990. There is no nearby gauge suitable for adjusting these records and the 1983 to 1990 records were used as representative of the 1981 to 1990 period. Flow characteristics measured at the gauge were transferred to the mouth using the ratio $(A_m/A_g)^n$; where A_m is the drainage area at the mouth, A_g is the drainage area at the Yalakom River gauge and n is equal to 0.8 for mean floods and 1.0 for all other flow characteristics.

B. STREAM SUMMARIES

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

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

B.1 Licensed Water Demand

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

B.2 Mean Annual Hydrograph

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

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

B.3 Sensitivity Indices

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

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

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

B.4 7 Day Low Flows

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

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

7 Day Low Flow Frequency Curve

The frequency curve shows an Extreme Value Type III (Gumbel) Distribution fit to the annual 7 day low flows recorded at the gauging station. The curve shows the predicted annual 7 day low flow, in m^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.

SETON RIVER

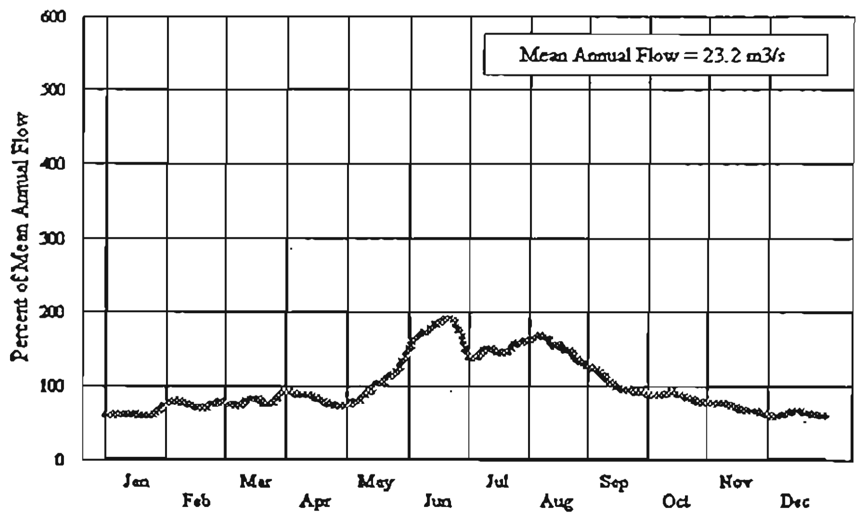
Stream number 00-1800-000-000-000-000-992
Water Survey of Canada Station 08ME003
Seton River near Lillooet
Records 1914 to 1990
Drainage Area =1,040 km²

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	97,000 g/d	5.1	5.1	5.1
Irrigation	2,028 ac.ft.		233.5	96.5
Waterworks	108,500g/d	5.7	5.7	5.7
Industrial	5,000 g/d	0.3	0.3	0.3
Conservation	110 cfs			

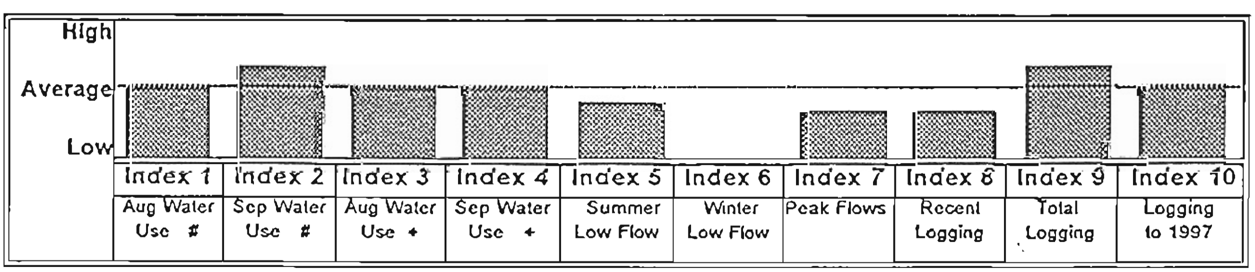
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	17,900	36,500	24,700

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

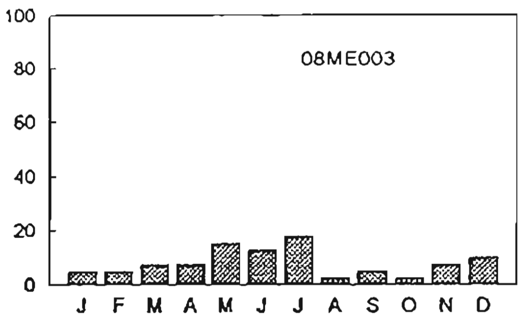
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



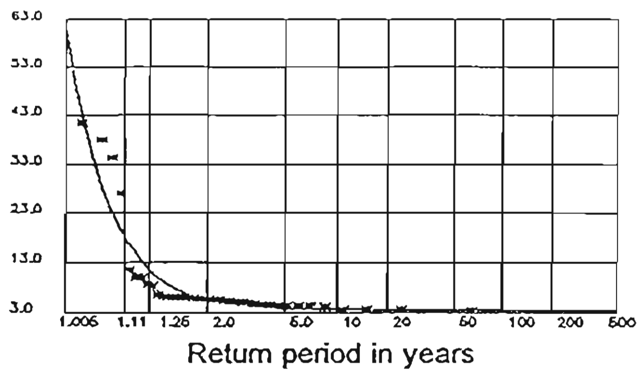
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

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	5.41 m^3/s	3.53 m^3/s	3.47 m^3/s	3.45 m^3/s	3.44 m^3/s
Annual Flood	107 m^3/s	162 m^3/s	177 m^3/s	194 m^3/s	206 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. The delta of the Seton River is growing; noticeable enlargement occurred following the 1991 flood spills from Seton Lake. Some of the sediment is from Cayoosh Creek but a large part of it is from bank erosion and, possibly, bed degradation along the Seton River.

2. There are two main water diversions: Ainsworth Lumber extracts water for fire prevention in their log storage area; and the Town of Lillooet has an infiltration gallery downstream of the highway bridge which they are planning to upgrade and enlarge.

3. Fisheries and Oceans, by letter to B.C.Hydro, specify ranges of flows in the Seton River to optimize fish passage. B.C.Hydro monitor fish passage. B.C.Hydro are also studying alternatives for screening the upper end of the power canal against downstream migrants.

CAYOOSH CREEK

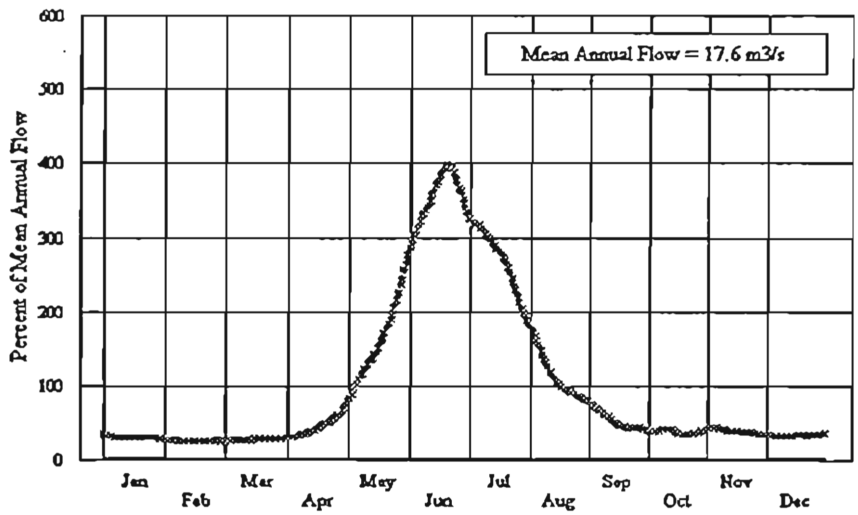
Stream number 00-1800-050
Water Survey of Canada Station 08ME002
Cayoosh Creek near Lillooet
Records 1914 to 1990
Drainage Area = 878 km²

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	5,500 g/d	0.30	0.30	0.30
Irrigation	14 ac.ft.		1.61	0.67
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	200 cfs			

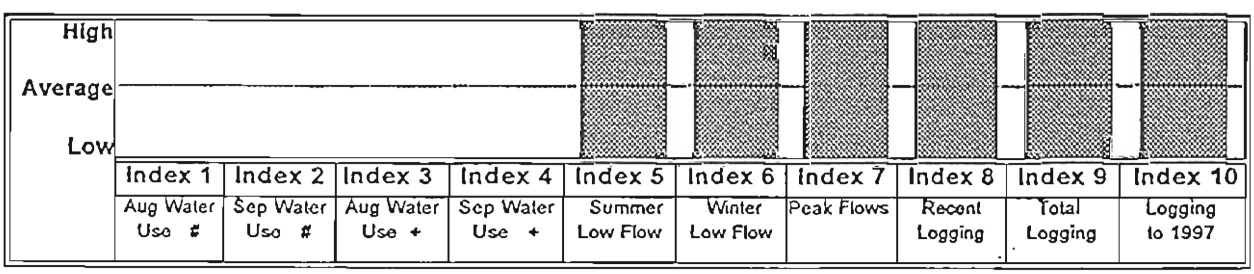
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	4,540	19,500	10,200

MEAN ANNUAL HYDROGRAPH



SENSITIVITY INDICES

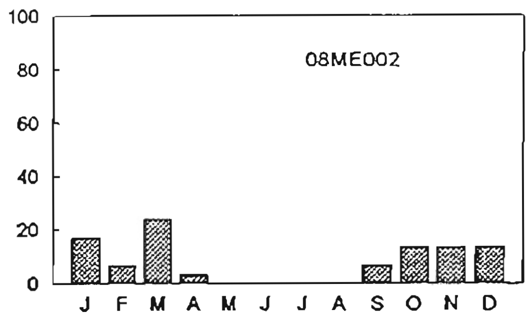
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



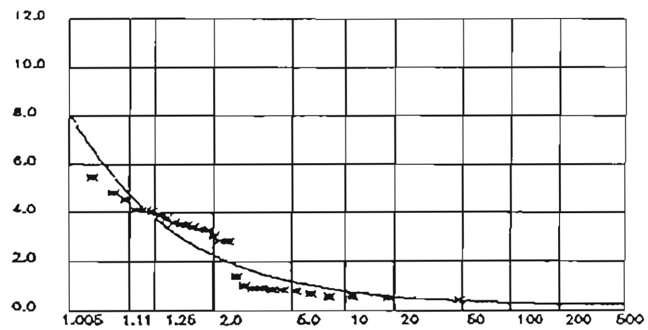
\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	2.25 m^3/s	0.77 m^3/s	0.54 m^3/s	0.37 m^3/s	0.30 m^3/s
Annual Flood	95 m^3/s	158 m^3/s	181 m^3/s	208 m^3/s	227 m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. Some work has been done at the tailrace of the hydroelectric powerhouse located just upstream of the diversion to Seton Lake, to reduce erosion and improve flow conditions in Cayoosh Creek downstream.

2. There is a proposal to build another, small hydroelectric powerhouse further upstream, as part of a placer mining operation. As proposed, this project would divert flow from the creek, drying up about one kilometre of streambed.

PORTAGE RIVER

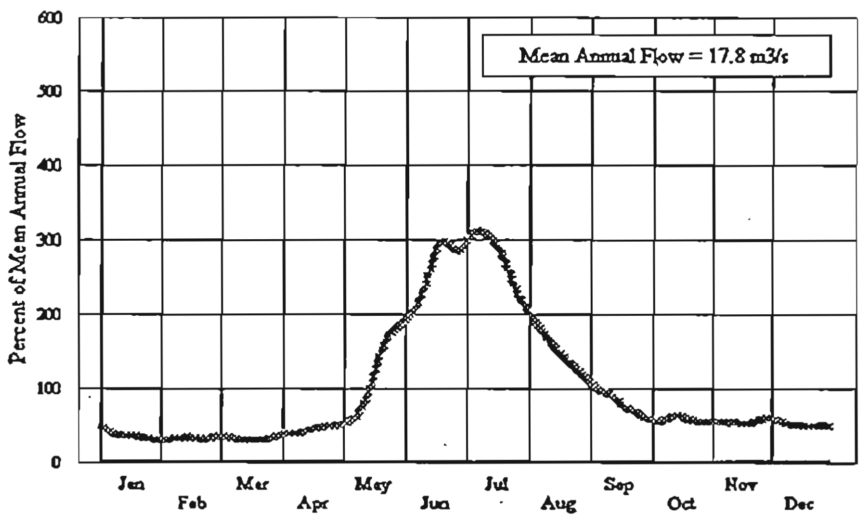
Stream number 00-1800-000-000-000-000-991
Water Survey of Canada Station 08ME015
Portage River near Seton Lake P.O.
Records 1949 to 1955
Drainage Area = 728 km²

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	78,500 g/d	4.13	4.13	4.13
Irrigation	1,536 ac.ft.		176.9	73.1
Waterworks	56,000 g/d	2.95	2.95	2.95
Industrial	5,000 g/d	0.26	0.26	0.26
Conservation	60 cfs			

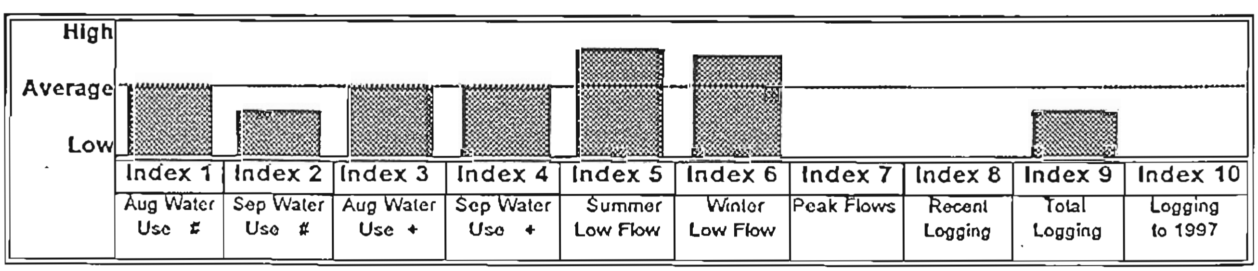
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	5,870	25,500	13,700

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

PORTAGE RIVER

SUMMARY NOTES AND RECOMMENDATIONS

1. Major slides in Whitecap Creek, a tributary to Portage River, produces large quantities of coarse material that has built a fan out into the river. Persistent problems have been experienced by B.C. Rail, who cross the fan and have had to divert the creek. Adjacent landowners have made attempts to halt bank erosion. The Department of Fisheries and Oceans is concerned over logging in the Whitecap Creek Watershed because it may be accelerating erosion and the sediment supply to the fan.

GATES RIVER

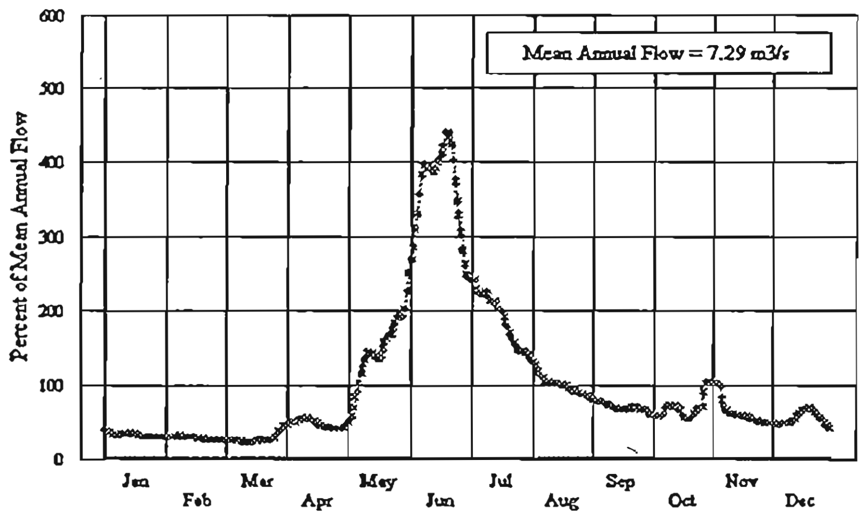
Stream number 00-1800-650
Water Survey of Canada Station 08ME022
Gates River below Haylmore Creek
Records 1965 to 1968
Drainage Area = 326 km²

LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	25,000 g/d	1.32	1.31	1.31
Irrigation	788 ac.ft.		90.7	37.5
Waterworks	17,000 g/d	0.89	0.89	0.89
Industrial	0 g/d			
Conservation	40 cfs			

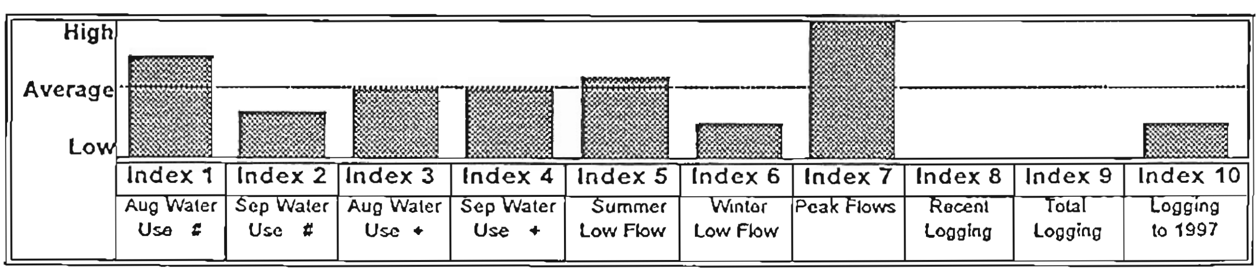
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	3,220	8,240	4,640

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

GATES RIVER

SUMMARY NOTES AND RECOMMENDATIONS

1. There have been several years of above average annual floods on Gates River. Landowners have been repairing damage to the river banks and removing log jams.

BRIDGE RIVER

Stream number 00-1900
Ungauged below Terzaghi Dam
Tributary to Fraser River

Drainage Area = 3,650 km²

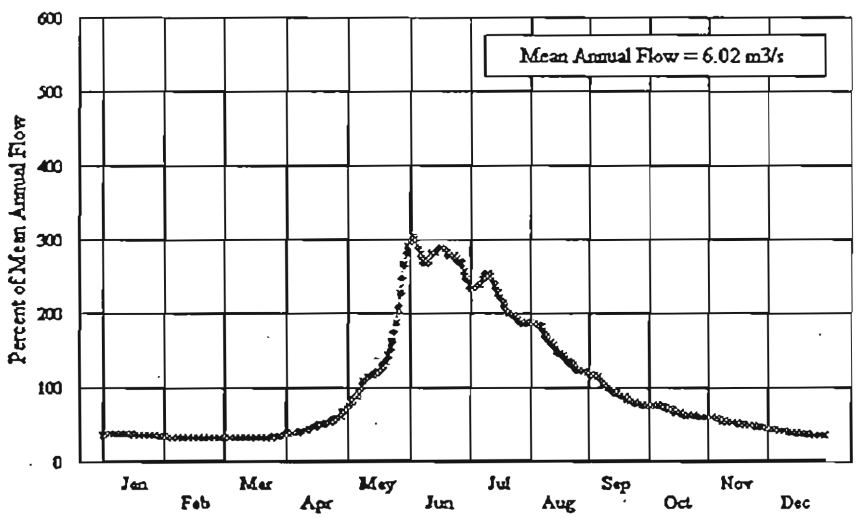
LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	81,000 g/d	4.26	4.26	4.26
Irrigation	2,307 ac.ft.		265.7	109.8
Waterworks	191,000 g/d	10.0	10.0	10.0
Industrial	379,419 g/d	20.0	20.0	20.0
Conservation	661 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S	15,100	223,000	122000

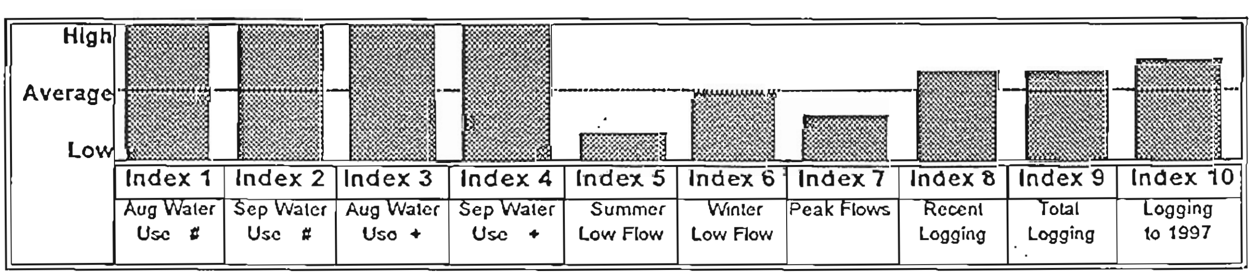
MEAN ANNUAL HYDROGRAPH

(Estimated,using Yalakom River station 08ME025)



SENSITIVITY INDICES

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



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

BRIDGE RIVER

SUMMARY NOTES AND RECOMMENDATIONS

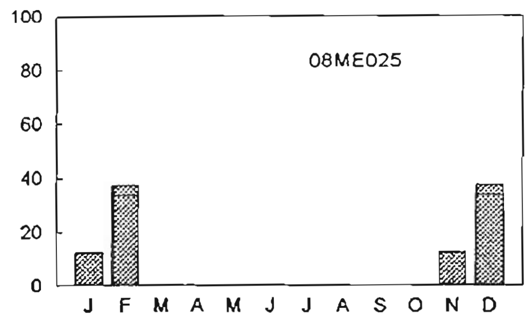
1. Flood spills in 1991 and 1992 from Terzaghi Dam into Bridge River washed out part of the road, eroded riparian vegetation, eroded spawning gravels, and deposited sediment along the river. After the 1991 spill, B.C.Hydro constructed "gravel platforms" along the river, by excavating the bed and placing suitable spawning gravels. Apparently they have worked well, although they were affected by the 1992 spill.

2. Bridge River between Terzaghi Dam and the Yalakom River is productive, but there are problems because the flows are sustained only by springs, groundwater inflows, and small tributaries. Little is known of the river downstream of the Yalakom. D.B. Lister and Associates Ltd. tried to examine this reach but were unable to obtain permission to enter the reserve.

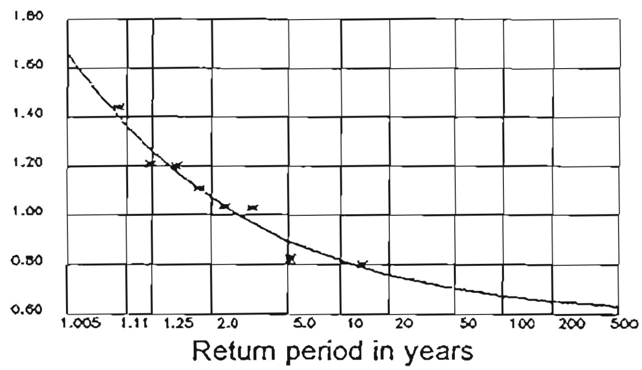
3. There are options for improving flows and fish habitat in the Bridge River. B.C.Hydro is examining the possibility of maintaining more freeboard on the reservoir, to better manage flood spills, and releasing a guaranteed flow to improve fish habitat below the dam.

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	1.07 m^3/s	0.81 m^3/s	0.76 m^3/s	m^3/s	m^3/s
Annual Flood	22 m^3/s	35 m^3/s	41 m^3/s	m^3/s	m^3/s

SUMMARY NOTES AND RECOMMENDATIONS

1. The Yalakom River has consistent flows over much of the summer and seldom experiences the late summer and fall floods that occur on the Bridge and Seton Rivers.

2. Attempts have been made, as far back as the 1960's, to recolonize sockeye and chinook salmon in the upper river. Also, the Salmon Enhancement Program tried to remove an upstream migration barrier by blasting, apparently with limited success. A joint biological assessment of the system by B.C. Environment and Fisheries and Oceans Canada is being planned for 1994.