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

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

by

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LE PLAN VERT DU CANADA

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## ABSTRACT

Indices of hydrologic sensitivities were developed for streams within the Fraser River Action Plan's Fraser Delta Habitat Management Area (HMA), where sensitivity refers to the state of those aspects of the hydrologic regime that affect habitat and are altered by human activities. The indices were used to rank 33 presently utilized salmon streams in the HMA according to water withdrawals, high flows, low flows and urbanization regarding impact from human activities and their ability to resist human impact. This study described those aspects of the climate, physiography, surficial geology and soils that affect the hydrology of the salmon streams. The local hydrologic regimes were described, and estimates of mean annual flows, mean annual floods, mean monthly flows, and seasonal 7-day flows were prepared for each of the salmon streams. Potential licensed demand on surface waters were calculated. The impact of urbanization on hydrology was reviewed, and areas of various land uses in the study stream watersheds were calculated. The main issues occurring on the salmon streams were summarized on a stream-by-stream basis. Watersheds of many of the salmon streams in the HMA have moderately impervious surficial geology with naturally occurring low flow problems during extended dry periods. Other watersheds underlain by deep glaciofluvial gravels (Nathan, Anderson, Murray and Fishtrap creeks and upper Salmon River) maintain greater base flows through groundwater discharge. In either case, urbanization may have only a small effect on low flows relative to effects of water extraction, and particularly groundwater extraction in the latter. The major surface water extractions were for irrigation from Nicomekl, Serpentine and Salmon rivers, and Matsqui and Gifford sloughs. Water storage requirements, except for the Coquitlam Reservoir, only represent a small portion of the water requirements for irrigation. Urbanization, and particularly effective impermeable areas from development, was found to be the main human activity affecting peak flows, particularly in areas that were developed prior to new municipal regulations restricting 2-year post-development floods to pre-development levels. There is no local evidence that these flows constitute a channel-forming discharge in the HMA. There is no systematic record that examines bank erosion or channel downcutting as they relate to land-use activities in the HMA. Technical recommendations and management alternatives were discussed, including a variety of monitoring projects, water management plans, opposition to further water withdrawals in some streams, water storage opportunities, shallow well inventories, examination of effectiveness of current stormwater management, examination of sediment budgets, development of GIS map layers on channel changes and bank status, and detailed hydraulic modelling in contentious watersheds.

## RÉSUMÉ

Dans le cadre du Plan d'action du Fraser, des indices de vulnérabilité hydrologique ont été établis pour certains cours d'eau du secteur de gestion de l'habitat (SGH) du delta du Fraser. On entend par «indice de vulnérabilité», l'état des éléments du régime hydrologique qui ont un effet sur l'habitat et qui sont modifiés par les activités humaines. Ces indices ont servi à classer 33 rivières à saumons du SGH sur lesquelles s'exercent à l'heure actuelle des activités humaines, en fonction des prélèvements d'eau, des débits de crue et d'étiage et de l'urbanisation (répercussions des activités humaines et capacité d'y résister). Cette étude porte sur les aspects du climat, de la physiographie, de la géologie de surface et des sols qui exercent une action sur l'hydrologie des rivières à saumons. On a décrit les régimes hydrologiques locaux et on a préparé, pour chacune des rivières à saumons, des estimations sur les écoulements annuels moyens, les crues annuelles moyennes, les écoulements mensuels moyens et les écoulements hebdomadaires saisonniers. On a calculé la demande potentielle liée aux permis d'utilisation des eaux de surface. On a examiné l'impact de l'urbanisation sur l'hydrologie et on a calculé les superficies occupées par les diverses utilisations du sol dans les bassins versants des 33 rivières étudiées. Les principaux événements se produisant dans les rivières à saumons ont été résumés cas par cas. Un bon nombre de ces bassins versants présentent des terrains à imperméabilité moyenne et connaissent des problèmes naturels d'étiage au cours des périodes prolongées de sécheresse. Dans d'autres bassins versants, qui reposent sur d'épais graviers fluvioglaciaires (criques Nathan, Anderson, Murray et Fishtrap et cours supérieur de la rivière Salmon), les débits de base résultant de l'émergence des eaux souterraines sont supérieurs. Dans l'un et l'autre cas, il se peut que l'urbanisation, c'est-à-dire les effets du prélèvement d'eau et surtout d'eau souterraine dans le dernier cas, n'ait qu'un faible effet sur les débits d'étiage. Les principaux prélèvements d'eau de surface, pour l'irrigation, concernaient les rivières Nicomekl, Serpentine et Salmon et les chenaux Matsqui et Gifford. Les exigences pour l'emménagement des eaux, à l'exception du réservoir de Coquitlam, ne représentent qu'une petite portion des exigences en eau pour l'irrigation. On a découvert que la principale activité humaine modifiant les débits de pointe était l'urbanisation, surtout la création de surfaces réellement imperméables, notamment dans les régions où le développement était antérieur à la nouvelle réglementation municipale prescrivant que les débits pour une période de deux ans suivant la réalisation du projet ne dépassent pas ceux du niveau antérieur. Rien ne semble montrer qu'à cet endroit les débits sont suffisants pour former un chenal. Il n'existe aucune étude systématique sur l'érosion des berges ou le creusement des chenaux en rapport avec les activités d'utilisation des terres dans le SGH. On a examiné les recommandations techniques et les stratégies de gestion proposées, dont divers projets de surveillance, des plans de gestion des eaux, l'objection d'effectuer d'autres prélèvements dans certaines rivières, des possibilités d'emménagement des eaux, des inventaires des puits peu profonds, l'examen de l'efficacité de la gestion actuelle des eaux d'orage, l'examen des bilans sédimentologiques, l'élaboration de cartes superposables sur SIG portant sur l'état des berges et les modifications des chenaux et une modélisation hydraulique détaillée de bassins versants dans les cas litigieux.

## FOREWORD

This report was commissioned by the Fraser River Action Plan (FRAP). FRAP was established in 1990 as part of the Government of Canada's and the Department of Fisheries and Oceans' (DFO) commitments towards achieving sustainable development of our fisheries resources. This report is another contribution to complement discussions on implementation of sustainable development in the Fraser River basin. As part of our strategic review of salmon habitats, this review was conducted on the hydrology of the Fraser Delta Habitat Management Area's salmon streams to better index habitat sensitivity.

The driving objective of the FRAP was to devise and complete a habitat management plan for the Fraser River. The plan must incorporate numerous considerations. It was recognized that salmon habitat has been significantly degraded in the Fraser River Basin over the past 100 years. Despite that, the salmon stocks are being actively rebuilt towards historic levels. Obviously a link between the capability of the habitat to produce fish and stock rebuilding goals had to be established. Also, we must begin the process of better protecting existing habitat and to restore and enhance what is desirable within a plan involving more than DFO habitat and harvest managers.

To address this overall task, the Fraser River Basin was divided into 15 Habitat Management Areas (HMAs). This division was based on major river systems and salmon stocks. Individual Habitat Management Plans are being developed for these 15 HMAs to attempt to define salmon habitat status, stock status and habitat restoration and protection priorities. These are a first step towards establishing a data base for long-term environmental sustainable development discussions with other stakeholders in the basin.

Although the stock rebuilding initiative began several decades ago, it received greater priority after the 1985 Canada-U.S.A. International Agreement. Serious attempts to include habitat considerations into the process began in late 1988. In 1990, the initiative was incorporated into the National Green Plan's Fraser River initiative and is now called the Fraser River Action Plan.

As part of our commitment to sustainable development and Canada's Green Plan we have defined specific goals for sustainable fisheries development. The Habitat Management Plan and associated DFO decisions and activities are guided by the goals of sustainable development, and particularly its two basic principles:

- a) To maintain ecological diversity of the basin; and
- b) To maximize the net economic benefits that can be derived from the resource.

In addition, DFO has defined seven measurable and achievable goals for sustainable fisheries development. They are as follows:

- 1) **Avoiding irreversible man made changes to fish producing habitats.**  
Avoiding alterations to fish habitat that reduce its capacity to produce valuable fish populations that cannot be reversed within a human generation.

- 2) **Maintaining the genetic diversity of fish stocks.**  
No fish stock, however small, will be arbitrarily written off, and where possible it will be attempted to conserve and rebuild small and remnant stocks.
- 3) **Maintaining the physical and biological diversity of fish habitats.**  
Physical and biological diversity of habitat provides fish with an opportunity to adopt alternative life history strategies, hence providing protection from natural variation.
- 4) **Providing a net gain in the productive capacity by habitat management.**  
Ecological limits control productive capacity. Natural and self-sustaining production systems are preferred over semi-natural and artificial or non-self sustaining systems.
- 5) **Maximizing the value of commercial, sport and aboriginal fisheries.**  
Consideration of both tangible and intangible market and extra-market values are measured in a way to permit comparison of competing uses of the fisheries resources.
- 6) **Maximizing the non-consumptive values of fishery resources.**  
Intangible and cultural values associated with fishery resources must be given due consideration in decision making.
- 7) **Distributing fishery net benefits in a fair and equitable manner.**  
Local communities must be involved in the decision-making process with respect to habitat conservation, enhancement and restoration, and particularly to who benefits and who pays.

It is intended that this report will enable more effective land use planning that will better protect aquatic habitat. This should translate to better protection and management of aquatic habitat, and contribute to a higher level of environmentally sustainable development.

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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 Fraser Delta HMA which includes streams in Vancouver, Burnaby, Coquitlam, Port Coquitlam, Delta, Surrey, Langley, and Matsqui that drain to the Fraser River or to Semiahmoo Bay and lie within the Fraser Lowland (Figure 2).

An understanding of hydrologic regime of the salmon streams is one important aspect of habitat management planning and our report describes both the regime in the salmon streams and the effect of human development on that regime. Within the Fraser Delta HMA, agricultural, municipal and industrial extractions from surface and ground water together with urban development 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.

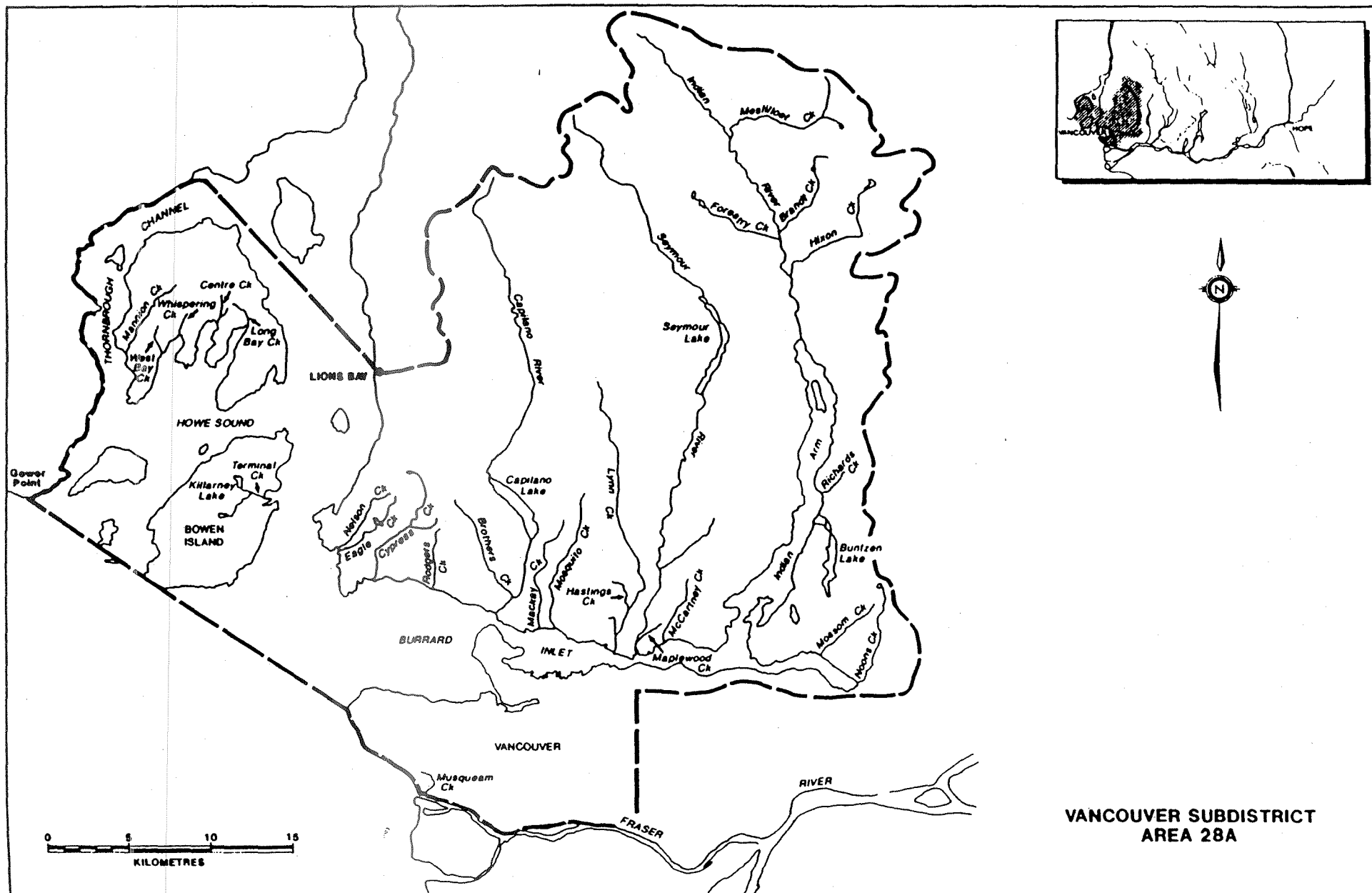
### **1.2 Scope of the Study**

Our study examines 33 of the known and presently utilized salmon streams within the Fraser Delta HMA that are listed in SSIS (the Stream Information Summary System; Table 1). Our analysis is based on information compiled by the Water Survey of Canada, the National Hydrologic Research Institute, the Ministry of Environment, Lands and Parks and the municipalities and interviews with staff of the various government departments and agencies.

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



Figure 2: Salmon Streams in the Fraser Delta HMA.



COQUITLAM LAKE

PITT LAKE

COQUITLAM RIVER

PITT RIVER

ALOUETTE RIVER

ALOUETTE LAKE

ABUETTE RIVER

COQUITLAM SUBDISTRICT AREA 29C

LOWER PITT RIVER

Maple Ridge

Port Coquitlam

Maple Ck

Scott Ck

Stoney Ck

Burnette River

Burnaby Lake

SIHI

Shooshoos Ck

Popoys Ck

Quintan Ck

Mundy Ck

DeBourville Slough

Perington Ck (Cedar Ditch)

Smith Ck

Hyde Ck

Denner Ck

MacIntyre Ck

Wissop Ck

Loon Lake

Mckenzie Ck

Blaney Ck

Spring Ck

North Alouette River

Alouette (S)

Millenare Ck

Coho Ck

McKenny Ck

Gordon Ck

Kanaka Ck

Thorvale Ck

Alvon Ck

York Ck

Gold Ck

0 2 4 6 8 10 KILOMETRES





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

Stream Name	SSIS Number	WSC Gauge Data			Total Drainage Area (km2)	Years of Record
		Gauge Name	Gauge No.	Drainage Area (km2)		
NORTH SHORE TRIBUTARIES						
1 Musqueam Ck.	00-0010		--	--	6.7	
2 Glen Lyon Ck.	Not in SSIS		--	--	3.7	
3 Sussex Ck.	Not in SSIS		--	--	1.0	
4 Byrne Ck.	Not in SSIS		--	--	9.1	
5 Brunette R.	00-0100	near Buena Vista at Sapperton	08MH021 08MH026	-- 68.6	76.9	1926-35 RS 1934-71 RS
6 Schoolhouse Ck.	00-0150-011		--	--	7.1	
7 Coquitlam R.	00-0180	Coquitlam	08MH141 08MH149 08MH002	54.7 -- 237.0	261.6	1982-91 RC 1984-91* RC 1986-91 RC
SOUTH SHORE TRIBUTARIES						
8 Cougar Canyon Ck.	00-0160		--	--	7.4	
9 Scott Ck.	Not in SSIS		--	--	4.8	
10 Bon Accord Ck.	00-0170		--	--	5.3	
11 - Unamed Ck.	00-0170-0220		--	--	3.8	
12 - Unamed Ck.	00-0170-0230		--	--	4.4	
13 Yorkson Ck.	00-0260	near Walnut Grove	08MH097	6.0	17.9	1965-78 MC
14 Salmon R.	00-0300	at 72 Ave, Langley at Seal Kap Farm	08MH090 08MH089	49.0 --	76.9	1968-91 RC 1960-63 MC
14a - Coghlan Ck.	00-0300-200	at 248th St, Langley	08MH127	--	14.2	
14b - Unnamed Ck	00-0300-150		--	--	0.9	
15 West Ck.	00-0330	near Fort Langley	08MH098	11.4	14.5	1965-91 RC
16 Nathan Ck.	00-0360	near Glen Valley	08MH084	--	33.8	1985-90 RS
17 Hanna Ck.	00-0425		--	--	8.1	
18 Coligny Ck.	00-0438		--	--	3.6	
19 McLennan Ck.	00-0440-010	near Mt Lehman	08MH082	9.07	30.9	1960-64 MS
19a - Gifford Sl.	00-0440	near Matsqui	08MH073	--	14.4	1960-64 MS
19b - Downes Ck.	00-0440-020	near Clearbrook	08MH145	--	6.4	1982-85 MS
20 Matsqui Sl.	00-0460	at Matsqui at Gladwin Road	08MH083 08MH132	-- --	69.3	1960-64; 69-71* 1969-70* RC
20a - Clayburn Ck.	00-0460-010	at Clayburn Rd near Clayburn	08MH068 08MH049	37 --	46.6	1961-64; 70-71 RS 1960-63 MS
20b - Willband Ck.	00-0460-010-020	at Abbotsford	08MH051	--	13.5	1955-56 MS
20c - Stoney Ck.	00-0460-010-022		--	--	7.6	
BOUNDARY BAY TRIBUTARIES						
21 Serpentine R.	90-0200	near Port Kells above Flood Gate below Flood Gate	08MH060 08MH119 08MH120	13.0 -- --	154.2	1961-66 MS 1965-66 * RC 1965-66 * RC
21a Mahood Ck.	90-0200-020	near Newton at 144 st, Surrey near Sullivan	08MH018 08MH154 08MH020	18.4 -- 34.4	38	1959-86 MC 1985-91 RC 1952-72 MC
22 Nicomekl R.	90-0100	below Murray Ck at 203 St, Langley at 192 nd St above Flood Gate below Flood Gate	08MH105 08MH155 08MH050 08MH121 08MH122	64.5 69.2 99.5 -- --	175.2	1965-84 MC 1985-91 RC 1952-63 MC 1965-66 * RC 1965-66 * RC
22a Anderson Ck.	90-0100-020	at the mouth	08MH104	27.2	27.2	1965-87 MC
22b Murray Ck.	90-0100-030	at 216th St, Langley	08MH129	26.2	28.9	1969-83 RC
23 Campbell R.	90-0080	near White Rock above Sam Hill Ck	08MH059 08MH123	63.7 --	78.4	1961-64 MS 1984-91 MS

- R is a recording gauge; M is a manual gauge. C refers to continuous records; S to seasonal records.  
 - "\*" refers to stage records only at the gauging station.

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 urbanization on hydrology and use Zoning Maps, Land Use Maps and air photographs to measure areas of various land uses in the watersheds of the salmon streams;
5. Use the hydrologic, water use and land use data to calculate sensitivity indices and rank, or prioritize the various salmon streams according to water withdrawals, high flows, low flows and urbanization.
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 33 salmon streams. The quality of information varied greatly from stream to stream and our method estimated flow characteristics so that streams within the study area could be compared and ranked. The estimated flows are not necessarily the best estimate for any individual stream and should not be used for design of structures or evaluation of projects without further, detailed study of that particular stream.

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

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

The sensitivity indices are described in Chapter 6. Table 11 presents the calculated indices that express the sensitivity of each of the salmon streams and Table 12 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**

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 Bob Edwards, Neil Peters, Colin Stewart, Paul Beck and Glen Carlson of the Surrey Office of the Ministry of Environment, Lands and Parks; Ken Wilson of the Ministry of Environment, Lands and Parks in Victoria; and Herb Klassen, Bruce Reid, Marissa Byrne, Steve McFarlane, and Matt Foy of the Department of Fisheries and Oceans.



## **2. THE FRASER DELTA 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 Fraser Delta HMA all lie within one climatic and physiographic region -- the Fraser Lowlands -- except Coquitlam River, which extends into the Coast Mountains and, as a result, except in its lower few kilometres, has a very different climate and terrain.

### **2.1 Physiography**

The Fraser Delta HMA lies in the Fraser Lowland physiographic region (Matthews 1986; Holland 1976). The lowland is a triangular-shaped depositional feature that extends eastward from Point Grey to Laidlaw and southward to near Bellingham and lies between the Coast and Cascade Mountains. The main feature of the Lowland is the Fraser River, which bisects the region in a 5 km wide valley that is cut up to 200 m deep into the surrounding terrain.

The rest of the lowland, particularly on the south side of the Fraser River, is characterized by broad, flat-topped or gently rolling uplands or hills (reaching up to 200 m above sea level) that are separated by wide, flat-bottomed valleys (Armstrong 1957). The three major valleys are the Serpentine-Nicomekl lowland, which is 30 km long and up to 5 km wide, and the Sumas Valley, which is 5 km wide but lies outside the study area, and the Matsqui Prairie. These lowlands are former embayments of the sea, exposed as a result of isostatic, eustatic and tectonic adjustments following the end of the most recent glaciation and are underlain by thick marine sediments (Halstead 1986). Smaller lowlands include the Langley lowland, extending from Langley towards Milner, which includes the upper Salmon and Nicomekl River drainages. Elevations in the lowlands are typically less than 15 m.

There are eight major uplands in the study area. Most of Vancouver and Burnaby are covered by the Burrard Upland. In Surrey, there are three uplands; the Newton Upland in north Surrey, the Sunnyside Upland at White Rock and the Campbell Upland which lies in southeastern Surrey and southwestern Langley. In Langley, there are two uplands; the Clayton Upland north of the City of Langley and the Langley Upland in south Langley that extends into Matsqui. In Matsqui, there are three uplands; the west half of the Langley Upland, the Abbotsford Upland, which lies south of Abbotsford and includes the Abbotsford Airport and Sumas Mountain. Sumas Mountain is a tertiary remnant that is covered with a thin layer of glacial drift, whereas the Abbotsford and Campbell Uplands consists of thick deposits (up to 30 m) of glaciofluvial sand and gravel overlying glaciomarine sediments (Armstrong 1981). The other uplands consist of glacial till and glaciomarine sediment as well as older interglacial deposits (Armstrong 1984).

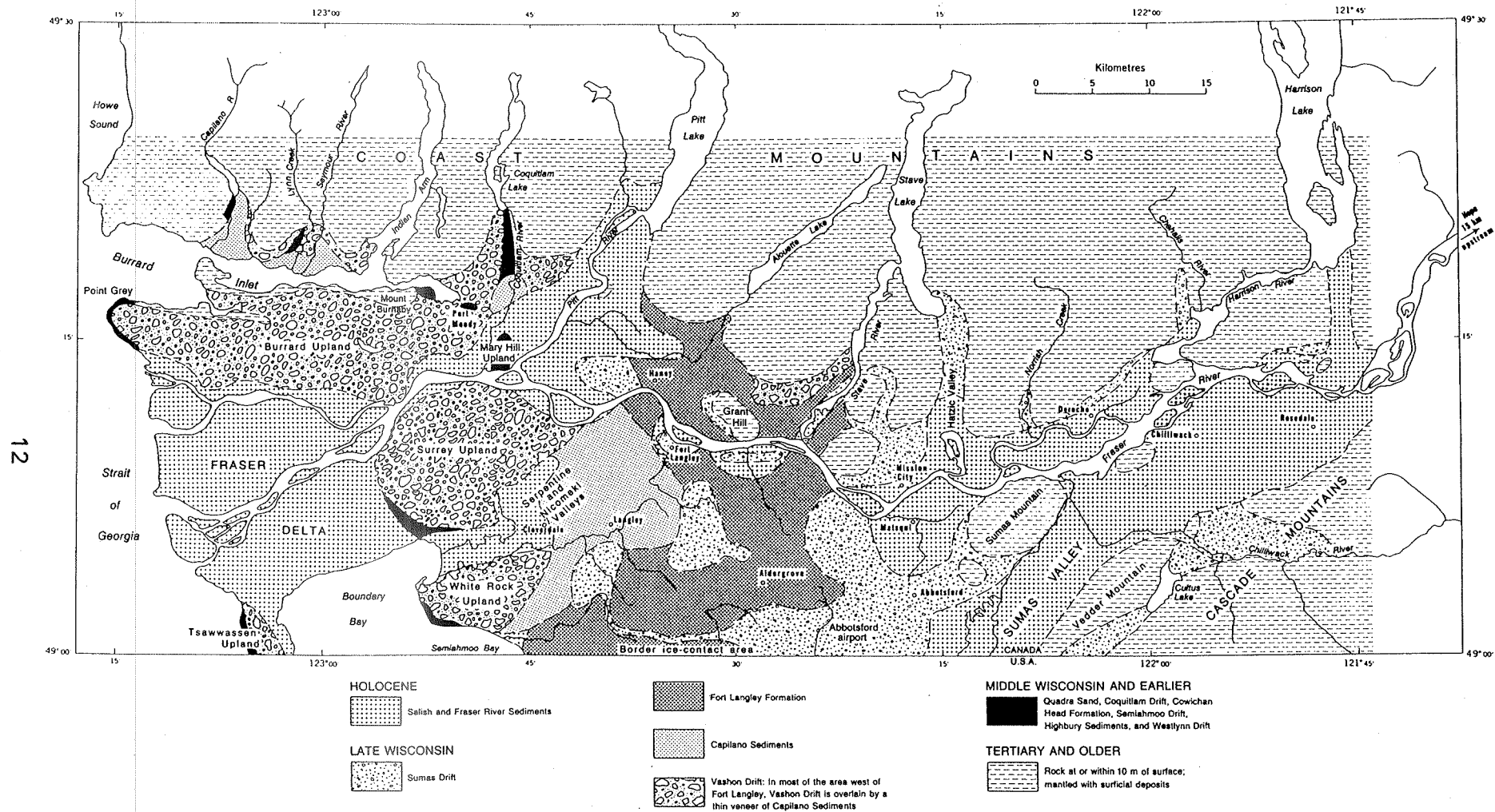
## **2.2 Surficial Geology**

Surficial deposits exposed in the lowland are either postglacial sediments or sediments deposited during the most recent glaciation. Detailed mapping of these sediments was completed by Armstrong (1956; 1957; 1960a; 1960b) and summarized in Armstrong (1983; 1984). Figure 3 (from Armstrong 1984) is a generalization of the surficial geology that shows "chronosequences", i.e. deposits from the same climatic and glacial period, rather than the type of surface sediments. Table 2 describes the typical character of the generalized surficial geology.

The pattern of surficial deposits in the Fraser Lowland is complicated as the Lowland was subjected to repeated glaciations, separated by non-glacial intervals, and sediments from all these periods are partly preserved in the 300 m of sediment that fill the Fraser Valley. Each major glaciation consisted of an advance of ice, a maximum when the ice reached thicknesses of 1,800 metres and over-rode the Coast and Cascade Mountains, and a retreat stage when ice mostly occupied major valleys, though surging glaciers produced local re-advances. Each advance was accompanied by isostatic, eustatic and tectonic adjustments of the land surface that resulted in relative sea level changes of up to 200 m and deposition of marine and glaciomarine sediments on what is now exposed land surface.

**Table 2: Quaternary Deposits in the Fraser Lowland (Armstrong 1984)**

Lithostratigraphic Units* (Mappable Units)	Probable Geologic-Climate Units and Radiocarbon Ages	Lithostratigraphic Units* (Mappable Units)	Probable Geologic-Climate Units and Radiocarbon Ages
FRASER RIVER SEDIMENTS Deltaic ( <i>Richmond Delta Deposits</i> ), distributary channel fill and overbank deposits ( <i>Fraser Floodplain Deposits</i> ). Overlies Postglacial estuarine and marine sediments in the Fraser River Delta.	POSTGLACIAL Present to 9000 BP	QUADRA SAND ( <i>Quadra Sediments, Colebrook Gravel, and Point Grey Beds</i> ) Advance proglacial sediments of Fraser Glaciation; in part synchronous with, in part younger than, and in part older than Coquitlam Drift.	18 000 - 26 000 BP
SALISH SEDIMENTS ( <i>Salish Deposits</i> ) Lowland and mountain stream sediments, lacustrine, eolian, colluvial, slide, beach, and bog deposits.	POSTGLACIAL Present to 12 500 BP	COQUITLAM DRIFT Till diamictos and till-like mixtures of possible glaciomarine origin.	Pre-Vashon Stade 19 000 - 22 000 BP; may be equivalent of Evans Creek Stade.
CAPILANO SEDIMENTS Raised deltas ( <i>Capilano Gravel</i> ), intertidal and beach deposits ( <i>Sunnyside Sand and Bose Gravel</i> ), glaciomarine ( <i>Newton Stony Clay</i> ), and marine ( <i>Cloverdale Sediments</i> ) deposits. Found to the west of Fort Langley beyond the area of Sumas Drift. Contains no recognized till diamicton.	FRASER GLACIATION (Late Wisconsin) Post-Vashon and pre-Postglacial 10 500? - 13 000 BP	COWICHAN HEAD FORMATION Bog and swamp deposits interbedded with flood- plain sediments overlying marine sediments.	OLYMPIA NONGLACIAL INTERVAL (Middle Wisconsin) ( <i>Olympia Interglacial</i> ) 25 800 - 43 000 BP
SUMAS DRIFT ( <i>Sumas Deposits</i> ) Till ( <i>Sumas Till</i> ), glaciofluvial channel, floodplain, and deltaic deposits ( <i>Abbotsford Outwash and Huntingdon Gravel</i> ), glaciolacustrine and glaciofluvial ice-contact deposits ( <i>Abbotsford Outwash</i> ).	Sumas Stade 11 000? - 11 400? BP	COWICHAN HEAD FORMATION (?) Organic colluvium, peat, silt, and sand.	Cowichan Head Formation probably extends back more than 58 000 BP, but this is the only finite date in this part of section.
FORT LANGLEY FORMATION Interbedded marine and glaciomarine deposits ( <i>Whatcom Glaciomarine Deposits</i> ); may include fluvial deposits. Glaciofluvial deltas ( <i>Huntingdon Gravel</i> ), glaciofluvial ice-contact deposits ( <i>Abbotsford Outwash</i> ), and till diamicton.	Probably represents more than one ice advance, originally called Everson Interstade 11 400 - 13 000 BP	SEMAHMOO DRIFT ( <i>Semiahmoo Deposits</i> ) At least two till diamictos ( <i>Semiahmoo Till</i> ), glaciomarine, glaciofluvial, and glacio- lacustrine sediments ( <i>Semiahmoo Sediments</i> ).	SEMAHMOO GLACIATION (Middle Wisconsin and earlier) 62 000 BP
VASHON DRIFT ( <i>Vashon Deposits</i> ) At least three till diamictos ( <i>Surrey Till</i> ), glaciofluvial channel, floodplain, and deltaic deposits ( <i>Maryhill Outwash and Haney Outwash</i> ), glaciofluvial ice-contact deposits ( <i>Maryhill Outwash</i> ), and glaciolacustrine deposits.	Vashon Stade 13 000 - 18 000 BP	HIGHBURY SEDIMENTS Intertill fluvial, organic, and marine sediments.	HIGHBURY NONGLACIAL INTERVAL (pre-Middle Wisconsin) Beyond the limit of radiocarbon dating.
		WESTLYNN DRIFT ( <i>Seymour Deposits</i> ) Till diamicton ( <i>Seymour till</i> ), glaciomarine, glaciofluvial ( <i>Lynn Outwash</i> ), and glacio- lacustrine sediments ( <i>Sisters Varved Clay</i> ).	WESTLYNN GLACIATION (pre-Sangamon)



**Figure 3: Distribution of Quaternary Deposits in the Fraser Lowland (Armstrong 1984).**

The recent or Holocene deposits shown on Figure 3 are mostly deltaic deposits of the Fraser River and overbank and channel fill deposits along the Fraser River. The Matsqui Prairie, which is underlain by marine and glaciolacustrine sediments is capped with deposits from the Fraser River. Other recent deposits include bogs, lowland and mountain stream sediments, beaches and colluvial or landslide deposits.

Much of the Fraser Lowland is covered by glacial deposits associated with the Sumas stade (dated about 11,000 years ago) and the Vashon stade (dated about 13,000 to 18,000 years ago). The glacial sediments associated with the two stades are of glaciomarine origin (primarily clays, stony clays and silty clays with interbedded sandy lenses deposited in marine environments), glacial tills (heterogenous mixtures of clay, silt, sand gravel and boulders deposited beneath moving or melting ice) and glaciofluvial origin (sands and gravels deposited by meltwater streams in front of the glaciers).

The older Vashon drift is primarily exposed on the Burrard, Surrey and White Rock uplands at the west end of the study area. The drift consists of sandy loam lodgement tills that have been modified by marine processes and may be covered by thin layers of beach sands or other marine sediments as well as gravel and sand deposited in channels, deltas and as ice-contact deposits. The Capilano sediments, which are a clay and silty clay marine unit deposited after the Vashon stade overlie the Vashon drift in much of Langley.

The final glacial advance was the Sumas stade and its deposits are confined to the eastern end of the study area (Figure 3). The Fort Langley formation consists of interbedded marine, glaciomarine and glacial sediments that were deposited between the Sumas and Vashon stades, whose surface expression consists of stony silty clay with thicknesses up to 60 m. The Sumas drift includes thin sandy loam tills but, more importantly, includes large areas of deltaic sand and gravel deposits which are exposed in the Campbell Upland and northeast of Langley (Figure 3), and glaciofluvial outwash which forms the Abbotsford Upland. The Fort Langley formation is also eroded by meltwater channels from the Sumas Stade which form the valleys of upper Bertrand and Campbell Creeks.

Halstead (1986; 1957; 1953) and Armstrong and Brown (1953) describe the hydrologic and hydrogeologic character of the various units. The marine and glaciomarine sediments that are at, or near, the surface throughout most of the study area are commonly less than 30 m thick and are of moderate to low permeability. A glaciomarine unit exposed in the Langley Upland and the Serpentine-Nicomekl Valley is stonier, much less permeable and more than 50 m thick. The deltaic sands and gravels are highly permeable, up to 40 m thick and generally have a flat or gently sloping surface. Most rain that falls on these sediments percolates to groundwater rather than leaving as surface runoff. The glacial tills are of varying grain size and compactness and consequently have varying permeabilities. The tills exposed at higher elevations are often ablation tills, that overly lodgement tills, and are not compact. Table 3 describes the distribution of various, generalized surficial units within the watersheds of the salmon streams.

### 2.3 Climate

The Fraser Lowland lies partly in the rainshadow of the Olympic Mountains and Vancouver Island and has a modified maritime climate. Annual precipitation averages about 1,000 mm at Vancouver Airport and increases to the north and, to a lesser extent, to the east as result of approach effects which produce enhanced precipitation prior to uplift over the Coast and Cascade Mountains. Annual precipitation reaches about 1,600 mm at the eastern edge of the lowlands and increases rapidly into the Coast Mountains so that the upper Coquitlam River watershed receives over 3,500 mm a year. Table 4 lists climate normals at a number of stations within the Fraser Lowlands.

There are effectively two seasons along the Pacific Coast. Winter extends from late September or October until March and consists of a continual procession of Pacific westerlies onto the coast, occasionally broken by the formation of high pressure ridges, and about three-quarters of the annual precipitation falls in this period. The second season occurs during summer when a high pressure zone dominates off the coast and little rain falls (Table 4). Drought, or periods without rain, which usually occur in July or August, can extend from a few weeks to 50 days or more. Summer storms are usually brief and intense; however, large

**Table 3: Surficial Geology of the Salmon Streams in the Fraser Delta HMA.**

Stream Name	Municipality	Total Drainage Area (km <sup>2</sup> )	Quaternary Post - Glacial Sediments (%)	Fraser River Sediments (%)	Capilano Sediments (%)	Glacio - Fluvial Sediments (%)	Glacial Till (%)	Bedrock (%)
<b>NORTH SHORE TRIBUTARIES</b>								
1 Musqueam Ck.	Vancouver	6.7	3.7	6.7	12.7	0	76.8	0
2 Glen Lyon Ck.	Burnaby	3.7	--	--	--	--	--	--
3 Sussex Ck.	Burnaby	1.0	--	--	--	--	--	--
4 Byrne Ck.	Burnaby	9.1	28.5	1.4	15.3	1.8	53.0	0
5 Brunette R.	Coquitlam/Burnaby	76.9	13.6	0	3.4	0	79.1	4.0
6 Schoolhouse Ck.	Coquitlam	7.1	7.5	3.9	3.2	0	86.1	0
7 Coquitlam R.	Coq./Port Coquitlam	261.6	--	--	--	--	--	--
<b>SOUTH SHORE TRIBUTARIES</b>								
8 Cougar Canyon Ck.	Delta	7.4	17.6	1.0	57.0	3.4	21.0	0
9 Scott Ck.	Surrey	4.8	25.1	0	57.1	0	17.7	0
10 Bonaccord Ck.	Surrey	5.3	5.1	0	71.0	0	23.8	0
11 -0220 Unamed Ck.	Surrey	--	--	--	--	--	--	--
12 -0230 Unamed Ck.	Surrey	4.4	43.4	5.1	29.1	0	22.3	0
13 Yorkson Ck.	Langley	17.9	14.0	0.8	45.9	5.7	33.5	0
14 Salmon R.	Langley/Matsqui	76.9	2.5	6.5	18.2	32.3	40.6	0
14a - Coghlan Ck.	Langley	14.2	4.8	0	0	42.6	52.6	0
14b - 00-0300-150	Langley	0.9	8.1	0	37.8	10.8	43.2	0
15 West Ck.	Langley	14.5	1.2	0	0	12.3	86.4	0
16 Nathan Ck.	Langley/Matsqui	33.8	5.7	1.8	0	0	92.3	0
17 Hanna Ck.	Matsqui	8.1	2.2	0	0	0	97.8	0
18 Coligny Ck.	Matsqui	3.6	19.3	6.2	0	16.6	57.9	0
19 McLennan Ck.	Matsqui	30.9	27.4	15.7	0	16.5	40.2	0
19a - Gifford Slough	Matsqui	14.4	33.3	22.5	0	14.0	30.2	0
19b - Downes Ck.	Matsqui	6.4	21.6	8.2	0	30.1	40.3	0
20 Matsqui Sl.	Matsqui	69.3	24.4	26.6	0	15.7	12.1	0
20a - Clayburn Ck.	Matsqui/Abbotsford	46.6	25.8	6.9	0	24.0	18.1	25.3
20b - Willband Ck.	Matsqui/Abbotsford	13.5	36.6	0.2	0	55.6	7.6	0
20c - Stoney Ck.	Matsqui/Abbotsford	7.6	10.2	3.0	0	48.4	16.4	22.0
<b>BOUNDARY BAY TRIBUTARIES</b>								
21 Serpentine R.	Surrey	154.2	25.4	0	61.3	0.7	12.7	0
21a Mahood Ck.	Surrey	38.0	8.9	0	79.2	0	12.0	0
22 Nicomekl R.	Surrey/Langley	175.2	18.0	0	37.0	21.1	23.9	0
22a Anderson Ck.	Langley	27.2	8.9	0	0.9	42.3	48.2	0
22b Murray Ck.	Langley	28.9	1.2	0	2.2	31.9	64.7	0
23 Campbell R.	Surrey/Langley	74.4	4.1	0	37.6	18.6	39.7	0

- Campbell River estimates do not include approx. 4 km<sup>2</sup> in U.S.A.

**Table 4: Regional Climate of the Fraser Delta HMA.**

Climate Station	Latitude	Longitude	Elevation (m)	Precipitation (mm)				Mean Annual Temperature
				Annual	May to Sept	Annual Snowfall	Greatest Daily	
<i>Vancouver Int. Airport</i>	49.11	123.1	3	1112.6	237.0	60.4	89.4	9.8
<i>White Rock</i>	49.02	122.5	61	1047.1	243.5	40.5	84.1	9.4
<i>Surrey Newton</i>	49.08	122.51	73	1423.9	303.5	69.1	106.7	9.5
<i>Langley Prairie</i>	49.09	122.39	87	1554.1	348.4	73.9	118.1	
<i>Abbotsford A</i>	49.02	122.22	58	1513	329.4	83.9	95	9.5
<i>New Westminster</i>	49.13	122.56	119	1578	333.5	61.5	132.3	10.1
<i>Port Moody</i>	49.17	122.53	130	1889.3	378.7	59.5	112.3	9.7
<i>Coquitlam Lake</i>	49.22	122.48	161	3616	670.4	148.2	203.2	8.4



storms occasionally disrupt the high pressure zone. These infrequent large storms often produce extreme flooding (Evans and Lister 1974; Schaefer 1973).

### **2.3.1 Temporal Variation in Climate**

Long-term climate records are available at the Vancouver International Airport (1897-1987: combined Steveston and Vancouver International A stations) and at Agassiz (1892-1990: Agassiz station). Quadra (1990) reviewed the variation of climate over time at the Airport and concluded that annual temperature and precipitation were increasing over the 90 year period of record, perhaps as part of a long fluctuation inherent in climate trends. There is no evidence of similar behaviour at Agassiz. At this station, climate fluctuations are confined to durations of several years to a decade and average trends remain close to the mean value (Figure 4).

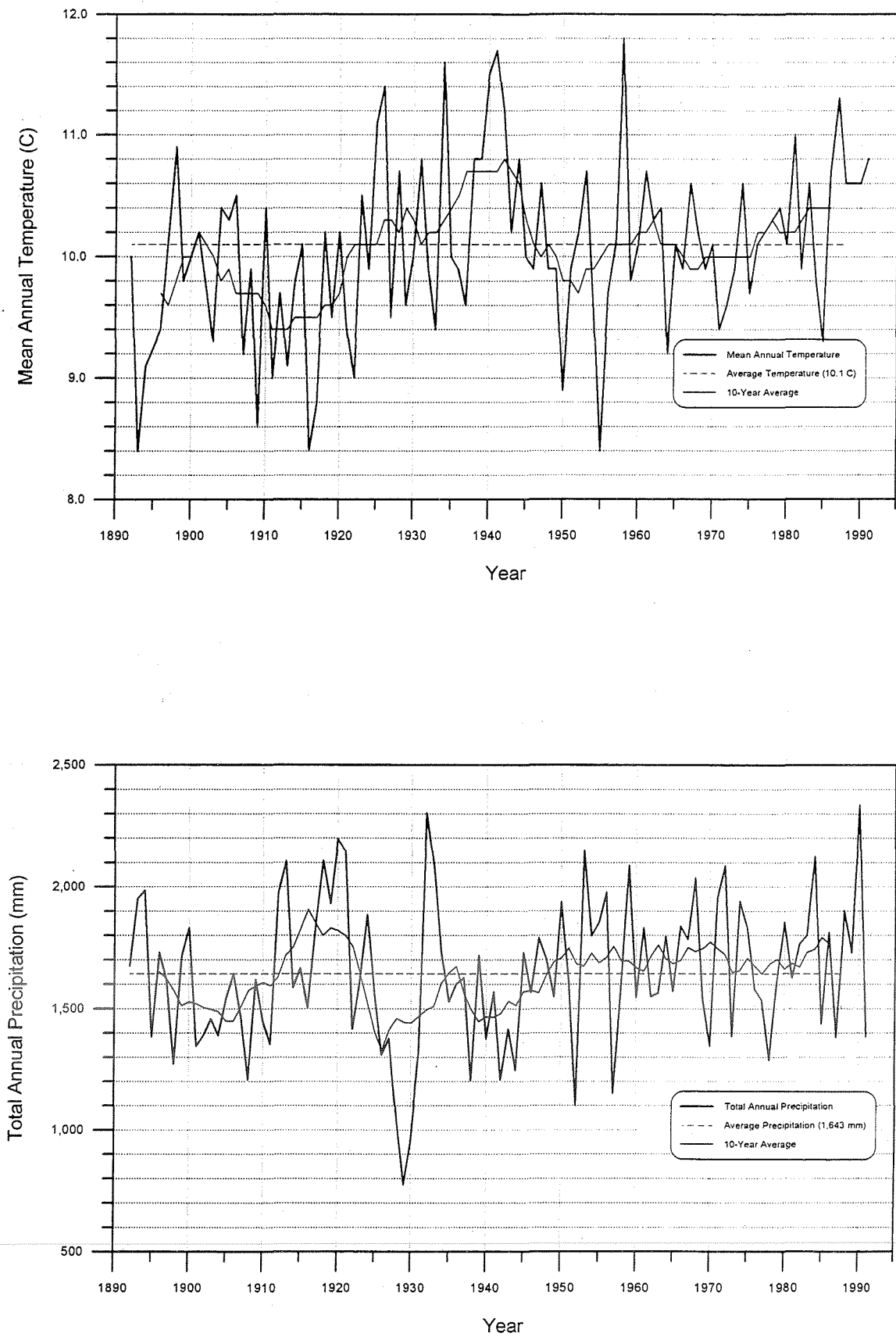
### **2.3.2 Global Warming and Climate Change**

Quadra (1990) and Levy (1992) discuss potential climate changes resulting from global warming and the potential changes to hydrologic regimes. Quadra (1990) summarizes the results of several general circulation models which indicate zero to small increases in mean annual precipitation. The models do not agree on the distribution of the increased precipitation and some predict increased summer precipitation while others predict increased winter precipitation. It is not possible, with the present state of knowledge, to determine when the increased precipitation would occur during the year.

If winter precipitation is increased, flood discharges in salmon streams probably will be slightly aggravated; however, the increase is expected to be small in comparison to natural fluctuations and particularly in comparison to increases induced by urbanization. Increased winter precipitation is also expected to improve winter base flows and enhanced groundwater recharge may increase base flows in the early summer.

Increased summer precipitation may improve base flows, particularly if the weather becomes more stormy. However, small increases in summer precipitation may not have a significant

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



effect on flow, as much of the increase in precipitation is expected to be consumed by evapotranspiration.

Temperatures are predicted to increase in all seasons by values ranging from 2° to 4°C. Increased summer temperatures are expected to offset any potential flow enhancement resulting from increased summer precipitation.

## **2.4 Streamflow**

### **2.4.1 Surface Drainage Patterns**

*Fraser River:* The Fraser River crosses the Lowland from east to west and drains much of the interior of British Columbia. Flows in the Fraser River are dominated by snowmelt in the interior of British Columbia and the river regularly rises in early April and peaks near the beginning of June. Flows typically decline following the peak of the freshet, reaching a minimum in February or March -- though large winter storms in the Lower Mainland that produce flooding on the Harrison, Chilliwack and other large tributaries may also raise water levels in the lower Fraser River. When Fraser River levels are low, some salmon streams discharge to the Fraser River through a dyke floodbox which is equipped with a flapgate. Rising levels close the flapgate and waters are pumped over the dyke and discharged to the Fraser. Typically, pumps are in operation from May through August. Pumps may also operate in the winter during high tides, particularly when discharge in the Fraser River has been raised by rainstorms and tributary flooding.

Throughout the Fraser Delta HMA, the Fraser River is tidal, and water levels follow a typical daily cycle. During the winter the effect of tides extend as far upstream as Sumas and, at Mission, the tidal range is about 1 to 1.5 m, compared to 4 or 5 metres near the mouth of the Fraser. In the spring and the summer, high discharges on the Fraser reduce the extent of the tidal fluctuations to Mission and reduce the tidal range.

*Mountain Rivers and Creeks:* The largest tributaries to the Lower Fraser River have drainage areas that extend into the Coast or Cascade Mountains and their flow regimes are controlled

partly by snow accumulation and snowmelt and partly by rainfall. Some streams in the eastern lowlands, such as the Chilliwack, exhibit both winter and summer peak discharges, while others, such as the Coquitlam River, primarily have winter rainfall peak flows. These creeks often have annual runoff of several thousand mm and a wide range of flows over the year. The Coquitlam River is the only mountain river in this HMA; its flow is regulated by a B.C. Hydro dam on Coquitlam Lake.

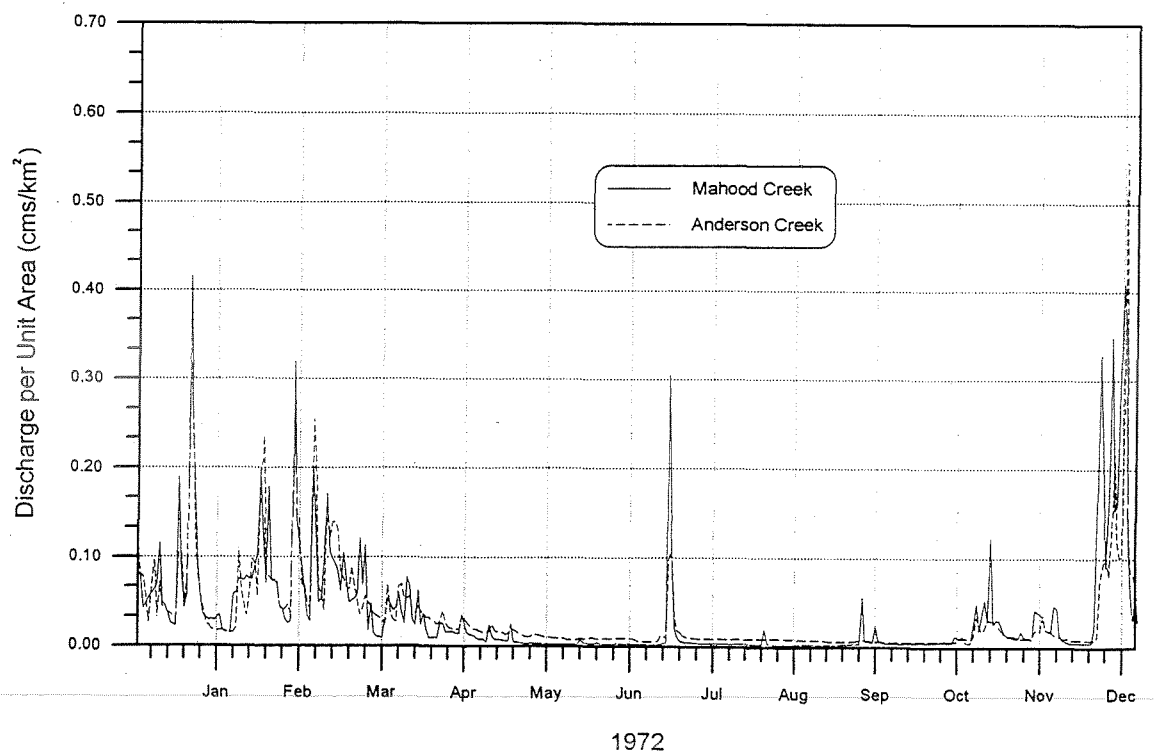
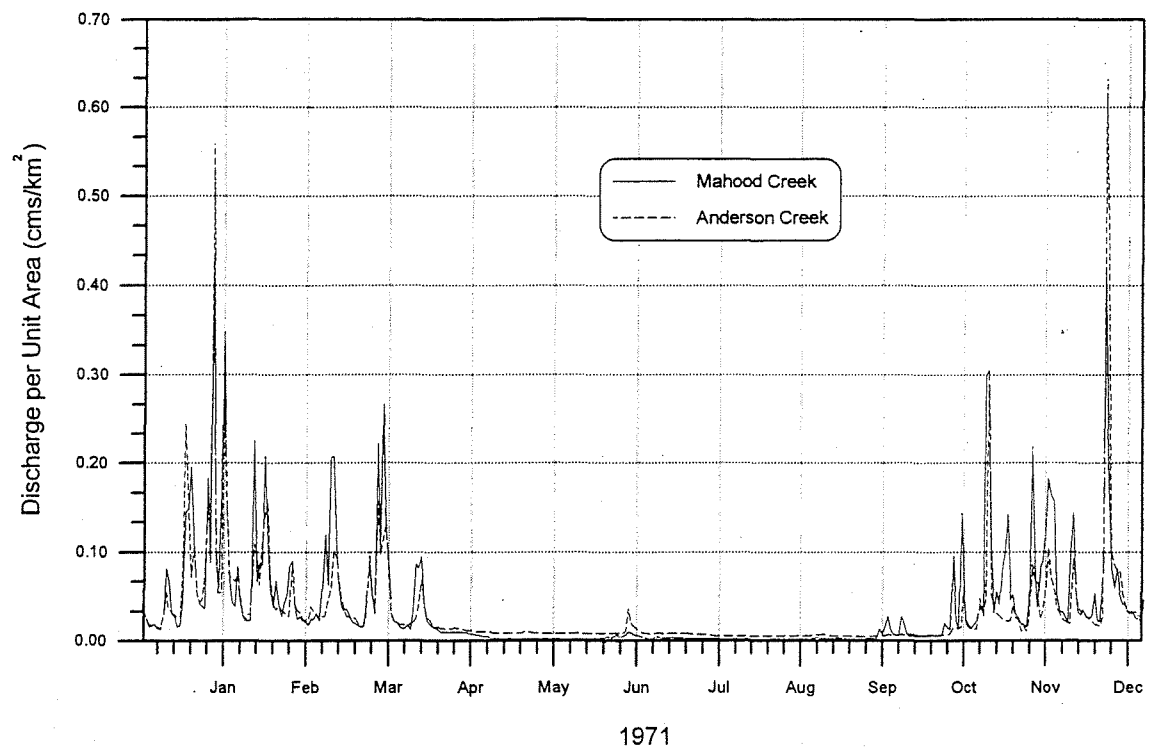
*Lowland Rivers and Creeks:* Nearly all of the salmon streams in this HMA are located entirely within the Fraser Lowland and flow directly to the Fraser River or to Boundary Bay. The streams typically originate in an upland where stream reaches are moderately steep, have gravel and cobble bed materials and a narrow creek valley incised into glacial deposits. The mid- and lower reaches of the salmon streams generally lie in one of the major lowlands or cross the floodplain of the Fraser River. These reaches are low-gradient, the channel bed is sand, and, for flood protection, the channel is often dyked, enlarged or artificially straightened.

#### **2.4.2 Hydrology of the Lowland Streams**

The mean annual hydrograph of these streams closely follows the annual precipitation cycle. Maximum monthly discharges are recorded in November, December and January and maximum daily discharges are also usually recorded in these months. Flows decline through the spring and summer and monthly discharges reach a minimum in July, August, or September. Minimum daily discharges are also usually recorded in July, August or September typically at the end of a long period without rain.

Annual runoff in these streams is near 1,000 mm though flows are highly variable and in any year maximum daily flows are often 500 times greater than minimum daily flows. In the winter, the hydrograph consists of a succession of storm peaks, corresponding to the passage of rainstorms, superimposed on a high base flow (Figure 5).

**Figure 5: 1971 and 1972 Hydrographs: Anderson Creek and Mahood Creek.**



### 2.4.3 Hydrology and Surficial Materials

Soils developed in glaciomarine and till deposits are often underlain by compacted, consolidated strata with very low infiltration rates. Water infiltrating the soil commonly moves laterally down slopes as interflow, along impervious horizons at the base of the soil, and only a small fraction of the rainfall reaches a groundwater reservoir. Interflow rapidly reaches streams, often re-emerging at the base of slopes, and the till and glaciomarine soils may saturate during large storms producing surface runoff along lower slopes.

The soils on gravel and sand deposits have high infiltration rates and creeks draining these deposits intercept the groundwater table and receive a large part of their flow from groundwater discharge. Response of these creeks to storms is slower, peak flows may be lower, recession from peak discharges is slower and base flows are higher -- in effect these basins have a much smaller range of flows and a more even distribution of flows.

These contrasting behaviours can be seen in the local streams (Halstead 1986; Figure 5). Mahood Creek, which drains the Surrey (Newton) Upland, has a dendritic drainage pattern established on stony marine clays and tills. These sediments are relatively impervious, most winter storm precipitation appears as surface runoff, and base flow during dry periods in the summer is very low, often close to zero.

In comparison, Anderson Creek partly drains a raised delta of glaciofluvial sands and gravels on the southern boundary of Langley. The creek flows in a deep narrow valley with no tributaries. Rain percolates into the sands and gravels and arrives in Anderson Creek, some time later, as groundwater. This reduces and delays peak flows, relative to Mahood Creek and at the end of the summer, the first few rainstorms go to groundwater recharge and produce only limited stormflow. Anderson Creek also has stable summer base flows that are 5 to 10 times greater than measured in Mahood Creek.

Table 3 summarizes the relative proportion of the major surficial units within the basin of each salmon stream, based on compilation of the units listed on Table 2. The percentage of glaciofluvial sediments in the watershed may be used to identify those streams that potentially have

groundwater-sustained base flows during the summer. Note that streams in other materials may also have above-average base flows, e.g. those that intersect aquifers.

#### **2.4.4 Losses to Groundwater from Streamflow**

Some of the salmon streams, or limited reaches of these streams, go dry during the lowest flows in most years. These streams may either be groundwater effluent (that is, water is discharged from the stream channel through its bed to a groundwater reservoir) or, at low flows, the discharge passes through the alluvial gravels in the bed of the channel. In the latter case, pools may remain full of water and receive some inflow from the surrounding gravels. Streams that are reported to have dry reaches include the Campbell River (Armstrong 1957), Anderson Creek and the small upper tributaries of many of the salmon streams.

### **2.5 Groundwater Resources**

Groundwater reservoirs (or aquifers, see next paragraph) recharge during the fall and winter when precipitation is greatest, 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.

The Fraser Lowland is underlain by a thick complex of glacial, glaciomarine and fluvial deposits of varying porosity and permeability and, as a result, has a complex hydrogeology. Aquifers, or deposits that contain or transmit significant quantities of water, occur both near the land surface -- these are called water table or unconfined aquifers -- and at depth. Aquifers at depth are often overlain and underlain by aquitards or aquicludes, deposits that transmit only small quantities of water such as clays, silts and tills. In these confined aquifers water levels will rise above the top of the deposit and wells tapping them are referred to as "artesian". In the Fraser Valley, water levels rise above the ground surface in a number of "flowing artesian" wells.

Flowing artesian wells are found along the south side of the Newton Upland and within the Nicomekl-Serpentine Valley. These tap a deep local groundwater system recharged by flow

from the Newton Upland. Wells also penetrate other deep, confined aquifers at various locations in the Fraser Lowlands. Halstead (1986) describes them in detail.

Halstead (1986) estimates a total groundwater production in the Fraser Valley of 30 million cubic metres in 1981. The Groundwater Section of the Ministry of Environment has records for about 8,000 drilled wells. Groundwater is used for a variety of purposes, such as domestic supply, irrigation, industry, and fish hatcheries. A large, but unknown, part of the groundwater production is from relatively deep wells penetrating confined aquifers and its extraction has little or no impact on quantities of surface water in the Fraser Lowland.

However, extractions from unconfined, or water table, aquifers may reduce streamflows. Thick glaciofluvial sands and gravels, deposited as deltas by meltwater streams, provide water table aquifers with excellent water quality. The large raised delta south of Langley, the large raised delta east and north of Langley, and the outwash plain south of Abbotsford that includes the Abbotsford Airport, are all underlain by stony clay glaciomarine deposits. Discharge of groundwater from springs is commonly observed along the margins of the contact with the glaciomarine deposits. These springs are important in maintaining base flows in Anderson and Fishtrap Creeks and the upper Salmon River.

Aquifers are also the source for many municipal and irrigation wells (Halstead 1986). Municipal, irrigation and industrial wells have rated withdrawals from outwash deposits that lie south of Abbotsford that total more than 600 L/s during the summer irrigation season (Halstead 1986; his Appendix C). This total does not include domestic and farm wells. The estimated annual production from springs along the edges of the aquifer was estimated at 263 L/s (Halstead 1986), prior to development of the most recent wells. Consequently, a significant portion of the annual discharge from this groundwater reservoir is consumed rather than provided as base flow to streams.

Other water table aquifers, including the large body beneath the Sunnyside Upland at White Rock, are also depleted through groundwater removal by wells. In most cases, information on the total quantities that are removed is incomplete. In addition, the return of unconsumed withdrawals to streams has not been estimated. As a result, it is difficult to estimate the



portion of total yield diverted to consumption and, hence, we have little knowledge of the impact of groundwater removals on streamflows.

## **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, urbanization increases 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 others, 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 Fraser Delta HMA starts in an upland area where the channel is often steep and contained in a gully or narrow valley. Bank and valley wall erosion and channel downcutting are the most likely channel responses to disturbance in these reaches. In their lower reaches, the streams generally flow onto the Fraser floodplain or a flat marine deposit producing low-gradient, meandering channels where sediment aggradation and overbank flooding are common. These reaches of the stream are often modified by human activities.

Table 5 summarizes reported channel response to disturbance and the kinds of human modification. Channel response includes bank and valley wall erosion, incision or downcutting, aggradation or channel filling, and bed material changes such as sedimentation and scour. Human modifications include channelization (straightening and deepening of channels), river training (including bank protection, diversions, revetments, spurs or other structures), channel encroachment (by land filling or by narrow dykes), dredging (including bar scalping), removal of riparian vegetation and removal of large organic debris. The table is not

**Table 5: Stability of Salmon Streams in the Fraser Delta HMA.**

Stream Name	SSIS Number	Channel Response					Human Modifications					
		Erosion	Incision	Aggradation	Bed Material		Channelization	River Training	Encroachment	Dredging	Veget. Removal	Debris Removal
					Scour	Sedimentation						
NORTH SHORE TRIBUTARIES												
1 Musqueam Ck.	00-1000							●				●
2 Glen Lyon Ck.												●
3 Sussex Ck.										●		●
4 Byrne Ck.						●		●				●
5 Brunette R.	00-1000		●			●		●		●		●
6 Schoolhouse Ck.	00-0150-011								●			●
7 Coquitlam R.	00-0180					●						
SOUTH SHORE TRIBUTARIES												
8 Cougar Canyon Ck.	00-0160	●				●				●		
9 Scott Ck.								●				
10 Bonaccord Ck.	00-0170							●				●
11 - Unamed Ck.	00-0170-0220											
12 - Unamed Ck.	00-0170-0230											
13 Yorkson Ck.	00-0260									●		
14 Salmon R.	00-0300		●							●		
14a - Coghlan Ck.	00-0300-200											
14b - Unnamed Ck	00-0300-150											
15 West Ck.	00-0330									●		
16 Nathan Ck.	00-0360			●				●	●	●	●	
17 Hanna Ck.	00-0425											
18 Coligny Ck.	00-0438											
19 McLennan Ck.	00-0440-010											
19a - Gifford Sl.	00-0440							●			●	
19b - Downes Ck.	00-0440-020											
20 Matsqui Sl.	00-0460							●			●	
20a - Clayburn Ck.	00-0460-010							●			●	
20b - Willband Ck.	00-0460-010-020							●			●	
20c - Stoney Ck.	00-0460-010-022	●				●			●		●	
BOUNDARY BAY TRIBUTARIES												
21 Serpentine R.	90-0200							●				
21a Mahood Ck.	90-0200-020	●										
22 Nicomekl R.	90-0100							●				
22a Anderson Ck.	90-0100-020	●	●			●						●
22b Murray Ck.	90-0100-030	●										
23 Campbell R.	90-0080							●				

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 Fraser Delta HMA. Some streams have long-term gauging records at stations that continue to operate, other streams have short-term or seasonal records of moderate quality from the 1960's and 1970's, while other streams have little or no information available. The average flow characteristics in the above list, as well as other characteristics, can be reliably estimated for salmon streams with long-term discharge records. Less reliable estimates can be prepared for streams with limited records and the least reliable estimates are for streams with no records.

**Table 6: Definitions of Flow Characteristics**

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

**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.

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

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

**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.

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

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

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

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

**Mean winter 7 day low flow** - Average of the winter 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.

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

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

**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. Changes in the watersheds of the salmon streams in the Fraser Delta HMA further complicate this issue. Urbanization affects the hydrologic regime -- particularly peak flows -- and records from the 1960's or 1970's may not be representative of the current regime.

We have adopted the most recent decade, 1981-90 (inclusive), as our standard period for analysis. This period includes a moderate drought in 1983, and moderate to large flood discharges in 1984, 1986, 1989 and 1990.

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

The Water Survey of Canada is the prime agency collecting and reporting flow data in British Columbia. Gauging stations in the Fraser Delta 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 6) and 16 of the salmon streams have had at least one operating gauging station. However, only three salmon streams (Salmon River, West Creek and Nicomekl River) have complete gauging records from 1981 to 1990 and only on West Creek is the gauge near its mouth. West Creek is the only stream where flow characteristics may be calculated directly from Water Survey of Canada records. These calculations are discussed in Section 3.5.

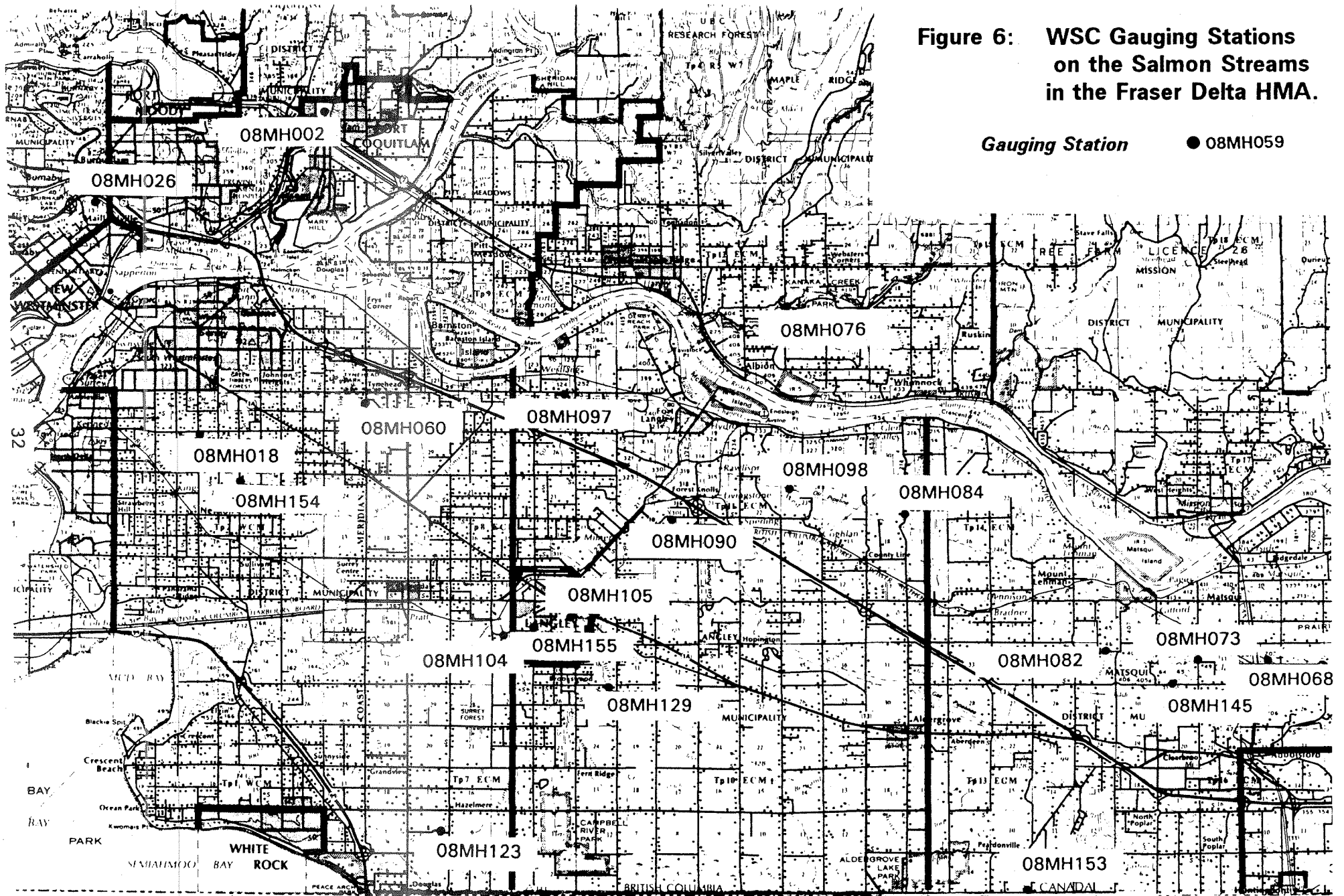
The salmon streams typically have either: 1) partial records between 1981 and 1990, 2) partial or complete records from earlier decades, such as the 1960's or 1970's, or 3) no records from the Water Survey of Canada (Table 1). Procedures for estimating flows on these streams are discussed in Section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

There are also gauging stations on streams that are not within the boundaries of the study area or are not salmon streams. Where these stations provide useful information on the hydrologic characteristics of watersheds in the Fraser Delta 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.

**Figure 6: WSC Gauging Stations on the Salmon Streams in the Fraser Delta HMA.**





Their miscellaneous program and their drought measurement programs (Richards 1977) were used to estimate or confirm 7 day low flows estimated for a number of the salmon streams (Appendix A).

### **3.5    Gauged Salmon Streams**

The gauged salmon streams are those 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 all regulation or extraction -- are best-suited for the sensitivity indices so that licensed extractions can be expressed as a percentage of the total available flow, rather than the measured flow.

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

For streams whose regulation consists of water extractions, the flow characteristics calculated from records were adjusted to represent the natural regime in the stream by adding potential water extractions, as calculated from summaries of water licences, to the flow recorded at the gauge (Figure 7). We have referred to these adjusted flows as **naturalized flows** to distinguish them from measurements of the natural regime.

This approach provides a reasonable estimate of the natural flows in the Fraser Delta HMA because developed storage in most watersheds consists of small, independently-operated reservoirs, because total storage is small in comparison to irrigation requirements (Table 10) and because licensed demand is often low in comparison to flows. In these circumstances, it is reasonable to ignore the contribution of storage to low flows, and naturalized flows may be assumed to represent the natural regime. The naturalized flows are close to the natural flows, but are expected to over-estimate these flows, because of differences between actual

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

Stream Name	WSC Gauge No.	Basin Area (mouth) (km <sup>2</sup> )	EIA Area (km <sup>2</sup> )	Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m <sup>3</sup> /s)					
				Domes- tic (g/day)	Irrig- ation (ac-ft)	Water- works (g/day)	Indus- trial (g/day)	Conser- vation (cfs)	Aug	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly		Mean 7-day Flow	
														Aug	Sept	Summer	Winter
<b>NORTH SHORE TRIBUTARIES</b>																	
Musqueam Ck		6.7	0.79	0	0	0	0	0	0	0	0	0.23	5.0	0.03	0.03	0.02	0.03
Glen Lyon Ck		3.7	0.84	0	0	0	0	0	0	0	0	0.13	2.7	0.02	0.02	0.01	0.02
Sussex Ck		1.0	0.07	0	0	0	0	0	0	0	0	0.03	0.7	0.01	0.01	0.00	0.00
Byrne Ck		9.1	2.49	0	0	0	0	0	0	0	0	0.31	6.7	0.04	0.04	0.02	0.04
Brunette River		76.9	20.65	0	0	0	0	0	0	0	0	3.18	63.4	0.55	1.16	0.18	0.58
Schoolhouse Ck		7.1	2.31	0	0	0	0	0	0	0	0	0.25	5.3	0.03	0.04	0.02	0.03
Coquitlam R		261.6	-	0	0	50,538,453	185,814	0	2669	2669	2669	30.32	256.7	10.33	10.66	3.68	4.21
<b>SOUTH SHORE TRIBUTARIES</b>																	
Cougar Canyon Ck		7.4	1.54	0	0	0	0	0	0	0	0	0.26	5.5	0.03	0.04	0.02	0.03
Scott Ck		4.8	1.84	0	0	0	0	0	0	0	0	0.17	3.6	0.02	0.03	0.01	0.02
Bon Accord Ck		5.3	1.20	0	0	0	0	0	0	0	0	0.18	3.9	0.02	0.03	0.01	0.02
-0220		3.8	0.12	0	0	0	0	0	0	0	0	0.13	2.8	0.02	0.02	0.01	0.02
-0230		4.4	0.14	0	0	0	0	0	0	0	0	0.15	3.3	0.02	0.02	0.01	0.02
Yorkson Ck		17.9	1.74	2,000	10	0	501	0	1	1	0	0.47	12.5	0.08	0.10	0.06	0.08
Salmon River		76.9	1.55	6,500	518	0	56,678	0	76	40	3	2.23	41.4	0.41	0.42	0.32	0.69
- Coghlan Ck		14.2	0.22	2,100	139	0	15,000	0	20	11	1	0.49	10.5	0.06	0.06	0.04	0.07
-00-0300-150		0.9	0.05	0	0	0	0	0	0	0	0	0.03	0.7	0.01	0.01	0.00	0.00
West Ck	08MH098	14.5	0.13	500	94	0	1,078,102	0	70	63	57	0.38	8.7	0.10	0.09	0.08	0.12
Nathan Ck		33.8	0.17	4,000	30	0	674,106	0	40	38	36	1.17	25.0	0.15	0.18	0.12	0.19
Hanna Ck		8.1	0.05	3,000	0	0	2,000	0	0	0	0	0.28	6.0	0.03	0.04	0.02	0.04
Coligny Ck		3.6	0.02	0	0	0	500	0	0	0	0	0.12	2.7	0.02	0.02	0.01	0.01

- Shading indicates gauged salmon streams.
- Effective Impervious Area (EIA) calculated as described in Section 4.
- Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
- Reference for all data in table is the mouth of the salmon stream.
- Licenced demands (L/s) calculated from total water licences as described in body of report.
- Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

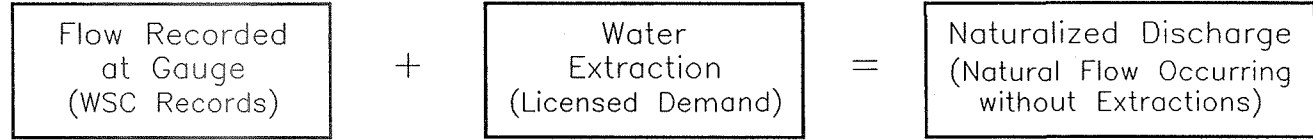
**Table 7: Continued.**

Stream Name	WSC Gauge No.	Basin Area (mouth) (km <sup>2</sup> )	EIA Area (km <sup>2</sup> )	Total Water Licenses					Licensed Demand (L/s)			Naturalized Flows in the Salmon Streams (m <sup>3</sup> /s)					
				Domes- tic (g/day)	Irrig- ation (ac-ft)	Water- works (g/day)	Indus- trial (g/day)	Conser- vation (cfs)	Aug	Sept	Feb	Mean Annual	Mean Flood	Mean Monthly		Mean 7-day Flow	
														Aug	Sept	Summer	Winter
<b>SOUTH SHORE TRIBUTARIES</b>																	
McLennan Ck		30.9	0.52	4,750	73	0	14,610	0	11	6	1	1.07	22.9	0.11	0.12	0.07	0.17
-Gifford Slough		14.4	0.41	1,000	51	0	4,500	0	7	4	0	0.50	10.7	0.06	0.07	0.04	0.09
-Downes Ck		6.4	0.38	1,000	1	0	4,500	0	0	0	0	0.22	4.7	0.03	0.03	0.02	0.03
Matsqui Slough		69.3	4.28	23,900	850	0	1,208,155	0	184	125	65	2.40	51.3	0.23	0.23	0.15	0.42
-Clayburn Ck		46.6	4.20	21,400	460	0	1,126,235	0	125	93	60	1.61	34.5	0.16	0.17	0.10	0.27
-Willband Ck		13.5	3.49	8,500	195	0	93,500	0	33	19	5	0.35	10.2	0.04	0.05	0.03	0.10
-Stoney Ck		7.6	0.61	6,000	73	0	5,000	0	11	6	1	0.26	5.6	0.03	0.04	0.02	0.03
<b>BOUNDARY BAY TRIBUTARIES</b>																	
Serpentine River		154.2	19.69	2,150	1,368	0	4,119,571	0	409	313	217	6.23	122.8	1.12	1.21	0.81	1.24
-Mahood Ck		38.0	8.86	0	1	0	11,000	0	1	1	1	1.19	21.4	0.18	0.28	0.06	0.20
Nicomekl River		175.2	10.97	8,900	383	0	4,600	0	54	28	1	5.49	108.1	0.68	0.82	0.46	0.90
-Anderson Ck		27.2	1.12	1,800	3	0	11,600	0	1	1	1	0.75	15.1	0.21	0.17	0.18	0.23
-Murray Ck		28.9	0.48	7,100	58	0	500	0	9	4	0	0.67	18.0	0.03	0.03	0.01	0.01
Campbell River		78.4	3.09	16,900	564	0	72,065	0	84	44	5	2.71	58.0	0.20	0.17	0.12	0.49

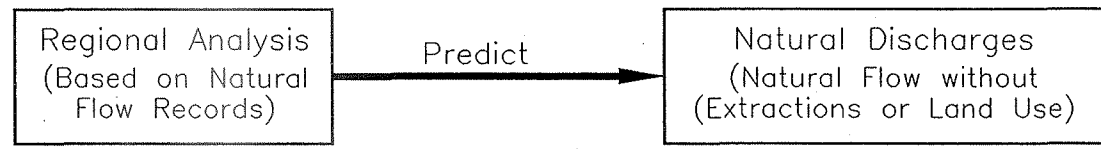
- Shading indicates gauged salmon streams.
- Effective Impervious Area (EIA) calculated as described in Section 4.
- Total water licences for each salmon stream expressed in imperial units, as provided by Water Management Branch.
- Reference for all data in table is the mouth of the salmon stream.
- Licenced demands (L/s) calculated from total water licences as described in body of report.
- Naturalized flows are estimates of those that would occur in the absence of all upstream regulation and water extractions.

**Figure 7: Calculation of Natural and "Naturalized" Flows for the Salmon Streams.**

GAUGED STREAMS



UNGAUGED STREAMS



and licensed water use upstream of the gauge, flow enhancement by releases from small storage projects and return flows from irrigation diversions. The degree of over-estimation is small for the gauged streams and can be evaluated by comparing storage volumes to irrigation demand and to typical flows in August and September on the salmon streams. Note also that well extractions, which are not licensed, may reduce low flows in some streams.

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

Coquitlam Reservoir is the only large storage reservoir in the Fraser Delta HMA. The GVRD operates Cariboo Dam on Burnaby Lake in the Brunette River watershed.

### **3.5.3 Annual Flow Characteristics**

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

### **3.5.4 Seasonal Flow Characteristics**

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

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

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

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

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

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

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

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

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

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

### **3.7 Ungauged Salmon Streams**

The ungauged salmon streams include all those streams where average flow characteristics for 1981 to 1990 must be estimated rather than calculated from Water Survey of Canada records. A variety of techniques were used to estimate the flows 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 hydrology of the salmon streams in the Fraser Delta HMA is altered, to some extent, by land use. Both agriculture and urbanization have the potential to alter the hydrologic regime. Agriculture mostly affects flows in the summer by extraction of surface and ground water for stock watering, domestic use and irrigation; but also has some limited impact on flood discharges through conversion of forest lands. Agriculture extractions are discussed in detail in Section 5 "Water Licensing".

Urbanization alters the hydrologic regime in several ways. Development of waterworks, either from groundwater or surface water, may reduce mean annual flows, mean annual floods and seasonal 7 day low flows. This is discussed in Section 5. However, the main impact of development is the creation of impervious surfaces that are directly connected to watercourses. These impervious surfaces change the runoff processes -- rapid flow over impervious surfaces and through pipes is substituted for less rapid interflow (lateral flow through soils) -- speeding the delivery of water to streams and increasing both the volume of rainfall runoff and the maximum discharges reached during a storm.

There are secondary effects associated with the increased flows. Channels often enlarge through bank erosion and, in suitable materials, incision or downcutting may result. These processes, along with sediment released from construction activities, often increase the quantity of sediment transported through the stream.

This section describes the measurement of impact of urbanization on the salmon streams through estimation of effective impervious area (EIA) within the watersheds and further discusses the changes in hydrological and sedimentological regimes typically associated with urbanization.

##### **4.1 Measurement of Effective Impervious Area (EIA)**

The effective impervious area in a drainage basin provides a quantitative measure of the potential alteration of the hydrologic regime imposed by urbanization. It is a measure of the



total area where water does not infiltrate into the soil and that is connected directly to the drainage network. The noneffective impervious area includes those impervious areas that drain to pervious terrain where stormwater infiltrates -- an example is a roof whose gutters discharge to a lawn rather than a stormwater drainage system.

Alley and Veenhuis (1983) and Dinicola (1990) describe how they estimated EIA from land use in Denver and King County, Washington. This approach was used to estimate EIA for the Fraser Delta HMA. The watershed area covered by low density, medium density and high density single family housing, multi-family developments and commercial, industrial, and transportation facilities was measured from Zoning Plans made available by the various municipalities and the actual use confirmed on recent air photographs. Once the total area of each different land use was measured then the total impervious area within each type was estimated from typical percentages (Table 8). The effective impervious area for each land use type was then estimated as a percentage of the total impervious area for each land use type (Table 8) and these were summed to calculate the EIA within each watershed (Table 9). The conversion to EIA assumes that not all impervious surfaces, particularly rooftops, are directly connected to the drainage network.

#### **4.2 The Effect of Urbanization on Hydrology**

Urban development is accompanied by changes in the watershed that affect its hydrologic response. Roads and drains are constructed which collect and concentrate surface and shallow subsurface runoff; vegetation is cleared, soil is compacted and partly stripped which reduces or eliminates transpiration and increases the potential for surface flow; the ground surface is re-graded and depressions are filled, eliminating ground surface water storage; and subsurface utilities and drainage trenches intercept deeper subsurface flow and pipe it to surface drainage. Buildings create additional impervious area, reduce infiltration, and accelerate surface runoff to streams.

**Table 8: Calculation of Effective Impervious Area  
(from Dinicola 1990).**

<i>Land Use</i>	<i>Lot Size (acres)</i>	<i>Percentage Impervious (%)</i>	<i>Percentage Effective Impervious (%)</i>
<b>Single Family Residential</b>			
- low density	2 to 5	10	40
-medium density	1	20	50
-high density	0.25	35	66
<b>Multi-Family</b>	varies	60	80
<b>Commercial</b>	varies	90	95
<b>Industrial</b>	varies	90	95

Percentages from Dinicola (1990)

**Table 9: Effective Impervious Area in the Watersheds of the Salmon Streams of the Fraser Delta HMA.**

Stream Name	Municipality	Total Drainage Area (km2)	E.I.A. % of Drainage Basin	Single Family Development			Multi-Family (km2)	Commercial Industrial (km2)	Farming/ Vacant (km2)	Greenhouses Etc. (km2)
				Low Density (km2)	Medium Density (km2)	High Density (km2)				
NORTH SHORE TRIBUTARIES										
1 Musqueam Ck.	Vancouver	6.7	11.81%	0	0	2.744	0.029	0.168	3.759	0
2 Glen Lyon Ck.	Burnaby	3.7	22.83%	0	0	1.292	0.377	0.430	1.611	0
3 Sussex Ck.	Burnaby	1.0	6.60%	0	0	0.269	0	0.007	0.756	0
4 Byrne Ck.	Burnaby	9.1	27.41%	0	0	3.081	0.498	1.811	3.717	0.038
5 Brunette R.	Coquitlam/Burnaby	76.9	26.85%	0.257	0.735	31.652	4.482	12.987	26.787	0
6 Schoolhouse Ck.	Coquitlam	7.1	32.49%	0	0	4.336	0.593	1.194	0.977	0
7 Coquitlam R.	Coq./Port Coquitlam	261.6	—	—	—	—	—	—	—	—
SOUTH SHORE TRIBUTARIES										
8 Cougar Canyon Ck.	Delta	7.4	20.85%	0	0.109	3.904	0.072	0.696	2.618	0.001
9 Scott Ck.	Surrey	4.8	38.26%	0	0.086	3.292	0.092	1.197	0.134	0
10 Bonaccord Ck.	Surrey	5.3	22.60%	1.443	0.068	2.990	0.125	0.447	0.226	0.001
11 -0220 Unamed Ck.	Surrey	3.8	—	—	—	—	—	—	—	—
12 -0230 Unamed Ck.	Surrey	4.4	3.11%	1.080	0	0.226	0	0.045	3.035	0.014
13 Yorkson Ck.	Langley	17.9	9.71%	3.795	0.294	1.111	2.012	0.387	10.282	0.019
14 Salmon R.	Langley/Matsqui	76.9	2.02%	12.455	3.822	1.230	0.047	0.350	58.670	0.326
14a - Coghlan Ck.	Langley	14.2	1.56%	3.853	0.399	0	0	0.002	9.815	0.131
14b - 00-0300-150	Langley	0.9	5.69%	0	0.150	0	0.047	0.016	0.687	0
15 West Ck.	Langley	14.5	0.90%	2.410	0.027	0.025	0	0.013	11.956	0.069
16 Nathan Ck.	Langley/Matsqui	33.8	0.49%	2.869	0	0	0	0.028	30.773	0.130
17 Hanna Ck.	Matsqui	8.1	0.58%	0.893	0.018	0	0	0.002	7.148	0.039
18 Coligny Ck.	Matsqui	3.6	0.46%	0.203	0.049	0	0	0	3.331	0.017
19 McLennan Ck.	Matsqui	30.9	1.70%	2.222	0.369	1.057	0	0.141	26.936	0.175
19a - Gifford Slough	Matsqui	14.4	2.87%	0.881	0.286	1.057	0	0.111	12.013	0.052
19b - Downes Ck.	Matsqui	6.4	6.00%	0.689	0.162	1.057	0	0.111	4.374	0.007
20 Matsqui Sl.	Matsqui	69.3	6.18%	1.291	0.324	5.578	2.040	2.205	57.629	0.233
20a - Clayburn Ck.	Matsqui/Abbotsford	46.6	9.02%	1.168	0.268	5.507	2.040	2.185	35.376	0.056
20b - Willband Ck.	Matsqui/Abbotsford	13.5	25.83%	0.297	0.033	3.362	1.945	2.060	5.803	0
20c - Stoney Ck.	Matsqui/Abbotsford	7.6	8.04%	0.108	0.185	2.102	0.095	0.064	5.036	0.010
BOUNDARY BAY TRIBUTARIES										
21 Serpentine R.	Surrey	154.2	12.77%	21.566	8.354	25.099	4.824	11.462	82.493	0.402
21a Mahood Ck.	Surrey	38.0	23.32%	2.941	1.323	14.057	1.594	5.367	12.658	0.060
22 Nicomekl R.	Surrey/Langley	175.2	6.26%	24.097	9.875	10.598	2.296	6.265	121.505	0.564
22a Anderson Ck.	Langley	27.2	4.10%	3.941	0.118	3.074	0.092	0.205	19.683	0.087
22b Murray Ck.	Langley	28.9	1.65%	4.544	0.538	0.108	0.130	0.150	23.295	0.135
23 Campbell R.	Surrey/Langley	74.4	3.94%	15.635	1.683	3.919	0.594	0.885	47.675	0.222

\*- Campbell River estimates do not include approx. 4 km<sup>2</sup> in U.S.A.

Booth (1990) discusses three effects of urbanization on hydrology and drainage:

- Concentration of storm runoff into surface channels. In regions where subsurface runoff dominates under natural conditions, this may erode surface soils and create gullyng;
- The total volume of surface (storm) runoff increases, increasing the mean annual discharge from the watershed;
- Peak discharges increase at the outlet of the developed area. Booth (1990) shows consistent increases of the ratio of the (simulated) development flood to the pre-development flood with EIA for small basins. With effective impervious areas exceeding 20%, the 100-year discharge is doubled and the 1.5 year flood discharge is increased about 2.5 times.

#### **4.2.1 Urbanization and Streamflow Quantities**

A common result of urbanization is an increase of the overall mean annual runoff. The increase results from increased stormflow, as a result of reduced infiltration, and reduced evapotranspiration. Booth (1990) describes increases of mean annual runoff amounting to several hundred mm in King County, Washington. Similar results might be expected in the Fraser Delta HMA, as surficial geology and climate are similar, but there are no studies in the Lower Mainland to confirm these values.

It is often assumed that reduced infiltration and increased storm runoff reduces soil and ground water recharge, ultimately leading to reduced base flows during the late summer. However, removal of vegetation tends to counteract this effect as decreased transpiration usually leads to increased low flow in late summer. There are no studies in the Lower Mainland that demonstrate the effect of urbanization on summer low flows.

In King County, the effect of urbanization on low flows has not been studied very often. Leytham (personal communication) indicates that effects are expected to be site-specific and at least partly dependent on surficial materials. In small basins in relatively impervious surficial materials (tills, glaciomarine sediments) flows tend to be near-zero or zero between rain storms. In these circumstances on-site detention stores water and releases it gradually and acts to improve base flows. For low density developments on permeable sediments (i.e., glaciofluvial sands and gravels) sufficient recharge may reach the groundwater table to maintain the low flow regime experienced under pre-development conditions.

Low flows are a critical aspect of habitat in the Fraser Delta HMA and the uncertainty of the effect of urbanization on their regime makes it difficult to manage these streams.

#### **4.2.2 Urbanization and Flood Flows**

Studies elsewhere have demonstrated increased storm volumes and peak flows following urbanization; however these results have not been confirmed by studies in the Lower Mainland. In King County, Booth (1990) indicates a consistent increase of the ratio of post- to pre-development storm peaks with increasing EIA for small basins. Based on simulation, the increase of the 100-year discharge averages about 2 times and that of the 1.5-year flood about 2.5 times for an EIA of 20%, and these values increase with increasing EIA.

There is wide variation in the ratio of post- to pre-development flood discharges in individual basins, partly as a result of variable terrain and surficial sediments. Detention or retention structures or other stormwater control measures in the urban environment also reduce the simulated post- to pre-development ratios.

Studies from King County do not indicate a "threshold" level of EIA needed for impact on the hydrologic or geomorphic regime. However, studies by Morisawa and Laflöre (1979) indicate a threshold level, where more than 25% of watershed needs to be covered by housing with at least 5% impermeable area (an EIA of about 5%), prior to detectable channel enlargement. Major channel enlargement appeared to begin at an EIA of about 10%. These results cannot be directly applied to the Fraser Delta HMA because of different materials in channel banks and beds.

#### **4.2.3 Urbanization and Sedimentation**

Urban development generally results in increased fine (suspended) and coarse (bedload) sediment delivery to streams through erosion of roads and cut-banks, and other types of disturbance. Of more general concern are the channel changes that may be initiated by changes in peak flows following urbanization. In erodible materials, the channel is expected to respond to increased peak discharges by enlarging its channel cross section, with this eroded material contributing to the suspended and bed load of the stream. Channels also respond by lowering gradient or degrading their channel bed, and this eroded material will also contribute to the bed and suspended load, and coarsening their bed sediments. These changes, and the elevated sediment supply regime, may persist over many years, depending on the local surficial material, the degree of urbanization, the history of storm events and the transport capacity of the stream channel.

#### **4.3 Agricultural Land Use**

Agricultural land use was not measured for the watersheds of the salmon streams.

#### **4.4 Physiography**

Drainage area was measured for each watersheds in the Fraser Delta HMA. Areas upstream of stream gauging sites were extracted from Water Survey of Canada publications, and areas above the mouths of salmon streams were measured with a planimeter (using a drainage boundary constructed by joining the heights of land on 1:50,000 maps), or extracted from SSIS records, or consulting or municipal reports. The various sources are not always consistent as it is very difficult to establish exact drainage areas for small, urbanizing basins. However, the differences often amount to only a few percent of the total basin area and are of the size of typical measurement errors.

For preference, we have utilized quoted drainage areas from municipal or engineering reports or measurements of drainage area from 1:50,000 maps of the watersheds.

## **5. WATER LICENSES**

The Water Rights Branch of the Ministry of Environment maintains a computerized data base of water licenses in British Columbia. Summaries (by license 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 Licenses**

Figure 8 reproduces the water license classification system used by the Water Management Branch. Water licenses 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 8, 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 Licenses**

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. Land Improvement licenses, which are classified separately by the Water Management Branch, are included under our Industrial category and discussed further in Section 5.2. Table 7 reports the sum of all licenses, of each type, above the mouth of the salmon stream.

#### **5.1.2 Non-Consumptive Licenses**

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

**Figure 8: Classification of British Columbia Water Licences.**

No.	USE CLASS	DESCRIPTION (uses included)	UNITS
<i>CONSUMPTIVE:</i>			
1	Waterworks	<ul style="list-style-type: none"> <li>- conveyed by local authority (municipality, regional or improvement district)</li> <li>- conveyed by others (individual, utility, Indian band)</li> </ul>	gallons/day, gallons/year
2	Domestic use		gallons/day
3	Pulpmills		cubic feet/second
4	Industrial	<ul style="list-style-type: none"> <li>- processing (sawmills, food, manufacturing, etc.)</li> <li>- cooling</li> <li>- enterprise (hotels, motels, restaurants, etc.)</li> <li>- ponds</li> <li>- watering</li> <li>- bottling for sale</li> <li>- commercial bulk export</li> <li>- mineral water sold in containers and used in bathing pools</li> <li>- all other industrial uses</li> </ul>	any
5	Irrigation	<ul style="list-style-type: none"> <li>- conveyed by local authority (municipal)</li> <li>- private agricultural use</li> </ul>	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
<i>NON-CONSUMPTIVE:</i>			
8	Power generation	- residential, commercial, general	cubic feet/second
9	Storage - nonpower		acre-feet
10	Storage - power		acre-feet
11	Conservation	<ul style="list-style-type: none"> <li>- storage (e.g., waterfowl habitat enhancement)</li> <li>- use of water (e.g., hatchery)</li> <li>- construction of works in and around a stream (e.g., fish culture, fish ponds, personal)</li> </ul>	any



The total non-power storage licenses in each salmon stream are listed on Table 10. The total includes all storage for domestic, waterworks, irrigation, and industrial licenses; though, in most streams, the majority of the licenses are for irrigation. Table 10 also compares the irrigation licenses to the non-power storage in each salmon stream. Storage affects flow by being accumulated during the spring freshet and released during low flows, or during the irrigation season. In many watersheds, licensed storage volumes are matched to some irrigation licenses, 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, Waterworks and Industrial Licenses**

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 license-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 Fraser Delta HMA are insignificant when compared to irrigation use or to streamflow.

Land improvement licences are used to provide water for ponds, which may be used for landscaping or to raise fish. On older licenses, removal rates were set from an evaporation

**Table 10: Storage in the Salmon Streams of the Fraser Delta HMA.**

Stream Name	Basin Area (mouth) (km <sup>2</sup> )	Total Non-Power Storage (ac-ft)	Total Conservation Storage (ac-ft)	Total Irrigation Licences (ac-ft)	Percent with Storage (%)
<b>NORTH SHORE TRIBUTARIES</b>					
Musqueam Ck	6.7	0	0	0	0
Glen Lyon Ck	3.7	0	0	0	0
Sussex Ck	1.0	0	0	0	0
Byrne Ck	9.1	0	0	0	0
Brunette River	76.9	0	0	0	0
Schoolhouse Ck	7.1	0	0	0	0
Coquitlam R	261.6	0	0	0	0
<b>SOUTH SHORE TRIBUTARIES</b>					
Cougar Canyon Ck	7.4	0	0	0	0
Scott Ck	4.8	0	0	0	0
Bon Accord Ck	5.3	0	0	0	0
-0220	3.8	0	0	0	0
-0230	4.4	0	0	0	0
Yorkson Ck	17.9	3	0	10	32
Salmon River	76.9	82	0	518	16
- Coghlan Ck	14.2	82	0	139	59
-00-0300-150	0.9	0	0	0	0
West Ck	14.5	0	0	94	0
Nathan Creek	33.8	0	0	30	0
Hanna Ck	8.1	0	0	0	0
Coligny Ck	3.6	0	0	0	0
McLennan Creek	30.9	0	0	73	0
-Gifford Slough	14.4	0	0	51	0
-Downes Ck	6.4	0	0	1	0
Matsqui Slough	69.3	2	0	850	0
-Clayburn Ck	25.8	2	0	460	0
-Willband Ck	13.5	0	0	195	0
-Stoney Ck	7.6	0	0	73	0
<b>BOUNDARY BAY TRIBUTARIES</b>					
Serpentine River	154.2	0	1000	1,368	0
-Mahood Creek	38.0	0	0	1	0
Nicomekl River	175.2	0	0	372	0
-Anderson Ck	27.2	3	0	3	100
-Murray Creek	28.9	0	0	58	0
Campbell River	78.4	50	0	564	9

- Nonpower includes all storage for domestic, waterworks, industrial, and irrigation licences. Conservation licences are not included in the nonpower totals.
- Irrigation licences for each salmon stream are from Table 6.
- Percent with storage calculated by dividing nonpower storage by total irrigation licences for each stream.

of one-eighth inch per day (doubled to one-quarter inch for a factor of safety), multiplied by the pond surface area, and converted to gallons/day. On newer licenses, the licensee is permitted to divert whatever quantity is required to maintain water levels in his pond.

The Land Improvement licenses are consumptive as most water is lost to evaporation though some may enter groundwater and re-appear as return flow. Most withdrawals will be during hot, dry weather when evaporation is greatest and streamflow is least. Much smaller withdrawals are expected during winter or rainy, cold weather.

### **5.2.2 Irrigation Licenses**

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 which is assumed to be about 20 cm (8 inches) in the Lower Mainland (UMA Engineering 1988) -- is used to calculate the total amount of water needed for irrigation. However, the portion of the farmland which is irrigated is not known and the theoretical duty and the actual amount applied can be very different, as a result of farming practices and, as well, the duty varies with location and elevation and from year to year. Year-to-year variations are significant in many areas: for example, from 1975 to 1988, duty in the Vernon Irrigation

District varied from 31 to 48 cm (Rood 1989), with the greatest amount required during low flow, dry years; and in dry years the actual extraction approaches the licensed volume.

Irrigation demand can be estimated following the above procedure; however, we prefer to use the water license summaries for several reasons. First, areas of cultivated farmland do not always correspond with the total irrigation licenses and some basins with cultivated land have no licensed irrigation withdrawals. This may result from non-use of licenses, 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 licenses 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 licenses may compensate for licenses that are only partly used, or not used at all.

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

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

Licensed amounts expressed as a volume (ac-ft) were converted to cubic decameters ( $\text{dam}^3$ ), where 1  $\text{dam}^3$  is equivalent (approximately) to 0.81 ac-ft. In any time period, the total demand

is calculated by adding the demand from waterworks, domestic and industrial licenses, which are assumed to be constant throughout the year, to the irrigation demand. Irrigation volumes are assumed to be distributed as follows: May (10%), June (15%), July (30%), August (30%) and September (15%). (These percentages are quoted by UMA Engineering Ltd (1988) in their study of the Matsqui Prairie and reflect the main moisture deficiency which occurs in July and August.) Monthly irrigation volumes (in  $\text{dam}^3$ ) were converted to discharges (L/s) by multiplying by  $10^6$ , and dividing by the number of seconds in the month.

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

## 6. SENSITIVITY INDICES FOR THE SALMON STREAMS

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

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

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

The indices are expressed as percentages of mean annual flow, except for peak flows, which are expressed as a ratio of the mean annual flow. The use of percentages and ratios permits easy comparison of streams of different watershed areas and allows ranking of the streams. The most sensitive streams were defined as those with the most extreme indices or those whose indices exceeded some critical value. On Table 11 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 7 day average 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 discharge	expresses the typical portion of flow during the rearing season that is used for water demand
4	as above for September	as above
5	natural 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	effective impervious area as a percent of total basin area	roughly expresses the potential for changes in peak flows and low flows as a result of development

## 6.1 Summer Water Demand

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

**Table 11: Sensitivity Indices -- Fraser Delta HMA.**

		SUMMER WATER USE				LOW FLOWS		PEAK FLOWS	URBAN
Stream Name	Status	Index 1 Aug Use/ Sum Q7L2	Index 2 Sept Use/ Sum Q7L2	Index 3 Aug Use/ mean Aug	Index 4 Sept Use/ mean Sept	Index 5 Sum Q7L2/ QAA	Index 6 Win Q7L2/ QAA	Index 7 Q2/ QAA	Index 8 EIA/ Basin
NORTH SHORE TRIBUTARIES									
Musqueam Ck		0	0	0	0	8	13	21	12
Glen Lyon Ck		0	0	0	0	8	12	21	23
Sussex Ck		0	0	0	0	10	10	21	7
Byrne Ck		0	0	0	0	8	13	21	27
Brunette River	OR	0	0	0	0	6	18	20	27
Schoolhouse Ck		0	0	0	0	8	13	21	32
Coquitlam R		86	86	92	87	2	4	8	--
SOUTH SHORE TRIBUTARIES									
Cougar Canyon Ck		0	0	0	0	8	13	21	21
Scott Ck		0	0	0	0	8	12	21	38
Bon Accord Ck		0	0	0	0	8	12	21	23
-0220		0	0	0	0	8	12	21	3
-0230		0	0	0	0	8	12	21	3
Yorkson Ck		2	1	2	1	13	18	27	10
Salmon River	RNW	24	12	19	10	13	31	19	2
- Coghlan Ck	RNW	57	30	36	17	5	14	21	2
-00-0300-150		0	0	0	0	10	10	21	6
West Ck		84	76	70	68	5	17	23	1
Nathan Creek		33	31	26	21	7	16	21	0
Hanna Ck		1	1	1	1	8	13	21	1
Coligny Ck		0	0	0	0	8	12	21	0
McLennan Ck		16	9	10	5	6	16	21	2
-Gifford Slough		19	10	13	6	7	18	21	3
-Downes Ck		2	2	1	1	8	13	21	6
Matsqui Slough		126	85	82	54	1	15	21	6
-Clayburn Ck		121	90	78	56	1	13	21	9
-Willband Ck		121	70	87	37	2	27	29	26
-Stoney Ck		72	38	33	15	4	13	21	8
BOUNDARY BAY TRIBUTARIES									
Serpentine River	PWS	51	39	37	26	8	16	20	13
-Mahood Ck		1	1	0	0	5	17	18	23
Nicomekl River	FR	12	6	8	3	8	16	20	6
-Anderson Ck		1	1	1	1	24	30	20	4
-Murray Ck		69	36	30	14	1	1	27	2
Campbell River		70	37	41	25	3	18	21	4

- Status refers to restrictions noted by the Water Management Branch: FR, fully recorded with exceptions for storage; OR, office reserve, no licencing; PWS, possible water shortages, RNW, Refused, no water.
- Aug and Sept Use are total demands in these months; Sum and Win Q7L2 are summer and winter mean 7 day low flows; mean Aug and Sept are mean August and September monthly flows; QAA is mean annual flow; Q2 is the mean annual flood; EIA is effective impervious area in the watershed; Basin is basin area above the mouth.
- Indices expressed as percentages except 7, which is a direct ratio. Low values for Indices 5 & 6 indicate extreme conditions. For other indices, higher values indicate extreme conditions.
- Shading indicates salmon streams with most extreme values for the various indices. The most extreme 25% are shown for Indices 1 to 7; values of Index 8 exceeding 10% are shaded.



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 Coquitlam River results from storage, diversion to Buntzen Lake and diversion to waterworks. Water use was calculated from the difference between the naturalized flows at the mouth and the flows measured at the Coquitlam River near Port Coquitlam gauge, as a percentage of the naturalized flows.

Large values of Indices 1 through 4 indicate streams with great potential demand, primarily from irrigation, on summer low flows. On Table 11, those streams whose indices are the top 25% of the values are shaded.

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

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

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

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

On Table 11, those streams whose indices are in the lowest 25% of the values are shaded. Most of the streams with low indices have small drainage basins and some have licensed demand while others are unaffected by diversion or storage. Typically, smaller streams have more extreme response to drought.

### **6.3 Peak Flows**

Index 7 compares the mean annual flood to mean annual flow, expressing the mean annual flood as a ratio of the mean annual flow. Higher values of the index indicate streams with a greater range of flow, and, potentially, lower channel stability, though channel slope and bed materials also affect stability. Typically, the ratio of mean annual flood to drainage area increases with decreasing drainage area. This occurs because small basins are often completely covered by individual storms, whereas not all of a large basin is exposed. As a result, large basins often have lower mean annual floods per unit area. For the small watersheds in the Fraser Delta HMA, the ratio of mean annual flow to drainage area or to mean annual flood is reasonably constant at around 20. Many of the streams have values of Index 7 equal to 21 because of the linear regression technique used to estimate mean annual floods (Appendix A). Because values of Index 7 are nearly constant we have not shaded any streams on Table 11 nor identified the most sensitive streams on Table 12.

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

### **6.4 Urbanization**

Index 8 is equivalent to the effective impervious area (EIA) of the watershed expressed as a percentage of the total watershed area. It indicates the potential increase in peak flows as a result of urbanization; though the actual increase will depend on detention storage constructed to manage stormwater, soils and underlying materials and the physiography and geometry of the watershed.

There is no critical level for Index 8 that indicates detectable changes in the hydrologic regime (see Section 4.2.2). Consequently, we have used a value of 10% to indicate the potential for major changes in the hydrologic regime or the channel. Watersheds exceeding this value are shaded on Table 11.

## **7. DISCUSSION OF THE SALMON STREAMS**

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

### **7.1 Sensitive Streams**

Table 12 identifies the most sensitive salmon streams in the Fraser Delta Habitat Management Area. A number of the salmon streams potentially have a significant portion of their summer flows utilized by irrigation, industrial or land improvement licenses or storage and diversion. The Coquitlam River is the most affected stream in the HMA and its summer flows are reduced by storage, diversion for power and diversion for waterworks. A recent agreement between B.C. Hydro and Fisheries and Oceans Canada will improve flows downstream of the dam, reducing the calculated indices.

The larger streams, such as Salmon, Nicomekl, Serpentine, and Campbell Rivers have the greatest summer flows but also have the greatest number of irrigation licenses and total licensed volumes. However, Campbell Rivers is the only one of the larger streams listed on Table 12. Streams crossing the Matsqui Prairie -- Stoney, Willband and Clayburn Creeks and Matsqui Slough -- also potentially have most of their summer flows devoted to irrigation and industrial uses. There are also two smaller streams, Coghlan and West Creeks, with only a few licenses; however, summer flows are low in these small creeks and the potential extractions are a large percentage of the available flow.

Most of the salmon streams have small watersheds. Summer 7 day low flows are typically less than 50 L/s, only a small percentage of the mean annual flow. Those streams that are judged particularly sensitive to further extractions are shown on Table 12; however it should be noted that many of the other salmon streams have only slightly greater summer low flows.

**Table 12: Most Sensitive Streams -- Fraser Delta HMA**

<i>Water Demand</i>	<i>Summer Low Flows</i>	<i>Winter Low Flows</i>	<i>Urbanization</i>
<i>1 to 4</i>	<i>5</i>	<i>6</i>	<i>8</i>
Coquitlam River	Coquitlam River	Glen Lyon Creek	Musqueam Ck
Coghlan Creek	Coghlan Creek	Sussex Creek	Glen Lyon Ck
West Creek	West Creek	Coquitlam River	Byrne Ck
Matsqui Slough	Matsqui Slough	Scott Creek	Brunette River
Clayburn Creek	Clayburn Creek	Bon Accord Creek	Schoolhouse Ck
Willband Creek	Willband Creek	0220 Creek	Cougar Canyon Ck
Stoney Creek	Stoney Creek	0230 Creek	Scott Creek
Murray Creek	Mahood Creek	00-0300-150 Ck	Bon Accord Ck
Campbell River	Murray Creek	Coligny Creek	Yorkson Ck
	Campbell River	Murray Creek	Willband Ck
			Serpentine River
			Mahood Creek

The salmon streams that have the greatest alteration to their hydrologic regime from urbanization include small streams in Vancouver, Burnaby and New Westminster, including Brunette River; small streams that drain north Surrey to the Fraser River; Yorkson Creek; and Willband Creek in Matsqui. Twelve of the salmon streams have EIA of greater than 10% of their watershed area, though the Serpentine River is the only large stream whose hydrologic regime may be altered by urbanization.

## **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 Fraser Delta Habitat Management Area (Section 8). We recommend further study and investigation of all the sensitive salmon streams identified on Table 12.

The streams are discussed in the order given on Table 1. Table 3 lists the municipalities that contain the watershed of the various creeks. Not all salmon streams are discussed as interviewees were unable to provide information on some streams.

**Musqueam Creek:** The lower stream, through the Musqueam Reserve, is channelized and a residential area has been developed along one reach. The lower creek flows through a golf course and large, long culverts beneath Marine Drive are impassable.

Sediment quality is reasonable but there are water quality concerns (chlorine spills from swimming pools and chemical runoff from the golf course) and much of the riparian vegetation has been removed. Gravel instability and erosion of channel banks are also a concern.

A water reservoir on the UBC Endowment Lands, with an overflow pipe leading to the stream, was once a source of water during low flows. As a result of concern about chloramine-treated water entering the stream, the overflow pipe has been eliminated.

Low flows are reported on this creek. Proposals to enhance low flows include drilling a well and pumping water to the creek, and developing storage in Camosun Bog. The stream has been cleaned up and the Musqueam Band operates a hatchery for Chum from Kanaka Creek. The Salmon Enhancement Program has identified opportunities for weir placement and flow augmentation by storage.

**Glen Lyon (Kaymar) Creek:** The original large organic debris in the creek has either rotted away or been removed and there is now no source for new debris. Maintenance of adequate water quality is of particular concern.

**Sussex (Nelson) Creek:** A lack of large organic debris is a problem. An impassable culvert at Marine Drive limits the usable habitat in the stream and annual dredging threatens the most productive section of the creek which has suitable pool and riffle habitat.

There is 300 to 400 m of productive habitat upstream of the culvert which may be used by resident fish. There are no plans to improve passage through the culvert.

**Byrne Creek:** The creek was re-located to accommodate a golf course. A PIP project is placing rocks to form pools and reduce velocities in the reach upstream of Marine Drive. The Vancouver Angling and Game Association cleans up the stream and transplants coho into Byrne Creek.

The watershed is highly urbanized, as measured by its EIA, which has affected its hydrologic regime and there are concerns about the quality of storm water drainage. Proposed high rises in the upper watershed are likely to result in further changes to the hydrologic regime, producing higher peak flows and, possibly, changes in channel morphology.

**Brunette River:** The lower river is channelized and dykes on both side of the river have eliminated most of the floodplain. Downstream of the Cariboo Dam, the GVRD has worked on the river to reduce flooding downstream of Brunette Avenue. In 1982, a relief channel was built downstream of Braid Street and dykes along the river were raised. There is no instream cover in the channel (large organic debris or boulders) and the channel is reported

downcut into underlying glaciomarine sediments. High water temperatures and low dissolved oxygen content have been reported downstream of Cariboo Dam. The Still Creek channel, upstream of Burnaby Lake, has also been enlarged and straightened to reduce flooding.

Stoney Creek provides productive habitat and has good gravel and water quality. It has been encroached on by a pipeline and service road that run parallel to the creek.

The GVRD has constructed a new fishway at the Cariboo Dam and it plans to improve fish passage through a culvert into Deer Lake. Gravels have been placed to enhance Deer Lake Creek and boulders and gravels have been placed in Robert Burnaby Creek.

The lower river has not been enhanced or restored. It has been suggested that "setting back" the dykes along the lower river to provide floodplain would be one option. However, there may not be sufficient room to move the existing dykes.

**Schoolhouse Creek:** Summer low flows and high temperatures are a problem near the Lougheed Highway, partly as a result of the lack of riparian vegetation. Flows originate from a complex series of tributaries, which are partly in culverts. Culverts along the lower creek pose access problems and industrial development has lead to concerns for water quality and water quantity.

There appears to be little opportunity for enhancement along this creek because habitat is affected by a number of different factors.

**Cougar Canyon Creek:** Cougar Canyon Creek drains a residential area which has created a high effective impervious area. The creek, which flows in a ravine, is eroding its banks and valley walls. Gabions were installed to stabilize the lower slopes but they have fallen apart over the years. There has been some sedimentation along the creek as a result of erosion and urban development.

The reach near the mouth is used by chinook and chum juveniles. This reach parallels two sewer trunk main lines and the railroad. Delta plans to construct a road on the top of the lines



which could severely affect the creek. Annual dredging of a section of the creek along the railway is also a cause for concern.

The Cougar Canyon Enhancement Society runs a small coho incubator on the creek which is occasionally damaged by large floods.

**Scott (Road) Creek:** There is suitable habitat in the lower, flat reaches of the creek. The creek flows through a culvert for part of its course. Access to the creek was improved during highway development for the Alex Fraser Bridge. A highway widening project is providing further opportunities for fish access through better designed culverts.

**Bon Accord Creek:** There is a potential passage problem at the lower end of the creek because of a long culvert beneath the rail yard. The creek is channelized but is in a Municipal Park which provides some protection to the channel.

An old wooden dam about one kilometre from the mouth provides a large pool with resident cutthroat. The dam is believed to be passable to upstream migrants because of its poor condition and should be left in place for the resident cutthroat.

One tributary receives some groundwater inflow and provide suitable habitat but has a very narrow leave strip.

**Yorkson Creek:** The lower reaches of the creek are in an industrial zone and filling of the floodplain extends to the edge of the creek. Increased flood discharges apparently result from inadequate stormwater detention storage at some urban developments. Encroachment occurs along parts of the creek and increased sediment loading has apparently resulted from urban development, particularly at Walnut Grove.

Low flows in Yorkson Creek and its main tributary, Munday Creek, as well as high summer water temperatures limit production (Schubert 1977). East Munday Creek particularly suffers from extreme summer low flows. Access to upper Yorkson and West Munday Creeks has been improved by baffles in culverts.

The local municipality and Fisheries and Oceans Canada originally co-operated in storm water management planning in this watershed. Fisheries and Oceans Canada marked the top of bank along the creek so that urban development guidelines could be used. There has been no further study to determine if the guidelines were followed or if they were successful.

Schubert (1977) recommended gravel placement above 93A Avenue and instream improvements for rearing habitat.

**Salmon River:** Several irrigation licenses along the lower reaches of Salmon River account for a significant portion of summer low flows. Although the river is classified as RNW (Reserved, no Water) no water shortages have been reported. Flooding along the lowermost reaches has been reported. Reclaimed farmland land and a golf course encroach on the floodplain.

The river is reported to have a more rapid response to rainfall than some of the other mostly rural streams. This may partly be owing to field drainage channels which somewhat mimic a storm water runoff network.

Overwintering habitat is probably a significant limitation on this stream. Entrances to some side channels of the Salmon River are well above the main channel and remain dry during nearly all the year. This may result from downcutting of the main channel. Channel incision is reported between 48th and 56th Avenues and downstream of the fishway on 64th Avenue, near 232nd Street.

There are plans to restore riparian vegetation along parts of the Salmon River. Paish (1979, 1980) identified a number of specific habitat problems and remedial measures.

**West Creek:** West Creek provides habitat for immigrant juvenile salmon from the Fraser River at its lower end. There is also a small wetland near the mouth the creek and a small tributary with good gravel deposits and groundwater-fed base flows joins near the mouth (Schubert 1977). Summer low flows and a poor pool to riffle ratio limit rearing in the main stream (Schubert 1977).

The floodplain along the lower river lies in the Agricultural Land Reserve. Farmers reclaiming and improving their land have filled parts of the floodplain. The upper river is in a lightly developed ravine but it is thought that low flows may be limiting in these reaches. Schubert (1977) recommends pool creation as an enhancement strategy.

**Nathan Creek:** The lower 2 km of Nathan Creek are straightened and channelized. Regular removals of gravel are required to maintain the channel and reduce flooding. Gravel removals are site-specific and consist of scalping bars to the water line. Farmers also remove gravel from the stream; their excavations provide pools along the lower reach.

Most of the watershed is agricultural. Resultant encroachment onto the stream, filling of the floodplain and bank protection all affect the stream channel. Water quality problems also result from farming. Riparian vegetation has been removed and parts of the lower reaches have high temperatures in the summer.

Nathan Creek provides substantial rearing habitat as it is mostly undisturbed with extensive instream debris and pools. Ground water discharge to the stream maintains moderately high base flows and suitable temperatures during the summer, though low flows may limit production in the upper tributaries. Fencing is required to keep cattle out of the stream.

Nathan Slough, once a side channel of Nathan Creek, is no longer connected to the main channel. It has potential for fish habitat if reconnected.

**Coligny Creek:** There is good habitat in this creek but the upper reaches of the creek may go dry naturally. The local Indian Band has recently cleaned the channel, improved fish access to the creek and are building a hatchery.

**Gifford Slough:** Gifford Slough has been straightened and channelized in its lower reaches and riparian vegetation has been removed. Velocities are very low during the summer in the lower reaches, though these reaches are reported to provide some habitat in the fall and winter.

The Municipality is interested in annual dredging to improve drainage and reduce overbank flooding.

**Matsqui Slough:** The lower reaches have been channelized and straightened and riparian vegetation has been removed, as along Gifford Slough. There is a proposal for dredging of the lower creek to improve agricultural drainage and reduce overbank flooding.

An ARDSA community irrigation project, which includes expansion of a network of ditches along Gifford Slough, Matsqui Slough and Clayburn Creek, and pumping from the Fraser River is planned. The license would be held by Matsqui District Municipality.

Schubert (1977) recommended bank stabilization, gravel introduction, pool creation and re-planting of riparian vegetation as suitable enhancement opportunities along Matsqui Slough and Clayburn Creek.

**Stoney Creek:** Urban developments have little or ineffective stormwater detention storage which apparently has increased flood discharges. Removal of riparian vegetation has increased summer water temperatures (Schubert 1977). Erosion along the creek from landfilling, removal of vegetation and higher flood flows contributes to chronic siltation problems. Bank stabilization and re-planting of riparian vegetation are the main enhancement opportunities.

**Serpentine River:** The Serpentine River is the most urbanized of the large streams within the Fraser Delta HMA. Irrigation in the lower reaches imposes a considerable demand on summer low flows and there are a number of outstanding water license applications for this river (Appendix C). Velocities are very low in the lower reaches in the summer and water temperatures often exceed 23°C. The lower river is dyked and riparian vegetation has been removed.

Agriculture affects water quality in the lower reaches. Leachate from corn silage has a very high oxygen demand and can deplete water of oxygen. Excess fertilizer applied to the fields is flushed by fall runoff and can also deplete water of oxygen.

Several of the tributaries provide fish habitat. Lattimer Creek has limited habitat because of

agricultural drainage, high temperatures and low dissolved oxygen. Bear (Mahood) Creek has extreme low flows in the summer and flooding and erosion in the winter. This watershed was one of the first urban developments in Surrey. Highland Creek has several small tributaries with groundwater inflow but flows in the main channel approach zero in summer, with discharge passing through the gravel substrate.

The Serpentine Enhancement Society operates a hatchery at Tynehead Park. The City of Surrey enhanced Hyland Creek through bridging, side channels, creation of instream habitat and riparian planting.

**Nicomekl River:** The lower Nicomekl River has similar problems to the Serpentine River. Some of the tributaries provide fish habitat.

High summer base flows are maintained in Erickson Creek by ground water discharge. Erickson Creek now mostly flows in ditches. The ditches need to be managed properly because removal of vegetation and cleaning generally destroys habitat. It has been suggested that ditches be designed so that grass and other vegetation can be controlled by mowing rather than removal. Summer base flows in Anderson Creek are also maintained by groundwater discharge. The middle reaches of the creek go dry during low flows and the lower reaches (below 32nd Avenue) are incised or downcut, possibly because of removal of organic debris from the stream in the 1970's. Both of these streams have gravel and benthic production, but lack cover.

Springs in the upper Nicomekl River, near the divide with the Salmon River drainage, maintain summer base flows in Wagon Wheel Creek and other tributaries. Other than some low density urban development, agriculture is the main activity in Murray Creek. Summer low flows in this creek limit habitat.

Archimedes screws were installed for fish passage into Erickson Creek. In addition, a private fishway was installed about 4 km from its mouth. A fishway on Anderson Creek at 200th Street needs maintenance. Fencing and instream habitat improvements have been recommended to increase fish production. Removal or replacement of culverts that prevent

fish passage would also enhance fish production.

**Campbell River:** The Campbell is the least affected of the large streams in the Fraser Delta HMA. Summer base flows in the upper river are maintained by groundwater discharge. These reaches, which lie in Langley, are in an urban area.

In the middle reaches of the river, at the Campbell Valley Regional Park, the river flows through a large wetland, where there is no clearly defined channel, and flow disperses through the Park. Several sections of the river go dry in the summer partly due to losses to groundwater and to subgravel flow, and to licensed withdrawals.

A floating dredge to remove peat from the channel has been proposed to resolve a flooding problem near 232nd Street. Lowering the channel bed will also improve drainage of septic tanks which are built close to the river. Beaver dams along the river also raise water levels and aggravate flooding problems.

Several tributaries to Campbell River have had enhancement programs. Instream and bank habitat were improved on McNalley Creek. A fishway was installed at the mouth of Fergus Creek, stop logs and spawning gravels were placed in Jacobson Creek and spawning gravels were placed in Jenkins Creek. Beaver dams have been cleared at one time or another on most tributaries. Further enhancement work could improve fish passage through culverts at 10th Avenue on McNalley Creek and on Sam Hill Creek.

The Semiahmoo Fish and Game Club operates a hatchery which has a good source of water. There are a number of other opportunities for enhanced production in the Campbell River, such as placement of boulders or anchored root wads in the main river, but a comprehensive plan is required. The Campbell River is a good candidate for a demonstration watershed, where agriculture and urban development are managed to maintain fisheries production.

## **8. RESULTS AND CONCLUSIONS**

### **8.1 Effects of Development on Hydrology**

The salmon streams in the Fraser Delta HMA have an annual hydrologic regime that follows the precipitation regime with high monthly discharges in the fall and winter and low monthly discharges during July and August. The winter months see a succession of storms cross the Fraser lowlands causing the streams to experience a series of steeply rising and falling storm hydrographs. Overwintering or refuge habitat is a critical requirement during the storms. Base flows between the storms, or during dry periods, are typically several times greater than those occurring during the summer.

Urbanization is the main human activity that affects peak discharges. Connection of impermeable areas to stream channels, filling and grading in subdivisions, and channel improvements all act to increase flood peaks in small watersheds. Effective impermeable area (EIA) was measured for each of the salmon streams as this provides a direct indication of the potential increase of flood discharge resulting from urbanization.

The watersheds of many of the salmon streams have surface soils developed from moderately impermeable glaciomarine or morainal deposits. In these watersheds, most precipitation enters the soil and quickly reaches stream channels through lateral flow or travels to channels as overland flow. Only small quantities of precipitation go to groundwater recharge and flows decline during the dry, hot summer months, with low flows approaching zero in small basins. Urbanization may have only a small effect on low flows in these systems, however low flows may be reduced by water extractions.

The soils in the watersheds of some of the salmon streams are formed on deep glaciofluvial gravels. In these watersheds, most precipitation enters the soil and percolates to the ground water table, arriving at the stream after some delay. These streams often do not respond immediately to storms at the beginning of winter because precipitation goes to recharge the aquifer, but once recharge is completed they respond rapidly. Discharge from the aquifer maintains summer base flows that are well in excess of those in watersheds with moderately

impermeable surface materials. Urbanization may have only a small impact on low flows in these systems but extractions from surface water and, particularly, from the ground water aquifer, may reduce low flows.

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 the Nicomekl River, Serpentine River, Salmon River and Matsqui and Gifford Sloughs. Agricultural activity is concentrated along the lower reaches of these streams. Consequently, water extractions are mostly from low-gradient, channelized reaches where streamside vegetation has been removed and velocities are often minimal during summer discharges. High water temperatures and low dissolved oxygen levels, due in part to reduced flows because of high irrigation demand, may limit fish use.

Further agricultural irrigation development is proposed for the Serpentine and Nicomekl Valleys and for the Matsqui Prairie. There are 26 outstanding applications for irrigation licenses on the Nicomekl and Serpentine Rivers as well as applications on small streams (Appendix C). Note that a number of the salmon streams have reserves or restrictions imposed by the Water Management Branch. Coghlan Creek and Salmon River are classed as RNW (Refused, no water), the upper Nicomekl River, including Erickson Creek, is classed as FR (Fully recorded) and the Serpentine is classed as PWS (Possible Water Shortages). Appendix D provides details.

UMA Engineering Ltd (1988) reported on irrigation development for the Matsqui Prairie. Currently, there are 485 hectares licensed for irrigation with a typical water duty of about 203 mm, mostly applied in July and August, but with an irrigation season extending from mid-May through early September. UMA indicates that the potential irrigable land on the Prairie is about 2,100 ha. The report anticipates that water for irrigation would be supplied from surface runoff and, during particularly dry periods, by pumping from the Fraser River into the irrigation ditches. The District of Matsqui currently has an application for irrigation extractions from the Fraser River in anticipation of this development.



The Water Management Branch does not keep records of the degree of utilization of the outstanding water licenses and some licenses may no longer be used. Recent increases in annual fees have lead to some licenses being abandoned by their holders.

**Ground Water Use:** The Groundwater Section of MELP has logs for about 8,000 wells in the Fraser Lowlands. A large number of the wells extract water from confined aquifers, at depth, whose recharge areas lie in the various uplands. Annual recharge seems adequate to maintain water levels in the aquifers and because these aquifers are not connected to the streams, these extractions have little or no impact on stream flows.

On the other hand, summer base flows in Nathan Creek, Anderson Creek, Murray Creek, the upper Salmon River and Fishtrap Creek are maintained by ground water discharge from free surface aquifers in glaciofluvial sands and gravels. These streams often provide good summer rearing habitat. Records do not permit calculation of the utilization rate of these aquifers nor is it a simple matter to determine the reduction in streamflow resulting from the extractions. However, the potential extractions can be large. Halstead (1986) indicates, based on pumping records from production wells, that ground water may potentially be extracted at rates in excess of 600 L/s in the aquifer south of Abbotsford, which maintains summer discharges in Fishtrap Creek.

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

Existing storage in the Fraser Delta HMA consists mostly of small storage structures developed and operated by individual farmers or by Ducks Unlimited. In most basins, the total developed storage only represents a small portion of the water requirements for irrigation (Table 10).

The Coquitlam Reservoir is the largest storage reservoir in the Habitat Management Area. It is owned and operated by B.C. Hydro and is used to divert water to Buntzen Lake and to the B.C. Hydro generating system. The reservoir also provides water to the Greater Vancouver Water District. Fisheries and Oceans Canada and B.C. Hydro have recently signed an

agreement that provides minimum flows from the dam that are adjusted monthly to the various species life history requirements and commits funds for restoration and enhancement projects.

The GVRD operates Cariboo Dam on Burnaby Lake on the Brunette River. A fishway has been installed at the dam. The dam is mostly operated to minimize upstream and downstream flooding during storms.

**Urbanization and Floods:** The effective impervious area (EIA) in the watersheds of the salmon streams provides a measure of the potential change in peak flows. The streams with the greatest EIA include: those with small drainage basins in Surrey and Delta, such as Cougar Canyon Creek and Scott Creek; those creeks draining the south slope of Burnaby and New Westminster; Schoolhouse Creek in Coquitlam; the Serpentine River (including Mahood Creek); and Willband Creek. The actual change in peak flows in these systems depends on the presence or absence of detention storage, the types of soils and surficial materials and the distribution of urban area within the basin and requires reasonably sophisticated computer modelling of the watershed for accurate comparison of pre- and post conditions.

Many of the watersheds have effective impervious areas that are only a small portion of their total area so urbanization has only a limited impact on peak flows. However, if urbanization is concentrated in one part of the watershed, it may cause greatly altered peak flows within some tributaries to the salmon streams. This is particularly true in the larger watersheds, such as the Salmon River, where urbanization increases peak flows in upland tributaries. Increased stormwater volumes from these tributaries may aggravate the depth and duration of flooding in the main valley.

Most municipalities currently manage stormwater from developments by limiting releases so that the post-development offsite 2-year flood remains the same as the pre-development 2-year flood. In practice, this is usually accomplished by detention storage on the site that may also have some retention or infiltration capacity. These regulations only apply to recent developments and, as indicated by the EIA measurements, flood flows in some salmon streams may already have been radically altered by urbanization constructed prior to various land development guidelines. In these streams, increases in channel dimensions and channel degradation may be underway that will require decades to run their course.

Detention designed to control the post-development mean annual, or 2-year flood, produces a longer, flatter hydrograph than the pre-development basin because of the greater stormwater volumes produced by urbanization. This may increase the duration of the assumed channel-forming discharges, increase the frequency of channel erosion, and increase sediment transport in the salmon streams. One other seldom-discussed consequence is the more frequent occurrence and greater duration of very high velocities in main streams. Installation of overwintering, or refuge, habitat along the streams is required to mitigate this change in velocity patterns.

It is generally assumed that the 2-year, or mean annual, flood is the channel-forming discharge in streams in the Fraser Lowland. However, there is no local evidence for this assumption and channel-forming discharges may actually occur at much greater return periods. Detention storage designed to control the post-development 2-year flood often has little impact on floods at greater return periods; thus, the pre-development twenty-year flood will occur much more often, perhaps as regularly as every ten years, in urbanized basins with sufficiently high EIA.

Both retention and detention ponds settle sediment during floods, though the ponds must be very large to settle out the finest fraction of the suspended load.

**Urbanization and Low Flows:** Urbanization is often assumed to reduce low flows by limiting ground water recharge through the development of impervious surfaces. As previously discussed, urbanization may only have a limited effect on low flows in basins underlain by moderately impervious sediments and, in these basins, retention structures built to control flood flows may actually improve low flows. The situation is also uncertain in basins underlain by permeable sands and gravels, though winter precipitation is often more than sufficient for groundwater recharge, even with much less permeable area.

**Flooding, Erosion and Sedimentation:** Applications for bank protection or channel improvements are common in the Lower Mainland and the Water Management Branch receives about 700 applications a year for instream works. One result of historic channel filling, floodplain encroachment and current channel improvements is the loss of off-channel habitat

along the streams. Many streams also lack large organic debris. Existing debris has been removed or rotted away and the lack of riparian vegetation often prevents further recruitment.

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

Channel downcutting is often thought to be one of the major consequences of uncontrolled urbanization. This might be typically expected to occur in the steeper reaches of small tributaries, well above any base-level control, where they leave the uplands and before they join their main streams.

Downcutting has not been studied in detail in the salmon streams but anecdotal evidence indicates problems in Anderson and Murray creeks, which are tributaries to the Nicomekl River. Urban development has not proceeded very far in these streams and degradation may be a natural process, or related to other human activities, such as removal of organic debris from streams during clearing programs in the 1970's.

## **8.2 Technical and Management Recommendations**

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

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

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

*We recommend for the ungauged streams that estimated flows, particularly low flows, should be confirmed by measurement programs perhaps in conjunction with the Water Management Branch and the Water Survey of Canada. 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 license types. As well, demand varies from year-to-year, based on a number of factors. *Management of the salmon streams requires some knowledge of the annual variation of demand and we recommend regular monitoring of withdrawals to establish the demand on the most sensitive streams.*
2. Management procedures to ensure adequate instream flows for fish have not been established. *We recommend that instream flow requirements be assessed for the more sensitive salmon streams and that appropriate water management plans be developed in conjunction with other agencies (Hamilton 1992).*

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

Salmon streams in the Fraser Delta HMA typically have small watersheds, minimal low flows in July and August and limited natural or artificial storage. A few of the streams have large potential water demands. Storage development, riparian zone management, and erosion control are important issues.

**Salmon River, Coghlan Creek, West Creek, Matsqui Slough, Clayburn Creek, Willband Creek, Stoney Creek, Murray Creek, Serpentine River and Campbell River** have a considerable portion of their typical summer flows potentially utilized by licensed demand, principally for irrigation, and are under the greatest threat from existing water use. *We recommend that further water withdrawals from these stream systems -- even with compensating storage -- should be opposed until actual licensed demand is established and water management options for the*

*stream system are reviewed. Opportunities for storage development within these systems should be reviewed.*

Appendix C indicates that there are a number of outstanding irrigation license applications on the Serpentine River, though this system is recorded as PWS (Possible Water Shortages). There are also outstanding applications on Clayburn Creek and Campbell River and Matsqui District is planning further irrigation development along Matsqui Slough. Salmon River is recorded as RNW (Reserved, No Water) and there are no outstanding applications on this river. There also appears to be no outstanding applications on West, Willband, or Stoney Creeks.

Some salmon streams on the south shore of the Fraser River, such as **Nathan Creek, McLennan Creek, and Gifford Slough** are relatively unaffected by water demand, but have natural summer low flows that are small in relation to their mean annual flow. They are not restricted or reserved and there remains a potential for future increased water demand. *We recommend that low flows be monitored on these streams and instream flow needs assessed.* If demand increases, low flow agreements, or restrictive licensing, may be used to maintain instream flows. Storage opportunities in the basin should also be investigated. Storage may either supplement existing flows or meet future demand.

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

In basins with significant storage development it may be possible to improve low flows. In the Coquitlam River, operating procedures for the reservoir have been altered to provide more water during critical periods, based on an agreement between B.C. Hydro and Fisheries and Oceans Canada. There are no other large surface water reservoirs in the Fraser Delta HMA. However, Fisheries & Oceans Canada may participate in developing extra storage, or improving existing storage, on some salmon streams to provide additional water for release during low instream flows. In both instances, it should be ensured that some contractual relationship clearly spells out the reservoir operator's obligations.

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

### **8.2.3 Groundwater Extractions**

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

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

*We recommend that shallow wells be inventoried in basins of those salmon streams whose base flows may be substantially maintained by ground water discharges and that the potential reduction in streamflow from pumping from groundwater be evaluated. This includes Nathan, Anderson, and Murray Creeks and the upper Salmon River.*

### **8.2.4 Urbanization**

**Musqueum Creek, Glen Lyon Creek, Byrne Creek, Brunette River, Schoolhouse Creek, Cougar Canyon Creek, Scott Creek, Bon Accord Creek, Yorkson Creek and Mahood Creek**, 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, urbanization is the main land use that has altered the hydrologic or sediment regimes and has the potential to alter channel morphology. **Serpentine River and Willband Creek** are affected by urbanization and also by water demand.

The hydrologic regime is generally managed in urbanizing basins by developing detention storage to maintain frequent floods (i.e., the 2-year flood) at the pre-development discharge downstream of the development site. It is assumed that erosional and habitat changes to streams are caused mostly by frequent floods and that by maintaining pre-development discharges for these floods that the channel and habitat will be maintained. There have been no studies related to this issue in the Fraser Lowlands and the approach to management of storm water and channel maintenance is based on results from other areas, primarily Western Washington. *We recommend a study to evaluate whether the current management of stormwater is effectively maintaining channels in the Fraser Lowlands. All the streams listed on the previous page are candidates for study, though Mahood Creek in the upper Serpentine River is particularly suitable because of its Water Survey of Canada gauges.* Other candidates include Yorkson Creek in Langley and Cougar Canyon, Scott and Bon Accord Creeks in Surrey.

One further weakness is that the cumulative effect of alterations in tributaries and at development sites on the overall hydrologic regime in the mainstem is not managed by onsite stormwater management. This issue has not been addressed in planning for stormwater management. Hydrologic modelling (simulation) remains the best approach to evaluation of the hydrologic regime in the basin. *We recommend that modelling be used in contentious watersheds, as is currently carried out in Washington State.* Initially, it may be preferable to select one watershed to demonstrate the effectiveness of hydrologic modelling, describe the typical effects of urbanization on streamflow regime, and test various stormwater retention and detention options.

#### **8.2.5 Sedimentation and Sediment Sources**

There is a copious amount of anecdotal information on the history of erosion, flooding, sedimentation and channel changes in the salmon streams in the Fraser Delta 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 Fraser Delta 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 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.* An example of this combination of various aspects of the watersheds that potentially affect fish habitat is contained in the *Soos Creek Basin Plan* prepared by King County Surface Water Management Division (1989).

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## **APPENDIX A**

### **REGIONAL HYDROLOGY OF THE FRASER DELTA HMA**

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

Many of the salmon streams have either been gauged by the Water Survey of Canada or have miscellaneous measurements by the Water Management Branch. However, only West Creek met the requirements for a gauged salmon stream, as it has a Water Survey of Canada station operating near its mouth and continuous records from 1981 to 1990.

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

### **A.1 Regional Hydrologic Analysis**

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

#### **A.1.1 Criteria for Selecting Gauging Records**

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

1. All stations should have a complete or nearly complete record of flows during a common base period. In this report our base period is 1981 to 1990, inclusive;
2. The length of the base period should be at least 10 years, though some compromise is necessary between long base periods and the number of stations available for inclusion in the analysis;

3. Typically, drainage areas at the gauging sites should exceed 100 km<sup>2</sup> and be less than several thousand km<sup>2</sup>. The lower limit avoids local anomalies, the upper limit avoids artificially high correlations induced by including large drainage areas that encompass most of the region. Much smaller limits were used in the Fraser Delta HMA where drainage basins are typically less than 100 km<sup>2</sup>;
4. The records should all be independent. Where there are multiple records on one stream, only one record should be used or the records should be subtracted to produce flow estimates for the independent portions of the total basin area; and
5. There should be no upstream regulation, water use, or diversion out of the basin.

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

#### **A.1.2 Water Survey of Canada Records in the Fraser Delta HMA**

Table A2 lists the Water Survey of Canada stations in the Fraser Delta HMA, or nearby, that were included for analysis. There are ten stations with drainage areas smaller than 100 km<sup>2</sup>. Small watersheds are used for the regression analysis because the majority of the watersheds of the ungauged salmon streams are also small.

Most of the stations do not have complete records during the 1980's, but it was necessary to include these older records in order to have sufficient data points for regression analysis. All older records were adjusted to the 1980's with the combined record at the gauges on the Nicomekl River (Stations 08MH105 and 08MH155). The adjustment consisted of determining the ratio of the flow characteristics over the gauging period, and over 1981-1990, at the Nicomekl gauges. These ratios were then applied to the flow characteristics calculated from the older record. Table A2 indicates the period of record used for the adjustment at the older gauges.

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

All the records in Table A2 are independent and require no adjustment.

### **A.1.3 Climate and Physiographic Data**

There is only a small variability of climate and physiography within watersheds in the Fraser Delta HMA but there is considerable variation in surficial sediments, which affect low flows. Urbanization, which increases the effective impervious area (EIA) in the watershed, can be expected to affect mean annual floods, mean annual flows and, perhaps, 7 day low flows. The watersheds listed in Table A2 have varying degrees of urbanization; with EIA ranging from near-zero for West and Nathan Creeks to 23% for Mahood Creek and 27% for Brunette River, though most of the watersheds in Table A2 have less than 10% EIA (Table 9).

Drainage area and the portion of glaciofluvial sediments were the watershed variables selected to correlate with the hydrologic characteristics at the gauging stations. The portion of glaciofluvial sediments contributed very little to explaining the variation in flow characteristics and was dropped from the analysis though it increases flows in individual watersheds. Regression equations were based on drainage area, and there are not enough stations in the Fraser Delta HMA to expand the regression to include other variables.

The regression equations are expected to be most appropriate for watersheds with low effective impermeable area.

### **A.1.4 Regression analysis of flow characteristics and physiography and climate**

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

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



2. The relationship with the highest  $r^2$  and the lowest standard error, for each flow characteristic, was established.
3. The selected relationship was used to predict flow characteristics at ungauged salmon streams.

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

Variable	Constant	Coefficient	$r^2$	SE <sub>y</sub>	N
Mean Flow	0.0	0.0346	0.93	0.26	8
Mean Flood	0.0	0.740	0.96	4.29	8

The coefficient of the mean annual flow equation is equivalent to an annual runoff of about 1090 mm. Because the equations were constrained to pass through zero, the ratio of the mean flood to mean flow is constant for all watersheds, where these values are estimated by the regression equations. The constant value is  $0.740/0.0346$ , or 21.

**Mean Monthly Flows:** Basin area was significantly correlated with both August and September mean monthly flows. Correlations were stronger with logarithmically-transformed variables. The constants and coefficients for the logarithmic-transformed regression equations, relating the logarithms of mean August and September flows to the logarithm of basin area are summarized in the following table. Standard errors of these equations, expressed in logarithms in the table, are equivalent to percent standard errors of, roughly, +80%; -45%.

Month	Constant	Coefficient	$r^2$	SE <sub>y</sub>	N
August	-2.256	0.8742	0.59	0.265	9
Sept	-2.156	0.8259	0.57	0.263	9

**Seven Day Low Flows:** Basin area was significantly correlated with both summer and winter 7 day low flows. Correlations were stronger with logarithmically-transformed variables. The constants and coefficients for the regression equations, relating the logarithms of summer and winter mean 7 day low flows to the logarithm of basin area are shown in the following table. Standard errors of these equations, expressed in logarithms in the table, are equivalent to percent standard errors of, roughly, +120%, -55% for summer low flows and +60%, -40% for winter low flows.

Flow	Constant	Coefficient	$r^2$	SE <sub>y</sub>	N
Summer	-2.470	0.8886	0.47	0.346	9
Winter	-2.470	1.1383	0.81	0.213	7

#### A.1.5 Predicting Flow Characteristics in Ungauged Salmon Streams

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

## **A.2 Estimates from Older or Incomplete Gauging Records**

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

*Brunette River:* The "Brunette River at Sapperton, 08MH026" gauge operated at the mouth of the Brunette River from 1934 to 1971. Mean annual flow, mean annual flood, mean monthly discharges and mean 7 day low flows were calculated from records for 1965 to 1969. The calculated characteristics were adjusted to the 1981-1990 period with the Nickomekl record as discussed in Section A.1.2. The older gauging record may not reflect the current hydrologic regime in this watershed because of changes to operation of Cariboo Dam, but it was preferred to the regression estimates.

*Nathan Creek:* The "Nathan Creek at Glen Valley, 08MH084" gauge provides seasonal records from 1985 through 1990. These were used to estimate mean August and September flows and summer 7 day low flows instead of the regression equations because it was thought that groundwater discharge maintained high summer base flows in this system which would not be adequately predicted by the equations. Mean annual flow, mean annual flood and winter 7 day low flows were estimated from the regression equations.

*Gifford Slough:* A seasonal gauge operated on the slough from 1960 through 1964. Records from the gauge were used to estimate mean September, and mean summer and winter 7 day low flows. Mean annual flows, mean annual floods and mean August flows were estimated from the appropriate regression equations.

## **A.3 Transfers from Upstream or Nearby Gauges**

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

*Coquitlam River:* The flows recorded "Coquitlam River at Port Coquitlam, 08MH002" gauge, which has operated near the mouth from 1968 through 1990, are affected by storage and diversion of water. Naturalized flows were estimated from the "Coquitlam River above Coquitlam Lake, 08MH141" gauge which has recorded natural flows in the watershed from

1982 through 1990. This record was used to estimate mean annual flow, mean annual flood, mean monthly discharges and mean 7 day low flows. The gauge records flows from about 21% of the watershed. Flows were adjusted from the gauge to the mouth using the ratio  $(A_m/A_g)^n$ ; where  $A_m$  is the drainage area at the mouth,  $A_g$  is the drainage area at the gauge and  $n$  is equal to 0.6 for mean annual flood and 1.0 for all other mean flows.

The difference between the naturalized flows and those recorded at the Coquitlam River at Port Coquitlam gauge permitted an assessment of the effect of storage and diversion of water to Buntzen Lake on flow characteristics.

*Yorkson Creek:* Flow characteristics were calculated from the record of the "Yorkson Creek near Walnut Grove, 08MH097" gauge and adjusted to 1981-1990 with the Nicomekl gauge record. The gauge recorded flows from about 33% of the watershed. Flows were adjusted from the gauge to the mouth using the ratio  $(A_m/A_g)^n$ ; where  $A_m$  is the drainage area at the mouth,  $A_g$  is the drainage area at the gauge and  $n$  is equal to 0.6 for mean annual flood and 1.0 for all other mean flows.

*Salmon River:* Flow characteristics were calculated for 1981 to 1990 at the "Salmon River at 72nd Avenue, 08MH090" gauge. The gauge records flows from about 64% of the watershed. Flows were adjusted from the gauge to the mouth using the ratio  $(A_m/A_g)^n$ ; where  $A_m$  is the drainage area at the mouth,  $A_g$  is the drainage area at the gauge and  $n$  is equal to 0.6 for mean annual flood and 1.0 for all other mean flows.

*Nicomekl River:* Flow characteristics were calculated for 1981 to 1990 using the combined records at the two gauges, "below Murray Creek, 08MH105" and "at 203rd Street, Langley, 08MH155". Drainage areas differ slightly at the two gauges but not sufficiently to adjust the records. The two gauges measure flows from about 39% of the total watershed. Flows were adjusted from the gauge to the mouth using the ratio  $(A_m/A_g)^n$ ; where  $A_m$  is the drainage area at the mouth,  $A_g$  is the drainage area at the gauge and  $n$  is equal to 0.6 for mean annual flood and 1.0 for all other mean flows.

*Serpentine River:* Flows estimated for the mouth of the Nicomekl River were transferred to the mouth of the Serpentine, using the ratio of drainage areas. Flows were adjusted to the

Serpentine by the ratio ( $A_s/A_n$ ); where  $A_s$  is the drainage area at the mouth of the Serpentine and  $A_n$  is the drainage area at the mouth of the Nicomekl.

*Campbell River:* Mean August and September flows were calculated for 1984 to 1990 at the "Campbell River above Sam Hill Creek, 08MH123" gauge. Flows were adjusted from the gauge to the mouth using the ratio ( $A_m/A_g$ ); where  $A_m$  is the drainage area at the mouth and  $A_g$  is the drainage area at the gauge. Mean annual flows and mean annual floods were estimated with regression equations.

#### **A.4 Miscellaneous Measurements**

Miscellaneous flow measurements were used to estimate mean summer 7 day lows on Clayburn, and Stoney Creeks and Campbell River. The 7 day low flows reported in Table 7 are an average of all miscellaneous measurements, or an average of the minimum flow measured during each year when there was more than one miscellaneous measurement. On Willband Creek, mean winter 7 day low flows were extracted from UMA Engineering Ltd (1988).

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

Stream Name	WSC Gauging Records		WMB Miscellaneous Measurements	Drainage Area (km2)	Mean Annual Flow	Mean Annual Flood	Monthly Discharges		7 Day Low Flows	
	Gauge Name	Drainage Area (km2)					Mean August	Mean September	Mean Summer	Mean Winter
NORTH SHORE TRIBUTARIES										
1 Musqueam Ck.				6.7	reg.	reg.	reg.	reg.	reg.	reg.
2 Glen Lyon Ck.				3.7	reg.	reg.	reg.	reg.	reg.	reg.
3 Sussex Ck.				1.0	reg.	reg.	reg.	reg.	reg.	reg.
4 Byrne Ck.				9.1	reg.	reg.	reg.	reg.	reg.	reg.
5 Brunette R.	at Sapperton (1934-71)	76.9		76.9	reg.	gauge	gauge	gauge	gauge	gauge
6 Schoolhouse Ck.			1984; 85	7.1	reg.	reg.	reg.	reg.	reg.	reg.
7 Coquillam R.	at Coquillam (1986-91)	237		261.6	gauge	gauge	gauge	gauge	gauge	gauge
SOUTH SHORE TRIBUTARIES										
8 Cougar Canyon Ck.				7.4	reg.	reg.	reg.	reg.	reg.	reg.
9 Scott Ck.				4.8	reg.	reg.	reg.	reg.	reg.	reg.
10 Bonaccord Ck.				5.3	reg.	reg.	reg.	reg.	reg.	reg.
11 -0220 Unamed Ck.				--	reg.	reg.	reg.	reg.	reg.	reg.
12 -0230 Unamed Ck.				4.4	reg.	reg.	reg.	reg.	reg.	reg.
13 Yorkson Ck.	near Walnut Grove (1965-78)	6		17.9	transfer	transfer	transfer	transfer	transfer	transfer
14 Salmon R.	at 72nd Avenue (1968-91)	49	1952-61	76.9	transfer	transfer	transfer	transfer	transfer	transfer
14a - Coghlan Ck.			1977	14.2	reg.	reg.	reg.	reg.	reg.	reg.
14b - 00-0300-150				0.9	reg.	gauge	gauge	gauge	gauge	gauge
15 West Ck.	near Fort Langley (1965-91)	11.4	1983; 87, 89	14.5	gauge	reg.	gauge	gauge	gauge	gauge
16 Nathan Ck.	near Glen Valley (1985-90S)	--		33.8	reg.	reg.	gauge	gauge	gauge	reg.
17 Hanna Ck.				8.1	reg.	reg.	reg.	reg.	reg.	reg.
18 Colligny Ck.				3.6	reg.	reg.	reg.	reg.	reg.	reg.
19 McLennan Ck.	near Mt. Lehman (1960-64S)	9.1		30.9	reg.	reg.	reg.	reg.	reg.	reg.
19a - Gifford Slough	near Malsqui (1960-64)	--		14.4	reg.	reg.	reg.	gauge	gauge	gauge
19b - Downes Ck.				6.4	reg.	reg.	reg.	reg.	reg.	reg.
20 Malsqui Sl.	at Malsqui (1960-64)	--		69.3	reg.	reg.	reg.	reg.	reg.	reg.
20a - Clayburn Ck.	at Clayburn Rd (1961-64; 70-71)	37	1972; 82, 86, 87	46.6	reg.	reg.	reg.	reg.	misc.	reg.
20b - Willband Ck.	at Abbotsford (1955-56S)	--		13.5	reg.	reg.	reg.	reg.	reg.	misc.
20c - Stoney Ck.			1987	7.6	reg.	reg.	reg.	reg.	reg.	reg.
BOUNDARY BAY TRIBUTARIES										
21 Serpentine R.				154.2	transfer	transfer	transfer	transfer	transfer	transfer
21a Mahood Ck.	near Sullivan (1952-72)	34.4		38.0	gauge	gauge	gauge	gauge	gauge	gauge
22 Nicomekl R.	08MH105/155 (1959-91)	69.2		175.2	transfer	transfer	transfer	transfer	transfer	transfer
22a Anderson Ck.	at the mouth (1965-87)	27.2		27.2	gauge	gauge	gauge	gauge	gauge	gauge
22b Murray Ck.	at 216th Street (1969-83)	26.2	1977	28.9	gauge	gauge	gauge	gauge	gauge	gauge
23 Campbell R.	above Sam Hill Ck (1984-91S)	--	1951-61	78.4	reg.	reg.	transfer	transfer	misc.	reg.

\* "reg.", refers to calculation from, a regional regression equation; "gauge", refers to calculation from available WSC gauging records; "transfer" to adjustment of records from an upstream gauge or gauge on a nearby stream; "misc.", refers to calculation from miscellaneous observations collected by the WMB or others.

**Table A2: Flow Characteristics at Stations in the Fraser Delta HMA.**

Gauging Station	Number	Period for Flow Calculations	Drainage Area (km <sup>2</sup> )	% Drainage in Glacio-Fluvial	Flow Characteristics (m <sup>3</sup> /s)					
					Mean Flow	Mean Flood	Mean August	Mean September	Mean Summer 7 Day Low	Mean Winter 7 Day Low
Brunette R at Sapperton	08MH026	<i>1965-1969</i>	76.9	0.1	3.18	63.4				
Yorkson Ck near Walnut Grove	08MH097	<i>1965-1977</i>	6	5.7	0.16	5.2	0.03	0.03	0.02	0.03
Salmon R at 72nd Avenue	08MH090	1981-1990	49	32.3	1.42	28.8	0.25	0.26	0.20	0.44
West Ck near Fort Langley	08MH098	1981-1990	11.4	12.3	0.38	8.7	0.05	0.04	0.03	0.06
Anderson Ck at the mouth	08MH104	<i>1966-1986</i>	27.2	42.3	0.75	15.1	0.21	0.17	0.18	0.23
Murray Ck at 216th Street	08MH129	<i>1970-1983</i>	26.2	31.9	0.67	18.0	0.03	0.03	0.01	0.06
Mahood Ck near Newton	08MH018	<i>1975-1985</i>	18.4	0.1	0.58	12.0	0.09	0.14	0.03	0.10
Nicomekl R below Murray Ck & at 203rd Street, Langley	08MH105 & 08MH155	1981-1990	64.5	21.1	2.02	48.6	0.28	0.32	0.19	0.33
Campbell R above Sam Hill Ck	08MH123	<i>1984-1990</i>	63.7	18.6			0.13	0.12	0.09	
Nathan Ck near Glen Valley	08MH084	<i>1985-1990</i>	25	0.1			0.09	0.11	0.07	

- italicized flow periods indicate adjustment to 1981-1990, as described in Appendix A.

## **APPENDIX B**

### **STREAM SUMMARY SHEETS**



## **B. STREAM SUMMARIES**

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

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

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

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

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

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

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

### B.3 Sensitivity Indices

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

The bar graphs show how the indices for the stream compare with the indices for the other streams in the Fraser Delta Habitat Management Area. For example, if Index 7 is above the median it indicates that peak flows are more severe than average, relative to the other streams.

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

### B.4 7 Day Low Flows

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

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  $\text{m}^3/\text{s}$ , 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.

# MUSQUEAM CREEK

Stream number 00-0010

Ungauged

Flows through the Musqueam Reserve

Drainage Area = 6.7 km<sup>2</sup>

## LICENSED WATER DEMAND

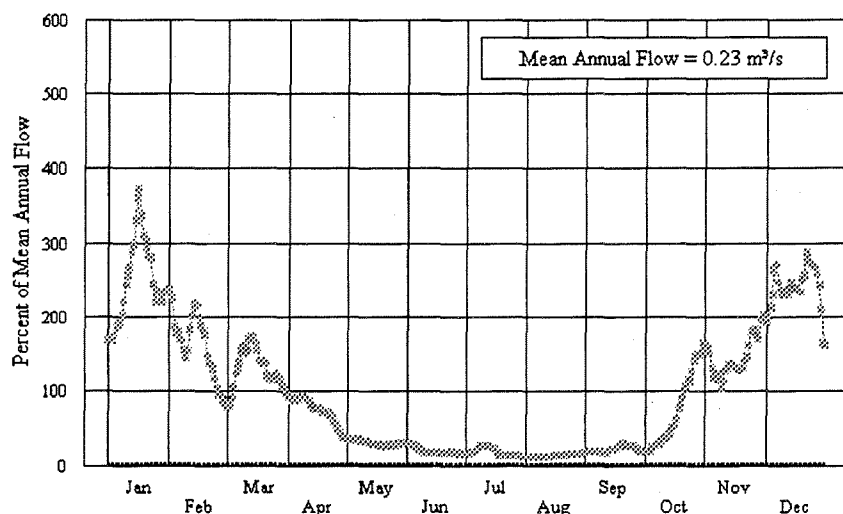
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

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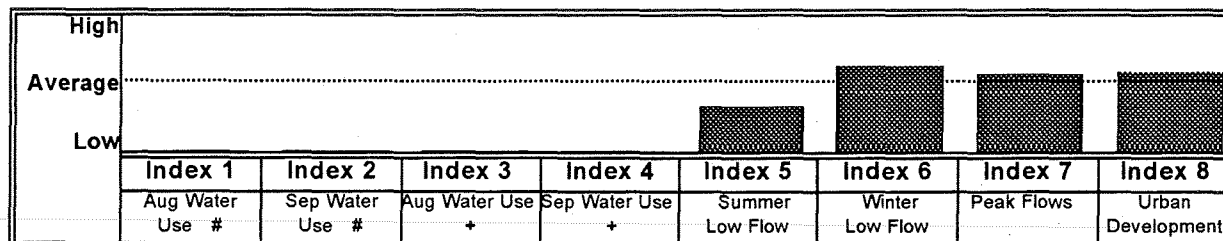
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097 )



## 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

# MUSQUEAM CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The lower part of Musqueum Creek has been affected by channelization, residential development and a golf course. There are concerns over water quality; chlorine spills from swimming pools and chemical runoff from the golf course. Much of the riparian vegetation has been removed and channel banks are eroding.*
- 2. There is a proposal to drill a well and pump water into the creek and to develop storage in Camosun Bog to alleviate low flows.*
- 3. The creek has been cleaned up and the Musqueum Band operates a hatchery for chum salmon from Kanaka Creek. The Salmon Enhancement Program has identified opportunities for weir placement and flow augmentation by storage.*

# GLEN LYON CREEK

## LICENSED WATER DEMAND

Stream number

Ungauged

North Shore tributary to Fraser River

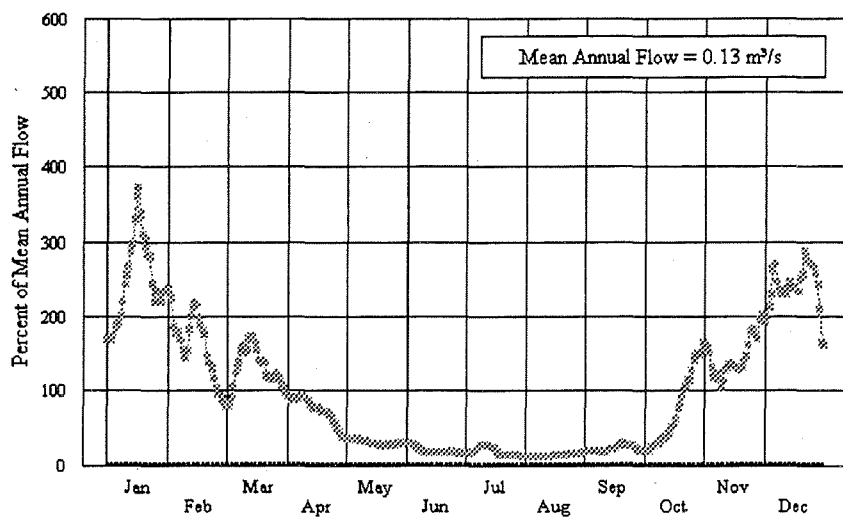
Drainage Area = 3.7 km<sup>2</sup>

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

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		20	20

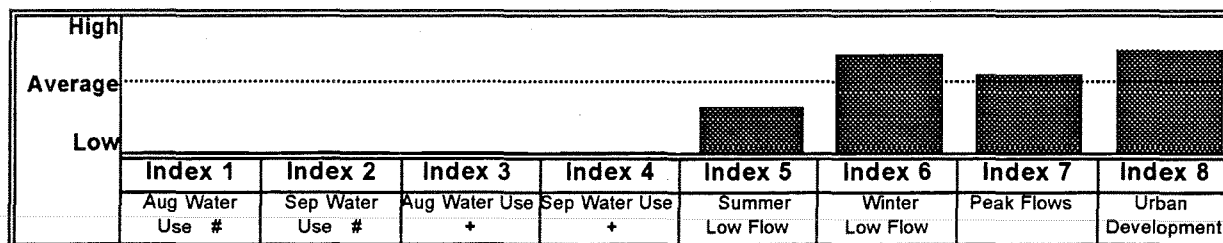
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# GLEN LYON CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The original large organic debris, which provided fish habitat, has either rotted away or been removed and there is now no natural source for new debris. Maintenance of adequate water quality in the creek is also a concern.*

# GLEN LYON CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The original large organic debris, which provided fish habitat, has either rotted away or been removed and there is now no natural source for new debris. Maintenance of adequate water quality in the creek is also a concern.*



# SUSSEX CREEK

Stream number  
Ungauged  
North Shore tributary

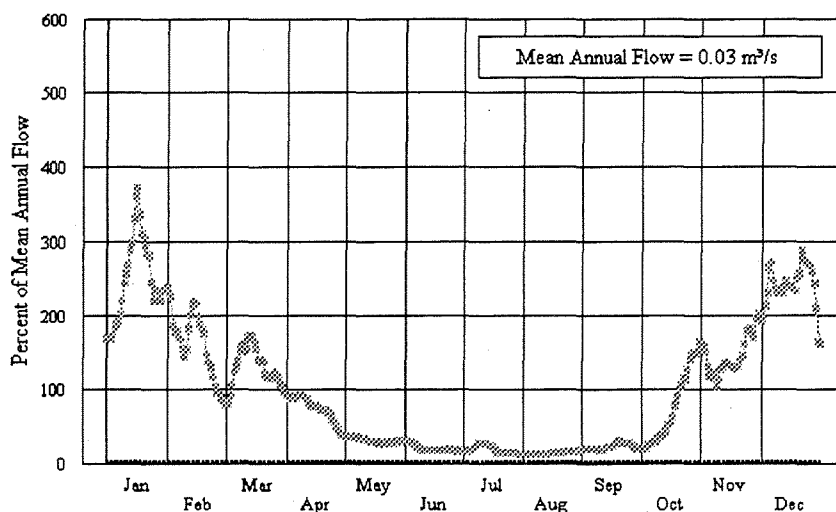
Drainage Area = 1.0 km<sup>2</sup>

## LICENSED WATER DEMAND

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

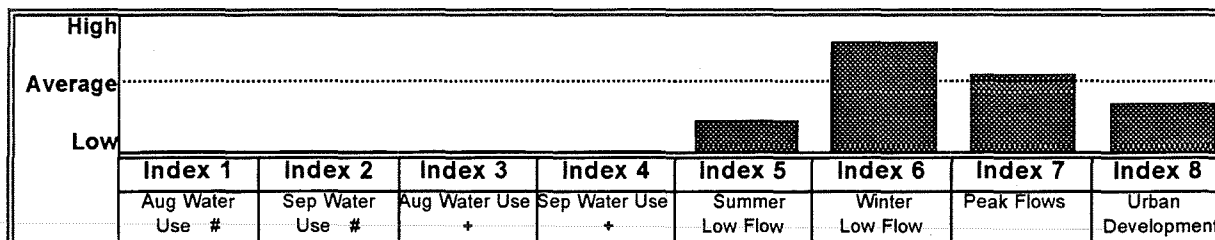
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# SUSSEX CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Lack of large organic debris is a problem. An impassable culvert at Marine Drive limits the usable habitat in the stream and annual dredging threatens the productive section of the creek, which has suitable pool and riffle habitat.*

# BYRNE CREEK

## LICENSED WATER DEMAND

Stream number

Ungauged

North Shore tributary

Drainage Area = 9.1 km<sup>2</sup>

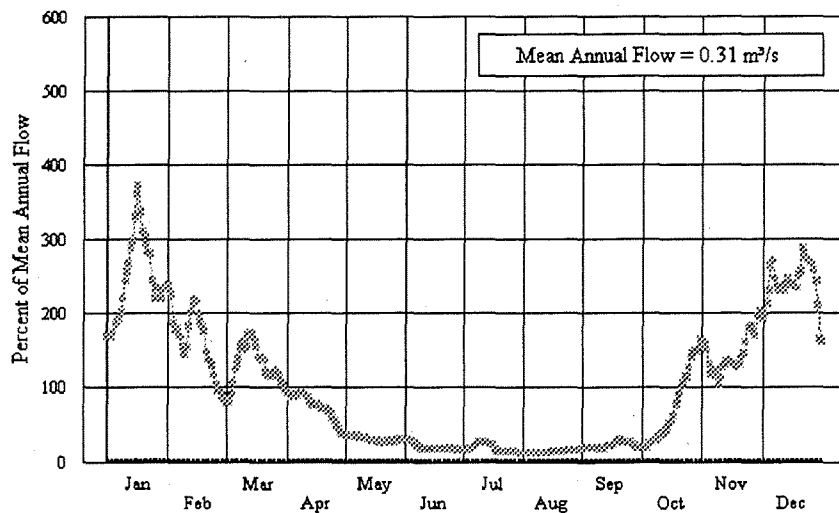
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

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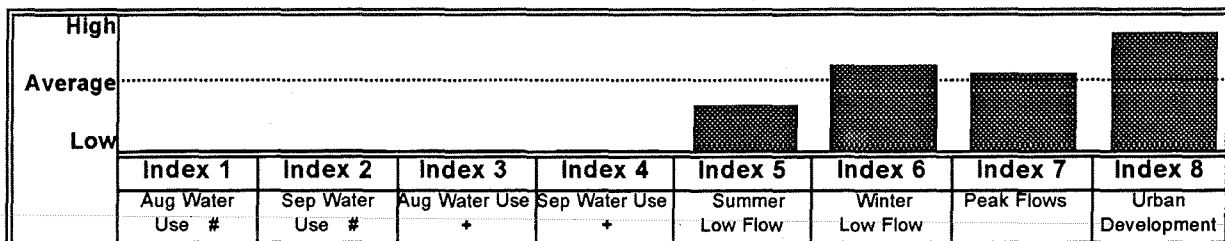
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# BYRNE CREEK

Stream number  
Ungauged  
North Shore tributary

Drainage Area = 9.1 km<sup>2</sup>

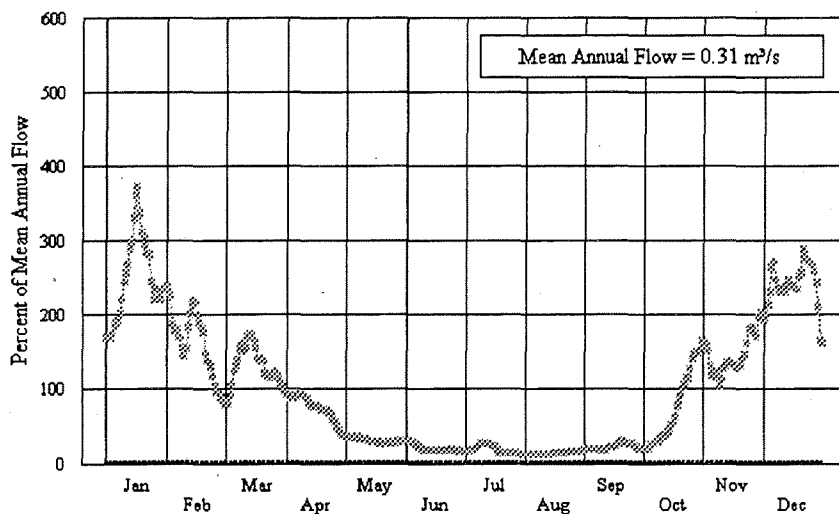
## LICENSED WATER DEMAND

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

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		40	40

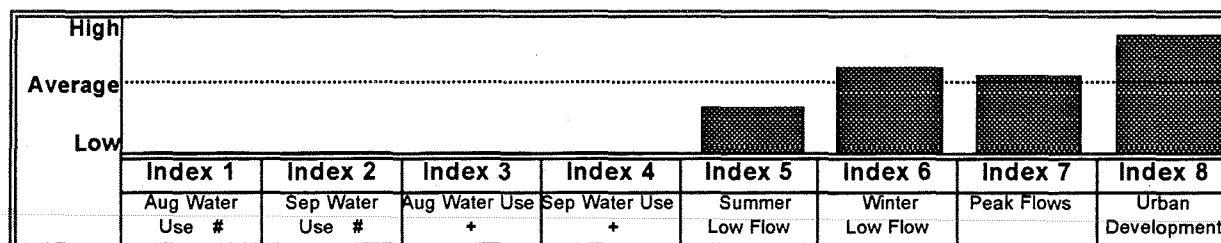
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# BYRNE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The watershed is highly urbanized, which has affected the hydrologic regime. Proposed high rise development in the upper watershed is likely to result in further changes, producing higher peak flows and possible changes in channel morphology.*
- 2. Part of Byrne Creek was relocated to accommodate a golf course. There is an ongoing community project involving the placement of rocks in the reach upstream of Marine Drive to form pools and reduce velocities.*
- 3. The Vancouver Angling and Game Association cleans up the stream and introduces coho young.*

# BYRNE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The watershed is highly urbanized, which has affected the hydrologic regime. Proposed high rise development in the upper watershed is likely to result in further changes, producing higher peak flows and possible changes in channel morphology.*
- 2. Part of Byrne Creek was relocated to accommodate a golf course. There is an ongoing community project involving the placement of rocks in the reach upstream of Marine Drive to form pools and reduce velocities.*
- 3. The Vancouver Angling and Game Association cleans up the stream and introduces coho young.*

# BRUNETTE RIVER

Stream number 00-1000

Water Survey of Canada Station 08MH026

Brunette River at Sapperton

Records 1934 to 1971

Drainage Area = 68.6 km<sup>2</sup>

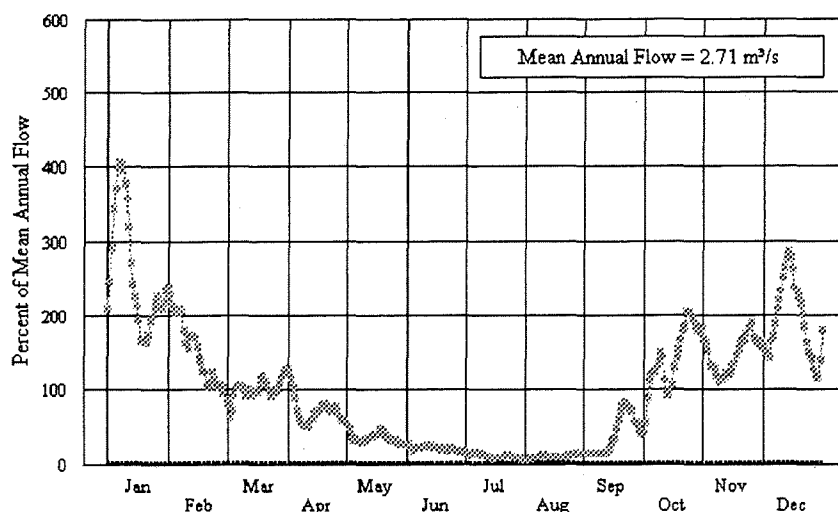
## LICENSED WATER DEMAND

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

Feb Aug Sep

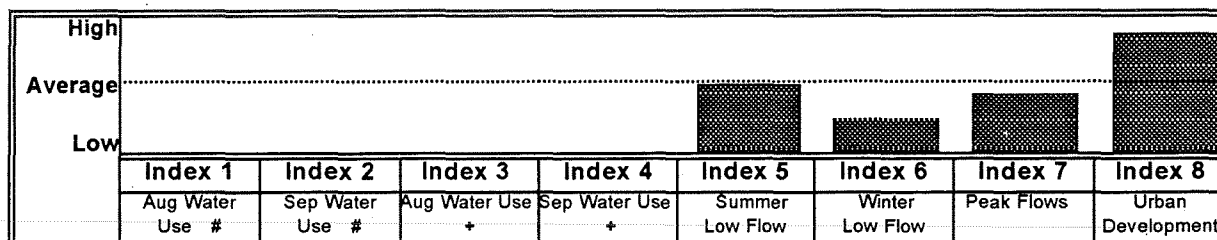
MEAN STREAM FLOW L/S		526	1,190
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## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

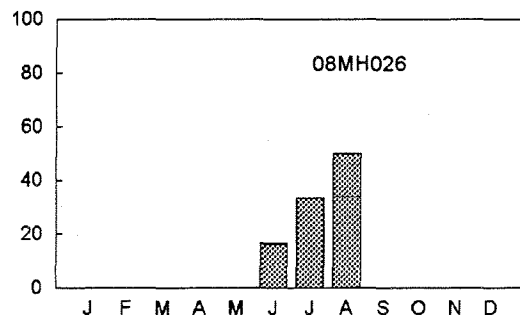


# Water use as a proportion of the 7 day low flow

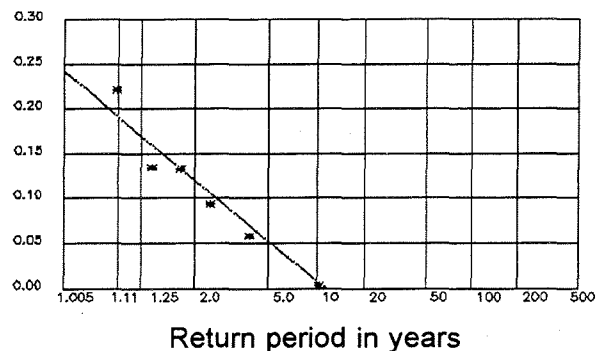
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	0.119 m <sup>3</sup> /s	0.086 m <sup>3</sup> /s			
<b>Annual Flood</b>	28.5 m <sup>3</sup> /s	47.6 m <sup>3</sup> /s	55.3 m <sup>3</sup> /s	65.5 m <sup>3</sup> /s	73.4 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The lower river is channelized with dykes on both sides. In 1982 the GVRD built a flood relief channel and raised some dykes downstream of the Cariboo Dam. It has been suggested that the dykes along the lower river could be set back to provide more floodplain and restore fish habitat, but there may be insufficient room to do this.*

*2. There is no instream cover (large organic debris or boulders) in some reaches and high water temperature and low dissolved oxygen have been reported downstream of Cariboo Dam.*

*3. The GVRD has constructed a new fishway at Cariboo Dam and it plans to improve fish passage through a culvert into Deer Lake.*

*4. Gravels and boulders have been placed to enhance Deer Lake and Robert Burnaby creeks.*



# SCHOOLHOUSE CREEK

## LICENSED WATER DEMAND

Stream number

Ungauged

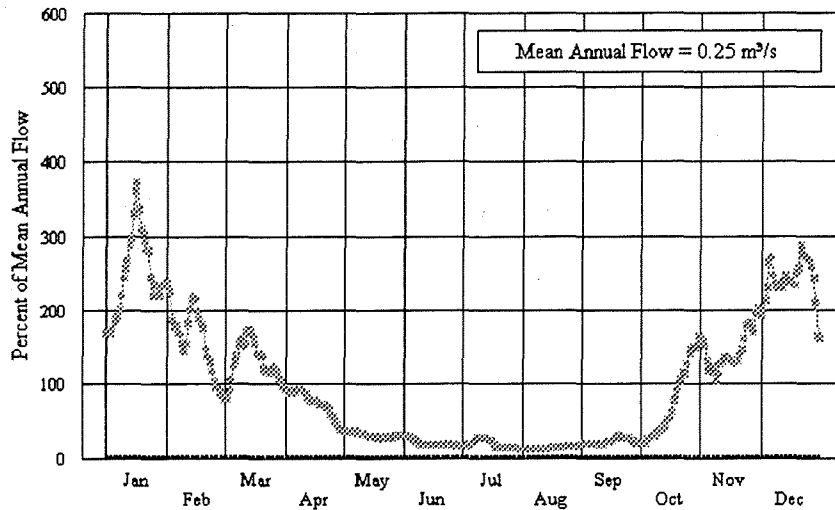
North Shore tributary to Fraser River

Drainage Area = 7.1 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S			30	40

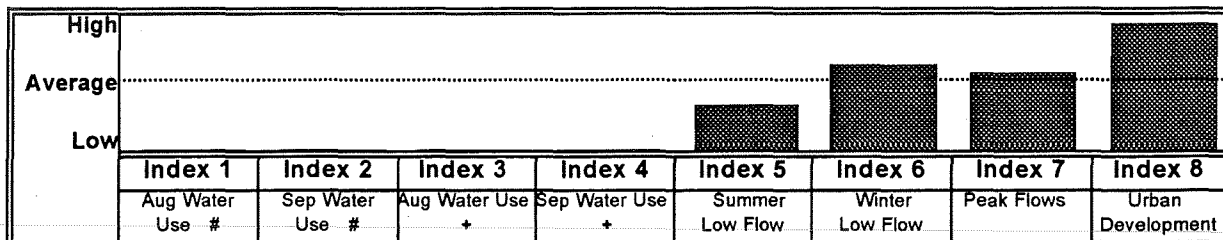
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# SCHOOLHOUSE CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Summer low flows and high temperatures are a problem near the Loughheed Highway, partly as a result of the lack of riparian vegetation. The many culverts restrict access; and industrial development is affecting water quality and quantity. There appears to be little opportunity for enhancement because habitat is affected by too many factors.*

# COQUITLAM RIVER

## LICENSED WATER DEMAND

Stream number 00-0180

Water Survey of Canada Station 08MH002

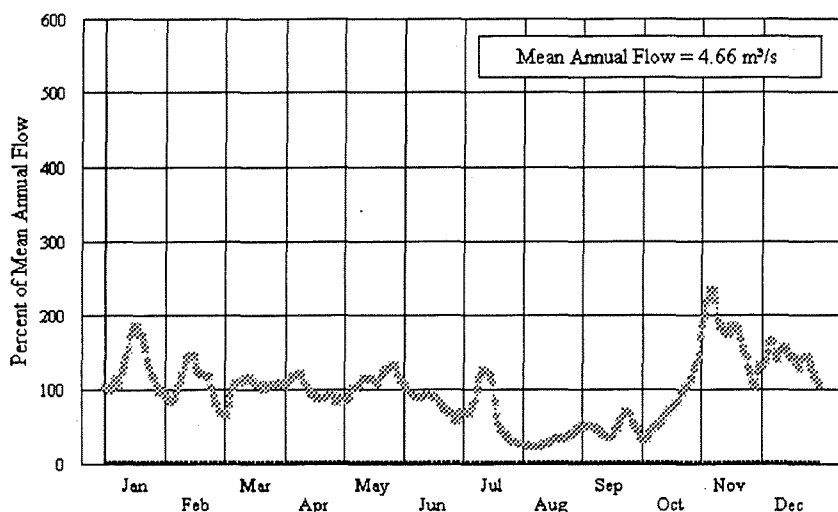
Coquitlam River at Port Coquitlam

Records 1915 to 1990

Drainage Area = 237 km<sup>2</sup>

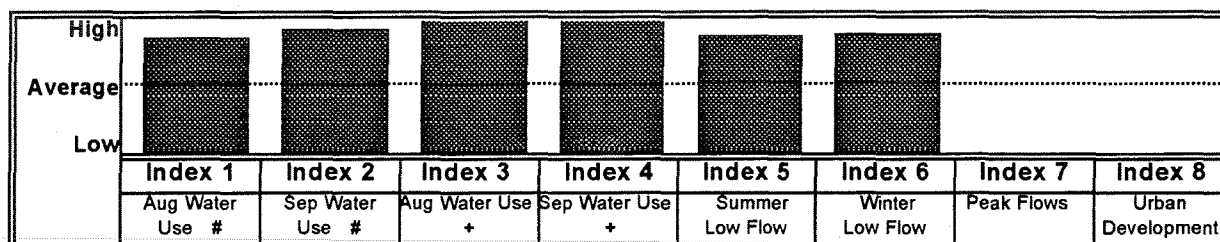
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	50538453g/d	2,660	2,660	2,660
Industrial	134,614 g/d	7.08	7.08	7.08
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S		8,590	1,500	2,300

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

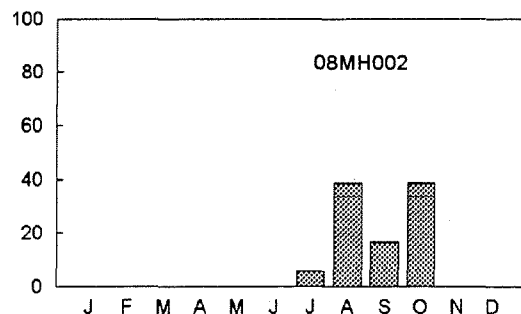


# Water use as a proportion of the 7 day low flow

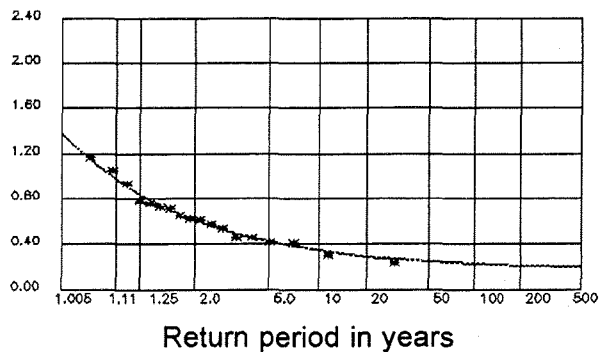
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	0.61 m <sup>3</sup> /s	0.34 m <sup>3</sup> /s	0.29 m <sup>3</sup> /s	0.24 m <sup>3</sup> /s	0.22 m <sup>3</sup> /s
<b>Annual Flood</b>	62.0 m <sup>3</sup> /s	117.5 m <sup>3</sup> /s	143.3 m <sup>3</sup> /s	181.0 m <sup>3</sup> /s	212.3 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The Coquitlam Reservoir is the largest reservoir in the Habitat Management Area. It is owned and operated by B.C.Hydro and is used to divert water to Buntzen Lake for power generation. The reservoir also provides water to the Greater Vancouver Water District. Fisheries and Oceans Canada and B.C.Hydro have recently signed an agreement that provides minimum flows from the dam that are adjusted monthly to suit the various species life cycle requirements. Funds are also committed for restoration and enhancement.*

*2. Sediment production from gravel pits and from the Westwood Plateau is still a problem. Present agreements with gravel pit operators may not be satisfactory.*

# COUGAR CANYON CR.

## LICENSED WATER DEMAND

Stream number 00-0160

Ungauged

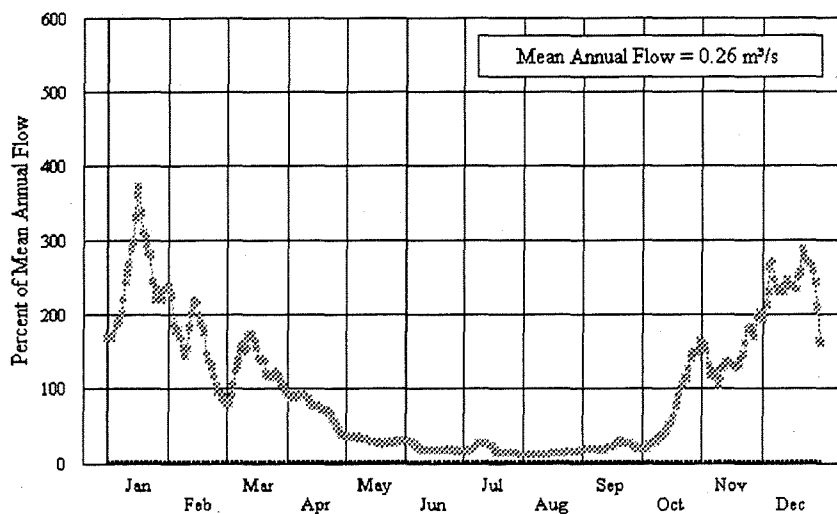
South Shore tributary to Fraser River

Drainage Area = 7.4 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S			30	40

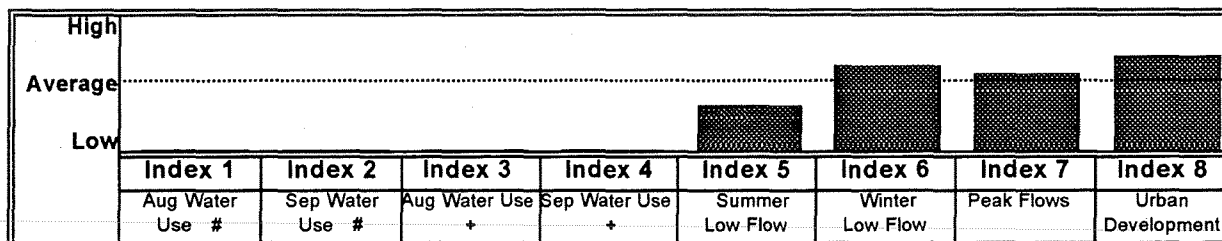
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# COUGAR CANYON CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Cougar Canyon Creek drains a residential area with a high effective impervious area. The creek, which flows in a ravine, is eroding its banks and the valley walls. Gabions were installed to stabilize the lower slopes but they have fallen apart over the years.*
- 2. The reach near the mouth, used by chinook and chum juveniles, parallels two sewer trunk main lines and the railroad. Delta municipality plans to construct a road on the top of the lines, which could severely affect the creek. Annual dredging of a section along the railway also causes problems.*
- 3. The Cougar Canyon Enhancement Society runs a small coho incubator on the creek. It is occasionally damaged by large floods.*

# SCOTT CREEK

## LICENSED WATER DEMAND

Stream number

Ungauged

South Shore tributary to Fraser River

Drainage Area = 4.8 km<sup>2</sup>

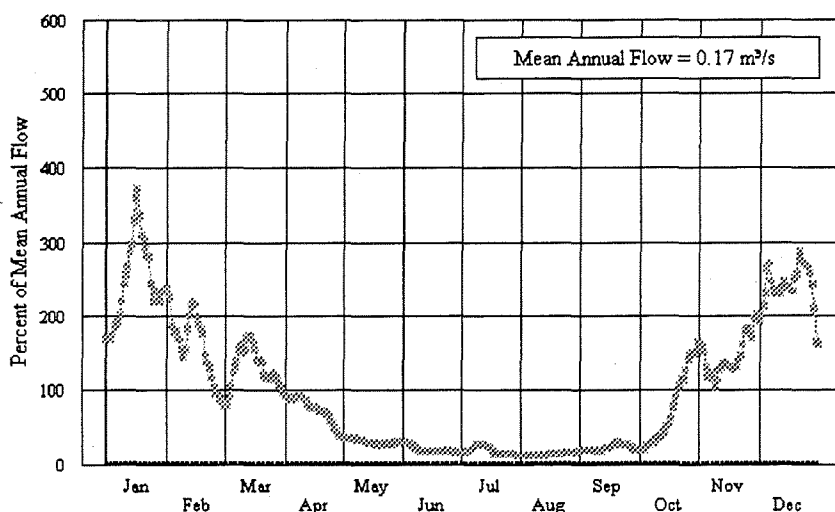
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S		20	30
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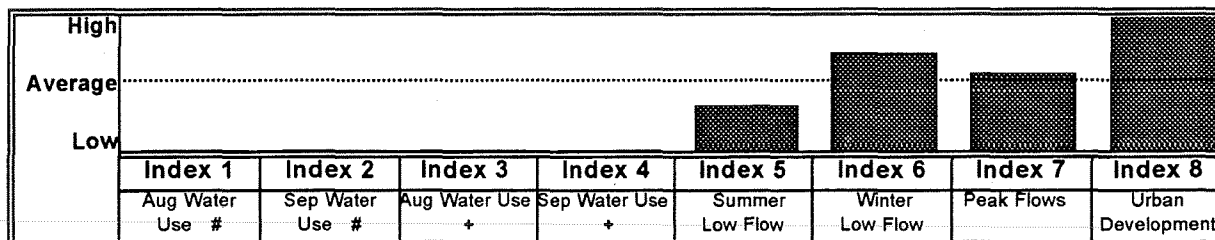
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# SCOTT CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is suitable fish habitat in the lower , flat reaches of Scott Creek. Fish access was improved during highway work for the Alex Fraser Bridge. Additional highway widening work, involving better designed culverts, is providing more opportunities for fish access.*



# BON ACCORD CREEK

## LICENSED WATER DEMAND

Stream number 00-0170

Ungauged

South Shore tributary to Fraser River

Drainage Area = 5.3 km<sup>2</sup>

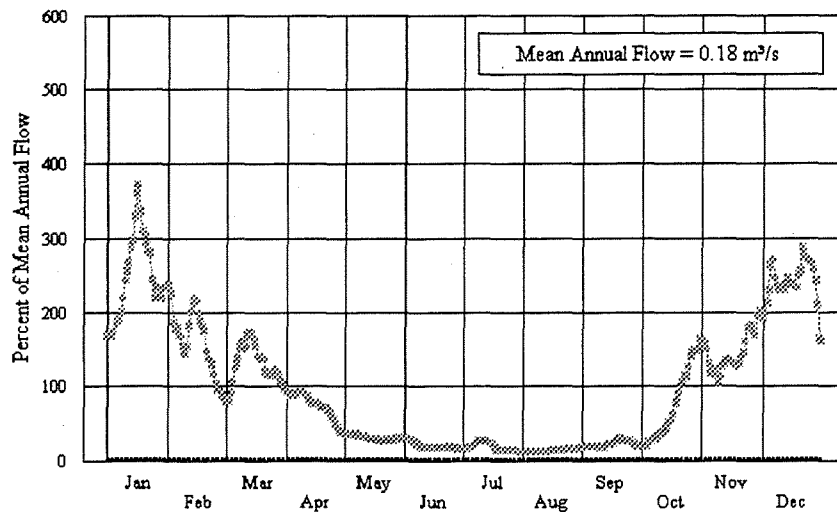
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S		20	30
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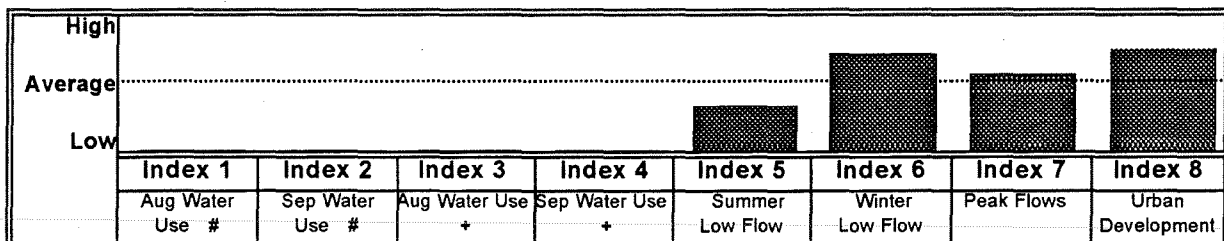
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# BON ACCORD CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is a potential passage problem at the lower end of Bon Accord Creek because of a long culvert beneath the rail yard. As the creek passes through a municipal park some protection is provided.*

*2. One of the tributaries has good fish habitat because of groundwater inflow, but leave strips are too narrow.*

*3. An old timber dam about one kilometre from the mouth provides a large pool with resident cutthroat. The dam is believed to be passable to upstream migrants because of its poor condition.*

# UNNAMED CREEK

Stream number 00-0170-0220

Ungauged

Flows into Bonaccord Creek

Drainage Area = 3.8 km<sup>2</sup>

## LICENSED WATER DEMAND

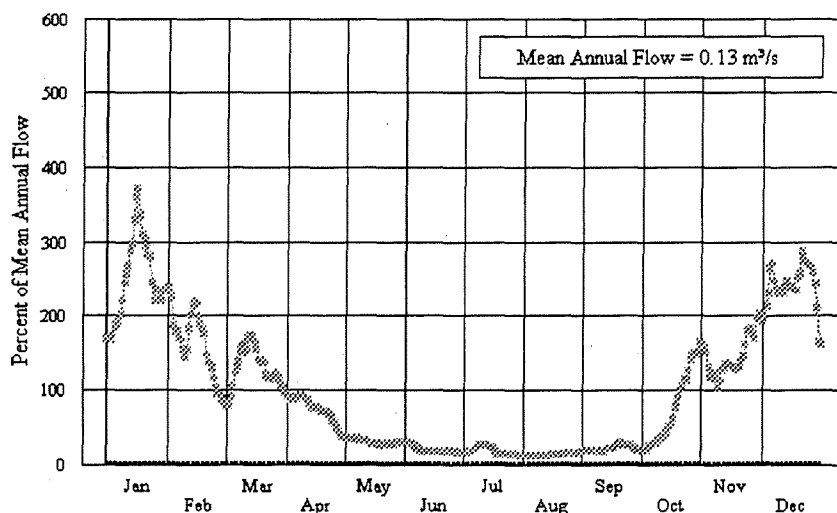
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S		20	20
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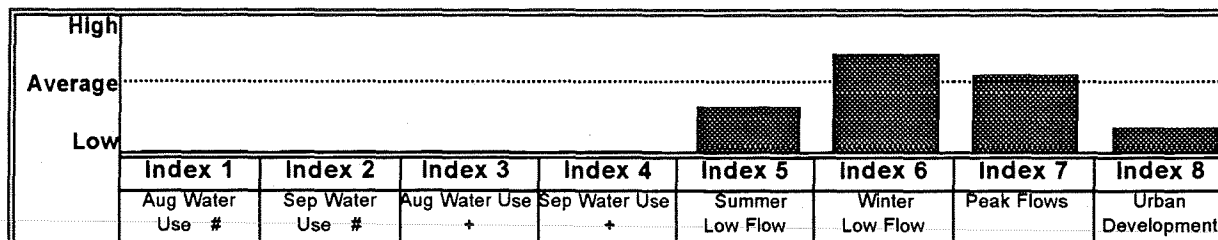
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# UNNAMED CREEK 00-0170-0220

## SUMMARY NOTES AND RECOMMENDATIONS

*1. This creek is a tributary of Bonaccord Creek. There are no water licences on the creek and urban development is relatively low.*

# UNNAMED CREEK

Stream number 00-0170-0230

Ungauged

Flows into Bonaccord Creek

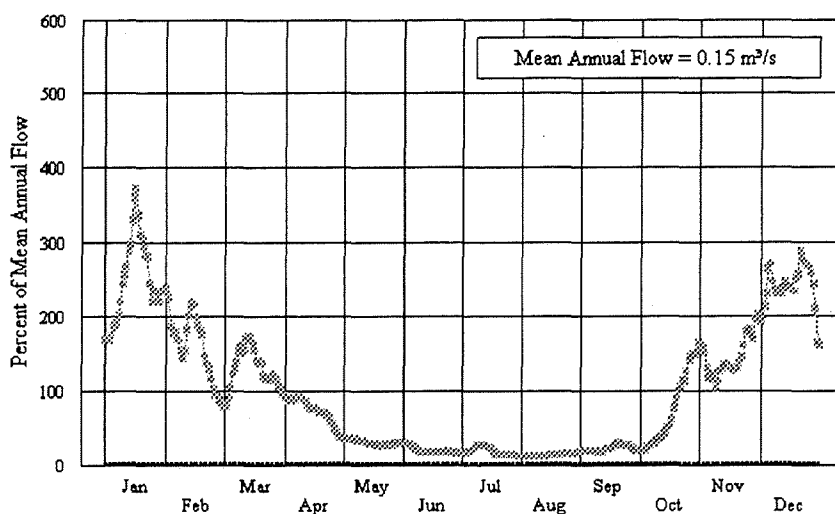
Drainage Area = 4.4 km<sup>2</sup>

## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S			20	20

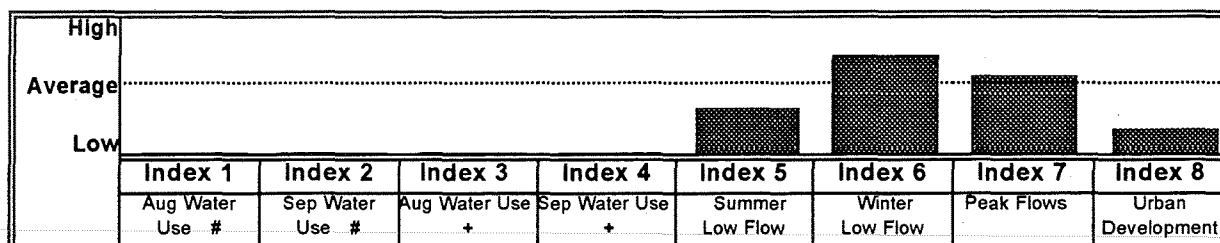
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



## 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

# UNNAMED CREEK 00-0170-0230

## SUMMARY NOTES AND RECOMMENDATIONS

*1. This creek is a tributary of Bonaccord Creek. There are no water licences on the creek and urban development is relatively low.*

# YORKSON CREEK

Stream number 00-0260

Water Survey of Canada Station 08MH097

Yorkson Creek near Walnut Grove

Records 1960 to 1978

Drainage Area = 5.96 km<sup>2</sup>

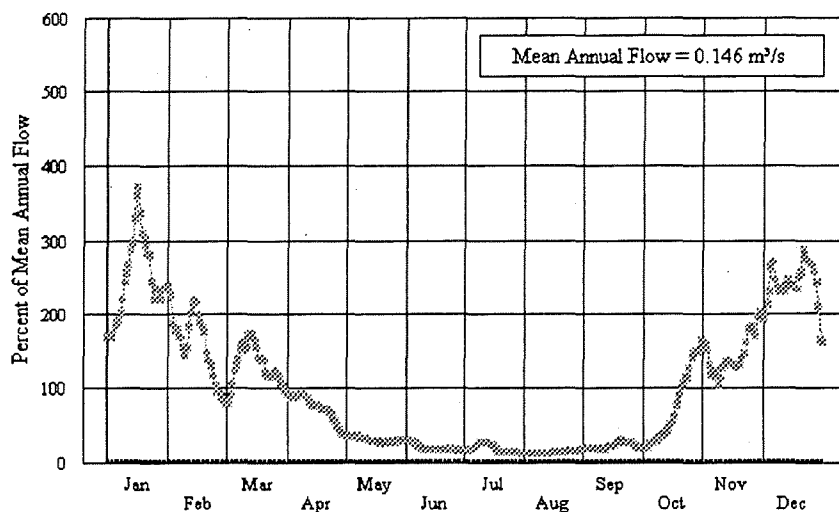
## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2000 g/d	0.11	0.11	0.11
Irrigation	10 ac.ft.		1.38	0.71
Waterworks	0 g/d			
Industrial	501 g/d	0.03	0.03	0.03
Conservation	0 cfs			

Feb Aug Sep

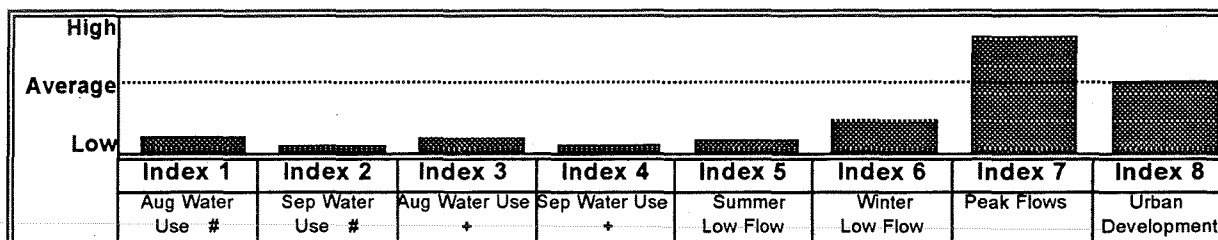
MEAN STREAM FLOW L/S	257	20	33
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## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

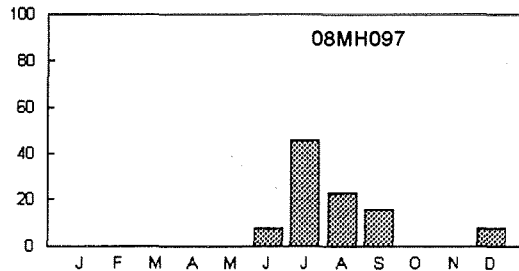


# Water use as a proportion of the 7 day low flow

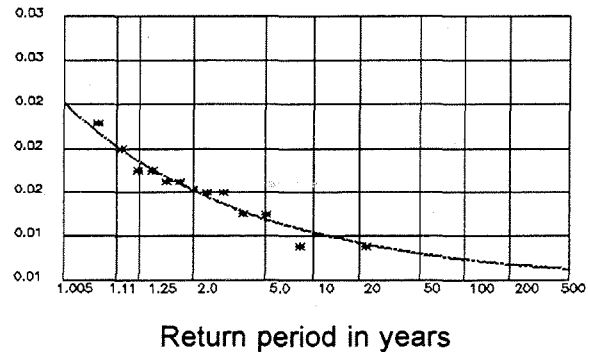
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	0.016 m <sup>3</sup> /s	0.012 m <sup>3</sup> /s	0.011 m <sup>3</sup> /s	0.010 m <sup>3</sup> /s	0.010 m <sup>3</sup> /s
Annual Flood	2.9 m <sup>3</sup> /s	4.8 m <sup>3</sup> /s	5.5 m <sup>3</sup> /s	6.4 m <sup>3</sup> /s	7.1 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The lower part of Yorkson Creek is in an industrial zone where land filling of the floodplain extends to the edge of the creek.*
- 2. Urban land development, particularly at Walnut Grove, is encroaching along parts of the creek. There has been an increase in sediment loading and an increase in flood flows, apparently resulting from inadequate stormwater detention storage.*
- 3. The upper tributaries, particularly East Mundy Creek, suffer from extreme summer flows, although fish access to these areas has been improved by baffles in culverts.*
- 4. The local municipality and DFO originally cooperated in developing a stormwater management plan. Setbacks from the creek were also laid out to limit urban development impact. There has been no further study to determine if the plans or guidelines were followed or if they were successful.*



# SALMON RIVER

## LICENSED WATER DEMAND

Stream number 00-0300

Water Survey of Canada Station 08MH090

Salmon River at 72nd Avenue Langley

Records 1960 to 1990

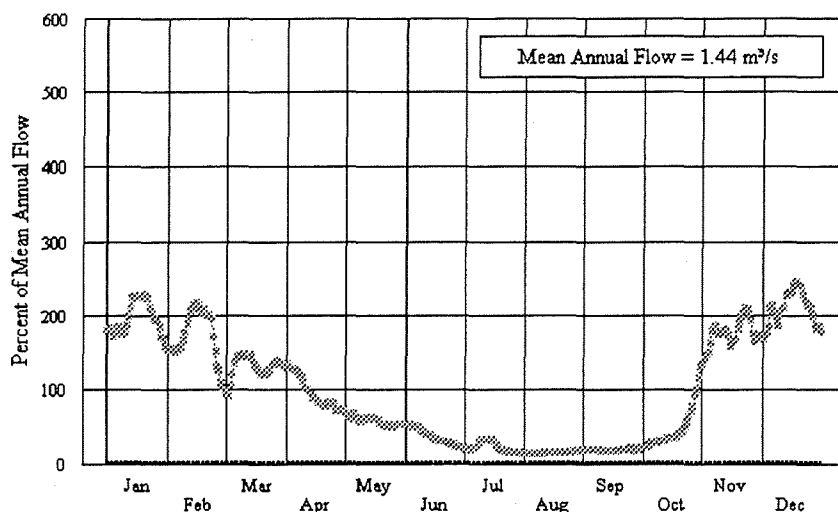
Drainage Area = 49 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	5,100 g/d	0.27	0.27	0.27
Irrigation	282 ac.ft.		39.0	20.1
Waterworks	0 g/d			
Industrial	30,000 g/d	1.58	1.58	1.58
Conservation	0 cfs			

Feb Aug Sep

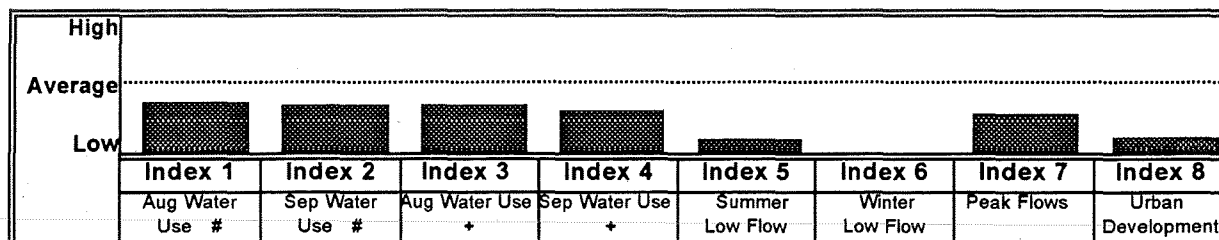
MEAN STREAM FLOW L/S	2,670	244	337
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## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

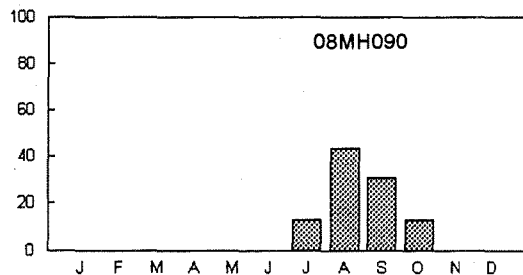


# Water use as a proportion of the 7 day low flow

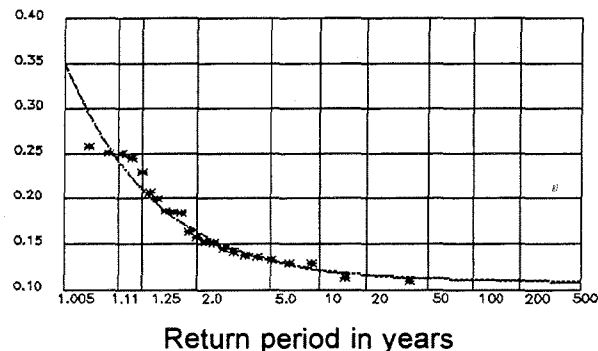
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	0.163 m <sup>3</sup> /s	0.121 m <sup>3</sup> /s	0.116 m <sup>3</sup> /s	0.112 m <sup>3</sup> /s	0.110 m <sup>3</sup> /s
Annual Flood	16.7 m <sup>3</sup> /s	31.0 m <sup>3</sup> /s	37.8 m <sup>3</sup> /s	47.7 m <sup>3</sup> /s	56.0 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Irrigation licenses along the lower part of Salmon River account for a significant portion of summer low flows, although no water shortages have been reported.*
- 2. The river is reported to have a more rapid response to rainfall than some of the other streams, due possibly to the prevalence of field drainage channels.*
- 3. Overwintering habitat may be limiting. Entrances to some side channels are well above the main channel, probably a result of downcutting of the main channel. This causes the side channels to remain dry most of the year.*
- 4. There are plans to restore riparian vegetation along parts of the river.*

# COGHLAN CREEK

Stream number 00-0300-200

Ungauged

Tributary to Salmon River

Drainage Area = 14.2 km<sup>2</sup>

## LICENSED WATER DEMAND

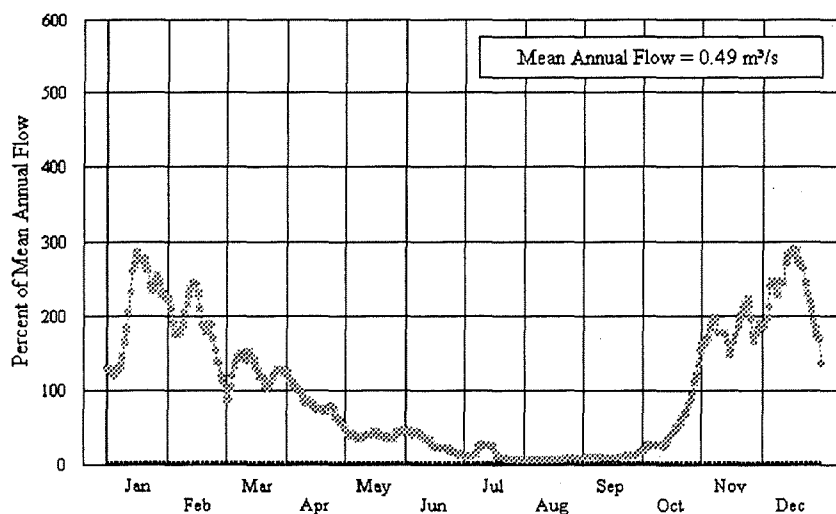
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2,100 g/d	0.11	0.11	0.11
Irrigation	139 ac.ft.		19.2	9.9
Waterworks	0 g/d			
Industrial	15,000 g/d	0.79	0.79	0.79
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		60	60

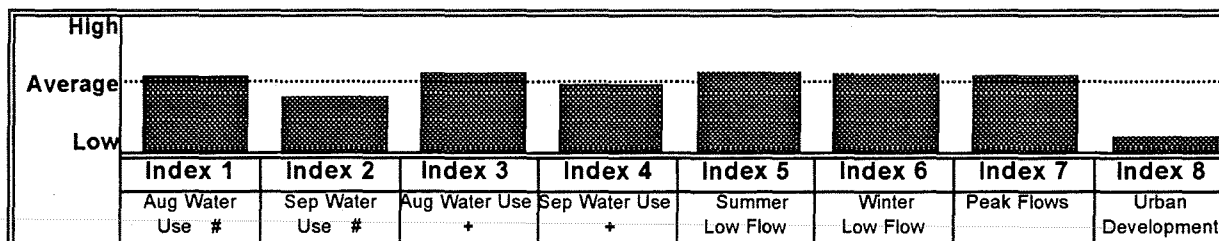
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# COGHLAN CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Coghlan Creek has a RNW (refused, no water) status with the Water Management Branch, although the indices for summer water use and low flows are not as severe as for some other streams.*

# UNNAMED CREEK

Stream number 00-0300-150

Ungauged

Flows into Salmon River

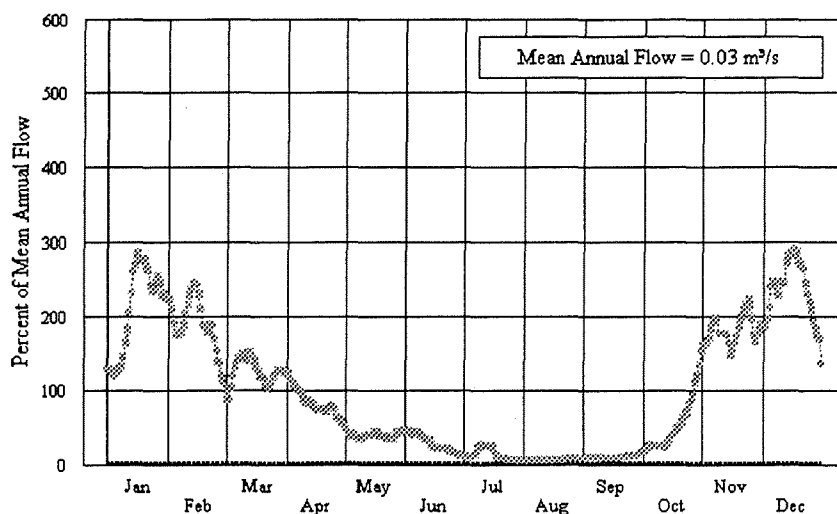
Drainage Area = 0.9 km<sup>2</sup>

## LICENSED WATER DEMAND

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

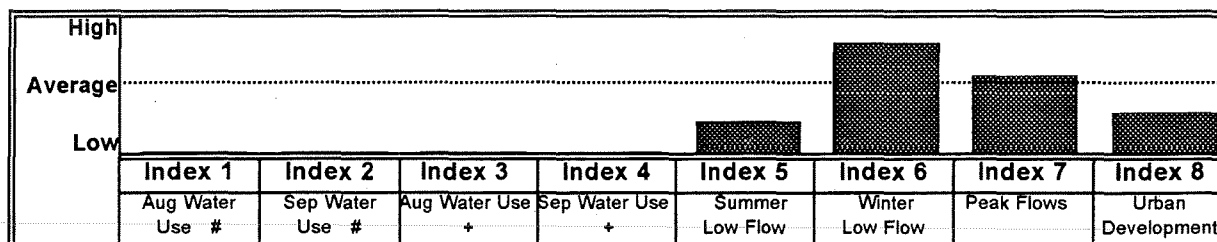
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# UNNAMED CREEK 00-0300-150

## SUMMARY NOTES AND RECOMMENDATIONS

*1. This creek is a tributary of the Salmon River. There are no water licences on the creek and urban development is moderate.*

# WEST CREEK

Stream number 00-0330

Water Survey of Canada Station 08MH098

West Creek near Fort Langley

Records 1960 to 1990

Drainage Area = 11.4 km<sup>2</sup>

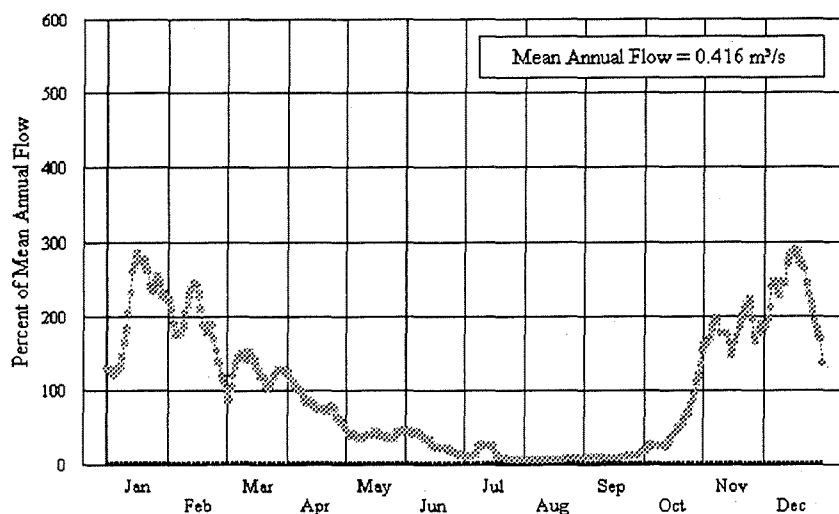
## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	500 g/d	0.03	0.03	0.03
Irrigation	45 ac.ft.		6.22	3.21
Waterworks	0 g/d			
Industrial	1,077,102g/d	56.7	56.7	56.7
Conservation	0 cfs			

Feb Aug Sep

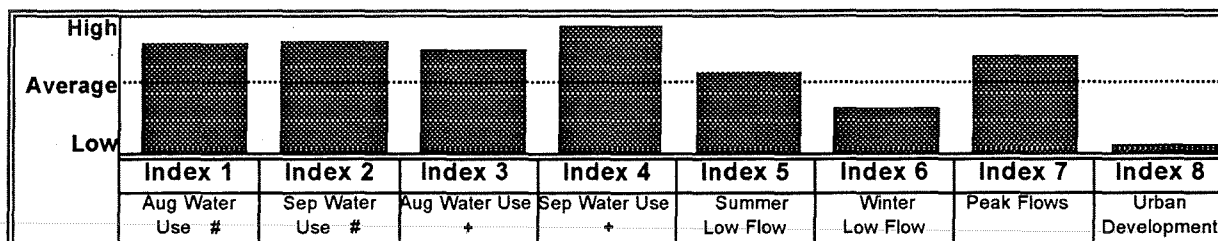
MEAN STREAM FLOW L/S	827	29	48
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## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

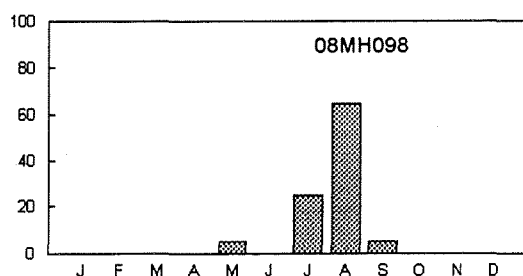


# Water use as a proportion of the 7 day low flow

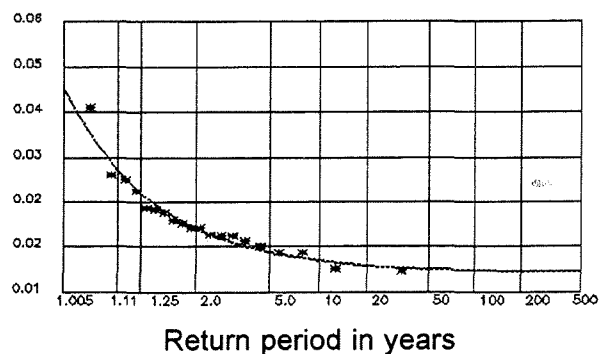
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	0.019 m <sup>3</sup> /s	0.013 m <sup>3</sup> /s	0.012 m <sup>3</sup> /s	0.012 m <sup>3</sup> /s	0.012 m <sup>3</sup> /s
<b>Annual Flood</b>	7.4 m <sup>3</sup> /s	12.9 m <sup>3</sup> /s	14.9 m <sup>3</sup> /s	17.4 m <sup>3</sup> /s	19.3 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The lower reaches of West Creek provide habitat for immigrant salmon from the Fraser River. There is also a small wetland near the mouth. The floodplain along the lower river lies in the Agricultural Land Reserve which allows farmers to reclaim and improve their land by filling parts of the floodplain.*

*2. The upper river is in a ravine in a lightly developed area. Low flows may be limiting fish habitat in this area.*



# NATHAN CREEK

## LICENSED WATER DEMAND

Stream number 00-0360

South Shore tributary to Fraser River

Drainage Area = 33.8 km<sup>2</sup>

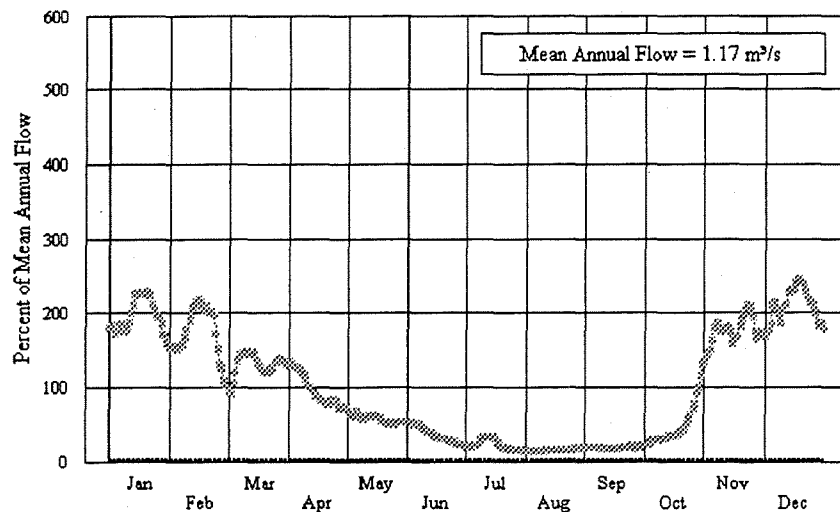
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	4000 g/d	0.21	0.21	0.21
Irrigation	30 ac.ft.		4.15	2.14
Waterworks	0 g/d			
Industrial	674,106 g/d	35.5	35.5	35.5
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S		150	180
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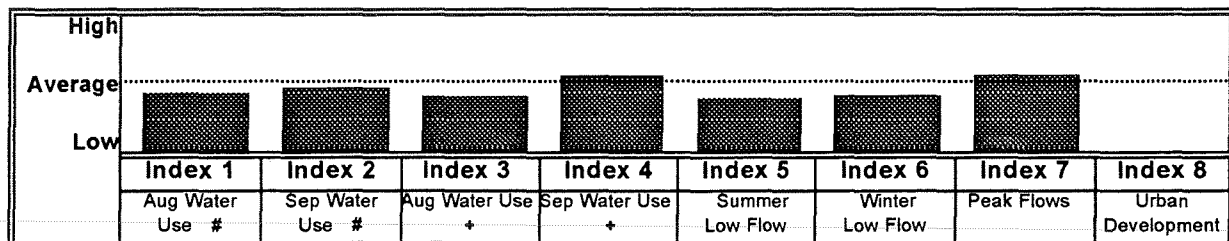
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Salmon River station 08MH090)



## 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

# NATHAN CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The lower two kilometres of Nathan Creek have been straightened and channelized. Regular removals of gravel are required to maintain the channel and reduce flooding. Excavations by farmers provide pools along the lower reach.*

*2. Most of the watershed is agricultural. Resultant encroachment onto the stream, filling of the floodplain and bank protection all affect the channel. Water quality problems also result from farming. Riparian vegetation has been removed and the lower reaches have high water temperatures in the summer.*

*3. Nathan Creek provides substantial rearing habitat. Groundwater inflows maintain moderately high base flows and suitable temperatures during the summer, though low flows may limit production in the upper tributaries. Fencing is required to keep cattle out of the stream.*

*4. Nathan Slough, once a side channel of Nathan Creek, is no longer connected to the main channel. It has potential for fish habitat if reconnected.*

# HANNA CREEK

Stream number 00-0425

Ungauged

South Shore tributary to Fraser River

Drainage Area = 8.1 km<sup>2</sup>

## LICENSED WATER DEMAND

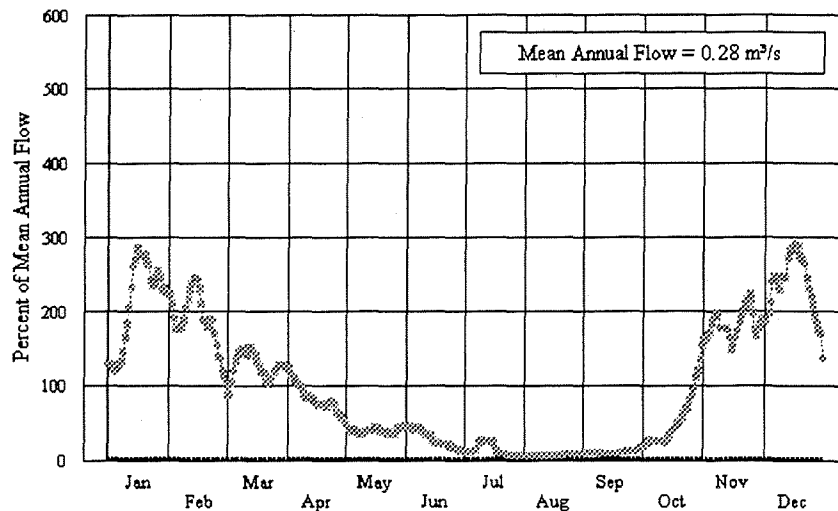
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	3,000 g/d	0.16	0.16	0.16
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	2,000 g/d	0.11	0.11	0.11
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		30	40

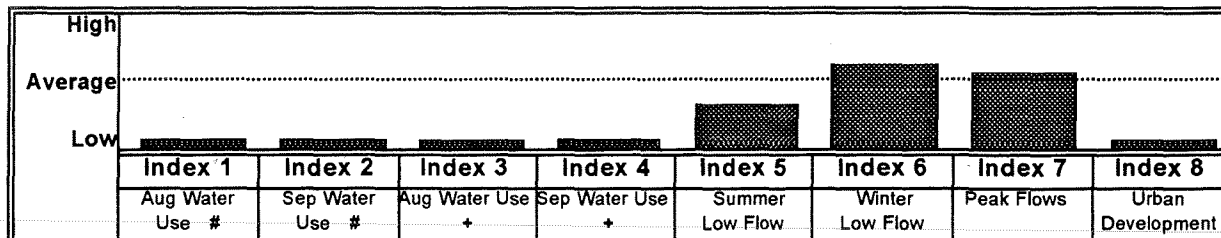
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# HANNA CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Hanna Creek seems not to have any water use problems at the present time. Urban development is relatively low. Winter low flows are a little more severe than other streams in the area.*

# COLIGNY CREEK

Stream number 00-0438

Ungauged

South Shore tributary to Fraser River

Drainage Area = 3.6 km<sup>2</sup>

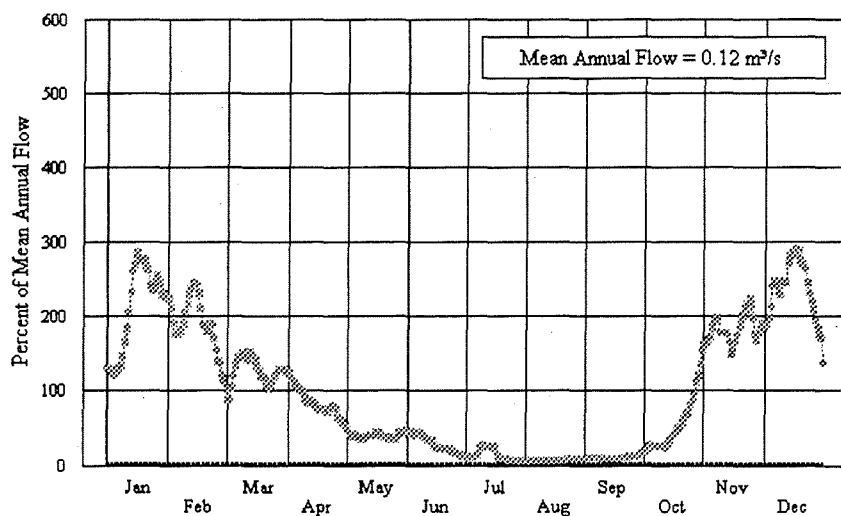
## LICENSED WATER DEMAND

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

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		20	20

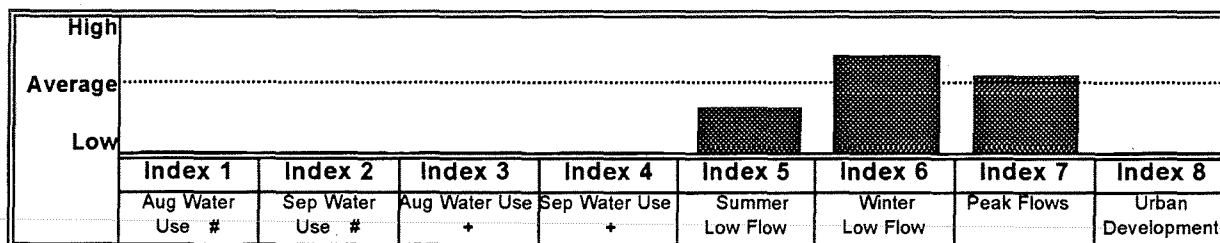
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# COLIGNY CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There is good habitat in Coligny Creek, although the upper reaches may go dry naturally. The local Indian Band has recently cleaned the channel, improved fish access, and are building a hatchery.*

# McLENNAN CREEK

## LICENSED WATER DEMAND

Stream number 00-0440-010

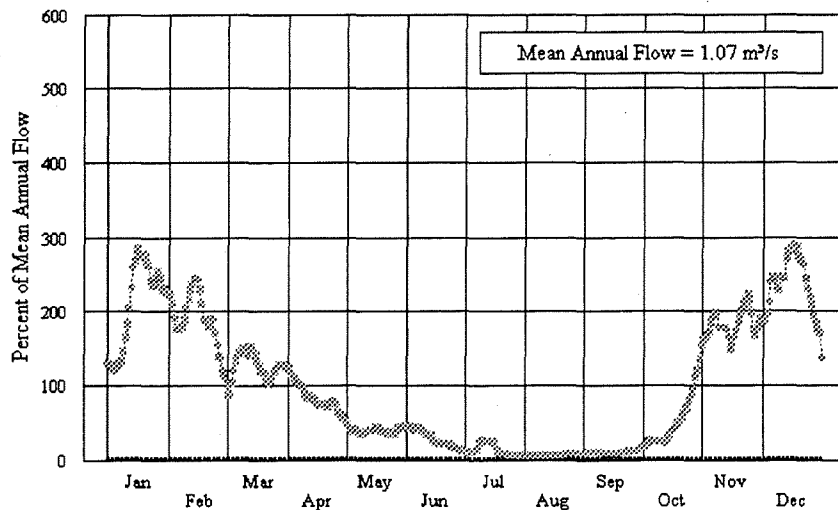
South Shore tributary to Fraser River

Drainage Area = 30.9 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	4,750 g/d	0.25	0.25	0.25
Irrigation	73 ac.ft.		10.1	5.21
Waterworks	0 g/d			
Industrial	14,610 g/d	0.77	0.77	0.77
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S			110	120

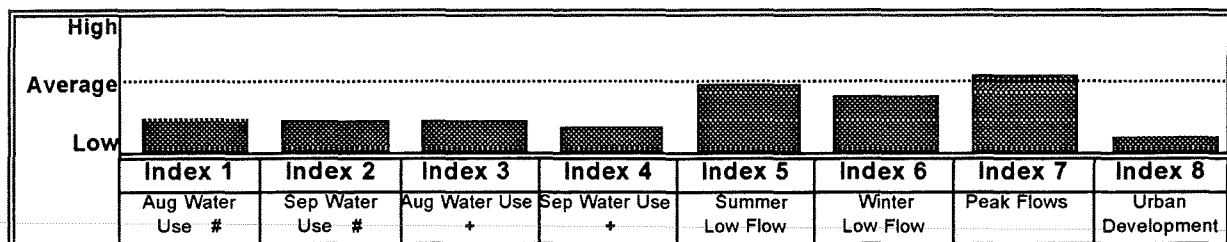
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# McLENNAN CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There appears to be few problems with respect to water use at the present time in the McLennan Creek watershed.*



# GIFFORD SLOUGH

Stream number 00-0440

South Shore tributary to Fraser River

Drainage Area = 14.4 km<sup>2</sup>

## LICENSED WATER DEMAND

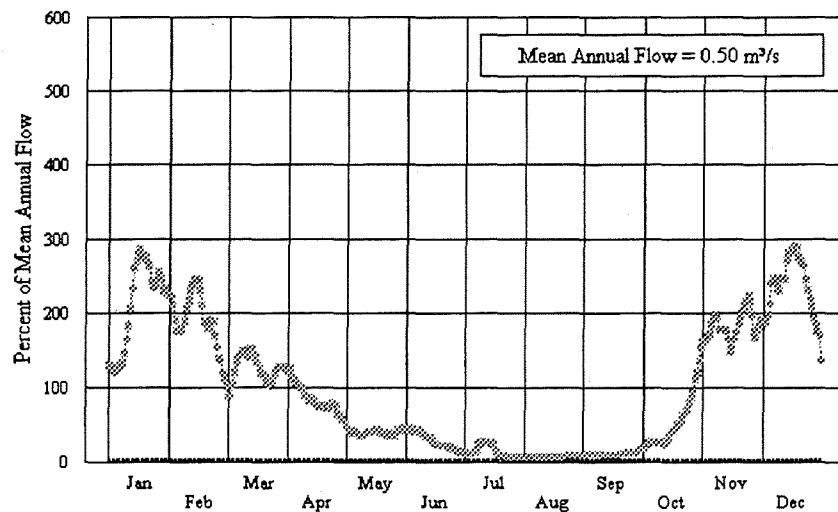
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,000 g/d	0.05	0.05	0.05
Irrigation	51 ac.ft.		7.05	3.64
Waterworks	0 g/d			
Industrial	4,500 g/d	0.24	0.24	0.24
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S		60	70
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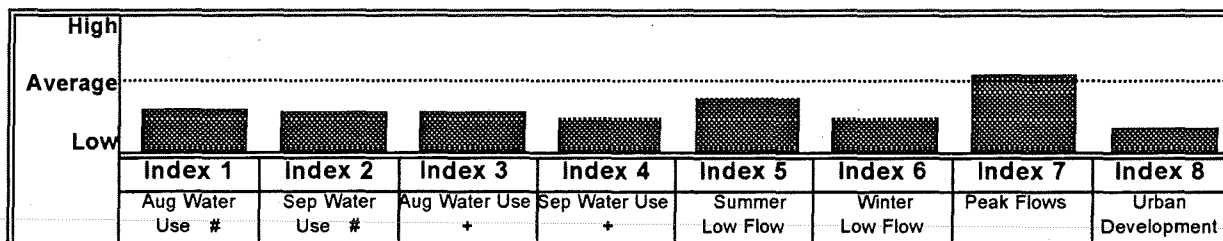
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# GIFFORD SLOUGH

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. Gifford Slough has been straightened and channelized in the lower reaches and riparian vegetation has been removed. Water velocities are very low during the summer in the lower reaches , though these reaches are reported to provide some habitat in the fall and winter.*
- 2. The municipality is interested in annual dredging to improve drainage and reduce overbank flooding.*
- 3. An ARDSA community irrigation project is being planned. It would include expansion of a network of ditches along Matsqui Slough, Gifford Slough and Clayburn Creek; and pumping from the Fraser River.*

# DOWNES CREEK

Stream number 00-0440-020

South Shore tributary to Fraser River

Drainage Area = 6.4 km<sup>2</sup>

## LICENSED WATER DEMAND

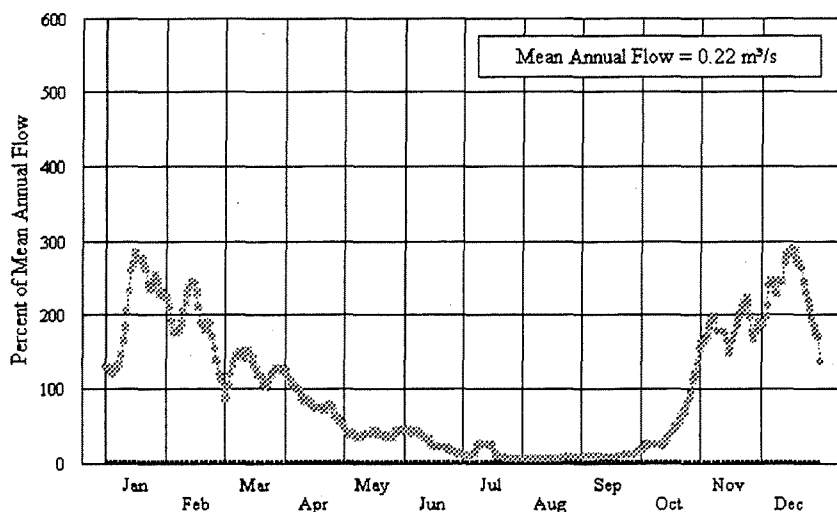
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,000 g/d	0.05	0.05	0.05
Irrigation	1 ac.ft.		0.14	0.07
Waterworks	0 g/d			
Industrial	4,500 g/d	0.24	0.24	0.24
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		30	30

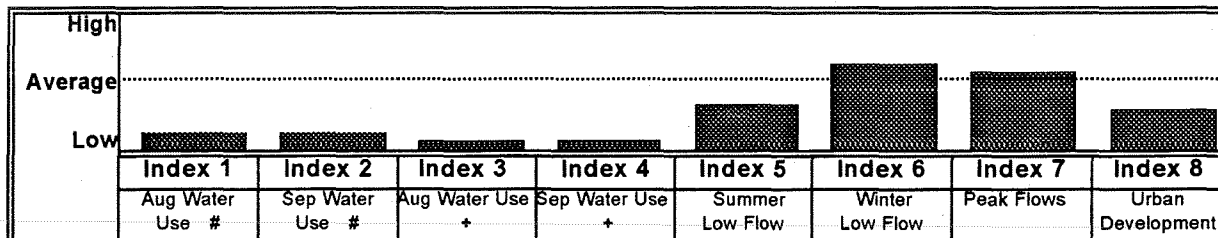
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# DOWNES CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. There appears to be few problems with respect to water use at the present time in the Downes Creek watershed.*

# MATSQUI SLOUGH

## LICENSED WATER DEMAND

Stream number 00-0460

South Shore tributary to Fraser River

Drainage Area = 69.3 km<sup>2</sup>

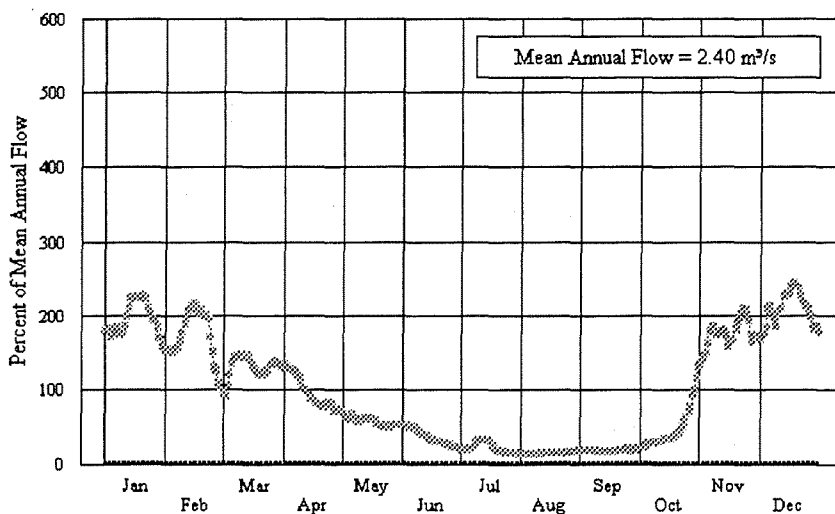
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	23,900 g/d	1.26	1.26	1.26
Irrigation	850 ac.ft.		117.5	60.7
Waterworks	0 g/d			
Industrial	1,208,155g/d	63.6	63.6	63.6
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		230	230

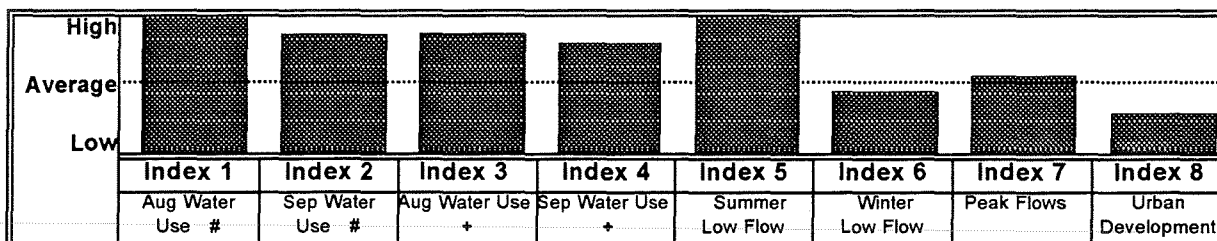
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Salmon River station 08MH090)



## 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

# MATSQUI SLOUGH

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The lower reaches of Matsqui Slough have been channelized and straightened, and riparian vegetation has been removed. There is a proposal for further dredging to improve agricultural drainage and reduce overbank flooding.*

*2. An ARDSA community irrigation project is being planned. It would include expansion of a network of ditches along Matsqui Slough, Gifford Slough and Clayburn Creek; and pumping from the Fraser River.*

# CLAYBURN CREEK

## LICENSED WATER DEMAND

Stream number 00-0460-010

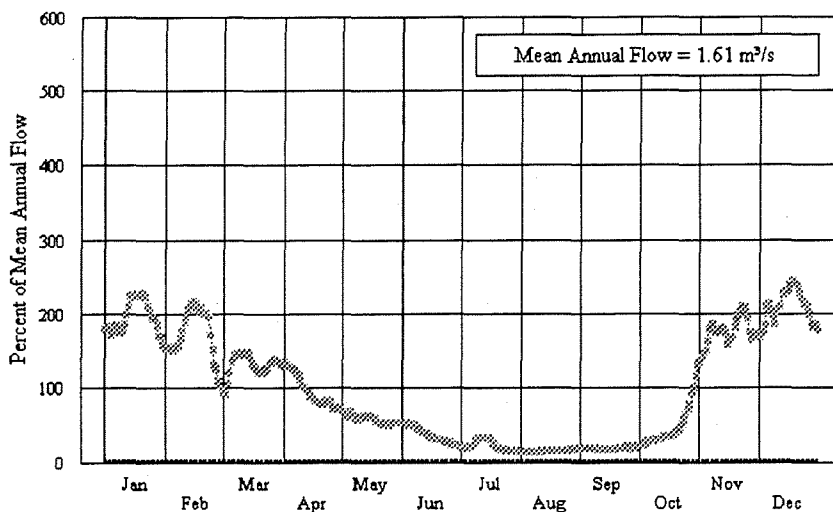
South Shore tributary to Fraser River

Drainage Area = 46.6 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	21,400 g/d	1.26	1.26	1.26
Irrigation	460 ac.ft.		117.5	60.7
Waterworks	0 g/d			
Industrial	1,126,235g/d	63.6	63.6	63.6
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S			160	170

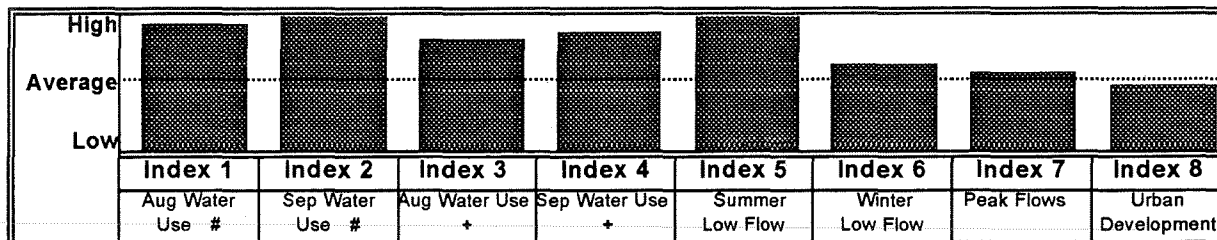
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Salmon River station 08MH090)



## 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

# CLAYBURN CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. An ARDSA community irrigation project is being planned. It would include expansion of a network of ditches along Matsqui Slough, Gifford Slough and Clayburn Creek; and pumping from the Fraser River.*



# WILLBAND CREEK

Stream number 00-0460-010-020

Tributary to Clayburn Creek

Drainage Area = 13.5 km<sup>2</sup>

## LICENSED WATER DEMAND

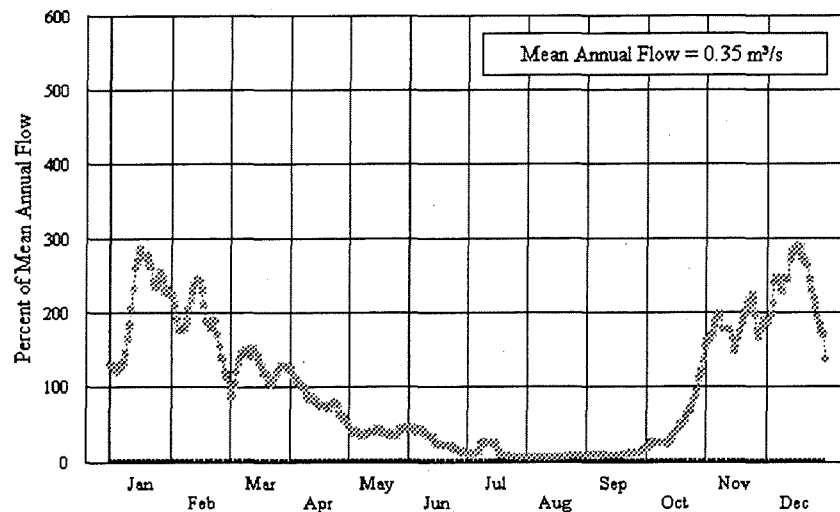
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	8,500 g/d	0.45	0.45	0.45
Irrigation	195 ac.ft.		26.95	13.92
Waterworks	0 g/d			
Industrial	93,500 g/d	4.90	4.90	4.90
Conservation	0 cfs			

Feb Aug Sep

MEAN STREAM FLOW L/S	Feb	Aug	Sep
		40	50

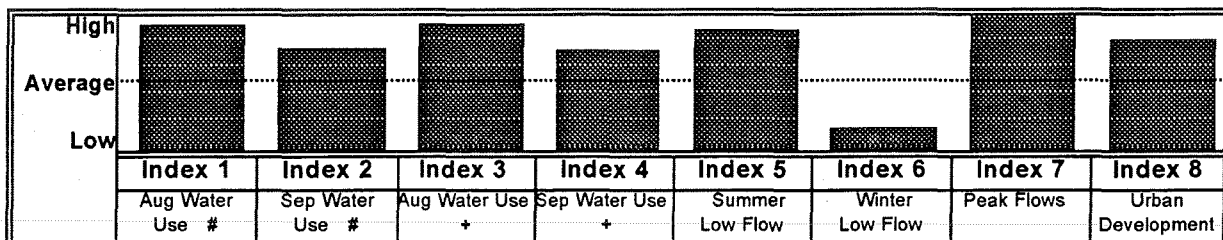
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# WILLBAND CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Potential water use and urbanization in the Willband Creek watershed are concerns.*

# STONEY CREEK

## LICENSED WATER DEMAND

Stream number 00-0460-010-022

Tributary to Clayburn Creek

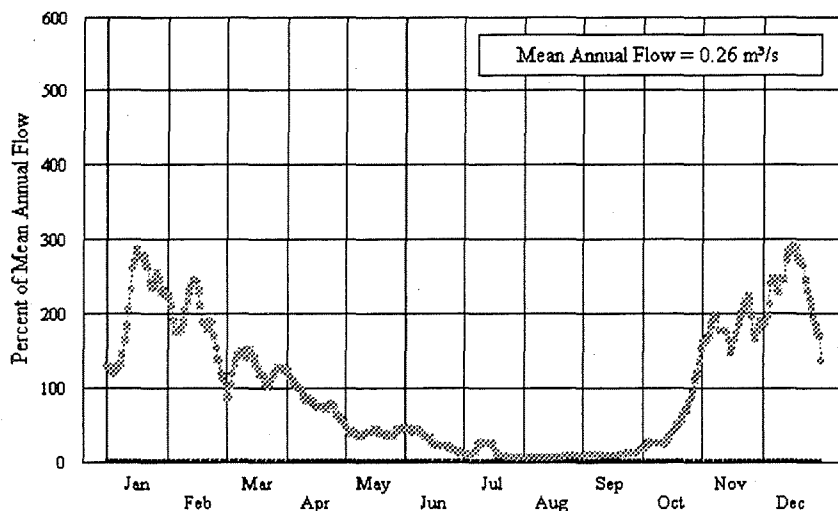
Drainage Area = 7.6 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	6,000 g/d	0.32	0.32	0.32
Irrigation	73 ac.ft.		10.09	5.21
Waterworks	0 g/d			
Industrial	5,000 g/d	0.26	0.26	0.26
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		30	40

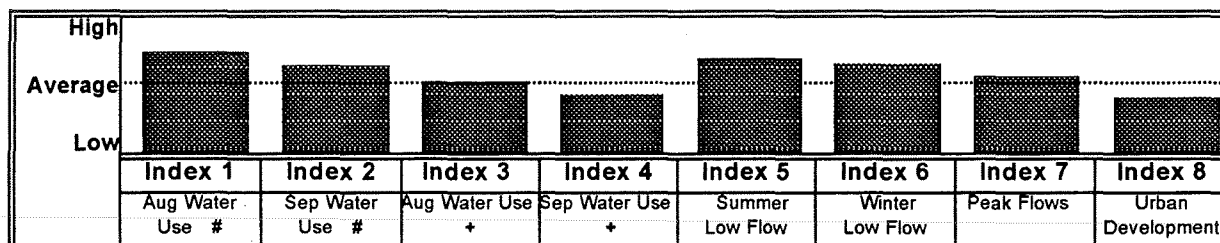
## MEAN ANNUAL HYDROGRAPH

(Estimated, using West Creek station 08MH098)



## 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

# STONEY CREEK

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Stoney Creek provides productive habitat with good gravel and water quality, but it has been encroached upon by a pipeline and service road paralleling the creek.*

*2. Flood peaks have apparently increased because of urban development with little, or ineffective, stormwater detention. Erosion along the creek contributes to chronic siltation problems.*

# SERPENTINE RIVER

Stream number 90-0200

Flows into Boundary Bay

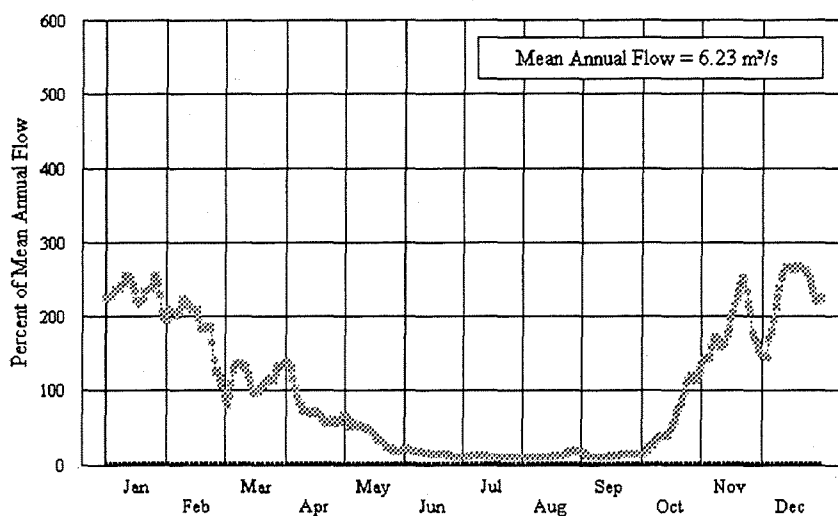
Drainage Area = 154.2 km<sup>2</sup>

## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	2,150 g/d	0.11	0.11	0.11
Irrigation	1,368 ac.ft.		189.0	97.7
Waterworks	0 g/d			
Industrial	4,119,571g/d	216.8	216.8	216.8
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S			1,120	1,210

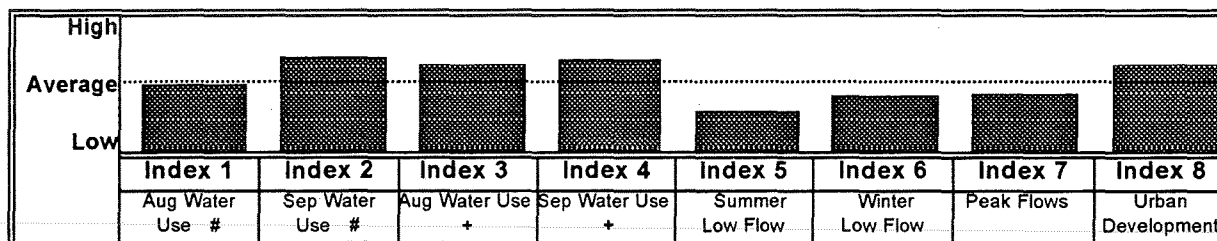
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Nicomekl River station 08MH050)



## 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

# SERPENTINE RIVER

## SUMMARY NOTES AND RECOMMENDATIONS

*1. The Serpentine River is the most urbanized of the large streams within the Fraser Delta HMA. Irrigation in the lower reaches imposes a considerable demand on summer low flows and there are a number of outstanding water license applications. Water velocities are very low in the lower reaches in the summer and water temperatures often exceed 23°C. The lower river is dyked and riparian vegetation has been removed.*

*2. Agriculture affects water quality in the lower reaches. Leachate from corn silage has a very high dissolved oxygen demand and produces slugs of water with no oxygen. Farmers also may be over-fertilizing.*

*3. Several of the tributaries provide fish habitat. Latimer Creek has limited habitat because of agricultural drainage, high temperatures and low dissolved oxygen. Highland Creek has several small tributaries with groundwater inflow in summer, but flows in the main channel are near zero in summer and the discharge passes through the gravel substrate.*

*4. The Serpentine Enhancement Society operates a hatchery at Tynehead Park. The City of Surrey enhanced Hyland Creek through bridging, side channels, creation of instream habitat and riparian planting.*

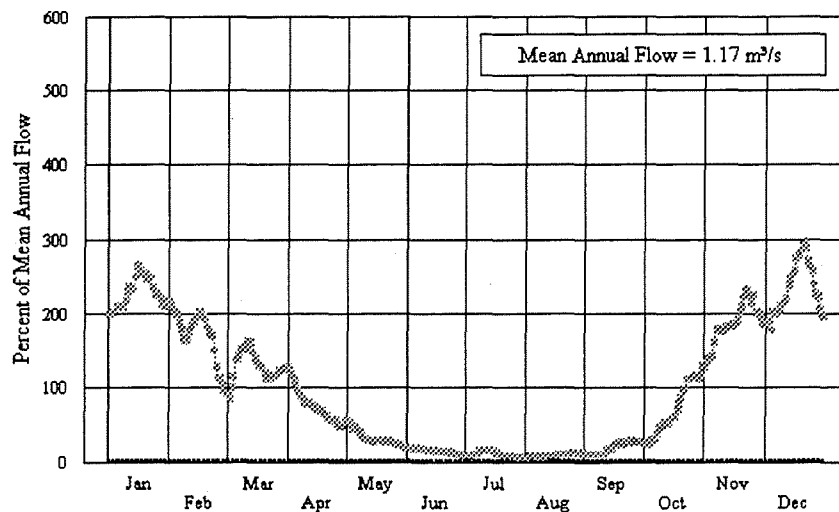
# MAHOOD CREEK

Stream number 90-0200-020  
 Water Survey of Canada Station 08MH020  
 Mahood Creek near Sullivan  
 Records 1926 to 1980  
 Drainage Area = 34.4 km<sup>2</sup>

## LICENSED WATER DEMAND

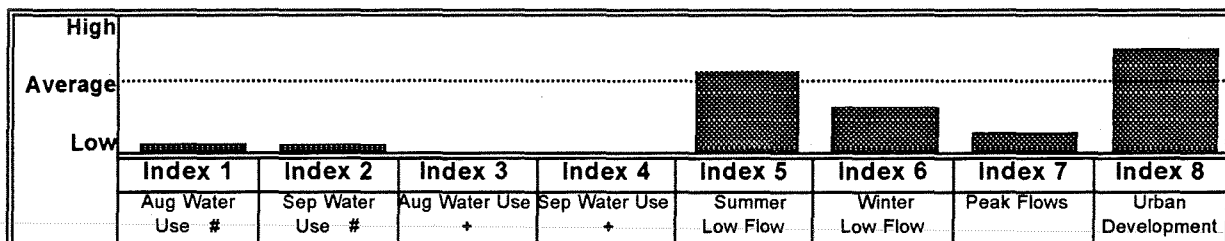
Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	1 ac.ft.		0.14	0.07
Waterworks	0 g/d			
Industrial	11,000 g/d	0.58	0.58	0.58
Conservation	0 cfs			
		Feb	Aug	Sep
MEAN STREAM FLOW L/S		2,020	132	223

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

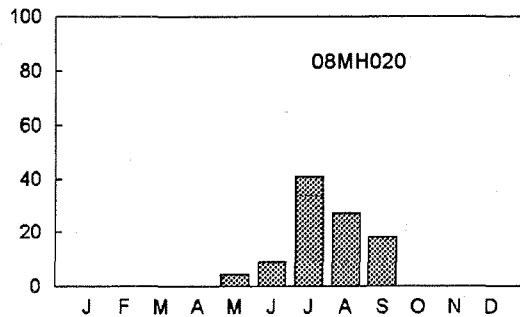
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



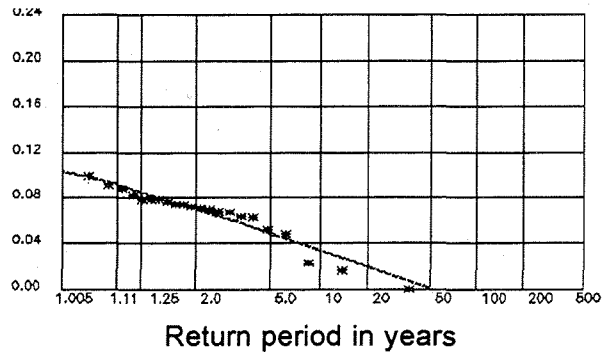
- # Water use as a proportion of the 7 day low flow
- + Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	0.070 m <sup>3</sup> /s	0.034 m <sup>3</sup> /s	0.019 m <sup>3</sup> /s	0.0 m <sup>3</sup> /s	
<b>Annual Flood</b>	15.9 m <sup>3</sup> /s	25.4 m <sup>3</sup> /s	28.6 m <sup>3</sup> /s	32.6 m <sup>3</sup> /s	35.5 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Mahood Creek has extreme low flows in the summer and flooding and erosion in the winter. One of the first urban developments in Surrey took place in its watershed.*



# NICOMEKL RIVER

Stream number 90-0100

Water Survey of Canada Station 08MH050

Nicomekl River at 192nd Street

Records 1952 to 1963

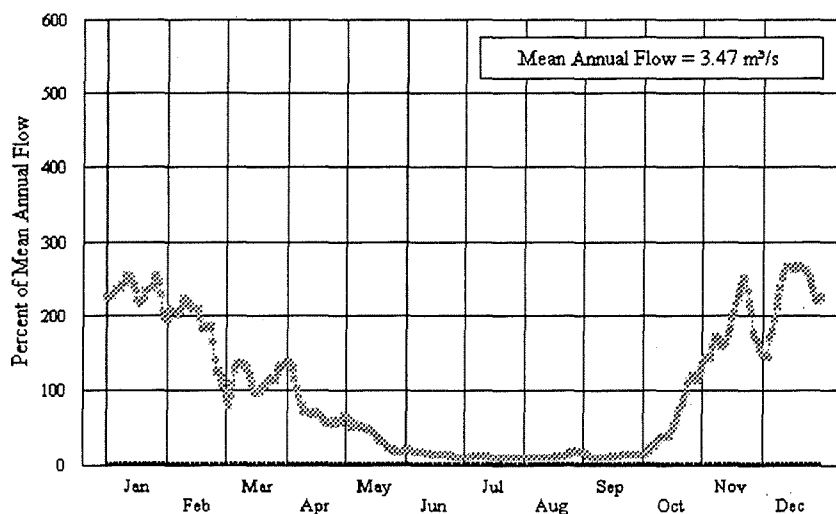
Drainage Area = 99.5 km<sup>2</sup>

## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	8,900 g/d	0.47	0.47	0.47
Irrigation	383 ac.ft.		52.9	27.3
Waterworks	0 g/d			
Industrial	4600 g/d	0.24	0.24	0.24
Conservation	0 cfs			

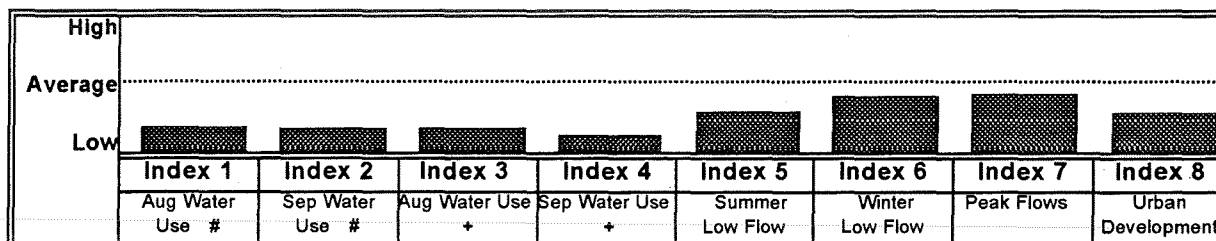
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	7,030	459	431

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

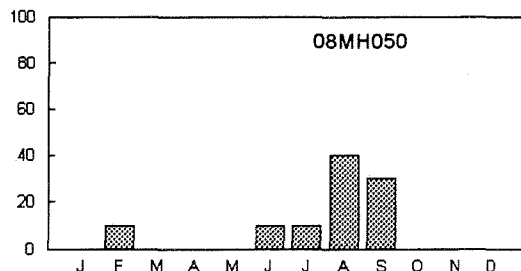


# Water use as a proportion of the 7 day low flow

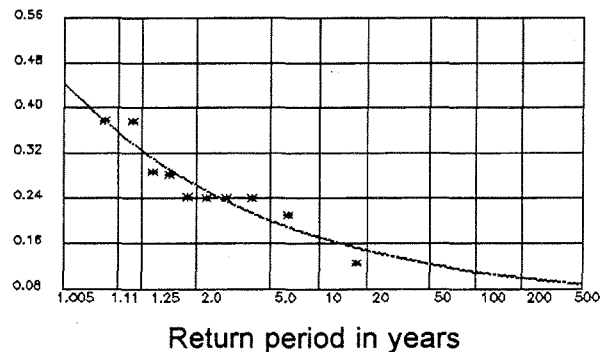
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	0.262 m <sup>3</sup> /s	0.170 m <sup>3</sup> /s	0.146 m <sup>3</sup> /s	0.123 m <sup>3</sup> /s	0.109 m <sup>3</sup> /s
<b>Annual Flood</b>	m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s	m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

- 1. The lower Nicomekl River has similar problems to the Serpentine River. Some of the tributaries provide fish habitat. There are springs in the upper river that maintain summer base flows in Wagon Wheel Creek and other tributaries.*
- 2. Ground water provides a good summer base flow in Ericson Creek, which now mostly flows in ditches. Ditches need to be managed properly because removal of vegetation and cleaning generally destroys habitat. It has been suggested that ditches be designed so that grass and vegetation can be controlled by mowing rather than removal.*
- 3. Archimedes screws were installed in Erickson Creek for fish passage. There is also a private fishway about 4 km from the mouth.*
- 4. Fencing and instream habitat improvements have been recommended to increase fish production. Removal or upgrading of culverts that obstruct fish passage would also be beneficial.*

# ANDERSON CREEK

## LICENSED WATER DEMAND

Stream number 90-0100-020

Water Survey of Canada Station 08MH104

Anderson Creek at the mouth

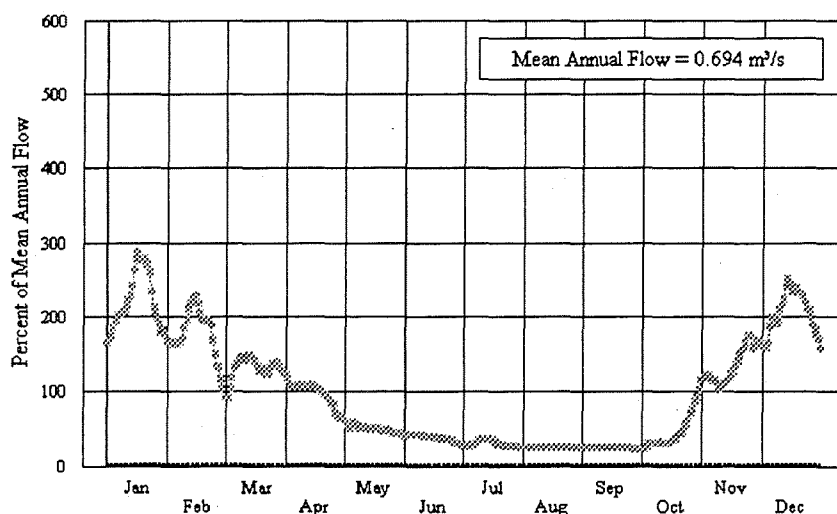
Records 1965 to 1987

Drainage Area = 27.2 km<sup>2</sup>

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	1,800 g/d	0.09	0.09	0.09
Irrigation	1 ac.ft.		0.14	0.07
Waterworks	0 g/d			
Industrial	11,600 g/d	0.61	0.61	0.61
Conservation	0 cfs			

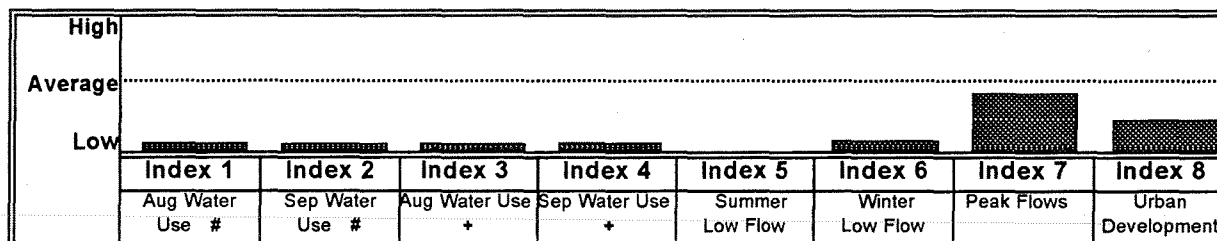
	Feb	Aug	Sep
MEAN STREAM FLOW L/S	1300	172	176

## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

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

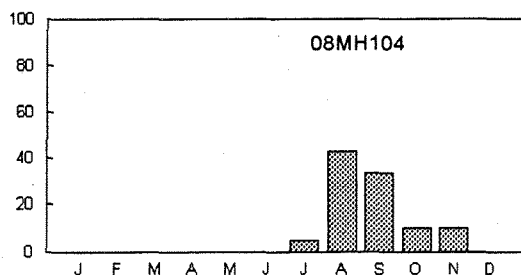


# Water use as a proportion of the 7 day low flow

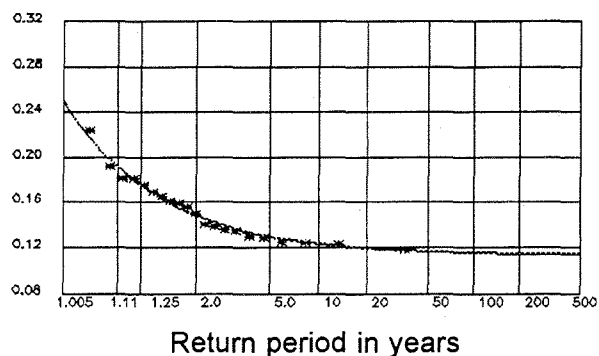
+ Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
7 Day Low Flow	0.148 m <sup>3</sup> /s	0.123 m <sup>3</sup> /s	0.119 m <sup>3</sup> /s	0.116 m <sup>3</sup> /s	0.115 m <sup>3</sup> /s
Annual Flood	10.1 m <sup>3</sup> /s	15.1 m <sup>3</sup> /s	16.7 m <sup>3</sup> /s	18.5 m <sup>3</sup> /s	19.8 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Summer base flows in Anderson Creek are maintained by groundwater inflow, nevertheless the middle reaches go dry during low flow periods. Storage might be developed in the upper lakes to augment low flows.*

*2. The creek below 32nd Avenue is downcut, possibly because of removal of large organic debris in the 1970's. There is gravel, supporting benthic production, but a lack of cover.*

# MURRAY CREEK

Stream number 90-0100-030  
 Water Survey of Canada Station 08MH129  
 Murray Creek at 216 Street, Langley  
 Records 1969 to 1983  
 Drainage Area = 26.2 km<sup>2</sup>

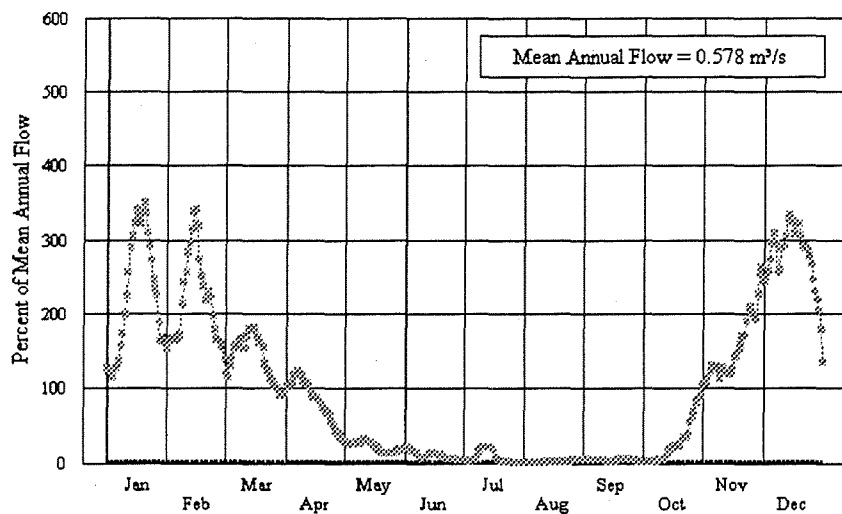
## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	7,100 g/d	0.37	0.37	0.37
Irrigation	58 ac.ft.		8.01	4.14
Waterworks	0 g/d			
Industrial	500 g/d	0.03	0.03	0.03
Conservation	0 cfs			

Feb Aug Sep

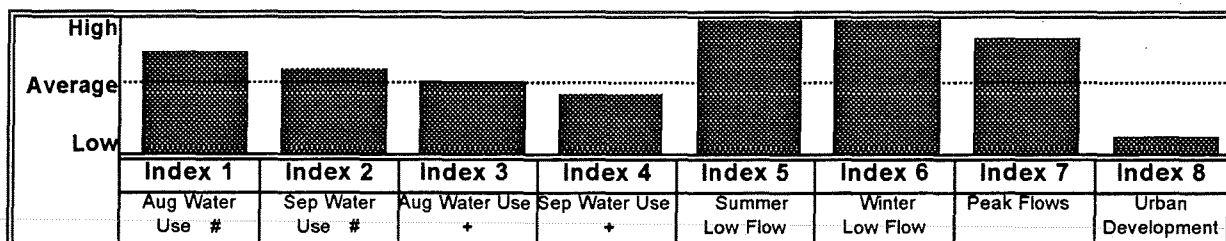
MEAN STREAM FLOW L/S		15	36
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## MEAN ANNUAL HYDROGRAPH



## SENSITIVITY INDICES

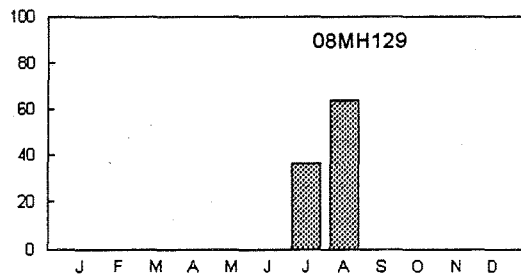
The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



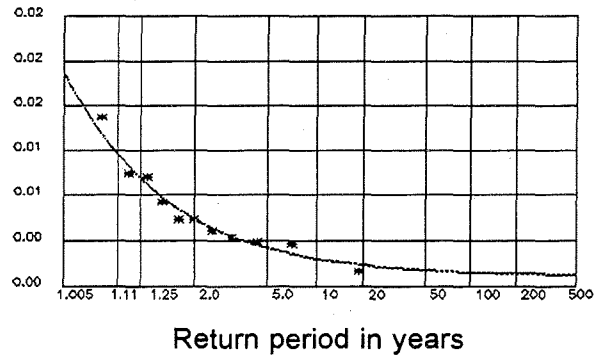
- # Water use as a proportion of the 7 day low flow
- + Water use as a proportion of the mean monthly flow for the same month

## 7 DAY LOW FLOWS

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



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



Return period	2 years	10 years	20 years	50 years	100 years
<b>7 Day Low Flow</b>	.0059 m <sup>3</sup> /s	.0024 m <sup>3</sup> /s	.0018 m <sup>3</sup> /s	.0014 m <sup>3</sup> /s	.0012 m <sup>3</sup> /s
<b>Annual Flood</b>	9.9 m <sup>3</sup> /s	17.4 m <sup>3</sup> /s	20.4 m <sup>3</sup> /s	24.6 m <sup>3</sup> /s	27.9 m <sup>3</sup> /s

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Agriculture is the main activity in Murray Creek watershed. Low flows limit fish habitat. A golf course is causing some erosion problems.*

# CAMPBELL RIVER

Stream number 90-0080

Flows into Boundary Bay

Drainage Area = 78.4 km<sup>2</sup>

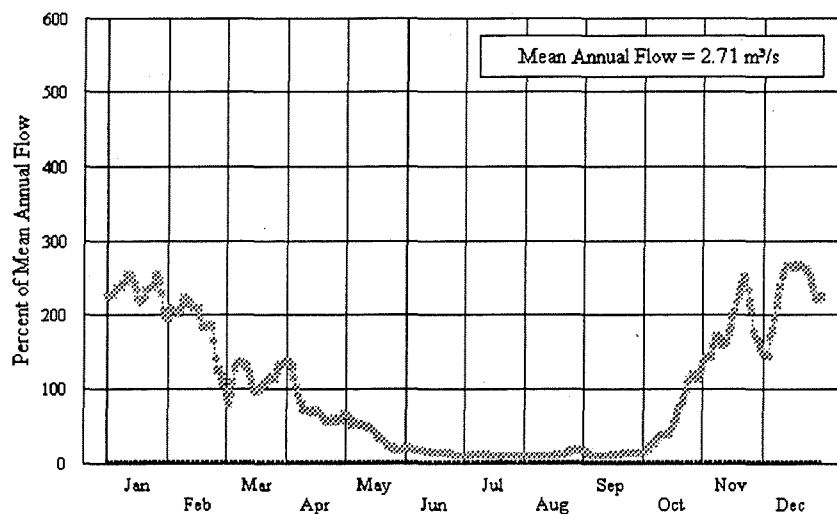
## LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	16,900 g/d	0.89	0.89	0.89
Irrigation	564 ac.ft.		77.9	40.3
Waterworks	0 g/d			
Industrial	72,065 g/d	3.79	3.79	3.79
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		200	170

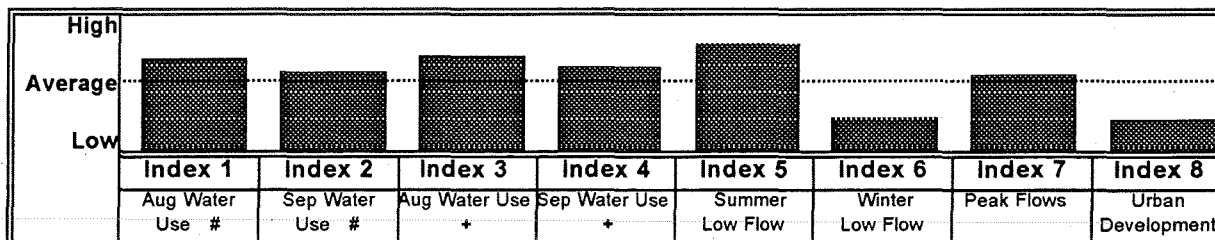
## MEAN ANNUAL HYDROGRAPH

(Estimated, using Nicomekl River station 08MH050)



## 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

# CAMPBELL RIVER

## SUMMARY NOTES AND RECOMMENDATIONS

*1. Summer base flows in the upper Campbell River, in an urban area of Langley, are maintained by groundwater inflows. In the middle part of the river, within the Campbell Valley Regional Park, the flow disperses through a large wetland with no clearly defined channel. Several sections of the river go dry in the summer due to losses to groundwater, subgravel flow and licensed withdrawals.*

*2. There is a proposal to dredge peat from the channel near 232nd Street to alleviate flooding. Beaver dams are also aggravating flooding problems.*

*3. Several tributaries to Campbell River have had enhancement programs: instream and bank habitat were improved along McNalley Creek; a fishway was installed at the mouth of Fergus Creek; stop logs and spawning gravels were placed in Jacobson Creek; and spawning gravels were placed in Jenkins Creek. Further enhancement work could improve fish passage through culverts at 10th Avenue on McNalley Creek and on Sam Hill Creek. The Semiahmoo Fish and Game Club operates a hatchery, which has a good source of water.*

*4. There remain a number of opportunities for enhancement, such as placement of boulders or anchored root wads in the main river, but a comprehensive plan is required. The Campbell River is a good candidate for a demonstration watershed, where agricultural and urban development are managed to maintain fisheries production.*



## **APPENDIX C**

### **WATER MANAGEMENT BRANCH LICENSE APPLICATION TRACKING SYSTEM**

02/17/93

Licence Applications Tracking System

1

File #	Applicant	Source	Precinct	Purpose	Priority	1st Allocation	2nd Allocation	Technician	Regional Engineer's Report	Decision Date
2001475	GLADWIN FARMS LTD.	BATEMAN/BLACKHM	ABB	IRR IND	03/12/91	04/04/91	04/16/91	CS	//	//
2001479	MATSQUI, DISTRICT	MILL LAKE	ABB	LIM	03/25/91	04/04/91	05/06/91	CS	//	//
2001560	QUALITY INDUSTRIAL MIN	MACKAY CREEK	ABB	MIN	10/21/91	10/25/91	10/26/92	CS	//	//
2001652	CLARK, NIGEL & SHIRLEY	ZZ SPRINGS	ABB	DOM IRR	08/05/92	08/10/92	08/17/92	CS	//	//
2001227	SURREY, DISTRICT OF	NICOMEKL RIVER	CLO	IRR	08/17/89	08/31/89	11/23/89	CS	//	//
2001228	SURREY, DISTRICT OF	NICOMEKL RIVER	CLO	IRR	08/17/89	03/31/89	11/23/89	CS	//	//
2001317	AVIGDOR, WALTER	ZZ	CLO	IRR	03/01/90	03/09/90	04/11/90	CS	//	//
2001319	WIKSHINE, JEKLIN	SERPENTINE	CLO	IRR	03/09/90	04/06/90	04/11/90	CS	//	//
2001320	RIVERDALE FARMS LTD.	SERPENTINE RIVER/DITCHES	CLO	IRR	03/09/90	04/06/90	04/11/90	CS	//	//
2001329	SUBEG SANGHA	SERPENTINE RIVER	CLO	IRR	03/15/90	04/06/90	04/11/90	CS	//	//
2001330	JEKLIN, A. & M.	ZZ	CLO	IRR	03/16/90	04/06/90	04/11/90	CS	//	//
2001377	A.S.RAI FARMS	NICOMEKL RIVER	CLO	IRR	07/20/90	07/26/90	05/01/91	CS	//	//
2001398	DUCKS UNLIMITED	ZZ CREEK	CLO	CON	09/19/90	09/27/90	03/19/91	CS	//	//
2001403	BELAIR GOLF LTD.	ZZ	CLO	IRR	09/25/90	09/27/90	11/14/90	CS	//	//
2001464	MACINNES, R. & W.	ZZ SP	CLO	IRR	02/22/91	02/28/91	05/14/91	CS	//	//
2001472	SEMAHMOO FISH & GAME	CAMPELL RIVER	CLO	IND	03/07/91	03/12/91	03/27/91	CS	//	//
2001482	AGW PARTNERSHIP	NICOMEKL RIVER	CLO	IRR	03/28/91	04/04/91	04/23/91	CS	//	//
2001500	MURMANN, A. K.	JOHN BROOK	CLO	LIM	05/15/91	05/16/91	02/04/92	CS	//	//
2001501	DESROSIERS, G.	SERPENTINE RIVER	CLO	IRR	05/17/91	05/28/91	//	CS	//	//
2001502	DESROSIERS, G.	SERPENTINE RIVER	CLO	IRR	05/17/91	05/28/91	//	CS	//	//
2001503	DESROSIERS, G.	SERPENTINE RIVER	CLO	IRR	05/17/91	05/28/91	//	CS	//	//
2001508	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001509	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001510	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001511	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001512	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//

Licence Applications Tracking System

File #	Applicant	Source	Preclnct	Purpose	Priority	1st Allocation	2nd Allocation	Technician	Regional Engineer's Report	Decision Date
2001513	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001514	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001515	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001516	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001517	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001518	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001519	UMARPURA ENT.	SERPENTINE RIVER	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001520	UMARPURA ENT.	ZZ	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001521	UMARPURA ENT.	ZZ	CLO	IRR	05/27/91	06/07/91	12/03/91	CS	//	//
2001523	SCOTT, A. & A.,	PEACOCK BROOK	CLO	IRR	05/28/91	05/30/91	08/07/91	CS	//	//
2001566	AUTAR SARAN	ZZ	CLO	IRR	10/31/91	11/28/91	02/03/91	CS	//	//
2001573	BOEHM, STAN	ZZ SPRING	CLO	DOM IRR	12/02/91	01/14/92	02/03/92	CS	//	//
2001580	LANGLEY, TOWNSHIP OF	ZZ	CLO	LIM	01/28/92	02/05/92	06/18/92	CS	//	//
2001581	REDWOOD FARMS	DEEP CREEK	CLO	LIM	01/30/92	02/28/92	//	CS	//	//
2001583	RIVER NSY LTD.	ZZ	CLO	IRR	02/10/92	02/28/92	//	CS	//	//
2001591	PARADISE FARMS LTD.	ZZ CREEK	CLO	IND	02/26/92	05/04/92	06/18/92	CS	//	//
2001592	PARADISE FARMS LTD.	ZZ SPRING	CLO	LIM	02/26/92	05/04/92	06/18/92	CS	//	//
2001595	MASICH, BRIAN & D.	ZZ	CLO	LIM	03/05/92	03/19/92	08/21/92	CS	//	//
2001597	SUNNYSIDE FARMS LTD.	ZZ	CLO	IND	03/12/92	05/04/92	06/22/92	CS	//	//
2001615	ANDERSON, E.P.	ZZ	CLO	LIM	05/07/92	06/05/92	06/18/92	CS	//	//
2001620	NORTHVIEW GOLF & COUNTRY	SERPENTINE RIVER	CLO	IND	05/15/92	06/24/92	07/10/92	CS	//	//
2001636	CILLIS, ANTONIO & MARGARET	ROBERTSON CREEK	CLO	LIM	06/08/92	07/09/92	07/27/92	CS	//	//
2001666	CHANG SHEW W	NICOMEKL RIVER	CLO	IRR	09/08/92	09/18/92	//	CS	//	//
2001672	M&G BROS. FARMS LTD.	zz pond	CLO	IRR	10/16/92	11/05/92	11/23/92	CS	//	//
2001690	BAINS FARM	BURROWS DITCH	CLO	IRR	01/26/92	02/03/92	//	CS	//	//
2001562	FISHERIES & OCEANS	COQUITLAM RIVER	COQ	CON	10/08/91	10/15/91	10/25/91	CS	//	//

02/17/93

Licence Applications Tracking System

3

File #	Applicant	Source	Precinct	Purpose	Priority	1st Allocation	2nd Allocation	Technician	Regional Engineer's Report	Decision Date
2001623	FISHERIES & OCEANS, DEPT.	COQUITLAM RIVER	COQ	CON	05/28/92	06/09/92	07/27/92	CS	//	//
2001673	WERNER P & S	WILLIAMS CREEK	COQ	DOM	10/16/92	10/27/92	11/23/92	CS	//	//
2001269	DELTA'S DUNES	BIG SLOUGH	FRA	IND	10/27/89	11/10/89	01/12/90	CS	//	//
2001308	DELTA DOWNS	CHILLUKTON	FRA	IRR	02/06/90	02/13/90	05/28/90	CS	//	//
2001408	B. C. PACKERS LTD.	FRASER RIVER	FRA	IND	10/03/90	10/10/90	10/25/90	CS	//	//
2001451	RICHMOND, CITY OF	N. FRASER RIVER	FRA	IRR	02/07/91	01/14/91	04/26/91	CS	//	//
2001630	MAYFIELD FARMS LTD.	FRASER RIVER	FRA	IRR IND	06/19/92	07/28/92	07/30/92	CS	//	//
2001631	AGRI MANAGEMENT CORP.	TASKER RD. DITCH	FRA	IRR IND	06/19/92	07/24/92	07/30/92	CS	//	//
2001684	PRIMO INDUSTRIES LTD	BARNSTON ISLAND	(KEE) CHO	IND LIM	12/10/92	12/15/92	12/18/92	CS	//	//

02/17/93

Licence Applications Tracking System

1

File #	Applicant	Source	Precinct	Purpose	Priority	1st Allocation	2nd Allocation	Technician	Regional Engineer's Report	Decision Date
2000843	FLINTOFT/TEARMS,W.	WAECHTER CR	ABB	IRR	12/01/87	//	//	NS	//	//
2001032	LITT, N. S.	FISHTRAP CREEK	ABB	IRR	09/29/88	10/04/88	01/24/89	NS	//	//
2001139	MATSQUI DISTRICT	FRASER RIVER	ABB	IRR	04/20/89	04/15/89	08/15/89	NS	//	//
2001445	B. C. ENVIRONMENT	ZZ	ABB	CON	01/22/91	01/30/91	02/06/91	NS	//	//
2001480	PENNER, E. & K.	ZZ	ABB	DOM	03/27/91	04/04/91	11/12/91	NS	//	//
2001481	FEENSTRA, DELLA	ZZ	ABB	DOM	03/27/91	04/04/91	05/09/91	NS	//	//
2001504	CAMERON, A.	CAMERON SPRING	ABB	DOM	05/17/91	05/29/91	07/16/91	NS	//	//
2001506	REED, LEONARD	ZZ	ABB	DOM IRR	05/17/91	05/28/91	08/07/91	NS	//	//
2001540	381029 B. C. LTD.	CLAYBURN SP	ABB	IRR LIM	08/01/91	08/28/91	10/11/91	NS	//	//
2001625	GREGSON, JOHN & LINDA	ZZ	ABB	DOM	06/02/92	06/24/92	07/27/92	NS	//	//

**APPENDIX D**

**WATER MANAGEMENT BRANCH RESERVE/RESTRICTION NOTICES**

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**LOWER MAINLAND**

For Precinct: 20A

ABBOTSFORD

SOURCE: Hallert Creek

HALLERT CREEK - FR-EXC

1986/04/22

FULLY RECORDED EXC. DOM. UNLESS STOR. 2000470.

SOURCE: Mill Lake

MILL LAKE - OR

1952/12/03

OFFICE RESERVE - REFER ALL APPLICATIONS TO ABBOTSFORD LIONS CLUB 0196749,  
0219736

SOURCE: Moss Spring

MOSS SPRING - FR

1988/09/15

FULLY RECORDED - 2000828

SOURCE: Paulgaard Brook

PAULGAARD BROOK - FR-EXC

1986/04/17

FULLY RECORDED EXC. SMALL DOM. OR WHERE STOR. IS PROVIDED 2000391.

SOURCE: Seldon Ditch

SELDON DITCH - RNW

1988/01/27

REFUSED NO WATER 2000798

SOURCE: Silley Spring

SILLEY SPRING - FR

1985/04/17

FULLY RECORDED 2000267.

SOURCE: Wickson Spring

WICKSON SPRING - FR

1991/01/14

FULLY RECORDED 1991/01/14 - 2001289

For Precinct: 20D

CLOVERDALE

SOURCE: 168th Street Ditch  
168TH STREET DITCH - FR  
FULLY RECORDED 2000136.

/ /

SOURCE: Bell Creek  
BELL CREEK - RNW  
FULLY RECORDED 0004500.

/ /

SOURCE: Best Creek  
BEST CREEK - RNW  
REFUSED NO WATER 0317482.

/ /

SOURCE: Brooklane Creek  
BROOKLAND CREEK - RNW  
REFUSED NO WATER 0316961.

/ /

SOURCE: Burrows Ditch  
BURROWS DITCH - PWS  
SEE COMMENTS ON REGIONAL ENGINEERS REPORT 0355147,  
REFUSED NO WATER 0244689, 0316940.

1984/05/22

SOURCE: Coghlan Creek  
COGHLAN CREEK - RNW  
REFUSED NO WATER 0198606.

/ /

SOURCE: Davidson Creek  
DAVIDSON CREEK - FR-EXC  
FULLY RECORDED EXC. FOR SMALL DOMESTIC 2000701.

1988/03/24

SOURCE: Eldon Brook  
ELDON BROOK - RNW  
REFUSED NO WATER 0317700.

/ /

SOURCE: Erickson Creek  
ERICKSON CREEK - FR  
NO. IRR. ALLOWED ON TRIBS. TO ERICKSON CREEK 0277326,  
REFUSED NO WATER 0305232, 0309816, 0322636  
1989/06/01 FULLY RECORDED 2000839.

1989/06/01



For Precinct: 20D

SOURCE: Gary Brook  
GARY BROOK - FR-EXC  
FULLY RECORDED EXC. DOM. 0270860.

1967/02/09

SOURCE: Gravelle Spring  
GRAVELLE SPRING - FR  
FULLY RECORDED 0215159.

1959/01/26

SOURCE: Green Brook  
GREEN BROOK - RNW  
REFUSED NO WATER 0239937.

/ /

SOURCE: Hooser Spring  
HOOSER SPRING - RNW  
REFUSED NO WATER 0216641.

/ /

SOURCE: Kensington Creek  
KENSINGTON CREEK - RNW  
REFUSED NO WATER 0248051, 0300811  
APPLICATIONS REFER TO R.E. REPORT ON FILE 0237262

/ /

SOURCE: Laura Brook  
LAURA BROOK - RNW  
REFUSED NO WATER 0290256.

/ /

SOURCE: Nicomekl River  
NICOMEKL RIVER - FR  
FULLY RECORDED - RNW - APPLIES TO TOP PORTION NEAR HEADWATERS OF STREAM 2000518,  
1975/11/21 NICOMEKL RIVER & TRIBUTARIES - NOTIFY SURREY DYKING DIST. OF  
APPL. & C/W - RNW 0355590

1987/07/31

SOURCE: Perry Homestead Brook  
PERRY HOMESTEAD BROOK - FR  
FULLY RECORDED 2000435.

1988/04/25

SOURCE: Ponding Creek  
PONDING CREEK - FR  
FULLY RECORDED 2000366, 2000358

1985/10/01

For Precinct: 20D

SOURCE: Salmon River  
SALMON RIVER - RNW  
REFUSED NO WATER 0202777.

/ /

SOURCE: Serpentine River  
SERPENTINE RIVER & TRIBUTARIES - PWS  
NOTIFY SURREY DYKING DIST. ENG. DIV., WIB OF APPL. & C/W

1975/11/21

SOURCE: Spohn Creek  
SPOHN CREEK - PWS

1984/11/13

LOW FLOW MEASUREMENTS BEFORE FURTHER LICENSING EXC. DOM. 2000127.

SOURCE: Trigg Brook  
TRIGG BROOK - FR  
FULLY RECORDED 2000426.

1986/04/14

For Precinct: 20E

*COQUITLAM*

SOURCE: Brunette River

BRUNETTE RIVER - OR

1983/01/05

OFFICE RESERVE. REFER ALL APPLICATIONS TO GREATER VANCOUVER SEWAGE & DRAINAGE  
DISTRICT. - MEMO C. STEWART. 1983/01/05.

For Precinct: 20F

*FRASER - DELTA*

SOURCE: Centre Slough

CENTRE SLOUGH - FR-EXC

1988/11/17

FULLY RECORDED UNLESS STORAGE - 2000491

SOURCE: Cohilukthan Slough

COHILUKTHAN SLOUGH - PWS

1964/02/27

POSSIBLE WATER SHORTAGE; 0253737.