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Province of British Columbia
Ministry of Environment, Lands and Parks

A State of the Environment Report

State of the Environment for the Lower Fraser River Basin

SOE Report No. 92-1

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State of the Environment for the Lower Fraser River Basin

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Foreword

The Fraser River is one of the most extensive and productive systems in Canada. It drains about one-quarter of British Columbia, and its lower reaches (referred to as the Lower Fraser River Basin) extend from Hope at the end of the Fraser Canyon to the Strait of Georgia. The Lower Fraser River Basin, set between mountains and the sea, comprises one of the most diverse and productive ecosystems in Canada with its coastal forests, fertile floodplains, delta marshes and abundant streams. It is this richness of natural environment, including the mild climate, which attracts people to this region. The area includes Canada's third largest urban region and contains one-half the population of British Columbia. Its population is growing at the rate of 45,000 new residents per year. But how much growth can be accommodated without substantially altering the quality of the natural environment? What is the present state of the environment and what are the prospects for ensuring the environmental health of the Lower Fraser River Basin?

To answer these questions, Environment Canada and the British Columbia Ministry of Environment commissioned the report "State of the Environment for the Lower Fraser River Basin". The report provides an overview of the state of the environment of the region, including the physical, biological, social and land use trends affecting air, water, land, and fish and wildlife resources. It summarizes the available information and defines some baseline conditions for future state-of-the-environment reporting.

The report was compiled by Quadra Planning Consultants Ltd. and Regional Consulting Ltd. of Vancouver. Support to this study was provided by a scientific committee co-chaired by Dr. V. Bartnik of Environment Canada and Mr. B. Turner of the British Columbia Ministry of Environment and comprised of representatives from six federal departments, eleven provincial ministries, four regional districts as well as from research institutions and academia.

This report is one of several undertaken for important ecological regions across Canada, and represents the regional case study input of the Pacific and Yukon Region of Environment Canada into the 1991 State of the Environment Report for Canada.

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Chapter 1

Introduction

A sustainable environment is one in which biophysical systems maintain their long-term diversity, quality, productivity, and relative stability. In the Lower Fraser River Basin of British Columbia, the increasing pressures of urban growth, resource use, and development are challenging our ability to sustain the quality of the environment.

The Fraser River drains about one-quarter of British Columbia. After leaving the Fraser Canyon, approximately 1 400 km from its headwaters, the river enters the lowlands of the Fraser Valley and the urbanized area of Greater Vancouver. This natural region, the *Lower Fraser River Basin,* encompasses an area of 17 000 km^2, including the surrounding drainage systems.

More than one-half the population of British Columbia lives here, and it is Canada's third largest urban region. Within the next twenty years, this population (1.7 million) is expected to increase by over 600 000. The natural environment is one of the major factors in attracting people to the region. But how much growth can be accommodated without substantially altering the quality of the natural environment? What is the present state of the environment and what are the prospects for a sustainable environment?

This report provides an overview of the state and sustainability of the environment of the Lower Fraser River Basin, including the physical, biological, and social systems affecting the air, water, land, and fish and wildlife resources. It summarizes the available information and defines some baseline conditions for future state of the environment reporting.

The Lower Fraser River Basin

The Lower Fraser River Basin extends from the Strait of Georgia to the Fraser Canyon. The watershed boundaries of the Lower Fraser River Basin, which were adopted for the purposes of this report, are consistent with those of the four regional districts covering the "Lower Mainland" of British Columbia (Figure 1).

Three physiographic (or landform) units shape the environment of the Basin. The *Coast Mountains* border the region on the north and east and contain various tributaries and lakes draining into the Fraser River. The *Fraser Lowland* is a broad plain of riverine and glacial deposits associated with the Fraser River floodplain, extending east of Greater Vancouver to the vicinity of Hope. The *Fraser Estuary* covers the delta and the brackish, tidal waters surrounding the outlet of the Fraser River at the Strait of Georgia.

The lower Fraser River valley lies in a trough within the granitic rock of the Coast Mountains. This trough has been filled by sediments up to 300 m deep during repeated glacial cycles and inundations by seawater. About 10 000 years ago most of the ice from the last glaciation had completely disappeared from the area.

The Fraser lowland consists of rolling uplands up to 175 m in elevation, separated by wide valleys. This lowland extends 110 km from Strait of Georgia to Laidlaw, with elevations ranging from 1 to 5 m above mean sea level.

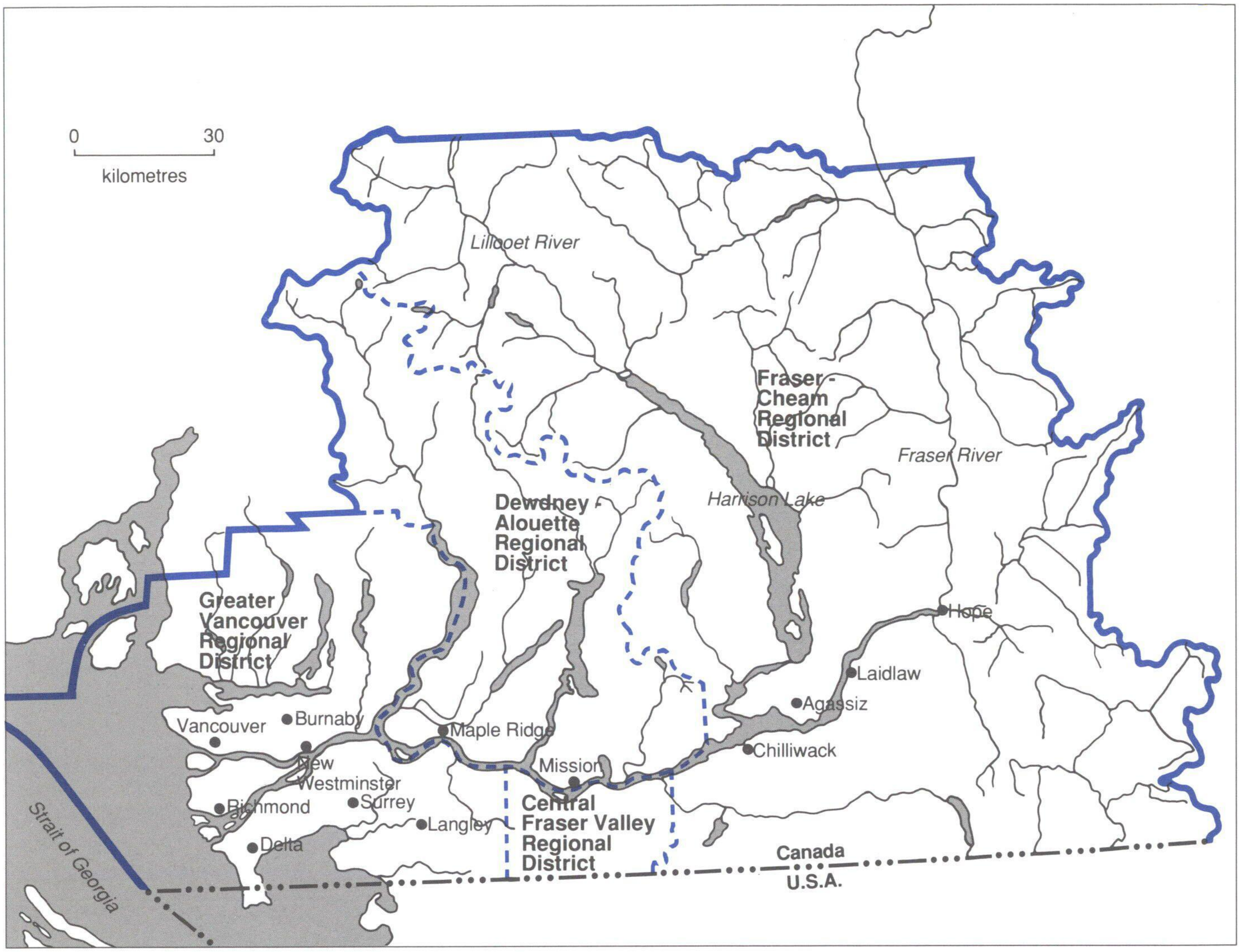
Burrard Inlet and the north shore communities are included within the Basin for the purposes of this report; however, the major focus of the discussion is on the state of the Fraser River, its floodplain and major tributaries, Boundary Bay, and Roberts and Sturgeon Banks.

Objectives

This report is part of a national series of reports which attempt to provide a summary of the condition of the environment in Canada. The report is guided by four questions for assessing the state of the environment:

- What is happening? (trends)
- Why is it happening? (human activity/environment linkages)
- Why is it important? (effects on health, economy, lifestyle, and natural ecosystems)
- What are we doing about it? (management response)

Figure 1
Lower Fraser River Basin



Data on the major components of the environment are summarized, based on the available information. In many cases, data do not exist or have never been compiled and analyzed to answer the above questions. In other cases, there is conflicting data or interpretation of data. These deficiencies provide a basis for identifying gaps in knowledge and highlighting the need for specific action to improve state of the environment reporting.

Sustainability

The concept of a sustainable environment implies the use of integrated ecosystem perspectives in managing resources and coordinating management institutions toward a common goal of maintaining environmental quality and resource abundance for the long-term.

The adoption of a sustainable approach to environmental management involves the need to:

- take account of the interactions between physical, biological, and human components of the environment in day-to-day decisions which affect the environment;
- recognize the environmental interdependencies between different areas of the Basin, between the Basin and the Fraser River and between the Basin and larger regional and world systems;

- consider the cumulative and additive effects over time of many small, incremental decisions on the long-term condition of the environment;
- accommodate unpredictable environmental events and uncertainty and provide a means of adapting to changes in the environment; and
- encourage public involvement at a personal and community level in environmental protection and conservation.

The air, water, land, and fish and wildlife resources are discussed below in terms of the critical factors associated with sustaining a healthy environment in the Lower Fraser River Basin.

Chapter 2

Air

The issues affecting air resources involve both global concerns, such as climate change and high-level ozone depletion, and more local concerns related to air pollution and air quality trends. The critical aspects include the potential impact of climate change, the contaminant loadings from automobiles and industry, and the ambient levels of air quality.

Climate

Temperature and Precipitation

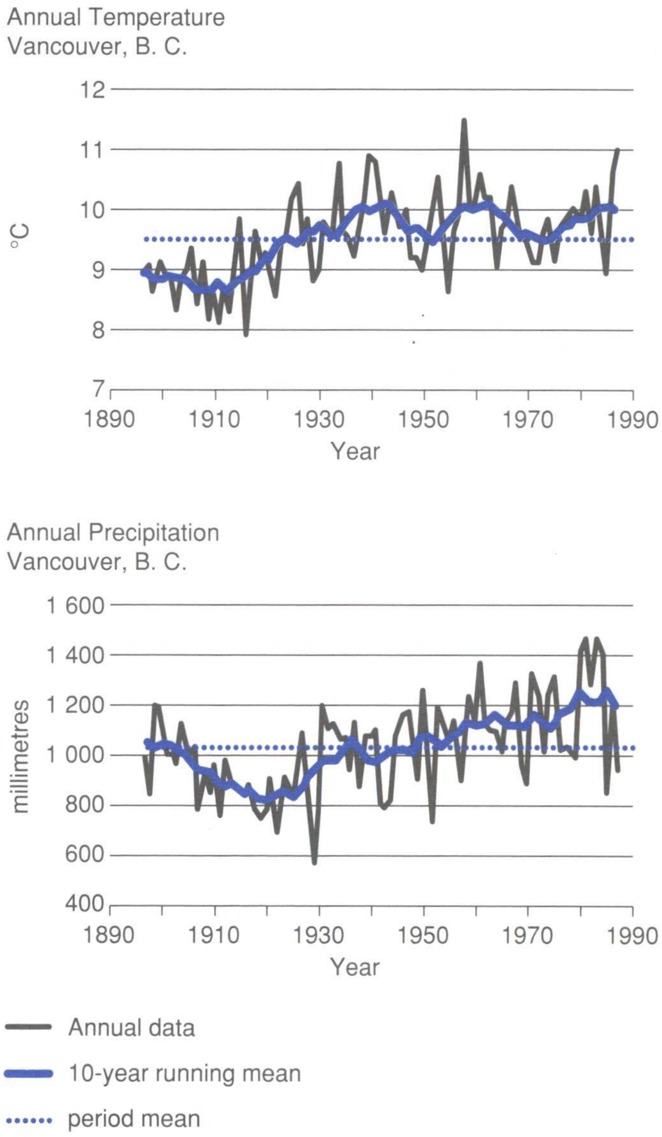
The lower Fraser Valley climate is dominated by maritime air masses and the passage of high- and low-pressure systems travelling from west to east. High-pressure systems are most frequent during summer, producing warm, dry, settled weather. The frequency of low-pressure (cyclonic) systems increases during autumn and winter, creating more unsettled weather. Occasional outbreaks of Arctic air during winter produce periods of extreme cold.

Temperatures are relatively uniform throughout the lowlands and have an annual average of about 10° C. Mean monthly temperatures range from approximately 1° C in January to 17° C in July; however, temperatures lower than -20° C and greater than 35° C have been recorded. Temperatures near developed areas are often a few degrees warmer than surrounding rural land, especially at night and during winter, due to the urban "heat island" effect.

Precipitation is highest in autumn and winter, while rainless periods can last for weeks during summer. High evaporation demand and low rainfall frequently combine during summer to produce drought conditions, particularly in areas with coarse soils. Consequently, irrigation is required to maintain agricultural production. Most of the precipitation falls as rain in the lowlands, but at elevations greater than 1 000 m a substantial snowpack often develops which persists into spring and sometimes summer.

In recent years precipitation and temperature levels have been increasing in Vancouver (Figure 2), but this may be part of the natural cycle of fluctuations inherent in climatic trends.

Figure 2
Temperature and Precipitation Trends



Steveston 1897–1937
Vancouver International Airport 1938–1987

SOURCE: Environment Canada, Atmospheric Environment Service.

Table 2-1
Precipitation Chemistry at Agassiz and Other Sites in the Strait of Georgia Region for 1985.
Value given is the mean, with the standard deviation in brackets. All values except pH are in μEq/L.

Parameters	Victoria	Pender Island	Squamish	Sechelt	Agassiz
pH	4.56 (1.10)	4.68 (1.08)	4.59 (1.09)	4.74 (1.09)	5.68 (1.11)
H	33.6 (28.5)	33.6 (28.5)	34.4 (40.5)	24.4 (16.8)	5.5 (13.0)
SO_4	60.0 (47.8)	31.0 (27.9)	47.1 (53.3)	30.7 (22.5)	29.9 (28.3)
xs SO_4[1]	52.1 (45.0)	23.3 (11.8)	44.8 (51.5)	28.5 (21.5)	28.0 (26.1)
NO_3	29.6 (40.0)	20.2 (10.8)	26.3 (31.9)	28.0 (22.6)	24.8 (22.8)
NH_4	14.5 (18.2)	7.9 (15.9)	7.1 (13.2)	10.7 (16.1)	54.6 (49.9)
Cl	77.0 (87.4)	34.9 (32.1)	22.1 (16.2)	21.6 (17.7)	18.1 (25.2)
Na	70.7 (76.6)	31.9 (28.9)	21.8 (17.4)	21.5 (17.1)	15.7 (25.6)
Mg	16.6 (19.7)	5.7 (5.5)	3.9 (3.7)	4.2 (5.1)	3.6 (5.1)
Ca	13.0 (14.0)	8.1 (6.9)	13.1 (10.9)	14.7 (32.3)	8.8 (9.7)
K	3.4 (3.0)	2.3 (3.4)	3.2 (4.8)	3.8 (4.5)	2.8 (3.2)
AC-F	42.1 (47.9)	26.4 (20.0)	37.9 (45.1)	24.7 (17.3)	5.4 (13.4)
AC-T	98.3 (73.5)	73.3 (28.4)	82.5 (54.1)	70.6 (37.3)	72.6 (49.9)
AK-T	0.3 (1.2)	0.8 (4.7)	0.1 (0.4)	2.2 (11.5)	10.3 (14.1)
No. of samples	29.0	36.0	33.0	42.0	40.0
Rainfall (mm/yr)	591.6	575.9	1400.3	663.9	1373.5
(+)/(-)	0.94 (0.09)	0.97 (0.08)	0.95 (0.10)	0.96 (0.15)	1.06 (0.18)

pH = Geometric mean
xs SO_4[1] = SO_4 corrected for sea salt
AC-F: Acidity free
AC-T: Acidity total
AK-T: Alkalinity total

SOURCE: B.C. Ministry of Environment and Parks 1988.

Precipitation Chemistry

Table 2 - 1 shows the results of chemical analyses of precipitation at Agassiz for 1985. Results from other stations in the Strait of Georgia region are shown for comparison (B.C. Ministry of Environment and Parks 1988). Of note are the relatively high concentrations of ammonium (NH_4) at Agassiz, which likely derive locally from agricultural waste. Sulphate (SO_4) and nitrate (NO_3) concentrations are substantially higher than the estimated background levels of 6-10 μEq/L and 1-3 μEq/L, respectively (Environment Canada 1986). The elevated levels are caused by local emissions from industry and automobile exhaust.

Total deposition of sulphate at Agassiz totalled 11.4 (10.4) and 12.5 (11.2) kg/ha in 1985 and 1986, respectively (the value in brackets represents the "excess" amount when contributions from sea salt are deducted). Total sulphate deposition at Vancouver was 22.2 (19.9) and 22.4 (20.4) kg/ha in 1982 and 1983, respectively (B.C. Ministry of Environment and Parks 1987).

Fog samples collected on Mount Seymour during January to March, 1988, (nine samples in total) had pH levels ranging from 3.63 to 7.26, nitrate from 2.56 to 15.6 μEq/L and excess sulphate from 1.46 to 9.03 μEq/L (Kotturi 1988). While this suggests some higher than expected levels of contaminants, the small sample size and high variability do not permit conclusions to be drawn from the data.

Wind Patterns and Pollutant Dispersion

Wind patterns are strongly influenced by the terrain and vary greatly through the study region. Strong winds accompany cyclonic storms, while weaker wind systems dominate when high-pressure cells extend over the region, especially in summer when incoming solar radiation is high. During the day, sea-breeze and slope wind systems[1] drive air flow up the Fraser Valley; land-breeze and down-valley wind systems drive flow down the valley at night.

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[1] Slope wind systems are generated by heating of a hill slope; they tend to blow upslope during the day and downslope at night.

During anticyclonic (high atmospheric pressure) conditions, the extent of vertical mixing is often limited to approximately 100 to 500 m above the surface by subsidence inversions, or stable atmospheric layers. Because these inversions "cap" the mixed layer at elevations lower than the surrounding mountains, a closed circulation results in which "stale" air and pollutants flow up and down the valley. Inversions can thus trap pollutants in the valley and prevent vertical mixing, particularly during fall and winter. This situation can occur for weeks. Anticyclonic conditions can persist for up to four weeks during late summer and autumn, accompanied by reduced air quality. The lack of rain during summer worsens air pollution, since rain is one of the most effective agents for removing pollutants from the air and transferring them to land and water.

Climate Change

Global Warming

Many human activities, particularly the production of carbon dioxide through the burning of fossil fuels, are believed to be causing global warming. The "greenhouse effect" is created when carbon dioxide, methane, and other gases absorb infrared radiation emitted by the earth and re-emit this radiation back to the earth rather than permitting it to be lost to space. The magnitude and distribution of climate changes induced by global warming, and the related effects on sea level rise, water and soil resources, and biological systems are uncertain, especially at regional scales. However, it is possible to offer some observations of the more likely and obvious effects upon the Lower Fraser River Basin.

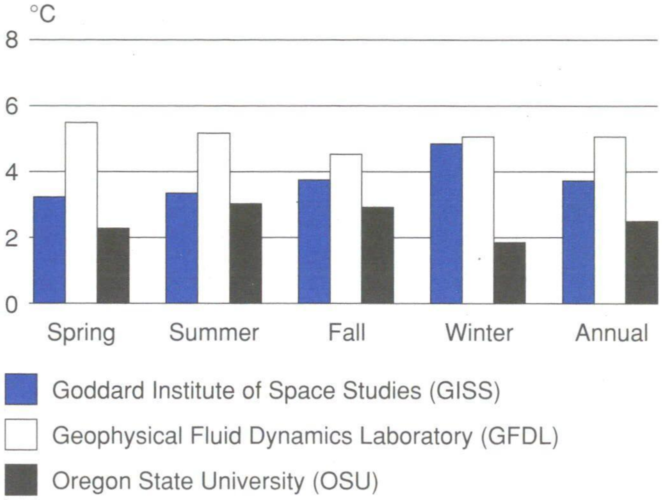
Potential Physical Impact

Climatologists have estimated the effects of increasing concentrations of greenhouse gases on climate using the following information: (1) computer models to simulate the general circulation of the atmosphere; (2) information about past climates, especially warm episodes; and (3) recent climate data recorded during warm years.

Temperature

Figure 3 shows the temperature change in the lower Fraser Valley predicted by three General Circulation Models (GCMs): Goddard Institute of Space Studies (GISS), Geophysical Fluid Dynamics Laboratory (GFDL), and Oregon State University (OSU). All three models indicate that a doubling of atmospheric carbon dioxide would increase air temperature in all seasons by about 2.5° to 5° C.

Figure 3
Temperature Change – Fraser Valley, B.C.
2 x CO_2 by 2050



SOURCE: Environment Canada, Atmospheric Environment Service.

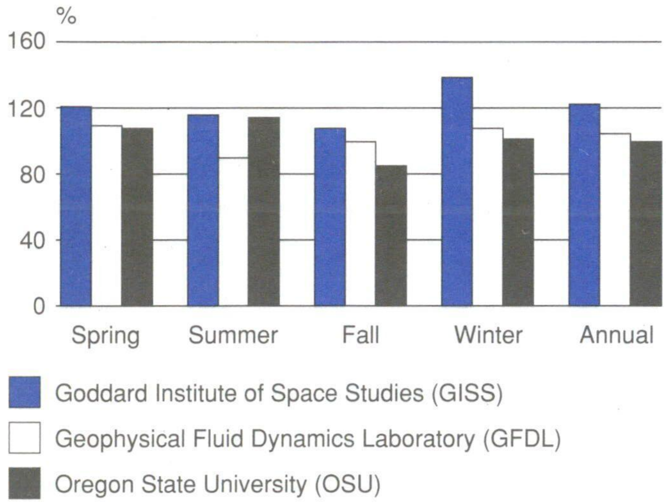
Precipitation

The GCMs predict mean annual precipitation with doubled atmospheric carbon dioxide to be about 99% to 122% of the current normal (Figure 4). The GISS model predicts increases in all seasons, particularly winter; the GFDL model predicts increases in spring and winter, little change in autumn and decreases in summer; and the OSU model predicts increases in spring and summer, little change in winter, and decreases in autumn. Evidence based on reconstructions of past climates indicates that during globally warm geological periods, the lower Fraser Valley had about 10% greater mean annual precipitation than at present, with greater increases during winter than summer (Brooks 1984). However, recently recorded climate data, for years in which the surface air temperature was warmer than average, indicate that precipitation would increase more in summer than winter. Thus, global warming may result in an increase in mean annual precipitation in the lower Fraser Valley, but the seasonality of change is not well defined by available evidence. A warmer, moister atmosphere would be more energetic due to the greater release of latent heat during condensation. This heat would generate more unstable conditions during storms and produce more intense precipitation.

Sea Level Rise

Changes in sea level can result from changes in the

Figure 4
Precipitation (% Normal) – Fraser Valley, B.C.
2 x CO_2 by 2050



SOURCE: Environment Canada, Atmospheric Environment Service.

volume of sea water and/or from changes in the local radius of the earth near a coastline due to movement of the earth's crust. The short-term impact of global warming would be on the volume of sea water. A rough consensus of projections suggests that the global sea level could rise by about 20 cm to 1.4 m over the next century through melting of small glaciers and ice caps, plus the thermal expansion of sea water due to warming (Titus 1986; Environment Canada 1986a). If a warming trend persisted over a number of centuries, the Antarctic and Greenland ice sheets could melt and raise sea level by up to tens of metres. The uncertainty in the magnitude of local sea level rise is greater than that for global sea level rise because the rise would not be globally uniform and would be complicated by local movement of the earth's crust.

For a sea level rise of up to a metre or so, the human response would probably be to upgrade dykes in the Fraser delta. Hence, no new wetland would be created and some existing wetland would be lost due to higher tidal levels.

River Flow Regime

Global warming could alter streamflow. As shown by the General Circulation Model results, a warmer atmosphere would hold more water vapour and be more energetic, resulting in greater precipitation. However, winter warming could cause snow line elevations to rise by up to several hundreds of metres, resulting in a smaller area of snowpack and a larger area below the snow line receiving rainfall. Changes in total snow accumulation would depend upon the relative magnitude of increases in winter precipitation and decreases in snow-covered area.

Increases in snowfall would likely tend to dominate in the interior and northern mountain ranges of the Fraser Basin, where winter temperatures are normally several degrees below the transition temperature between rain and snow. Decreases in snow-covered area might dominate in the south Coast Mountains and Cascades, where winter snow line elevations presently range between 500 m and 1 000 m above sea level. Hence, the Fraser River might experience increases in snowmelt runoff from its northern and interior tributaries, while the tributary rivers to the lower Fraser Valley (e.g., the Chilliwack) could experience greater winter runoff and decreased spring snow melt runoff.

Higher snow lines would increase the proportion of area receiving rainfall during winter storms. This effect, in conjunction with a possible increase in rainfall intensity, would increase the magnitude of winter rainfall floods, which produce the highest flows in many of the streams feeding the lower Fraser River, such as the Alouette River. Increased rainfall intensities would, in particular, increase flooding in urbanized catchments.

Potential Biological Impact

A warmer climate would probably include warmer ocean temperatures and changes in oceanic circulation which would affect the growth, survival, and migration of anadromous[2] fish species such as salmon. The exact nature of changes cannot be predicted with the current state of knowledge.

The freshwater environment could be changed in a number of ways. Warmer air temperatures could lead to warmer stream and lake temperatures, which would stress cold water species such as trout and salmon. Warmer conditions could also lead to greater eutrophication[3] of waterbodies and possible fish kills. Moreover, increased rainfall intensities could increase erosion and sediment input which is harmful to fish.

Loss of wetlands due to rising sea level would decrease habitat for a number of species, in particular migratory birds. Changes in terrestrial vegetation including, for example, shifts in forest composition due to changes in soil moisture conditions, would alter habitat and thus change the species present in the ecosystem.

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[2] Migrate from the sea up rivers and streams to spawn.

[3] Increased enrichment in dissolved nutrients, which causes increased algae and plant growth and decreased oxygen levels.

Agricultural productivity would potentially increase because of higher temperatures, longer growing season, and increased atmospheric carbon dioxide. However, realization of this potential could place greater demands on soil nutrient supply and may ultimately increase the need for fertilizer application. If improperly applied, the additional fertilizer could become a source of pollution to fish bearing streams.

Global warming could have an impact on the current plant species distribution. Species now confined to lower slopes because of adaptation to a certain temperature range would be able to grow comfortably at higher elevations. Forest productivity could potentially increase for the same reasons as agricultural productivity. If the assumption is made that global warming will lead to a more humid and wetter climate, then species with high moisture needs will be able to grow well in previously drier ecosystems. However, higher summer temperatures and possible greater summer drought could stress trees, making them more susceptible to disease and insect infestation, and could increase the risk of forest fires.

Potential Social Impact

About 80 km of the sea dykes protecting Richmond and Delta have approximately 0.5 m of freeboard above the high tide level expected to occur on average once in two hundred years (Brooks 1984). A rise in sea level of greater than 0.5 m could thus threaten these areas if dykes are not upgraded. While detailed topographic and settlement data are not available to allow impacts to be quantified, failure to adequately upgrade dykes could result in catastrophic flooding of low-lying areas.

Domestic water use generally increases with air temperature. Hence, the increase in use of water due to climatic warming would be additional to increases expected from population and industrial growth in the lower Fraser Valley. Increased carbon dioxide concentrations may increase the water use efficiency of plants and tend to decrease the need for irrigation. However, greater use of irrigation may be required to realize greater productivity, especially if summers become drier. This increase in irrigation may increase water demands on fish-bearing streams.

Many of the impacts on wildlife and fisheries noted above could decrease commercial, recreational, and Native fisheries. Forest productivity may increase as noted above, but soil nutrient supply may be a limiting factor and necessitate more intensive management including fertilization. Erosion potential, caused by greater autumn and winter rainfall, could produce a need for changing logging practices on steep slopes.

Warmer conditions could change the range of agricultural crops that thrive in the region. A longer growing season would allow staggered plantings and improve local marketability of agricultural crops. In a larger context, climate change could decrease the productivity and/or crop mix of many of the areas currently producing food for export, such as California. Consequently, crops grown in the lower Fraser Valley could become more valuable for export to other regions. However, warmer conditions could increase problems with disease, pests and weeds, and higher sea levels could produce problems with salinity in the lower-lying fields such as on Westham Island and around Boundary Bay (Brooks 1984).

Increased energy conservation and further expansion of renewable energy sources are required on a global scale if major cuts in carbon dioxide are to be achieved. Maintaining forest vegetation can also assist in reducing levels of carbon dioxide. Some measures can be taken to manage the more direct impacts of climate change including higher dykes, limiting development on floodplains, and developing impoundments to better regulate surface runoff. If warming occurs over the long-term, society will have no choice but to alter current settlement patterns and adjust to major environmental change.

Air Contaminants

There are numerous sources of air pollution in the Lower Fraser River Basin including motor vehicles, petroleum and forest industries, municipal incinerators, home heating, and outdoor fires. Mobile sources, such as private automobiles and other forms of transportation, account for nearly 85% of the total air pollution loadings in the Lower Fraser River Basin (Greater Vancouver Regional District 1988). Private automobiles are the single greatest source of all measured contaminants except for sulphur dioxide which originates primarily from industry. The level of contaminants is directly tied to the growth in population and motor vehicle use and the countering effects of more stringent new car emission standards.

A study of air contaminant loadings in the Lower Fraser River Basin estimated an annual total discharge of 730 000 tonnes of sulphur dioxide, particulates, carbon monoxide, nitrogen oxides, and volatile organic compounds (VOCs) in 1985 (Greater Vancouver Regional District 1988). More than 600 000 tonnes of this total originates from sources within Greater Vancouver. Air movements also cause pollutants to be carried eastward as far as Hope.

In addition to air contaminants from within the Basin, there are also loadings which originate from sources outside the Basin. These are not quantified but, nevertheless, contribute to overall loadings.

Air Quality

Air quality is assessed in relation to objectives set by the federal and provincial governments. Three levels of air quality objectives are used: Level A (desirable: unpolluted); Level B (acceptable: minimal effects on public health and the environment); and Level C (tolerable: lower protection evident and abatement required). Figure 5 shows air quality trends from 1978 to 1987 in the Greater Vancouver Regional District (GVRD) for the six contaminants described below (Greater Vancouver Regional District 1988a). For ozone, the period of record was 1978 to 1988. Figure 6 shows the current system of air quality monitoring stations in the GVRD.

Nitrogen Dioxide

In the Greater Vancouver Regional District, 80% of all combustion discharges, which include nitrogen dioxide, are from motor vehicles. Nitrogen dioxide levels have shown no discernable trend between 1978 and 1987. The one-hour Level B objective for nitrogen dioxide was exceeded once, while the 24-hour Level B objective was exceeded on four occasions. Mean nitrogen dioxide levels were highest in the downtown recording stations, where they approached or exceeded the Level A annual objective of 30 parts per billion (ppb) throughout the period of record.

Carbon Monoxide

Motor vehicles are responsible for approximately 90% of carbon monoxide emissions, which have shown little trend over the 10-year period of record. Exceedances of the 8-hour Level A objective occurred on several days most years at monitoring stations adjacent to major traffic arteries: in the eastern end of Burrard Inlet (T10), at downtown Vancouver (T1), Kitsilano (T2), and Marpole (T3) monitoring stations. This happened especially during the fall and winter months when poor atmospheric dispersion conditions are common.

Sulphur Dioxide

Sulphur dioxide is formed primarily by the combustion of sulphur-bearing fossil fuels. Emissions of sulphur dioxide in the GVRD were low relative to other similar sized urban areas because natural gas is the principal heating fuel as opposed to coal or oil. The Level A objective was exceeded on a total of 24 occasions over the decade, with most occurring at stations near major oil refineries. Sulphur dioxide levels were lower than many other urban regions due to the lower heating requirements and fewer industrial polluters.

Ozone

Formed from the reaction of sunlight with nitrogen oxides and reactive hydrocarbons, ozone levels are typically highest during the afternoon hours of the summer months. High ozone levels adversely affect human health and can damage plant growth. Between 1978 and 1987 exceedances of both Level A and B ozone objectives declined, then increased in 1988 due to unusually warm weather. Peak ozone levels have declined, particularly in the western portions of the region, with no apparent explanation.

Total Suspended Particulate

Total suspended particulates include smoke, fumes, dust, fly ash, and pollen ranging in size from 0.1 to 100.0 micrometres. Levels of total suspended particulates declined between 1978 and 1987. Less than 3% of the particulate measurements exceeded Level B. Most exceedances occurred at monitoring stations along the Fraser River between Marpole (T3) and Coquitlam (Station 32), related to wood processing industries.

Suspended Lead Particulate

The major source of suspended lead particulates is leaded gasoline. Decreased use of leaded gasoline corresponded to a major decline in suspended lead particulate between 1978 and 1987. Ambient lead levels in Vancouver declined by 75% since 1975 (Environment Canada 1988). Annual concentrations did not exceed the "desirable" objective of 2 micrograms/m^3 since 1978. No exceedances of the 24-hour "desirable" objective have been recorded at any of the 12 monitoring stations since 1984.

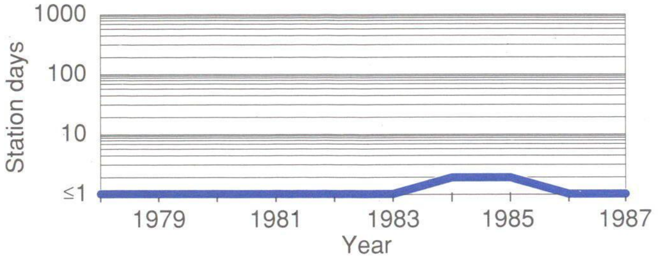
Air Management

In September 1988 the GVRD implemented a two-stage air quality management plan. Stage 1 of the plan has been completed. It assessed the current and future air quality based on historical monitoring data, the 1985 inventory of emissions, and the projections of population and industrial growth to the year 2005. Table 2 - 2 compares the tonnage of pollutant emissions in 1985 to projected tonnages in 1995 and 2005. The report indicates that:

- the region will experience an overall decline in emissions largely due to a drop in carbon monoxide;
- declines in nitrogen oxides and hydrocarbons, which are precursors of ozone, will result from more

Figure 5
Ten-year Trend in GVRD Air Quality (1978–1987)

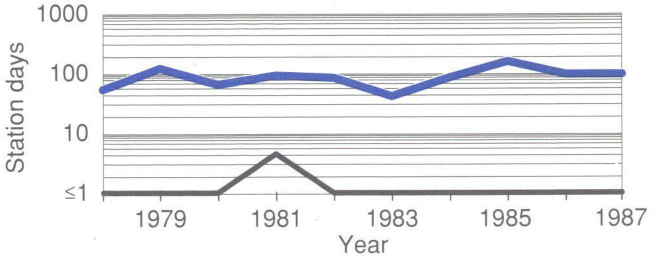
Nitrogen dioxide
Total level B objective exceedances at Stations T1 thru T9



Government of Canada Air Quality Objectives (parts per billion)

	1 hour	24 hour	1 year
Level A	none	none	30
Level B	210	110	50
Level C	530	160	none

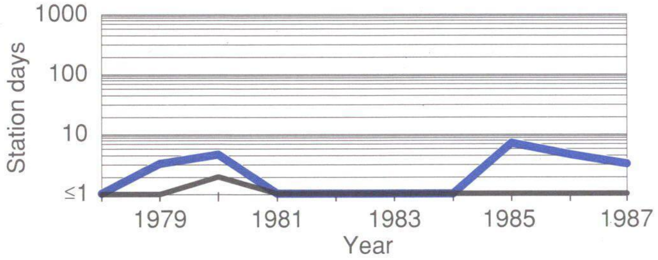
Carbon monoxide
Total objective exceedances at Stations T1 thru T9



Government of Canada Air Quality Objectives (parts per million)

	1 hour	8 hour
Level A	13	5
Level B	30	13
Level C	none	18

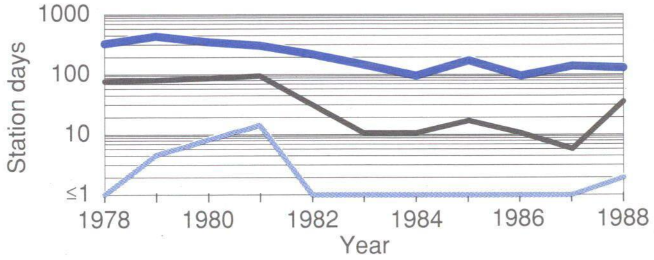
Sulphur dioxide
Total objective exceedances at Stations T1 thru T9



Government of Canada Air Quality Objectives (parts per billion)

	1 hour	24 hour	1 year
Level A	170	60	10
Level B	340	110	20
Level C	none	310	none

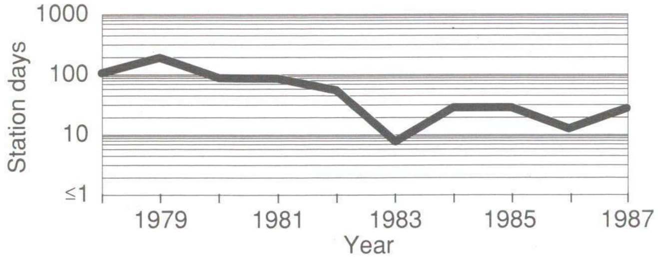
Ozone
Total objective exceedances at Stations T1 thru T9



Government of Canada Air Quality Objectives (parts per billion)

	1 hour	8 hour
Level A	51	none
Level B	82	15
Level C	153	none

Total suspended particulate
Total level B objective exceedances at 32 GVRD Stations

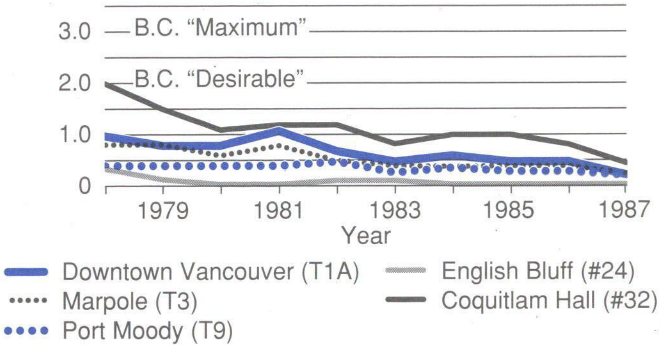


Government of Canada Air Quality Objectives (µg/m³)

	24 hour	1 year
Level A	none	60
Level B	120	70
Level C	400	none

- Level A
- Level B
- Level C

Suspended particulate lead (µg/m3)
Annual geometric mean



Province of B.C. Air Quality Objectives (µg/m³)
(No federal objectives exist for this parameter)

	24 hour	1 year
Desirable	4	2
Maximum	6	3

SOURCE: Greater Vancouver Regional District 1988a.

Figure 6
Lower Mainland Air Quality Monitoring Network

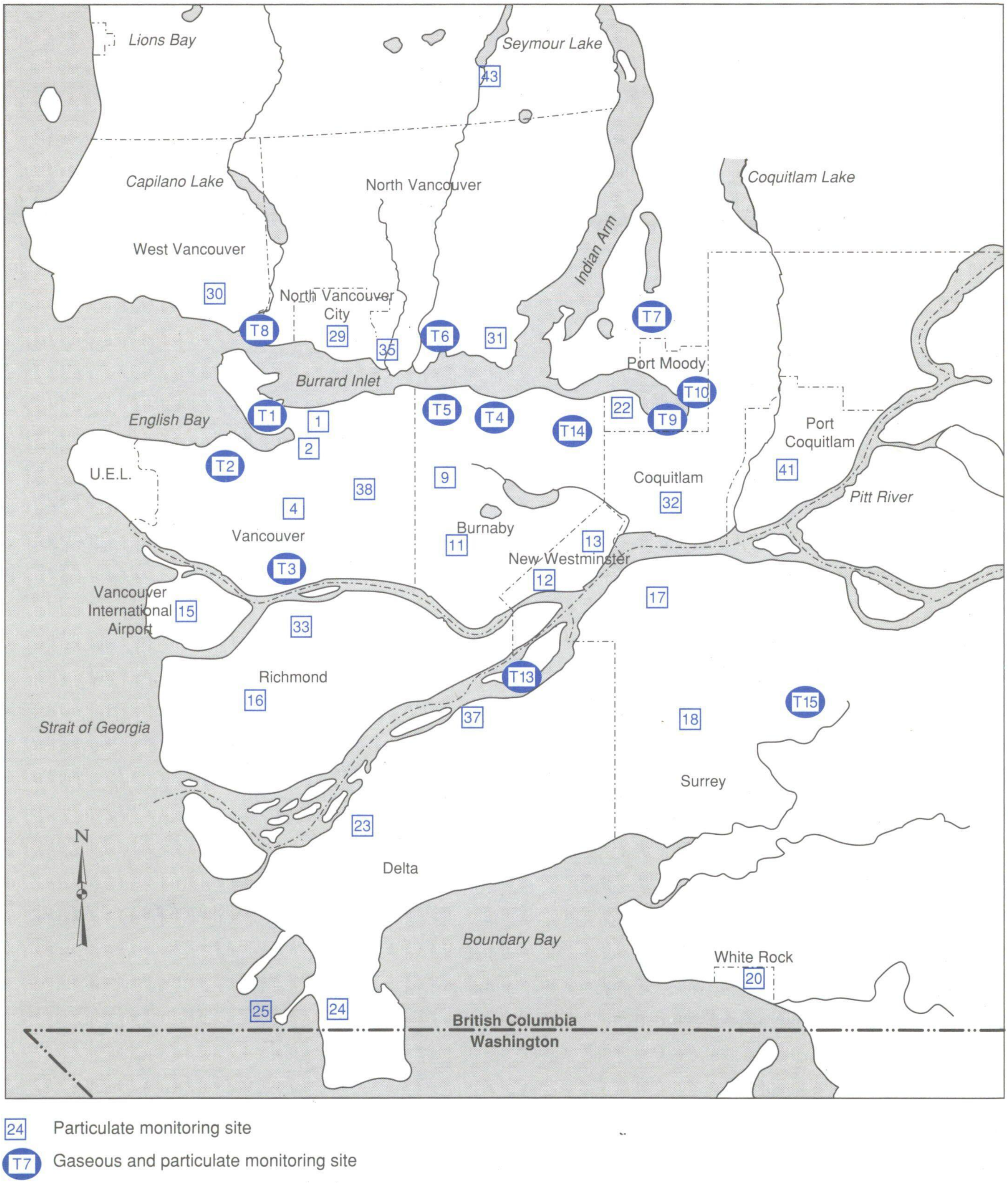


Table 2 - 2
Current and Projected Air Pollutant Loadings in the GVRD

Pollutant	Loadings (1 000 tonnes/year) 1985	1995	2005	% Change 1985-2005
Sulphur Oxides	12	16	19	58%
Nitrogen Oxides	50	51	55	10%
Suspended Particulates	121	136	151	25%
Carbon Monoxide	334	236	233	(30%)
Hydrocarbons	78	66	69	(12%)
Total	595	505	527	(11%)

Note: Figures have been rounded off from original report.

SOURCE: Greater Vancouver Regional District 1988b.

stringent vehicle emission standards; however, these decreases in vehicle emissions of nitrogen oxides will be more than offset by increasing industrial point source emissions;

- sulphur oxides and suspended particulates will increase steadily due to increased industry and vehicular traffic.

Stage 2 of the study will address specific air quality management goals and strategies, including monitoring. The provincial government also plans to expand its network of air quality monitoring stations in the upper Fraser Valley and to upgrade the stations to provide data on all key pollutants. The province and the GVRD are currently initiating mandatory vehicle emission tests.

Results of preliminary modelling suggest that future episodes of high ozone levels will remain above the Maximum Tolerable Level, if emissions projected for 2005 and current meteorological conditions prevail. The model also estimates that total emissions will decline to 505 000 tonnes by 1995 as a result of emission controls, following which emissions will begin an increasing trend in relation to the growth of vehicle traffic volumes.

Sustaining Air Quality

Is air quality being maintained in the Lower Fraser River Basin? Over the past decade there has been a dramatic decline in lead levels, and a pattern of decline in ozone and particulate concentrations. The other major air contaminants show no apparent trends. With the exception of ozone levels, no major change in exceedances for any of the key air quality parameters has occurred in recent data.

Air quality is generally good in the region, except during episodes of limited air movement, but this may not remain so over the long-term, primarily due to the projected growth in traffic volumes. Given the role of vehicle emissions in affecting air quality, increased air pollution can be anticipated during peak traffic hours along major routes, notwithstanding the significant effects of new car emission standards and vehicle emission inspections. Transportation decisions related to future patterns of urban settlement, the role of the private automobile and public transit, and vehicle emission standards and inspections will play an increased part in the management of air quality in the region. The continued reliance on fossil fuels will also influence the extent to which activities in the Lower Fraser River Basin contribute to the global production of greenhouse gases.

References

B.C Ministry of Environment and Parks. 1987. Western and Northern Canada Acid Rain Deposition/LRTAP Activities Annual Report, 1986. Victoria.

B.C. Ministry of Environment and Parks. 1988. Assessment of the 1985 Precipitation Chemistry Data Collected in the Strait of Georgia Area. Victoria.

Brooks, K. 1984. Planning Implications of a Carbon-Dioxide-Induced Global Warming in the Vancouver Area. Vancouver: University of British Columbia. Unpublished M.A. Thesis.

Environment Canada. 1986. Background Concentrations of Sulphate in Precipitation Along the B.C. Coast. Report PAES 86-1. Vancouver: Atmospheric Environment Services, Scientific Services Division.

Environment Canada. 1986a. The Impacts of Global Warming. Fact Sheet. Downsview, Ontario: Atmospheric Environment Service.

Environment Canada. 1988. Lead and Lead Free Gasoline Regulations Monitoring Program, Regional Program. Annual Report 88-04.

Greater Vancouver Regional District. 1988. 1985 Lower Mainland Emission Inventory. Burnaby.

Greater Vancouver Regional District. 1988a. Ten Year Trend in GVRD Air Quality (1977-1987). Burnaby.

Greater Vancouver Regional District. 1988b. Air Quality Management Program. Burnaby.

Kotturi, M.S. 1988. Assessment of the Chemistry of Precipitation and Fog in Southwestern B.C. Pacific Northwest Air Pollution Control Association Conference, November, 1988.

Titus, J.G. 1986. The Greenhouse Rising Sea Level and Society's Response. In: Devoy, R.J.N., ed. Sea Surface Studies: A Global View. London: Croom Helm.

Chapter 3

Water

The state of the region's water resources is affected by the complex interactions between climate, streamflow patterns, hydraulic and sedimentation processes, groundwater patterns, instream and extractive water uses, land use and effluent discharge, and the water quality objectives adopted by society.

Hydrologic Regime

Streamflow

The hydrology[1] of the Lower Fraser River Basin is dominated by snowmelt within the Fraser River watershed, by the stream and lake systems of the mountain watersheds bordering the Basin, and by the low-gradient streams and groundwater systems of the Fraser Lowlands (Figure 7). While the hydrologic pattern of the Fraser River and its major tributaries is largely driven by snowmelt, smaller streams in agricultural and urban areas are greatly influenced by rainfall. The flow of streams in urban areas is particularly affected by changes in land use within the receiving watershed. In agricultural areas, irrigation withdrawals can also have an impact on stream flow. The peak rainfall occurs during winter low flow periods on the Fraser River and urban runoff during such periods can adversely affect water quality.

The annual average discharge of the Fraser River at Hope is about 2 800 cubic metres per second (m^3/s), but flows can be as high as 15 000 m^3/s during spring and as low as 400 m^3/s in winter. Adjacent to the Fraser River drainage system, Burrard Inlet and Indian Arm comprise a fjord draining the coastal watersheds north of Vancouver. The freshwater plume of the Fraser River often extends into western Burrard Inlet.

During freshet, or spring runoff, the Chilliwack and Harrison Rivers increase flows in the Fraser by 10 to 15%. However, local rainstorms during autumn and winter can increase flows in the Fraser up to 45% between Hope and Mission. Figure 8 shows the annual and long-term mean flows of the Fraser River at Hope. Between 1925 and 1945 flows averaged about 10% lower than the long-term mean, while flows between 1945 and 1977 averaged several percent higher than the long-term mean. Since 1977 the river appears to have entered another low flow regime, which may reflect climatic trends.

At New Westminster, the river splits into the Main Arm, carrying an estimated 85% of the flow, and the North Arm, carrying the remaining waters. Saltwater under-rides freshwater due to the greater density of sea water, forming a saltwater wedge. During winter low flow periods the salt wedge can extend as far upstream as Annacis Island. During freshet, however, the salt wedge is pushed downstream and sometimes completely out of the channel at Sandheads. Reversals of flow direction in the channel due to tidal variations have important influences on the transport of sediment, nutrients, and contaminants in the estuary.

The flow pattern of the Fraser River is important to the dilution and dispersion of pollutants. Land uses and water withdrawals which alter this regime have a critical impact on water quality. The tidal influence during low flow periods also dramatically reduces the dilution capacity and increases the risk of exposure to contaminants by organisms in the lower estuary.

Sedimentation

The natural sediment load characteristics of the Fraser River have played an important role in the physical, biological, and economic aspects of the Basin. Sediments are responsible for creating much of the aquatic habitat associated with the Fraser River delta. Thousands of years of sedimentary deposits have also been responsible for the creation of rich agricultural lands. Dredging of sediments, along with river training structures, are necessary on an ongoing basis in order to maintain navigation on the lower Fraser River.

The major input of sediment to the lower Fraser River comes from the drainage area upstream of Hope. This input is correlated with the streamflow, so that trends in sediment

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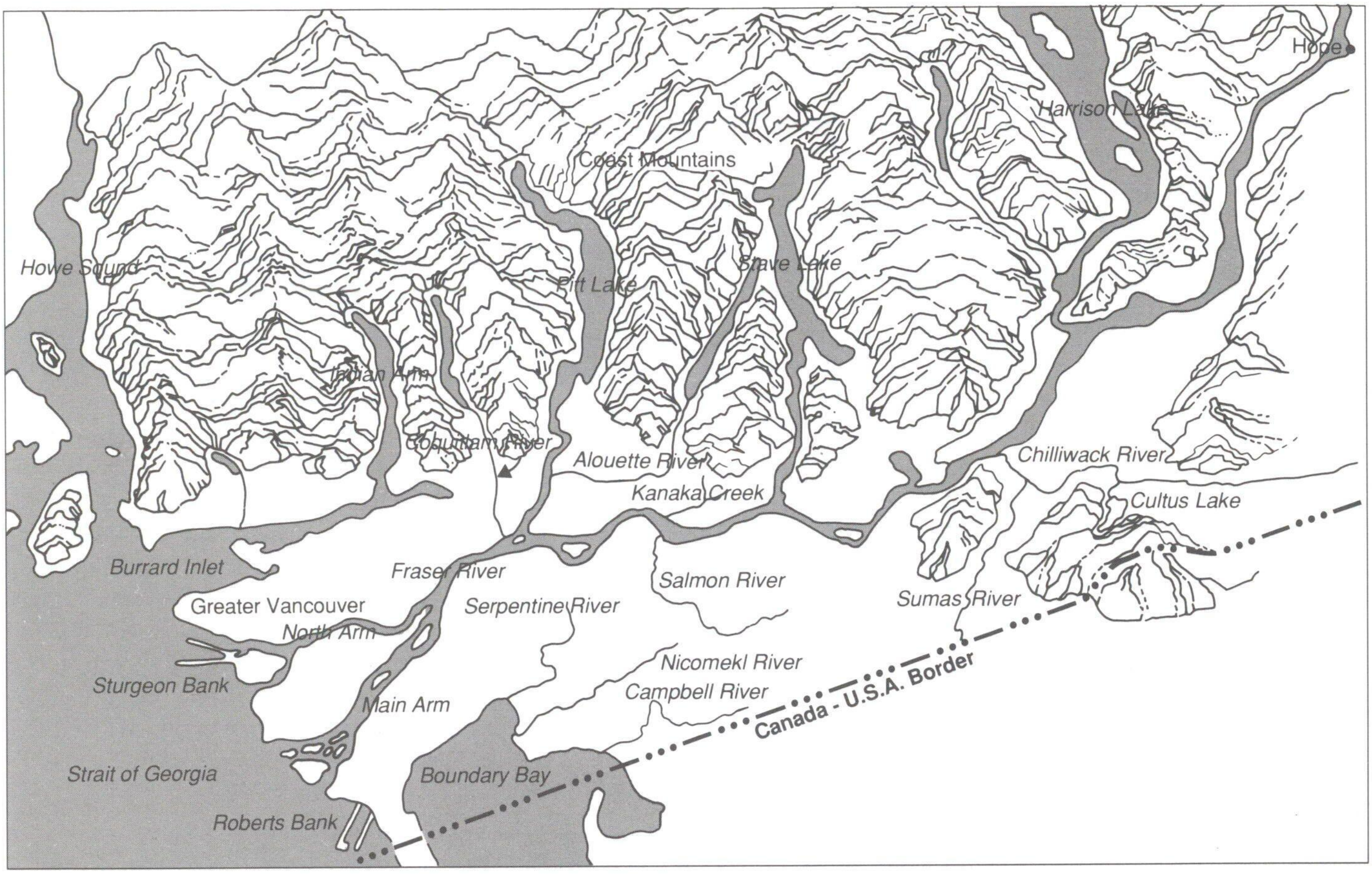
[1] The properties, distribution, and circulation of water on the land surface, in the soil and rocks, and in the atmosphere.

Figure 7
Topography and Drainage

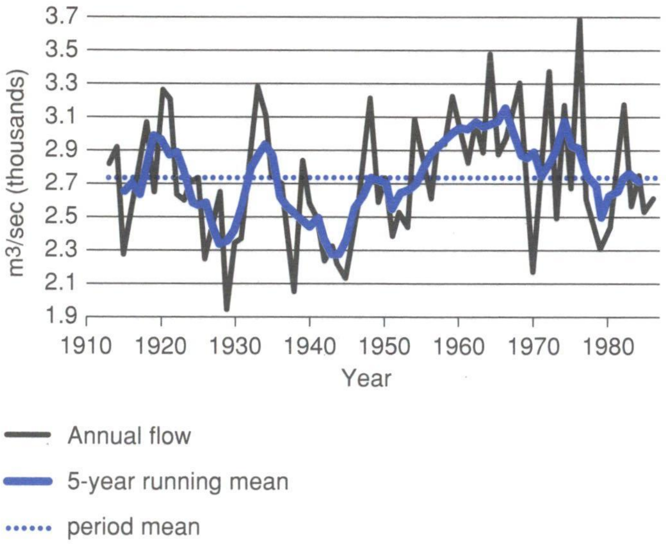


supply are similar to those for streamflow. The mean annual total sediment load at Mission is 17.3 million tonnes per year, ranging in individual years from 8 million to 26 million (Stewart and Tassone 1989). The total sediment load may be subdivided into bed material load and wash load components. The mean bed material load (particles coarser than 0.177 mm) is approximately 3 million tonnes per year. The wash load, averaging 14.3 million tonnes per year, consists of material finer than that found in the river bed and it is transported directly out to the Fraser River delta and the Strait of Georgia. A sediment budget indicated that, on average, about one-third of the bed material load also was transported to the delta between 1974 and 1983 (McLean and Tassone 1991).

The delta is growing due to the deposition of the silt and fine sand which is not deposited in the river channel. The -10 m contour (i.e., 10 m below mean sea level) remained stable between 1932 and 1974, while the -90 m contour advanced on average 4.5 m/yr. At the river mouth the -90 m contour advanced approximately 8.6 m/yr between 1929 and 1979 (Stewart and Tassone 1989).

Dredging is performed to remove the sediment which is deposited and to lower the river bed for navigation. Since 1965, dredging has resulted in an average lowering of the bed of the main channel of the river between New Westminster and the mouth by approximately 2.0 m (or 10 cm/year) (G. Tofte, Water Survey of Canada, pers. comm., 1989). Dredging also appears to have caused a deepening of the North Arm of the Fraser by about 1.5 m (Hay and Tamburi 1978). Available flow data indicate that the proportion of the total Fraser River's flow reaching the sea through the North Arm increased from about 7% in 1926 to over 13% in the 1970s (Hay and Tamburi 1978). Although the data are subject to interpretation, this flow increase could have resulted from an increase in the channel's conveyance of streamflow due to deepening from dredging and river training.

Figure 8
Fraser River Streamflow at Hope



SOURCE: Environment Canada, Water Survey of Canada.

Groundwater

Groundwater consumption in 1981 totalled approximately 30 million m^3 or 44% of total water consumption in the Fraser Lowland (Halstead 1986). No updated estimates are available. Groundwater is used for domestic supply, irrigation, industrial uses such as washing gravel, and for stabilizing water temperatures in fish hatcheries. Although local groundwater supplies occasionally fail during the summer dry season, winter recharge restores the supply so that no long-term lowering of aquifer levels appears to have occurred.

Water Management

Water Use

Water is allocated for domestic, industrial, agricultural, recreational, and fish and wildlife conservation purposes in the Lower Fraser River Basin. There are 15 community watersheds in the region, encompassing 4 200 km^2 (B.C. Ministry of Environment 1980). Water consumption in the GVRD has increased from an average 335 million litres/day in 1951 to 944 million litres/day in 1986 (Greater Vancouver Regional District 1989). The water is collected from the mountainous Capilano, Seymour and Coquitlam watersheds, an area of about 585 km^2, which is closed to the public to safeguard the quality of the supply.

It was estimated in 1985 that 40% of the watersheds used for irrigation in the Fraser Valley were experiencing irrigation water shortages (B.C. Ministry of Environment 1985). Particular conflicts occurred between demands for irrigation, instream fisheries, and water quality requirements during summer periods on certain streams.

High water tables pose a limit to agricultural activity in many areas; consequently, a network of drainage canals has been constructed. The largest such project was the Sumas drainage works, which involved the draining of Sumas Lake in the 1920s and a large loss of aquatic habitat, and construction of a major drainage canal and pumping system. Water is also diverted from the Coquitlam River to Buntzen Lake for water supply but this does not significantly influence flows in the Fraser River.

Flood Protection

Major flooding of the lowlands of the Lower Fraser River Basin occurred in 1894 and 1948. The 1:200-year floodplain, based on the 1894 flood, comprises approximately 708 km^2. A one-in-three chance that a flood at least as severe as the 1894 flood is predicted to occur within the next sixty years (Fraser River Flood Control Board n.d.). In 1971, 10% of the region's population lived within the floodplain (Book and Princic 1975) while today this has risen to about 15% (B.C. Ministry of Environment 1989). A federal-provincial floodplain mapping program is underway, which assists the regulation of development to ensure adequate floodproofing and flood protection.

There are 574 km of public dykes in the Lower Fraser River Basin, protecting more than 750 km^2 of the region from flooding, including heavily urbanized areas around Richmond and Delta. The Fraser River Flood Control Program, launched in 1968, provides funds for improvements to the system of dykes. While dykes have provided essential flood protection, they have also historically alienated environmentally important intertidal and riparian, or shoreline, habitat. Recent initiatives have sought to incorporate green strips as part of the dyke upgrading program by utilizing riparian vegetation in conjunction with dyke armouring.

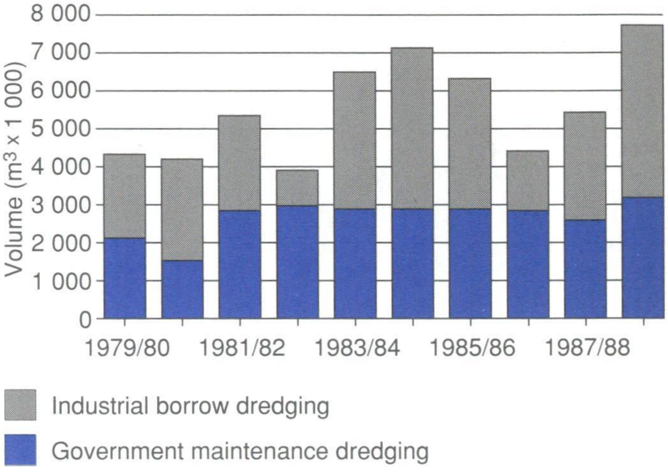
River Dredging and Training

Mechanical dredges are used in shallow water and hydraulic dredges in deeper water to remove sediments which restrict ship navigation in the river. Dredging removes 5.5 million m^3 of sediment each year (Fraser River Estuary Management Program 1991). The spoil material, or dredgeate, can have a harmful impact on the aquatic environment and is, therefore, only permitted to be deposited at designated sites on land or at sea. River training structures are also used along 20 km of the river to increase scouring of the river bottom and thereby reduce dredging requirements for navigation.

Channel maintenance dredging on the Fraser River is supplemented by industrial borrow dredging involving the removal of river sand for construction purposes. Figure 9 shows the growth in dredging activities in the last decade.

Dredging and training can have significant environmental impacts, such as destruction of fish and wildlife habitat. Dredging can result in the direct loss of bottom-dwelling flora and fauna and the resuspension of sediments smothers benthic[2] communities. It can also reintroduce contaminants into the water column. Restrictions are, therefore, placed on dredging during annual downstream juvenile salmon migrations and on the disposal of dredgeates.

Figure 9
Fraser River, Total Dredging Effort South and North Arm Channels



SOURCE: Regional Consulting Ltd. 1991.

Pollution Sources

The major pollution sources to the Lower Fraser River Basin waters are domestic discharges, industrial effluent, urban runoff and agricultural discharges (Figure 10). Contaminated groundwater flows, accidental spills, leachates from landfills and woodwastes, discharges from floating homes and liveaboard boats, and other miscellaneous discharges also contribute contaminants to the Lower Fraser River Basin.

Inputs to the area from upstream municipal effluents from the Thompson and Fraser Rivers totalled approximately 140 300 m^3 day in 1985. This was a fourfold increase from 32 600 m^3 day in 1965. Industrial discharges from these upstream sources increased from 1 400 m^3 day in 1965 to 643 900 m^3 day in 1985 primarily as a result of the construction of six pulp and paper mills on the Fraser River. During this period (1965-85) it was determined that on average, the pulp mills met the provincial government toxicity objectives 77% of the time (Servizi 1989).

Recently, attention has focused on the occurrence of dioxins and furans, which are toxic compounds that have been found in fish and sediments in the vicinity of pulp and paper mills on the Fraser River. These compounds, which are highly toxic and persistent, are formed during the chlorine bleaching process in kraft pulp mills (Mah *et al.* 1988). Levels of these compounds were high enough in certain species of fish for Health and Welfare Canada to issue a public warning to limit human consumption of these species. Dioxin monitoring by Environment Canada and the Department of Fisheries and Oceans (as part of the National Dioxin/Furans Fish Sampling Program) was carried out in the Lower Fraser River Basin in 1989 in the vicinity of two paper mills. Dioxin levels in fish muscle tissues were below detection limits and Health and Welfare Canada placed no restrictions on consumption (Environment Canada, Water Quality Branch Report in prep. 1991).

Between Hope and Kanaka Creek, information is available only for point sources which discharge 38 million m^3 of effluent annually to the Fraser River (Swain and Holms 1985). Downstream of Kanaka Creek, approximately 865 million m^3 of effluent are discharged annually to the estuary from sewage treatment plants, urban and agricultural runoff, and industrial sources (Fraser River Estuary Management Program 1990). Figure 11 portrays the permitted discharges in the Lower Fraser River Basin. It should be noted that actual flows may vary from the maximum authorized by permits since monitoring of flows may not be systematic. Data on contaminant loadings are less readily available. Most permits specify maximum concentrations for only a few parameters, and compliance reporting by permit holders varies. Contaminant characterization also varies by the discharge source, but is generally poorly known.

Domestic Effluent

Over 90% of domestic flows are from the Iona Island, Lulu Island, and Annacis Island sewage treatment plants, which have total average dry weather flows of

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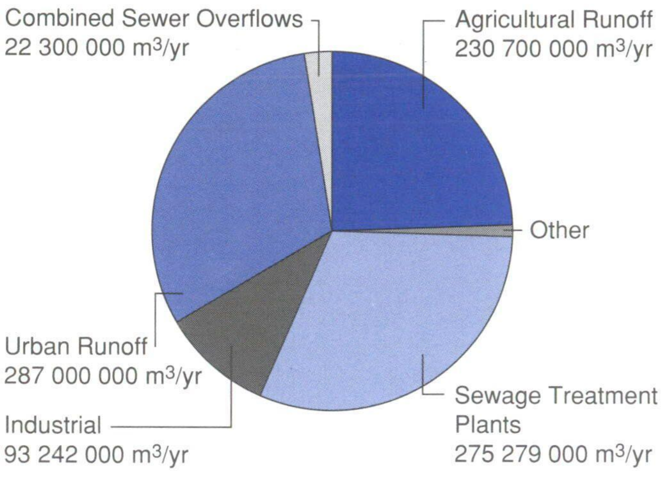
[2] Organisms that live on or in the bottom of a water body.

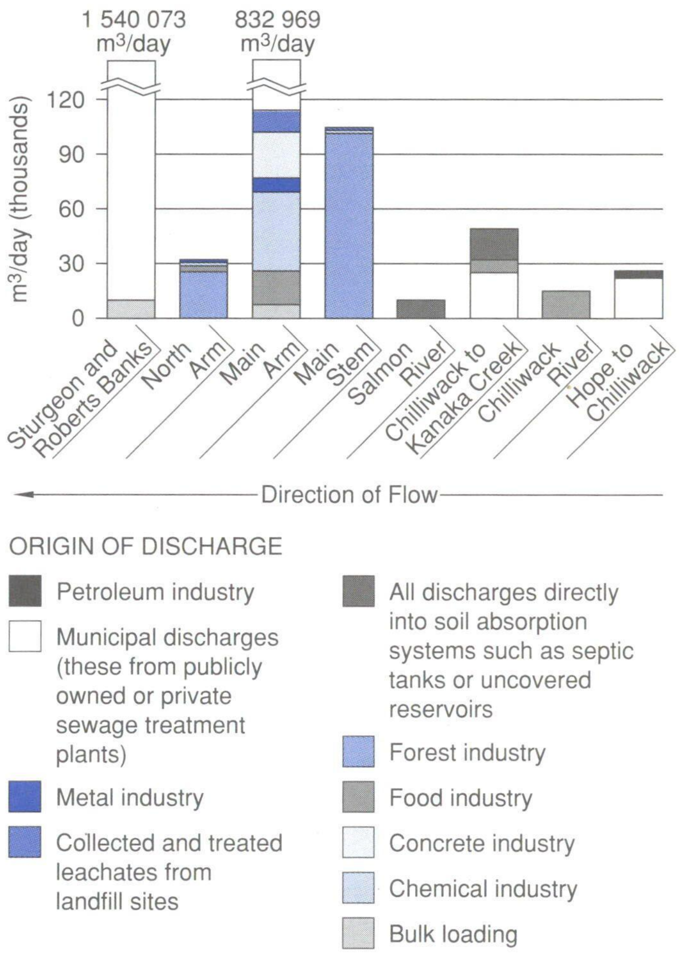
Figure 10
Summary of Wastewater Flows to the Fraser River Estuary and Boundary Bay, 1987



(Annual total: 9.08×10^8 m^3)

SOURCE: Fraser River Estuary Management Program 1990.

Figure 11
Distribution of Discharges in the Lower Fraser River Basin Authorized by B.C. Ministry of Environment Permits in 1987



Notes:
The figure includes the reaches downstream of Hope, through Chilliwack, past the mouth of Kanaka Creek to Sturgeon and Roberts banks. The basins of the Salmon and Chilliwack rivers are tributary basins.

- Origin of discharge refers to the industrial sector originating the discharge.
- Municipal discharges are based on maximum permitted flows, which are much higher than average daily dry weather flows.
- Hope Slough permitted discharges of 1 100 m^3/day, all to soil absorption systems, are included with the Chilliwack to Kanaka Creek discharges.
- Boundary Bay, not shown, had 1987 permitted discharges of 2 795 m^3/day, all but 336 m^3/day to soil absorption systems, and all to its tributaries.
- Sturgeon Bank discharges are dominated by Iona sewage treatment plant effluent, which is discharged to the Strait of Georgia through a deep-sea outfall effective April 1988.

SOURCE: B.C. Ministry of Environment, Waste Management Branch, permit files (1987); Fraser River Estuary Management Program (1990).

756 630 m^3/day and peak wet weather flows in excess of 2.16 million m^3/day of primary-treated sewage (Greater Vancouver Regional District 1988). These sewage treatment plants, which are operated by the Greater Vancouver Sewerage and Drainage District, discharge enough wastewater each year to fill B.C. Place Stadium 160 times. Flows have increased by 60% since 1976 for the Annacis plant, and are expected to double by 2036. Flows from the Iona plant, which are now discharged to a deep sea outfall in Georgia Strait, are expected to remain at their current level, while steady growth is expected for the Lulu Island plant. Primary sewage treatment removes suspended particles from the waste stream and the remaining waste water is chlorinated in the summer months. Sewage treatment plants also produce sludges which can be contaminated with heavy metals.

Between Kanaka Creek and Hope, six municipal sewage treatment plants discharge approximately 35 000 m^3/day of secondary-treated[3] effluent (B.C. Ministry of Environment 1989a). Steady growth is expected for these areas. Throughout the Lower Fraser River Basin there are approximately 20 small private sewage treatment plants treating effluent

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[3] After primary treatment, secondary treatment involves using either anaerobic bacteria (which do not use oxygen) or aerobic bacteria (which use oxygen) to treat the sewage.

from schools, marinas, trailer parks, or other developments. Almost one-half the 1 360 m^3/day of effluent discharges from these sources are to ground disposal systems (B.C. Ministry of Environment 1989a).

Effluents from the Annacis and Lulu Island sewage treatment plants (STPs) frequently contain higher levels of contaminants than permitted by the provincial government. For the Annacis plant permit, non-compliance is most apparent for Biochemical Oxygen Demand (BOD)[4], toxicity, oil and grease, and dissolved oxygen. For example, in 1985 toxicity levels were exceeded 50% of the time for Annacis and 66.7% of the time for Lulu Island sewage treatment plants (Greater Vancouver Regional District 1988). The toxic compounds identified in municipal sewage treatment plant effluent include un-ionized ammonia, cyanide, sulphides, chlorine, chloramines, phenols, anionic surfactants, heavy metals, and organic compounds. Table 3 - 1 provides a summary of annual contaminant loadings and characteristics for the Annacis, Lulu, and Iona STPs.

Due to tidal conditions in the Fraser River, this effluent can pool and spread across the river within two hours at slack tide, exposing millions of juvenile salmon and eulachon larvae during downstream migrations. During low river flows, the effluent from Annacis STP, for example, can reside in the river for up to 1.7 days. Major concerns exist regarding the lethal and sublethal effects of the toxicity of the effluent on both anadromous and non-anadromous fish in terms of bioaccumulation, stress, disease, reproduction, feeding behaviour, etc. Despite these concerns there are no techniques currently in place to link these effects to overall impacts on fish populations (Birtwell *et al.* 1988).

Industrial Effluent

Authorized discharges from chemical, concrete, food, forest, gravel washing, metal fabricating and finishing, port industries, and other industrial sectors in the Lower Fraser River Basin total almost 300 000 m^3/day, 90% of which occur in the estuary (B.C. Ministry of Environment 1989a). This is a drop from discharges of 351 571 m^3/day in 1973 (Hoos and Packman 1974) probably due to industrial hookups to Annacis Island STP in 1975. Of 116 authorized waste management permits, 11 contribute about 80% of total industrial effluent flows. Tables 3 - 2 to 3 - 5 summarize flows and loadings of industrial discharges.

Pollutant loadings include oil, grease, solids, metals, and organics. Total loadings are difficult to determine as permit requirements may not include all parameters; reporting periods and sampling methodology vary between permits; a few permit holders are in non-compliance situations; and unauthorized discharges may be occurring. Analysis of data for the 63 industrial permit holders on the Fraser River below Kanaka Creek show reported loadings of 4 739 kg/day of BOD, 7 226 kg/day of solids, 342 kg/day of oil and grease, and 5 780 kg/day of nutrients (Fraser River Estuary Management Program 1990). High priority industrial dischargers have been identified based on their flows and contaminant loadings (Working Committee on Fraser River Estuary Monitoring 1984). These are listed in Table 3 - 6.

Table 3-1
Sewage Treatment Plant Contaminant Loadings, 1985

Parameter (kg/day)	Iona	Annacis	Lulu
Discharge (m^3/day)	466 789	291 791	41 230
Oxygen demand	37 810	45 519	5 731
Suspended solids	26 607	20 717	2 639
Kjeldahl nitrogen	7 469	7 587	1 237
Ammonia	4 108	4 669	817
Fluoride	75	44	5.8
MBAS[1]	420	554	87
Sulphate	12 137	7 878	1 484
Calcium carbonate	33 609	30 930	4 535
pH	3 361	2 013	284
Phosphorus (diss)	840	905	136
Phosphorus (total)	1 354	1 314	219
Oil and Grease	7 469	8 462	1 278
Phenol	14	15	1.6
Boron (diss)	75	85	13
Aluminum (diss)	bdl	bdl	33
Aluminum (total)	ai	233	115
Cadmium (total)	ai	ai	0.07
Chromium (total)	bdl	bdl	6.2
Copper (diss)	19	15	2.1
Copper (total)	47	41	6.6
Iron (diss)	135	236	41
Iron (total)	415	525	111
Lead (diss)	ai	3.8	0.7
Lead (total)	20	12	2.4
Manganese (diss)	23	20	2.5
Manganese (total)	28	29	3.7
Nickel (diss)	bdl	ai	4.9
Nickel (total)	bdl	ai	6.2
Zinc (diss)	37	29	6.2
Zinc (total)	56	50	14

Notes:
Derived by multiplying finite effluent concentrations by the STP average reported flows for 1987.
ai: average indeterminate
bdl: below detection level
[1] MBAS: Methylene Blue Active Substances; ingredient in detergents and foaming agents.

SOURCE: Fraser River Estuary Management Program 1990.

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[4] BOD – the oxygen required for the biochemical breakdown of organic material and the oxidation of inorganic materials such as sulphides and iron.

Table 3-2
Significant Flows: Permits with Permitted Flows Greater than 5 000 m^3/day, 1987

Name,	Permit #	Industry Type	Discharge Type,	Authorized (m^3/day)	Actual (m^3/day)
MAIN ARM					
Chatterton	PE0041	Chemical	Combined	43 200	40 744
Canada Lafarge	PE0042	Concrete	Combined	6 360	5 075
Tilbury Cement	PE4513	Concrete	Cooling	18 200	9 323
Westshore Term.	PE6819	Wharf	Combined	10 000	158
BC Packers	PE1830	Food	Combined	8 086	na
Ocean Fish	PE1975	Food	Combined	7 240	na
FRHC	PE6276	Landfill	Leachate	10 000	na
Titan Steel and Wire	PE0161	Metal	Cooling	4 650	2 773
MAIN STEM					
Fletcher Challenge	PE0412	Forest	Cooling	55 500	1 552
Fletcher Challenge	PE2756	Forest	Combined	45 000	21 000
NORTH ARM					
Scott Paper	PE0335	Forest	Process	12 650	na
Paperboard Ind.	PE0017	Forest	Combined	11 400	9 562
Fraser Surrey	PE6452	Wharf	Stormwater	7 500	na
TOTAL				239 786	90 187

Notes:
Authorized: Maximum flows permitted by permit.
Actual: Flow reported by permit holder, 1987 data.
na: Not available.

SOURCE: B.C. Ministry of Environment, Waste Management Branch files.

In addition to authorized industrial discharges, recent attention has focused on operations using chlorophenols as wood preservatives and other anti-sapstain products. Average chlorophenol loadings for the Fraser River below Kanaka Creek have been estimated at 499 kg/yr from 25 operations (Krahn *et al.* 1987). The B.C. Ministry of Environment has recently introduced controls under the Waste Management Act which establish maximum discharge levels for these chemicals to both stormwater discharges and to runoff from areas where treated lumber is stored. Chlorophenol use is declining as forest companies change to other preservatives.

Urban Runoff

Storm sewers and ditches discharge urban runoff at numerous points in the Lower Fraser River Basin. There are 22 combined sewer overflow points on the Main Stem and North Arm with average annual flows of 22 million m^3. Annual urban runoff of about 165 million m^3 is discharged at 122 inventoried points in the Fraser estuary and accounts for about 29% of the flows into the lower Fraser River; another 122 million m^3 of urban runoff is discharged to the Boundary Bay drainage at an unknown number of points, comprising 53% of the total flows into Boundary Bay (Greater Vancouver Regional District 1988a). Tables 3 - 7 to 3 - 9 summarize data pertaining to urban runoff and combined sewer overflow loadings.

In areas of Vancouver, Burnaby, New Westminster, Chilliwack, and the District of Kent, combined sewer systems pass stormwater through the sewage treatment plants. However, capacities of combined sewers are often exceeded during storm events, leading to combined overflows of urban runoff and raw sewage.

Urban runoff loadings have only been characterized for a small industrial basin in Burnaby (Lawson *et al.* 1985) and a small residential basin in Vancouver (Swain 1983). These studies indicate that urban runoff has higher concentrations of nutrients and metals than in the Fraser River. Significant bacterial contamination has also resulted from combined stormwater and sewer overflows (Greater Vancouver Regional District 1988a).

Table 3-3
Industrial Loadings Summaries for 1979

Industrial Sector		Suspended Solids			BODs	
	MS	NA	MA	MS	NA	MA
Forest	5 263	23 700	-	7	4 972	-
Food	98	455	3 550	796	347	17 667
Metal	-	1 150	292	-	-	-
Cement	-	100	1 515	-	-	26
Municipal	4	6	9	6	3	10
Miscellaneous	67	-	23 831	24	-	-
Total	5 432	25 411	29 197	833	5 322	17 703
TOTAL		60 040			23 858	

Industrial Sector		Total Phosphorus			Total Nitrogen	
	MS	NA	MA	MS	NA	MA
Forest	2	2.5	-	15.8	38.2	-
Food	-	0.5	16.8	-	1.9	191.9
Metal	-	0.8	-	-	0.5	-
Cement	-	-	-	-	-	-
Municipal	0.6	0.1	0.2	4.4	0.1	1.8
Miscellaneous	-	-	5.3	-	-	17.8
Total	2.6	3.9	22.3	20.2	40.7	211.5
TOTAL		28.8			272.4	

Sector	Copper	Iron	Lead	Nickel	Zinc
NA Forest	0.9	15.7	1.8	0.3	53.0
NA Metal	1.2	105.0	4.8	-	89.5
North Arm Total	2.1	120.7	6.6	0.3	142.7
Main Arm Total	0.1	132.5	0.4	-	0.2
TOTAL	2.2	253.2	7.0	0.3	142.9

Notes:
Values in kg/day
MS: Main Stem; NA: North Arm; MA: Main Arm

SOURCE: Swain 1980.

Agricultural Discharges

Rural runoff from fields may be contaminated by agricultural practices such as manure spreading, over-fertilization, or improper application of pesticides which lead to high levels of Biochemical Oxygen Demand (BOD), nutrient, and organic pollutant loadings in watercourses and groundwater. These nutrient loadings and low dissolved oxygen levels have occasionally been toxic to fish and have resulted in major fish kills on the Serpentine and Nicomekl Rivers. Information is limited, but the estimated total runoff from agricultural land in the Fraser River estuary below Kanaka Creek is 632 000 m^3/day (Greater Vancouver Regional District 1988). Tables 3 - 10 and 3 - 11 provide estimates of flows and loadings of agricultural runoff.

Table 3 - 12 summarizes nutrient loadings from cattle by stream reaches while Table 3 - 13 illustrates the animal populations in the central Fraser Valley. If the nutrient loading data reflect average loading throughout the Basin, pollution standards may be exceeded. Studies of manure production and fertilizer use suggest that nitrogen application in the Lower Mainland far exceeds the recommended rate (Kowalenko 1987).

Table 3-4
Conventional Pollutant Loadings from Industry, 1987

Name	Permit Number	Reach	Industry Type	Discharge Type	Flow (m^3/d)	BOD	Suspended Solids	Oil and Grease	TOC	Ammonia	Phosphorous
Associated Foundry	PE1529	BB	Metal	Process	91		8.2	1.4			
Aviation Fueling	PE7160	NA	Petroleum	Storm	14		0.1				
B.C. Coast Vegetables	PE4505	NA	Food	Process	1 090						
B.C. Packers	PE1830	MA	Food	Combined	8 086			137.5	5 183	105.1	208
Bay Lumber	PE6832	MS	Forest	Cooling	275			0.8			
BCFP	PE2756	MS	Forest	Combined	21 000	210	378	63			
Chatterton	PE0041	MA	Chemical	Combined	40 744		187.4		275.8	4.48	
Crown Forest	PE0412	MS	Forest	Combined	1 200	172	43.6				
Domtar	PE3410	MS	Chemical	Cooling	51			0.2			
Fraser Wharves	PE1621	MA	Wharf	Process	53		0.1		0.5	0.02	
Genstar	PE4513	MA	Concrete	Cooling	9 323		1 743	121.2			
Lafarge Cement	PE0042	MA	Concrete	Combined	5 075			14.4			
Lamford Forest Prds.	PE0414	MS	Forest	Combined	80		3.3	02			
MacMillan Bloedel	PE1664	NA	Forest	Pro+Cool	124		3.3	2.5			
NEL Products	PE2063	NA	Food	Combined	370			0.4			
Paperboard Industries	PE0017	NA	Forest	Combined	9 562	4 351	4 848				
Richmond Cannery	PE5400	MA	Food	Combined	1.9	0.9	0.4	0.1			
Trans Mtn Pipeline	PE7171	NA	Petroleum	Storm	212						2.54
Western Canada Steel	PE2087	NA	Metal	Storm	45.5		0.9				
Westshore Terminals	PE6819	MA	Wharf	Sewage	158.4	5.2	9.7				
TOTAL						4 739.1	7 226	341.7	5 459.3	109.6	210.54

Notes:
These are 1987 data, the most recently compiled loading available. Some name changes, ownership changes, or closures have occurred since this summary was produced: BCFP and Crown Forest are now Fletcher Challenge, Genstar is now Tilbury Cement.
Units in kg/day
Gaps in table indicate no data
Reach: BB = Boundary Bay, MA = Main Arm, MS = Main Stem, NA = North Arm
BOD: Biochemical Oxygen Demand
TOC: Total Organic Carbon
Flow is actual reported, permit maximum if not

SOURCE: B.C. Ministry of Environment, Waste Management Branch files.

Landfills

Landfills consisting of municipal refuse, industrial debris, and woodwaste are responsible for substantial flows of leachates to surface and subsurface waters. Tables 3 - 14 and 3 - 15 provide leachate flow estimates and contaminant loadings for several large active and inactive landfills. Material deposited in landfills can be a complex mix and resulting leachates can be highly toxic.

Discharges from the Burns Bog, Port Mann, Braid Street, Kerr Road, and Terra Nova landfills are collected and discharged to the Annacis STP while leachates from the Richmond landfill are treated on site and discharged to the Fraser River under permit from the Ministry of Environment. One of the main issues with landfill leachates is the large contribution of ammonia to the Annacis STP. An additional concern has resulted from the fact that the Coquitlam landfill is currently used to store ash from the Burnaby incinerator. Leachate from the ash, which is contaminated with heavy metals such as lead, is also conveyed to the Annacis STP. There is little information about the volume or loadings of pollutants from industrial landfills and lagoons. Ten industrial sites have been identified as having potential leachate generation problems or as being potential groundwater contaminant sources (Fraser River Estuary Management Program 1990).

In 1987 an estimated 1.5 million m^3 of woodwaste was produced by mills located in the Fraser estuary and additional volumes were produced by mills in the Mission/Albion area. Most of the woodwaste was deposited in landfills, but another common use for this material is as a fill base on boggy soils. Highway construction, including the approach to the Alex Fraser Bridge and housing development in Richmond have been the greatest users.

Table 3-5
Organic and Metal Loadings from Industry, 1987

Name	Permit Number	Reach	Industry Type	Discharge Type	Flow (m^3/d)	Phenols	PCP	TCP/ TTCP	Aluminum	Arsenic	Barium
Chatterton	PE0041	MA	Chemical	Combined	40 744						
Domtar	PE3410	MS	Chemical	Cooling	51	0.05					0.000 1
Terminal	PE3950	NA	Forest	Combined	7.35			0.001			
MacMillan Bloedel	PE1664	NA	Forest	Pro+Cool	124	2.77	4.02/1.24	0.1	<.03	<.03	
Tree Island Steel	PE3190	NA	Metal	Combined	525			0.02		<.005	
Associated Foundry	PE1529	BB	Metal	Process	91				0.01		0.002
Western Canada Steel	PE2087	NA	Metal	Combined	24 094				0.5		1.2
Trans Mountain	PE7171	NA	Petroleum	Storm	212						
TOTAL						0.05	2.77	5.26	0.63	0.03	1.24

Name	Permit Number	Reach	Industry Type	Discharge Type	Flow (m^3/d)	Cadmium	Cobalt	Chromium	Copper	Iron	Lead
Chatterton	PE0041	MA	Chemical	Combined	40 744		0.6	0.45			
Domtar	PE3410	MS	Chemical	Cooling	51	<.000 5	<.005	0.00 2	<.005		
Terminal	PE3950	NA	Forest	Combined	7.35	<.000 7	0.000 7		0.000 1	0.002	<0.000 1
MacMillan Bloedel	PE1664	NA	Forest	Pro+Cool	124	<.001	<.01	<0.001	0.001	0.001	<.01
Tree Island Steel	PE3190	NA	Metal	Combined	525	0.04	<.05		0.08	<.5	0.3
Associated Foundry	PE1529	BB	Metal	Process	91	<.001	<.01		<.001	0.02	<.009
Western Canada Steel	PE2087	NA	Metal	Combined	24 094	<.23	<2.3		0.7	13.6	<2.4
Trans Mountain	PE7171	NA	Petrol	Storm	212				0.9		
TOTAL						0.27	2.98	0.001 5	1.23	15.02	2.72

Name	Permit Number	Reach	Industry Type	Discharge Type	Flow (m^3/d)	Magnesium	Manganese	Molybdenum	Nickel	Vanadium	Zinc
Chatterton	PE0041	MA	Chemical	Combined	40 744						
Domtar	PE3410	MS	Chemical	Cooling	51	0.006	<.000 5	<.000 5	<.003	<.000 5	<.000 5
Terminal	PE3950	NA	Forest	Combined	7.35	0.001 4	<.000 7	<.000 7	<.000 4	<.000 1	<.000 1
MacMillan Bloedel	PE1664	NA	Forest	Pro+Cool	124	0.07	0.02	<.001	<.01	<.001	0.004
Tree Island Steel	PE3190	NA	Metal	Combined	525	0.11	0.005	<.005	<.03	<.005	0.27
Associated Foundry	PE1529	BB	Metal	Process	91	0.02	0.002	<.001	<.005	<.001	0.003
Western Canada Steel	PE2087	NA	Metal	Combined	24 094	8.1	3.8	<.24	<1.2		0.7
Trans Mountain	PE7171	NA	Petroleum	Storm	212						
TOTAL						8.31	3.83	0.25	1.25	0.007 6	0.98

Notes:
These are 1987 data, the most recently compiled loading values available. Some name changes, ownership changes, or closures have occurred since this summary was produced. Western Canada Steel is now closed.
Units are kg/day. Blanks in table indicate no data. Totals are overestimated as "less than" designations are ignored.
Reach: BB = Boundary Bay, MA = Main Arm, MS = Main Stem, NA = North Arm.
PCP = Pentachlorophenol; TCP = Trichlorophenol; TTCP = Tetrachlorophenol.
Flow is actual if reported, permit maximum if not.

SOURCE: B.C. Ministry of Environment, Waste Management Branch files.

Leachates formed from woodwaste include toxic substances, may promote fungal growth, and may also include pollutants resulting from anti-sapstain treatments such as chlorophenols, arsenic, and copper (Fraser River Estuary Management Program 1990).

Miscellaneous Contaminant Sources

Other sources of pollutants within the Lower Fraser River Basin include septic tanks, underground storage tanks, houseboats, liveaboard boats, shipping, pollutants from docks

Table 3-6
High Priority Industrial Dischargers, 1984

Name	Reach	Industry Type
Paperboard Industries	NA	Forest Products
Chatterton Petrochemical	MA	Chemical
Lafarge Cement	MA	Cement
Titan Wire and Steel	MA	Metal Finishing
Scott Paper	NA	Forest Products
Fletcher Challenge, Fraser Mills	MS	Forest Products
MacMillan Bloedel New Westminster	NA	Forest Products
MacMillan Bloedel, Canadian White Pine	NA	Forest Products
B.C. Packers	MA	Food
Fletcher Challenge, Hammond	MS	Forest Products
Tree Island Steel	NA	Metal Finishing
Tilbury Cement	MA	Cement

MA = Main Arm, MS = Main Stem, NA = North Arm

SOURCE: Working Committee on Fraser River Estuary Monitoring 1984.

Table 3-8
Annual Urban Runoff by Waterbody

Receiving waters	Runoff Volume ($10^6 m^3$) Summer	Winter	Annual
Sturgeon Bank	0.2	1.1	1.3
Roberts Bank	0.1	0.7	0.8
Main Stem	6	36.1	42.1
Main Arm	2.5	14.1	16.6
Lower Main Arm	1.2	6.6	7.8
Upper North Arm	1.2	7.6	8.9
Lower North Arm	3	19.5	22.6
Brunette Basin	5.1	30.9	36
Pitt River	2.8	16	18.8
Coquitlam River	1.5	8.5	10
Fraser River Total	23.5	141.2	164.8
Boundary Bay	2.8	15.5	18.3
Serpentine River	9	51	60
Nicomekl River	5.4	30.4	35.8
Little Campbell River	1.2	6.8	8
Boundary Bay Total	18.3	103.7	122

SOURCE: Greater Vancouver Regional District 1988a.

Table 3-7
Contaminant Loadings from Urban Runoff and Combined Sewer Overflows

Parameter	Main Stem		Main Arm	North Arm		Boundary Bay	Annual Average	
(kg/day)	Urban Runoff	CSO	Urban Runoff	Urban Runoff	CSO	Urban Runoff	Urban Runoff	CSO
Flow (m^3/day)	111 600	21 260	68 900	93 800	39 700	327 700	602 000	62 100
BOD						3 615	8 215	3 700
F. Coliforms (MPN)	1.9×10^{12}	82×10^{12}	2.5×10^{12}	1.6×10^{12}	160×10^{12}	6.3×10^{12}	12.3×10^{12}	242×10^{12}
NFR	5 600	1 300	3 070	4 180	2 390	16 280	29 130	3 690
Ammonia							93	240
Total Nitrogen					584			
Total Phosphorus		7.4			44.6		58	116
Cadmium	0.6	0.1	0.3	0.4	0.14	1.6	2.9	0.2
Copper	4.5	1.7	2.6	3.6	3.1	13.4	24.1	4.8
Lead						27.6	33	5.5
Zinc		1		11.8	4	44.3	59	5

BOD: Biochemical Oxygen Demand
MPN: The most common coliform testing technique results in a Most Probable Number
NFR: Non-filterable residue

SOURCE: Greater Vancouver Regional District 1988a.

or boat hulls, deposits from bridge sandblasting, illegal dumping, and atmospheric deposition. Spills of chemicals and oil also arise from various sources. There were 61 reported spills during 1984-1986 in the Fraser estuary (Fraser River Estuary Management Program 1987). As well, industrial and municipal discharges from upstream of Hope also contributed an estimated 744 000 m^3/day of wastewater in 1985 (Servizi 1989).

Table 3-9
Annual Combined Sewer Overflow by Waterbody

Receiving waters	Runoff Volume ($10^6 m^3$) (Typical Frequencies) Summer	Winter	Annual
Main Stem	0.97 (37)	9.5 (114)	10.4 (151)
North Arm	0.9 (27)	11 (101)	11.9 (128)
Total	1.9	20.5	22.3

SOURCE: Greater Vancouver Regional District 1988a.

Table 3-10
Estimated Runoff from Agricultural Areas, 1987

Reach	Land Area in ALR[1] (ha)	Yearly Rainfall (mm)	Yearly Irrigation (mm)	Runoff (m3/day)
Main Stem	89	1 650	12	121 500
North Arm	24.6	1 200	12	24 700
Main Arm	46.3	114	12	44 700
Fraser Tributaries	85	1 780	12	126 900
Little Campbell	37.3	1 270	31	40 200
Nicomekl	86.5	1 520	64	112 300
Serpentine	56.6	1 400	21	65 800
Boundary Bay	99.3	1 140	38	95 900
TOTAL	524.6			632 000

[1] ALR: Agricultural Land Reserve

SOURCE: Greater Vancouver Regional District 1988a.

Table 3-11
Estimated Loadings from Agriculture, 1987

Reach	BOD5[1]	TN	TP	Fecal Coliforms	Cu	Pb	Zn
Main Stem	365	243	12	1 200	0.36	0.36	0.36
North Arm	74	49	2.5	250	0.07	0.07	0.07
Main Arm	132	88	4.4	440	0.13	0.13	0.13
Fraser Tributaries	379	253	12	13 000	0.4	0.4	0.4
Little Campbell	120	80	4	400	0.12	0.12	0.12
Nicomekl	337	225	11	1 100	0.34	0.34	0.34
Serpentine	198	132	6.5	660	0.2	0.2	0.2
Boundary Bay	288	192	9.5	960	0.29	0.29	0.29

[1] including suspended solids

Values are kg/day except fecal coliforms, number x 10^{10}

BOD5: the amount of oxygen used in the oxidative decomposition of a material by microorganisms over five days at a standard incubation temperature

TN: Total nitrogen

TP: Total phosphorus

SOURCE: Greater Vancouver Regional District 1988a.

Table 3 - 12
Estimated Nutrient Loadings[1] from Diffuse Agricultural Sources (kg/yr)

Reach	Cattle Population	Nitrogen	Phosphorus
Boundary Bay	2 199	43 117	31 063
Kanaka Ck. to Fraser Mouth	1 729	61 160	5 533
Hope to Kanaka Ck.	1 532	61 280	4 902

[1] These are total quantities; amount that enters receiving waters depends on soil conditions, waste handling practices, and distance between cattle and watercourses.

SOURCE: Swain and Holms 1985.

Table 3 - 13
Summary of Animal Populations, Central Fraser Valley

Municipality	Cattle	Sheep	Pigs	Horses
Surrey	14 407	937	6 608	1 235
Abbotsford	18 318	202	26 049	150
Langley	15 703	5 111	14 073	3 273
Matsqui	19 156	1 347	51 593	751
Total	67 584	7 597	98 323	5 409

SOURCE: Statistics Canada 1986.

Table 3-14
Landfill Sites

Large Active Municipal Landfills Name	Affected Water Body	Estimated Flows[1]	Comments
Burns Bog	Main Arm	1 200	Leachate collected, discharge to sewer
Port Mann	Main Stem	600	Leachate collected, discharge to sewer

[1] In m^3/day, flows approximately double during heavy rainfall.

Large Closed Municipal Landfills Name	Affected Water Body	Estimated Flows[1]	Comments
Braid Street	Main Stem	1 000	Monitored
Leeder Avenue	Main Stem	1 000	Monitored
Kerr Road	North Arm	500	Leachate collected, discharge to sewer
Richmond	Main Arm	5 000	Leachate collected, treated onsite
Stride Avenue	North Arm	200	Monitored
Terra Nova	Main Stem	600	Leachate collected, discharged to sewer

[1] In m^3/day, flows approximately double during heavy rainfall.

Small Municipal Landfills Name	Affected Water Body	Status	Leachate Impacts
Cottonwood, Maple Ridge	Main Stem	Open	Yes, sewer discharge
Johnston Road, Surrey	Main Stem	Closed 1969	Yes
Bear Creek, Surrey	Serpentine River, Bndy Bay	Closed 1967	Yes
Elgin, Surrey	Nicomekl River, Bndy Bay	Closed 1966	Unknown
Port Coquitlam	Coquitlam River, Main Stem	Closed 1979	Unknown
Sperling Avenue, Burnaby	Brunette River, Main Stem	Closed 1967	Unknown
Semiahmoo Bay, Surrey	Campbell River, Bndy Bay	Closed	Unknown
24th Avenue, Surrey	Nicomekl River, Bndy Bay	Closed	Unknown

SOURCE: B.C. Ministry of Environment, Waste Management Branch files 1987.

Quantified data regarding flows and contaminant loadings from miscellaneous sources in the Basin do not exist. In general, these sources are characterized as causing minor contaminant loadings which could produce significant localized impacts. However, in the absence of information about flows of contaminants from miscellaneous sources, the actual environmental impacts remain unknown. There are approximately 60 000 underground storage tanks in B.C., the majority of which are located in the Lower Mainland region. In 1988, it was estimated that between 125 and 250 were leaking gasoline, between 500 and 2 000 had the potential to leak heating oil, and between 20 and 200 were leaking undetected amounts of a wide variety of toxic chemicals (The B.C. Professional Engineer 1989). Small quantities of leaked fluid can cause significant damage. One litre of gasoline could render one million litres of drinking water unsafe for drinking.

Of particular concern recently is the atmospheric deposition of pollutants. In addition to being a source of acid rainfall, other substances deposited can include dioxins, furans, chlorophenols, lead, pesticides, and other metals and organics (Servizi 1989). Sources include wood combustion, the use of leaded gasoline, industrial gas discharges, pesticide spraying, and a host of other activities which release gaseous materials. The relationship between atmospheric pollution and contaminant loadings in water effectively illustrates the mobility of pollutants through various environmental compartments.

Water Quality

Fraser River

Water quality in the lower Fraser River is influenced by several factors: seasonality of flows, sediment load (which gives the river its muddy appearance), tidal movement which causes the intrusion of a dense salt wedge upstream in the Main Arm to New Westminster, natural background levels of

Table 3-15
Municipal Landfill Leachate Loadings, 1985

Parameter	Burns Bog	Coquitlam	Cottonwood	Kerr Road	Port Mann
Total Solids		1 437		507	1 289
Suspended Solids	131	42			100
Oil and Grease		5			
COD	538	329	58	42	288
BOD5		23	<9		74
TOC			99	17	107
Phenol	<0.7	0.059		0.001	
Chloride		278			180
Fluoride[1]	<.01	0.1			0.07
Sulphate[1]	81	18			4.2
Sulphide	<0.1	<0.06			
Total Kjeldahl Nitrogen		131			93
Ammonia	289	128	13	24	79
Nitrate	5	0.9	0.11	3	
Nitrite	0.1		0.018	0.051	
Phosphate[1]		0.6			0.14
Aluminum		<0.3	0.9	0.02	
Arsenic[1]	<0.1	0.03	<0.2	<0.12	0.002
Barium[1]			0.1	26	
Boron			0.4	0.95	
Cadmium[1]	<0.1	<0.004	<0.013	<0.005	0.001
Calcium[1]	210	108	60	41	171
Chromium[1]	<0.1	<0.03	<0.02	<0.005	0.003
Cobalt[1]		<0.03	<0.01	<0.049	
Copper[1]	<0.1	<0.012	<0.008	<0.005	<0.16
Iron[1]	17	18	2.3	0.1	37
Lead[1]	<0.8	<0.045	<0.04	<0.049	0.16
Magnesium[1]		30	16	19	32
Manganese[1]	2	1	0.9	0.1	1.1
Mercury	<0.000 7	<0.000 3	<0.02		
Molybdenum[1]		<0.06	<0.013	0.01	
Nickel[1]	<0.1	<0.03	0.3	<0.025	0.01
Phosphorus			10.6		0.6
Silver[1]		<0.012	<0.02		
Sodium[1]		154	36		129
Vandium[1]			<0.005	<0.005	
Zinc[1]	0.25	0.062	0.02	0.007	0.26

Notes:
Units in kg/day
[1] May be total or dissolved
Blanks indicate no data
COD: Chemical oxygen demand
BOD5: (see table 3-11)
TOC: Total organic carbon

SOURCE: Greater Vancouver Regional District 1988a.

inputs such as nutrients and metals (e.g., phosphorus and copper) and inputs from industrial, domestic, agricultural, and urban development activities.

Several studies of overall water quality have been carried out in the last 20 years. The Westwater Research Centre at the University of British Columbia published several technical reports in the 1970s (Dorcey 1976). These were followed by the work of the Water Quality Work Group as part of Phase I of the Fraser River Estuary Study in 1980. The Ministry of Environment updated the Fraser River Estuary Study findings in a technical report which also proposed provisional Water Quality Objectives (Swain and Holms 1985a). In 1987 and 1990, Status Reports on Water Quality in the Fraser River Estuary were published by the Fraser River Estuary Management Program (FREMP) (Fraser

River Estuary Management Program 1987a). As part of the GVRD's Waste Management Plan, an assessment was made of water quality in the major waterbodies and waterways within the Lower Mainland (Coastline Environmental Services/Envirochem Services 1987). In 1988, the Ministry of Environment published a report which assessed the attainment of water quality objectives in the Lower Fraser River Basin (Rochinni 1988).

Generally, these studies have all arrived at the same broad conclusions — namely that ambient water quality in the Main Arm of the Fraser River is fair to good, where large flows tend to flush out most contaminants. Provisional water quality objectives have been set by the provincial government as guidelines for protection of designated water uses. Monitoring of these objectives has occurred since 1986. Table 3 - 16 describes the relative attainment of these objectives on different reaches of the Fraser River. It should be noted that the objectives do not apply to the initial dilution zone, which is an area emanating from the point of waste discharge.

While water quality objectives are met in most areas, conditions are often much worse than indicated in those waters where flows are limited and flushing is restricted, such as sloughs, side channels, and small streams. Fish kills occur on a regular basis in these waterbodies (O. Langer, Fisheries and Oceans Canada, pers. comm., November 19, 1989). Even in the Main Arm, there are points at which waste discharges are known to be acutely toxic (i.e., sewage treatment plants and some industrial discharges). There is also a zone of severe biological degradation over a limited area of Sturgeon Bank that has been caused by the discharge from the Iona STP. This area is expected to recover now that a deep sea outfall is in place which discharges sewage into Georgia Strait rather than onto Sturgeon Bank. The following discussion examines in more detail the state of water quality in the major areas of the Lower Fraser River Basin based on the reports listed above.

Hope - Kanaka Creek

There is very little data on water quality conditions upstream of Kanaka Creek. Provisional water quality objectives have been established by the B.C. Ministry of Environment for six characteristics in this sub-basin: fecal coliforms, chlorine residuals (Fraser River only), un-ionized ammonia/nitrogen, total phosphorus (Cultus Lake only), dissolved oxygen, and pH. The monitoring results for these objectives have been published for 1986 and 1987 (Rochinni 1988). Generally, the objectives have been met; however, dissolved oxygen levels for Saar Creek, Hope Slough, Atchelitz Creek, Luckakuck Creek, and Chilliwack Creek were not always met. It is suspected that inputs of nutrients from agricultural activities were responsible for the low oxygen levels. The report suggests that the monitoring of these streams, especially the ones used for fish spawning, should be intensified.

A two-year monitoring program to determine levels of selected pesticides following crop spraying in farm ditches (including ditches leading to the Sumas, Fraser, and Nicomekl Rivers) found pesticide residue levels exceeded acutely toxic levels for fish and aquatic invertebrates (Wan 1989). Field personnel in the Department of Fisheries and Oceans also report that many smaller streams containing salmonids in this sub-basin have very low flows which have been known to dry up completely and, in other cases, have experienced fish kills. These streams, which often flow through farmland and forest lands, are very susceptible to inputs of contaminants and sediments.

Those mountain streams which are unaffected by logging activities are relatively pristine, although lower pH in streams such as Kanaka Creek have been observed in relation to precipitation events (Whitfield and Daily 1987). Acid precipitation levels are within the range of mild acidity (4.5-5.0), but due to the high sensitivity of soils and moderate to high sensitivity of lakes, such levels may cause long-term damage (B.C. Ministry of Environment 1985).

Main Stem and Tributaries

Representing an area from Kanaka Creek downstream to where the river splits in three at New Westminster, the Main Stem is considered to have relatively good water quality. River water is considered "soft" which provides a buffering capacity to acidic inputs, but is poorly buffered against alkaline inputs. Metal levels in the water, with the exception of copper and iron, generally met provincial water quality criteria for the protection of aquatic life. Those that did not were usually associated with high suspended solids concentrations (Fraser River Estuary Management Program 1987).

Dissolved oxygen levels have generally been met in monitoring programs from 1980-82, although very limited sampling in 1987 downstream of Langley reported levels slightly below the water quality objective of 7.75 mg/L minimum (7.5 and 7.4 mg/L) (B.C. Ministry of Environment 1987). Very little monitoring has been carried out in the sloughs and side channels in this reach. Fecal coliform levels were high at a monitoring site near Kanaka Creek, with a median value of about 275 MPN[5]/100 mL and a 90th percentile of 1 300 MPN/100 mL (Swain and Holms 1985).

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[5] MPN – The most common coliform testing technique results in a Most Probable Number (MPN).

Table 3-16
Attainment of Water Quality Objectives in the Lower Fraser Basin, 1988

Objective	Sturgeon and Roberts Banks	Boundary Bay	North Arm	Main Arm	Main Stem	Salmon River	Chilliwack, to Kanaka Creek	Chilliwack Vedder, and Sumas Rivers	Hope to Chilliwack
Fecal Coliforms	•	+	•	+	•	•	•	?	•
Suspended solids		+	-						
Ammonia nitrogen	-	•	?	•		•	•		+
Nitrite nitrogen		+							
Total phosphorus									
Chlorine residues	-			-			-		-
Dissolved oxygen	-	+	•	•	•	•	•	?	+
pH		+	•	•	-	•	•		•
Total copper			?	•					
Total lead		•	?	•					
Total zinc			?	•					
CPs in water			?	?	?				
CPs in sediment	•		?	?	?				
CPs in fish			•	•	•				
PCBs in water		?							
PCBs in sediment		?	?	?	•				
PCBs in fish		-	•	•	•				

Notes: <———— Direction of Flow ————

• Objective met
o Objective not met
+ Mixed results, objective met at some parts of reach, or at some times, but not at others
- Not checked
? Indefinite result, may be due to too few samples, or to a detection limit above the objective
If column entry is blank, the objective is not applicable
CPs: Chlorophenols
PCBs: Polychlorinated biphenyls
Hope Slough is included with the Fraser River from Hope to Chilliwack.

SOURCE: B.C. Ministry of Environment 1989b.

These values were substantially lower than values reported in 1973, 1974, and 1975 at Patullo Bridge (90th percentile values of 6 700, 4 800, and 13 000 MPN/100 mL, respectively) (Churchland 1980).

There are no discernible trends regarding PCBs in this part of the Basin. Sites sampled in 1985 found that sediments exceeded the water quality objective of 0.03 µ/g (dry weight) while a 1987 survey could not detect any PCBs in sediments (Swain and Walton 1988). During this same survey, the organochlorinated pesticide dieldrin, a very persistent compound which was banned from use several years ago, was found in sediments near Barnston Island. In sampling sediments and benthos throughout the Fraser River estuary, this particular survey determined that higher levels of contaminants (metals and organics) were correlated with smaller sediment sizes such as silt and clay.

While metal levels have been detected in limited samples of muscle tissue and livers from several species of fish taken near Barnston Island, they appear to be within acceptable levels and there are no discernible trends of increasing levels (Swain and Walton 1988).

Four main tributaries to the Fraser River in this reach include Kanaka Creek, the Pitt River, the Coquitlam River, and the Brunette River. In all four tributaries total copper, iron, and lead exceeded Canadian Council of Resource and Environment Ministers (CCREM) guidelines. CCREM guidelines for nickel were exceeded in the Coquitlam River, while guidelines for chromium and zinc were exceeded in the Brunette River. Dissolved oxygen levels were near saturation in the Pitt and Coquitlam Rivers, slightly lower than saturation in the Brunette River, and generally good in Kanaka Creek (Fraser River Estuary Management Program 1987).

Draft water quality objectives are being prepared for these tributaries. Some of these draft objectives are not being achieved. In particular, the Coquitlam River has experienced increased sediment loads from gravel washing operations, which have reduced salmon populations, while the Brunette River receives polluted urban runoff and has experienced fish kills and a chlorophenol spill (Fraser River Estuary Management Program 1987).

Main Arm

The Main Arm, which flows from New Westminster to the mouth is highly influenced by tidal action and the intrusion of dense saline water from the Strait of Georgia throughout its length. These natural conditions can greatly affect water quality conditions in the Main Arm. During periods of slack tide, effluents can take up to 72 hours to leave the river and may also pass a point several times before total flushing occurs. The salt wedge can have a dramatic effect in sloughs and backwaters where it can be trapped in depressions for several weeks resulting in very low dissolved oxygen levels.

The Main Arm is the recipient of major quantities of municipal waste from the Annacis and Lulu Island sewage treatment plants. It is not surprising that it is generally at sampling sites near these discharge points where the provisional water quality objectives for several variables were not met during the 1987 monitoring program. In 1987 (April-October), the maximum fecal coliforms objective of 4 000 MPN/100 mL was not met at sampling sites downstream of Annacis Island, both upstream and downstream of the Lulu Island STP and downstream of Steveston. Dissolved oxygen levels were also slightly below the objective at a sampling site upstream of the Annacis Island STP. The objective for total cadmium was exceeded at four sampling sites upstream and downstream of the Annacis and Lulu Island sewage treatment plants. The total lead water quality objective was also exceeded near the Lulu Island STP and, while the results were indefinite, samples up- and downstream of the Annacis Island STP exceeded the lead objective. The total zinc objective was also exceeded upstream of the Lulu Island STP. Levels of chlorophenols in sediments at sites near Annacis Island and Ewan Slough were slightly above the objective of 0.01 µg/g maximum.

In 1988, the B.C. Ministry of Environment monitored for these water quality parameters and found that most were being met except for some fecal coliform objectives near the Annacis Island and Lulu Island sewage treatment plants (B.C. Ministry of Environment 1989a). These results for 1987 and 1988 show how variable monitoring data can be from one year to the next.

Bioconcentration of metals such as nickel, strontium, barium, copper, and zinc from sediments to various benthos is occurring in the Main Arm (Swain 1986). However, overall metal levels do not appear to be increasing in fish muscles (Swain and Walton 1989).

North Arm

The North Arm of the Fraser River has the most degraded water quality conditions due, in large measure, to the heavy industry located there and the great number of stormwater and combined sewer outfalls that discharge into it. The lower flows relative to the Main Arm mean that waste discharges are not as readily diluted. Metal finishing plants, wood treatment plants, and urban runoff are considered to be the major sources of metal and organic contaminants in the North Arm.

During the 1987 water quality monitoring program, fecal coliform levels were exceeded at the Mitchell Island, Oak Street Bridge, west Sea Island, and Middle Arm sampling sites. Dissolved oxygen levels were not met in October at the North Arm Jetty and in September upstream of Scott Paper. The total cadmium objective was exceeded upstream and downstream of Scott Paper and at a site near the foot of Byrne Road. Lead and zinc levels were met. Chlorophenols in water were not met with levels ranging from 0.3-1.0 µg/L recorded at New Westminster, 0.6 µg/L downstream of Belkin, and 0.3-1.3 µg/L at Oak Street. Samples taken of chlorophenols in sediments from sites near Belkin and in McDonald Slough generally met the objective of 0.01 µg/g maximum although the results were not definite as some levels were very close to the objective. The levels of PCBs in sediments from these two monitoring sites were below the objective of 0.03 µg/g max.

The 1988 Fish Monitoring Program discovered PAHs in muscle tissue and livers only from fish in the North Arm (Swain and Walton 1989). Benthic organisms collected in 1985 showed bioconcentration from sediments of barium, cadmium, copper, strontium, and zinc. PCB levels in fish muscle tissue were found to be considerably lower than levels recorded in 1972/73.

Sturgeon and Roberts Banks

The water quality of Sturgeon Bank has been most affected by the twenty-five years of primary sewage discharge from the Iona sewage treatment plant. An area of approximately 3 km^2 extending around the sewage ditch outfall has been severely degraded biologically (Birtwell *et al.* 1983). With the construction of a deep sea outfall extending into Georgia Strait, this area is expected to rehabilitate over time. A monitoring program is in place to examine the impacts of the new outfall.

Prior to the deep sea outfall, fecal coliform objectives were constantly being exceeded. One study found that juvenile salmon exposed to the discharge from the Iona STP rapidly accumulated DDT, PCBs, PCP, and 2,3,4,6-tetrachlorophenol (Rogers 1987). Seven organic compounds and eight inorganic elements were detected in sediments in a 1986 survey. Concentrations of all organics, except phthalate esters, were within twice the detection limit (EVS Consultants 1986). During this same survey, cadmium and copper were detected in sockeye salmon livers, zinc and mercury in crab claws, and chromium and lead in clams.

Surveys of contaminant levels in sediments and in benthic fish and invertebrates undertaken by Environment Canada between 1984 and 1986 showed that total metals were high in sediments near the Iona STP discharge (Harding *et al.* 1987). Tissues of intertidal invertebrates reflected trace metal levels in sediments with those animals living near the outfall generally having much higher levels than those elsewhere on the estuary. The study concluded that limited long-term trend data suggested an overall decrease of trace metals in tissue levels.

Boundary Bay

Boundary Bay, and Sturgeon and Roberts Banks have been closed to bivalve harvesting since 1962 because of high fecal coliform levels. Agricultural operations in the Serpentine, Nicomekl, and Little Campbell River watersheds contribute large quantities of fecal coliforms, oxygen-consuming organic material, and nutrients to these rivers which flow into Boundary Bay. The rivers frequently have low dissolved oxygen levels which have resulted in fish kills. Water quality objectives for dissolved oxygen are not usually met in these rivers. Stormwater discharges also increase suspended solids and lead levels in the watersheds. High metal levels have been measured as well (Fraser River Estuary Management Program 1987).

Water quality objectives in Boundary Bay for pH, nutrients, and most metals have been met; however values for total copper, lead, mercury, and zinc have been occasionally exceeded. Dissolved oxygen levels usually met the proposed short-term water quality objectives but not the proposed long-term objective. Fecal coliform levels usually met objectives for swimming, but not for shellfish harvesting.

Groundwater

Water from flowing artesian groundwater supplies, or aquifers, is generally several hundred years old or older, and the quality of these waters has remained essentially constant over the last three decades (H. Liebscher, Environment Canada, Inland Waters Directorate, pers. comm., April 29, 1989). However, near-surface water table aquifers, which are comprised of younger waters, are vulnerable to contamination from pesticides, fertilizer, septic tanks, leaking underground fuel storage tanks, landfill leachate, and localized spills from surface transport of hazardous waste and fuel. For example, samples taken near the Abbotsford Airport in 1988 showed nitrate concentrations up to 20.6 mg/L, which is double the accepted maximum level for human consumption (10 mg/L) (Sather 1989).

A likely source of the nitrate contamination is poultry manure, which is locally stockpiled and spread on the land during winter when the water table is close to the surface and rainfall is high. Areas of the Fraser Valley with unconsolidated sand and gravel deposits and unconfined, shallow groundwater sources are the most vulnerable to contamination.

Water Quality Trends

Nearly all the published reports which have monitored or studied water quality in the Lower Fraser River Basin have concluded that insufficient information exists to determine trends in water quality conditions. The establishment of Provisional Water Quality Objectives by the Ministry of Environment and the inclusion of these into a water quality plan for the estuary as part of the Fraser River Estuary Management Program represents a start in establishing baseline conditions upon which to monitor changes. The five-year monitoring program being undertaken by the Ministry of Environment and the Fraser River Harbour Commission will also contribute to this information base.

The *Fish Monitoring Program* Report, recently published by the Fraser River Harbour Commission and the Province of British Columbia, compares data for metal levels in fish over a 15-year period (Swain and Walton 1989). This is one of the only published accounts of this type of data for the study area. Nevertheless, the authors express caution on the use of this data, given different sampling techniques, locations, fish species used, etc. In examining the levels of metals and organics in fish from three areas of the Fraser River, the authors concluded that, in many instances, the levels found in fish in the Fraser system are below those found in uncontaminated waters in other areas of the province. However, chlorophenols and polynuclear aromatic hydrocarbons (PAHs) may be accumulating in fish livers.

The available data indicate that water quality objectives for the protection of certain water uses on the Fraser River are generally met and that water quality in the main channels is similar to that reported in 1979 (Fraser River Estuary Management Program 1987). However, there are some important areas of concern, including the sloughs, side channels, and the North Arm where poor flushing occurs, and groundwater aquifers and small streams in agricultural areas.

The large volume of flow of the Fraser River masks many pollutants. Seven of 21 waterbodies in Greater Vancouver are rated as poor and nine are rated as having fair water quality (Greater Vancouver Regional District 1988). Although water quality is in fair condition in the main channels of the Fraser River, it was estimated in 1983 that up to 25% of the 148 permitted discharges may be adversely affecting receiving water quality at specific locations (B.C. Ministry of Environment 1985).

Provisional water quality objectives have been set by the provincial government as guidelines for protection of designated water uses. Table 3 - 16 describes the relative attainment of these objectives on different reaches of the Fraser River.

Agricultural streams such as the Serpentine, Nicomekl, Salmon, and Sumas Rivers are susceptible to low dissolved oxygen levels due to high nutrient loadings and low flow periods, and fish kills have frequently occurred.

Boundary Bay, Sturgeon Bank, and Roberts Bank have been closed to bivalve (clams, oysters) harvesting since 1962 because of high coliform counts. Bacterial contamination is also a factor in occasional bathing beach closures, although the opening of the Iona sewage treatment plant deep sea outfall in April 1988 has lowered coliform counts at Vancouver area beaches. Other concerns include nitrate contamination of groundwater in the central Fraser Valley from intensive agriculture, woodwaste leachates from wood processing plants, and both fecal coliform levels and contaminated sediments at certain locations in Burrard Inlet.

Toxic and persistent contaminants have also been identified in the ecosystem at different locations in the estuary. Metals and organics are of concern because of their tendency to bioaccumulate in the tissues (particularly livers) of organisms, although no definite trends have been observed (Harding *et al.* 1987). Recent concerns have also focused on metals and chlorophenols in the North Arm (Krahn *et al.* 1987), dioxins and furans and their possible impacts on fish and aquatic organisms, and the effects of chlorinated organics on Great Blue Heron production (Whitehead 1989; Elliott *et al.* 1989).

Sustaining Water Resources

Is water quality being maintained to safely meet human, fish, and wildlife requirements? The present database is inadequate to determine trends in conditions. Pollution problems exist at certain locations and tributaries within the urbanized and agricultural areas, and within Burrard Inlet, where recent analyses of fish provide evidence of significant pollution in some areas. It is also evident that increasing amounts of contaminants are being discharged via the sewage treatment plants and from storm sewer overflows. Many reports have suggested the need for greater emphasis on source control. The Greater Vancouver Regional District, as part of their Liquid Waste Management Program, are examining the implementation of a source control bylaw which would apply to municipalities within the region.

The establishment of Water Quality Objectives by the B.C. Ministry of Environment, and the inclusion of these into a water quality plan for the estuary by the Fraser River Estuary Management Program, is a start in establishing accurate baseline conditions from which to monitor change. However, more extensive water quality monitoring is necessary, particularly concentrating on chlorophenols, heavy metals, and organic contaminants in surface waters, and nitrate and organic pollutants in groundwaters. There is also a need to have consistent effluent monitoring of source discharges. Ambient monitoring is currently not done in the initial dilution zone and may not capture events such as spikes in pesticide runoff, anti-sapstain plumes, or acutely toxic or anoxic (low oxygen) conditions near outfalls.

There remains considerable uncertainty about the sources and fate of pollutants and the sublethal and chronic effects on biota and human health. There is, for example, a lack of site-specific toxicological data, insufficient planning of stormwater drainage and water quality protection, and limited knowledge of agricultural discharges and fish habitat interactions. These and other issues require more comprehensive and intensive efforts at environmental monitoring and research.

References

B.C. Ministry of Environment. 1980. Guidelines for Watershed Management of Crown Lands used as Community Water Supplies. Victoria.

B.C. Ministry of Environment. 1985. Fraser Delta Environmental Management Plan.

B.C. Ministry of Environment. 1987. Attainment of Water Quality Objectives. Victoria: Water Management Branch.

B.C. Ministry of Environment. 1989. 1989 estimate of population living in the Fraser River floodplain. Water Management Branch, Lower Mainland Region.

B.C. Ministry of Environment. 1989a. Information on effluent discharge sources. Surrey: Waste Management, Lower Mainland Region files.

B.C. Ministry of Environment. 1989b. The Attainment of Ambient Water Quality Objectives in 1988. Victoria: Water Management Branch.

The B.C. Professional Engineer. 1989. Control of Leaking Underground Storage Tanks. 1989 November.

Birtwell, I.K., C.D. Levings, J.S. Macdonald and I.H. Rogers. 1988. A Review of Fish Habitat Issues in the Fraser River System. Water Pollution Research Journal of Canada 23(1):1-30.

Birtwell, I.K., G.L. Greer, M.D. Nassichuk and I.H. Rogers. 1983. Studies on the Impact of Municipal Sewage Discharges onto an Intertidal Area within the Fraser River Estuary, British Columbia. Technical Report of Fisheries and Aquatic Sciences No. 1170. Vancouver: Fisheries and Oceans Canada.

Book, A.N. and R. Princic. 1975. Estimating Flood Damages in the Fraser River Basin. Environment Canada, Water Planning and Management Branch.

Churchland, L.M. 1980. Water Quality: Microbial Water Quality, 1970-1977. Fraser River Harbour Commission/B.C. Ministry of Environment.

Coastline Environmental Services Ltd./Envirochem Services. 1987. Greater Vancouver Receiving Water Quality Conditions. Liquid Waste Management Plan Stage 1. Burnaby: Greater Vancouver Regional District.

Dorcey, A.H.J., ed. 1976. The Uncertain Future of the Lower Fraser. Vancouver: Westwater Research Centre.

Elliott, J.E., R.W. Butler, R.J. Norstrum and P.E. Whitehead. 1989. Environmental Contaminants and Reproductive Success of Great Blue Herons *Ardea herodias* in British Columbia, 1986-87. Environmental Pollution 59:91-114.

EVS Consultants. 1986. Iona Deep Sea Outfall Project. Interim Report, Environmental Monitoring 1986. Vancouver.

Fraser River Estuary Management Program. 1987. Environmental Emergency Activity Program - Discussion Paper. New Westminster.

Fraser River Estuary Management Program. 1987a. Status Report on Water Quality in the Fraser River Estuary - 1987. New Westminster: Standing Committee on the Fraser River Estuary Water Quality Plan.

Fraser River Estuary Management Program. 1990. A Recommended Waste Management Activity Plan. New Westminster: Waste Management Activity Program Working Group.

Fraser River Estuary Management Program. 1991. Navigation, Dredging and Environment in the Fraser River Estuary. New Westminster.

Fraser River Flood Control Board. n.d. Brochure.

Greater Vancouver Regional District. 1988. Liquid Waste Management Plan - Stage 1 Draft Report. Burnaby.

Greater Vancouver Regional District. 1988a. Greater Vancouver Liquid Mangement Plan - Stage 1. Report of the Combined Sewer Overflow and Urban Runoff Committee. Burnaby.

Greater Vancouver Regional District. 1989. Data on water use in the GVRD. Burnaby: Information Services.

Halstead, E.C. 1986. Ground Water Supply - Fraser Lowland. NHRI Paper No. 26. IWD Scientific Series No. 145. Ottawa: Supply and Services Canada.

Harding, L., M. Pomeroy, A. Colodey and L.L. Grooms. 1987. Fraser River Estuary Marine Environmental Monitoring Results 1984-1986. Regional Program Report PR 87-18. Vancouver: Environment Canada, Environmental Protection Service, Pacific and Yukon Region.

Hay, D. and A.J. Tamburi. 1978. An Introduction to River Mechanics and the Lower Fraser River. Vancouver: Public Works Canada, Pacific Region.

Hoos, L. and G.A. Packman. 1974. The Fraser River Estuary: Status of Environmental Knowledge to 1974. Vancouver: Environment Canada.

Kowalenko, C.G. 1987. An Evaluation of Nitrogen Use in British Columbia Agriculture. Agriculture Canada Technical Bulletin 1987-3E. Agassiz, B.C.

Krahn, P.K., J.A. Shrimpton and R.G. Glue. 1987. Assessment of Storm Water Related Chlorophenol Releases from Wood Protection Facilities in British Columbia. Regional Program Report 87-14. West Vancouver: Environment Canada, Environmental Protection Service, Conservation and Protection.

Lawson, E.M., D. Walton and G. Mitchell. 1985. Stormwater Monitoring in an Industrial Catchment Basin Located in Burnaby, British Columbia. Surrey: B.C. Ministry of Environment, Waste Management, Lower Mainland Region.

Mah, F.T.S., D.D. MacDonald, S.W. Sheenan, T.M. Touminen and D. Valiela. 1988. Dioxins and Furans in Sediment and Fish from the Vicinity of Ten Inland Pulp Mills in British Columbia. Vancouver: Environment Canada, Inland Waters.

McLean, D.G. and B.L. Tassone. 1991. A Sediment Budget of the Lower Fraser River. In: Proceedings of the Fifth Federal Agency Sedimentation Conference (VI): 2-33 to 2-40. Washington, D.C.: Federal Energy Regulatory Committee.

Regional Consulting Ltd. 1991. Navigation, Dredging and Environment in the Fraser River Estuary. New Westminster: Fraser River Estuary Management Program, Navigation and Dredging Work Group.

Rochinni, R.J. 1988. The Attainment of Water Quality Objectives. Victoria: B.C. Ministry of Environment, Waste Management Branch.

Rogers, I.H. 1987. Organic Analytical Chemistry and the Fraser Estuary: Identification of Contaminants in Municipal Wastewater and Fish. Proceedings of the Water Quality Workshop. New Westminster: Fraser River Estuary Management Program.

Sather, S. 1989. Preliminary Results of 1988 Piezometer Monitoring, Nitrate Contamination, Abbotsford Area. Memorandum to A.P. Kohut, B.C. Ministry of Environment, Water Management Branch, March 2, 1989.

Servizi, J.A. 1989. Protecting Fraser River Salmon (*Oncorhynchus* spp.) from Wastewaters : An Assessment. In: Levings, C.D., L.B. Holtby, and M.A. Henderson, eds. Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Can. Spec. Publ. Fish Aquatic Sciences 105.

Statistics Canada. 1986. Census of Agriculture.

Stewart, I. and B. Tassone. 1989. The Fraser River Delta: A Review of Historic Sounding Charts. Environment Canada: Inland Waters Directorate.

Swain, L.G. 1980. Fraser River Estuary Study, Water Quality, "Industrial Effluents." Victoria: B.C. Ministry of Environment.

Swain, L.G. 1983. Stormwater Monitoring of a Residential Catchment Area. Victoria: B.C. Ministry of Environment, Waste Management.

Swain, L.G. 1986. A 1985 Survey of Metals, PCB's and Chlorophenols in the Sediments, Benthic Organisms and Fish of the Lower Fraser River. Victoria: B.C. Ministry of Environment.

Swain, L.G. and G.B. Holms. 1985. Fraser Delta Area Sub-Basin from Hope to Kanaka Creek: Water Quality Assessment and Objectives. Victoria: B.C. Ministry of Environment.

Swain, L.G. and G.B. Holms. 1985a. Fraser Delta Area Sub-Basin from Kanaka Creek to the Mouth: Water Quality Assessment and Objectives. Victoria: B.C. Ministry of Environment.

Swain, L.G. and D.G. Walton. 1988. Report on the 1987 Benthos and Sediment Monitoring Program, Fraser River Estuary Monitoring. Fraser River Harbour Commission/B.C. Ministry of Environment.

Swain, L.G. and D.G. Walton. 1989. Report on the 1988 Fish Monitoring Program. Fraser River Harbour Commission/B.C. Ministry of Environment.

Wan, M.T. 1989. Levels of Selected Pesticides in Farm Ditches Leading to Rivers in the Lower Mainland of British Columbia. Journal of Environmental Science and Health: Pesticides, Food Contaminants, and Agricultural Wastes B24(2):183-203.

Whitehead, P.E. 1989. Update on Current Studies of Dioxin in Great Blue Herons in the Georgia Strait Area. In: McDonald, D., ed. Proceedings of the Canada-British Columbia Workshop on Water Quality Guidelines and Objectives: Focus on the Fraser. Vancouver: Environment Canada.

Whitfield, P.H. and N.E. Dalley. 1987. Rainfall Driven pH Depressions in a British Columbia Coastal Stream. In: Nix, S.J., ed. Monitoring, Modelling and Mediating Water Quality. Bethesda, MD: American Water Resources Association.

Working Committee on Fraser River Estuary Monitoring. 1984. Fraser River Estuary Monitoring: A Recommended Approach. Victoria.

Chapter 4
Land

Forestry

The critical variables for measuring the sustainability of the forest resources include the supply and capability of land for timber production, the rate of timber harvest and timber loss from natural causes, and the level of silviculture for maintaining forest ecosystems.

Overview

Table 4-1 shows the distribution of the total 1 168 000 ha of public forest land within the Lower Fraser River Basin. Not all of this land is used for growing trees. Within that forest land base, the amount of land currently used for growing a commercial forest crop is 403 213 ha. Projected additions to the forest land base for the period 1985 - 2005 total 43 700 ha, although these will be offset by increasing exclusions from the land base.

The forests of the Lower Fraser River Basin fall within three biogeoclimatic classification zones: Coastal Western Hemlock (CWH); Mountain Hemlock (MH), and Alpine Tundra (AT). Each zone is further subdivided into subzones, associations, and finally, variants based on soil and nutrient regimes and on vegetative species (Krajina and Brooke 1969). This site-specific ecological information is used to aid in prescribing harvesting systems, post-harvest site preparation methods, and plantation species.

The CWH occurs at the lower elevations. The MH encompasses the subalpine elevations of the coastal mountains and has a cool, wet climate. The AT supports very little forest growth; the main vegetation is shrubs, herbs, lichens, and mosses.

Land Base

The Lower Fraser River Basin includes the forest resources within the Fraser Timber Supply Area (TSA) (11 680 km^2), the Greater Vancouver Water District (580 km^2), the District of Mission Tree Farm Licence (89 km^2), the University of B.C. Research Forest (51 km^2), and the Scott Paper Ltd. Tree Farm Licence (36 km^2). Of the 5 193 km^2 of productive forest land within the Crown Forest Land (TSA) portion of the study area, 2.3% (120 km^2) is classed as being on good growing sites, 38.7% (2 011 km^2) is on medium growing sites, and 59% (3 062 km^2) is poor or very poor forest land.

Table 4 - 1
Fraser Timber Supply Area (TSA) - Net Land Base Summary

Classification	Area (ha)	% of TSA
Total TSA	1 168 000	100.0%
Total Crown Land	940 100	80.5%
Crown Forest Land	519 300	44.5%
Non-Crown Forest Land	72 088	6.2%
Total Forest Land (Crown & Non-Crown)	591 388	50.6%
Deletions[1]	-187 975	
Net Forest Land Base (1985)	403 213	34.5%
Additions over 20-year plan[2]	+ 43 700	
Net Forest Land Base (2005)	447 113	38.2%

[1] Not Sufficiently Restocked (NSR) land, roads, trails, landings, environmentally sensitive areas, critical deer winter range, non-merchantable and deciduous timber.
[2] NSR restocking, deciduous rehabilitation, Timber License reversions.

SOURCE: B.C. Ministry of Forests 1985.

Rate of Harvest

The harvesting levels for the Fraser TSA are set for five-year periods, with the latest set in 1985. The current Allowable Annual Cut (AAC) of 1.925 million m^3 applies to all Crown and Non-Crown forest land. In the case of Crown (TSA) lands, the AAC of 1.70 million m^3 was exceeded by 34% in 1987 (B.C. Ministry of Forests 1989). This is not unusual as, within a five-year cut control period, the actual annual cut is allowed to fluctuate up to +/- 50% from the allowable in any given year, provided the difference at the end of the five-year period is within +/- 10% for the period. An accurate assessment of the allowable versus actual cut for the five-year period was to be possible in 1991.

The total AAC of 1.925 million m^3 annually is valued at $260 million; $230 million of which is derived from the Fraser TSA (Jacques 1988). On the basis of existing TSA projections for a 200-year harvesting cycle, the production target is expected to remain constant at the current AAC for the next 40 years, then drop to 1.57 million m^3 annually between the 50th and 80th years, then rise again to present levels for the remainder of the cycle (B.C. Ministry of Forests 1985). The production targets for the Mission Tree Farm Licence (TFL), Scott Paper TFL and Greater Vancouver Water District (GVWD) lands have been adjusted to allow for a sustained harvest.

The allowable timber harvest is determined through a yield analysis that considers the current area and volume of accessible mature timber; forest land alienated for other purposes; deletion of certain forest types; expected volume at maturity of immature stands; effects of silvicultural treatments; expected alienation and additions of land; land used for logging roads; delays in regenerating logged areas; expected fire, insect and disease losses; expected changes in utilization standards; stand treatment losses, such as blowdown; and breakage during harvesting operations (B.C. Ministry of Forests 1979). Other factors that affect the rate of timber harvest include operability (the ability to economically access and manage a site for forestry purposes) and the effectiveness of pest management programs.

Timber harvesting and road building activities create several environmental issues. Figure 12 illustrates some of the major linkages between forestry practices on environmental processes and the resulting biological effects on fish and fish habitat. Logging can have significant impacts on wildlife habitat. In particular, old growth forests are indispensable to such bird species as the Spotted Owl. Table 4 - 1, indicates that 11 500 hectares have been deleted from the forest land base for deer winter habitat. In addition, a 2% reduction has been made to the long-run sustained yield of the TSA to protect fish habitat from forestry activities. The B.C. Ministry of Environment ranks the loss of old growth timber as one of its major management issues in the Lower Fraser River Basin (B.C. Ministry of Environment 1989). The Ministry of Forests, Ministry of Environment, and Fisheries and Oceans Canada, however, consult frequently on fish and wildlife habitat protection measures.

The pre-harvest silvicultural prescription (PHSP) is required for all forest harvesting plans. It provides a biophysical description of the site and an assessment of the project's impacts on non-forestry values. The process is less detailed than an environmental impact assessment and does not require the involvement of experts in non-forestry values. Public viewing of PHSPs are held and valid public concerns are included in the final document. Any concerns not considered for inclusion in the final document must be justified in writing.

Apart from timber harvesting activities, it should also be noted that the forest industry produces a variety of other environmental concerns including the impacts of log storage on foreshore habitat and water quality; seepage and spills of wood preservatives into watercourses; the impact of woodwaste dumps on water quality; and the impacts of wood burning on air quality. These concerns illustrate how the effects of one industrial sector can impact upon the full range of environmental resources.

Timber Loss from Fire, Pests, and Diseases

Fires resulted in the loss of more than 60 000 m^3 of timber during 1986 to 1988; these losses far exceeded projections of 5 000 m^3 per year. This is attributable to an unusually bad fire year in 1986 and the uncertainty in projecting the year-to-year fire situation.

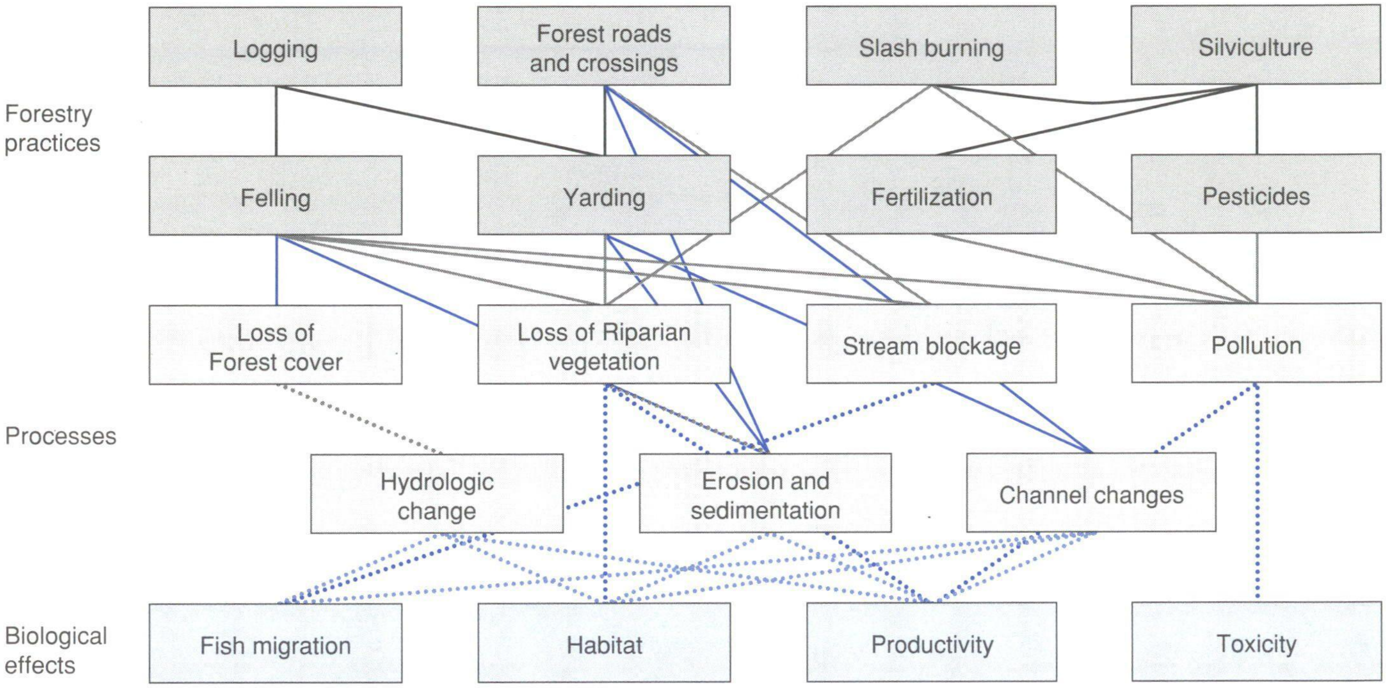
Losses to insects and tree diseases amount to 100 000 m^3 annually. The allowable harvest is set taking this into consideration and may fluctuate from year to year. These types of losses are measured in permanent growth and yield samples which, through periodic measurement of fixed areas in different forest areas, allow for projections to be made for the whole forest.

Silviculture

The third determinant of forest sustainability is silviculture practices. An adequate level of silviculture is essential to maintain and enhance the forest environment, as well as to maintain the harvest level. The overall purpose of silviculture is to produce more useable timber from a given area of land than could be achieved in an unmanaged forest. Silvicultural treatments have two general objectives: to remove competing vegetation (e.g., other trees or brush species) to allow more growing space for future crop trees; and, to enhance the productivity of a site by fertilization or by converting the site from growing non-commercial brush species to growing commercially useable species, or by other means.

Silvicultural treatments are divided into two main categories: crop renewal and crop enhancement. The renewal of harvested areas involves site preparation, planting, brushing and weeding, and statistical sampling (surveys) of renewed areas to determine treatment success. Crop enhancement involves putting previously logged forest land back into forest production and/or enhancing the growth rate of young stands of trees. This mainly entails planting on lands not satisfactorily restocked (NSR), converting sites to

Figure 12
Biological Effects of Forestry Practices



SOURCE: Adapted from Tœws and Brownlee, 1981.

commercial species growth, fertilization, and spacing juvenile stands of trees. For the period 1986 to 1988, Table 4 - 2 shows the target desired and achieved by activity.

Yield and Harvest Trends

In the TSA portion of the Basin, the trend in harvest levels will be downward. The current forest base is being lost due to several factors. Forest land is being converted to other uses, most notably urban development, recreation, and highways. There are increasing public concerns over the environmental and aesthetic impacts of forestry activities. There is increasing public demand for recreation and park land. Each of these trends will reduce the land area of the forest land base. For example, public demand led to 10 000 ha of forest land being deleted from the Fraser TSA for park purposes, mostly in the Coquihalla, Summit, and Cascade Recreation Areas (B.C. Ministry of Forests 1985).

Table 4 - 2
1986-88 Silvicultural Activities in the Fraser TSA

Activity	Target (ha)	Achieved (ha)
Crop Renewal:		
Planting	5 912	6 837
Site Preparation	1 131	302
Brushing and Weeding	2 176	1 812
Surveys	10 977	15 546
Sub-total	20 196	24 497
Crop Enhancement:		
Planting	1 420	1 217
Conversion	589	406
Fertilization	4 650	2 199
Juvenile spacing	4 018	1 648
Sub-total	10 677	5 470
TOTAL	30 873 ha	29 967 ha

SOURCE: B.C. Ministry of Forests 1989.

Several locations within the study area have been designated as Special Management Areas because of their proximity to urban centres and because of concerns expressed over the aesthetic impact of harvesting. If these areas are excluded from the forest land base, the harvest level will be further affected.

The yield analysis process is undertaken every five years to determine feasible harvesting rates for a 20-year period and to predict the long-term consequences of maintaining that rate with respect to the sustained yield capacity of the forest (B.C. Ministry of Forests 1979). As part of that process, a comparison is done using the assumption that the same conditions apply for the present analysis as applied in previous years. This comparison is useful for assessing trends in timber supply over a period of time.

Because of changes in land use and other factors, parameters used in the calculations can vary. For example, between the 1979 and the 1985 analyses in the Fraser TSA, the amount of productive forest land dropped from 535 217 ha to 519 300 ha, a decrease of almost 16 000 ha (3%) (B.C. Ministry of Forests 1985).

Other factors that can affect the reliability of the information stem from insufficient resources to continually update the inventory data base and to establish additional growth and yield plots to measure forest productivity, and the failure to meet targets set for silvicultural treatments (B.C. Ministry of Forests 1989). These shortfalls can usually be attributed to insufficient funding and all will have an impact on future yield analyses, either in the use of poor or inaccurate information, or in forcing a lowering of the AAC because forest productivity is lower than expected.

Another factor affecting the yield analysis is the increasing demand for deciduous species which, until recently, were considered commercially unusable and not included. There is now a demand for alder and aspen for manufacturing and stands of these species will have to be factored into future yield analyses.

These ever shifting parameters all affect the sustainability of the forest resource. If current expected reductions to the forest land base become reality, not even intensive silvicultural practices will increase the useable wood supply sufficiently to maintain the present yield on a reduced land base (R. Knutson, B.C. Ministry of Forests, pers. comm., 1989). Coupled with insufficient funding to carry out some essential activities, the sustainability of the forest resource within the study area is very much in question.

Forestry Outlook

Will society be able to enjoy sustained harvests from the forest resources of the Lower Fraser River Basin and enjoy the other benefits forests offer? Indications are that the forest resource will face continued pressures from competing uses and that the quality of the resource may decline due to inadequate silvicultural activities. The Ministry of Forests indicates that many of the Fraser TSA plan objectives are not being met, mostly because of a lack of funds (B.C. Ministry of Forests 1989). Coupled with expected reductions to the forest land base, future harvest levels will likely be reduced substantially.

Although funding for silviculture has increased dramatically since 1985 because of increased provincial funding and the joint federal-provincial Forest Resource Development Agreement (FRDA), there are still funding shortfalls in some areas that will have an effect on future forest management and harvesting. For example, a shortage of funds for road maintenance will mean that protection, silviculture, recreation, and inventory projects will suffer because of a lack of access.

If society determines that potentially productive forestry lands should be allocated to other uses, then sustaining timber production will require that more useable wood fibre be grown per unit area of forest land to maintain the current wood processing industry. The rate of timber harvest and growth is inextricably tied to the level of silvicultural work carried out in any given time period. A direct consequence of failing to meet the enhancement goals for juvenile spacing and fertilization could be a future reduction of about 2 200 m^3 in the AAC of the TSA (B.C. Ministry of Forests 1989). Failure to meet other program goals could result in further reductions.

Public forest land is presently managed on an integrated basis to provide for timber production, fish and wildlife habitat, livestock, recreation, and community water supplies (e.g., GVWD). In addition to timber supply, objectives for the Fraser Timber Supply Area include the provision of 1.58 million recreation user-day opportunities in all categories (recreation objectives) and 650 animal unit-months per year (range objectives). Despite the demand for recreational facilities such as trails and campsites outpacing the supply, program funding for recreation remains low (B.C. Ministry of Forests 1985). Few of the goals set in the TSA plan for recreation were met, and most of the site and trail achievements were accomplished through volunteer labour. As the population grows, recreational demand for forest land will expand as well.

Other concerns relate to the environmental impact of harvesting, transporting, and processing wood. For example, the industry also depends on the Fraser River for log storage, involving 970 ha in the estuary to provide mills with up to a three-month log inventory (Kennett and McPhee 1988). There are concerns about the environmental effects of such uses. In forest development, some concerns are addressed through the pre-harvest silviculture prescription, but these can be general and may not adequately address non-forest values.

As the urban environment continues to spread and the population grows, the forest resource will be subjected to increasing pressures from various potentially incompatible uses. This is evident in some parts of the study area where aesthetic impacts of harvesting are a concern.

The most recent TSA Annual Reports (February 1989) express concern about the ability to resolve increasingly prevalent and complex resource use conflicts within the present integrated resource management framework. Given the numerous pressures that are building on the forest resource from all quarters, the need to explore and develop a new framework for conflict resolution is essential.

Agriculture

The Lower Fraser River Basin is one of the most productive agricultural areas in Canada. The key factors for environmentally sustainable agriculture include protecting agricultural land supply, minimizing soil degradation, and controlling the application of chemicals and animal wastes on agricultural lands.

Agricultural Land Supply

There are 5 600 farms on 890 km^2 of agricultural land in the Lower Fraser River Basin, producing 50% of the total gross farm income in the province (Statistics Canada 1986). These farms represent some of the most valuable farmland in Canada with a total annual agricultural production value of $588 million (B.C. Agricultural Land Commission 1989), and an average return of $6 600/ha, more than 14 times the national average (B.C. Ministry of Agriculture and Fisheries 1989).

The protection of agricultural land is important because less than 5% of the land in the province is arable. Most of the development pressures on agricultural land have occurred at the fringes of the urban area. In the Vancouver urban area, the Canada Land Use Monitoring Program found that between 1967 and 1976, agricultural land use declined from 23.6% to 19.1% of the land area. From 1976 to 1982, 19% of the land which became built-up had high capability for agriculture and 59% had low to moderate capability for agriculture (Environment Canada 1985).

The introduction of the Provincial Agricultural Land Reserve (ALR) in 1973 has slowed the overall rate of conversion to non-agricultural uses. The ALR covers only 8% of the Lower Fraser River Basin. Table 4-3 shows the changes in land area within the ALR. Since 1973, the total area within the ALR has declined by 5.7%, from 148 421 ha to 139 906 ha, or an average net decline of 532 ha annually (B.C. Agricultural Land Commission 1989). In recent years (1985-1989), this decline has averaged 368 ha annually. Over 60% of the land in the ALR within the four regional districts is presently being farmed.

Table 4 - 3
Agricultural Land Reserve by Regional District, 1974-1990

Year	Area (ha) GVRD	DARD	CFVRD	FCRD
1974	32 551	23 765	55 344	36 761
1975	32 539	23 753	55 290	36 757
1976	32 388	23 740	55 187	36 745
1977	32 324	23 740	54 713	36 452
1978	32 307	21 452	54 626	36 415
1979	32 291	21 421	54 194	36 349
1980	32 271	21 413	54 192	36 224
1981	32 035	21 396	53 209	36 203
1982	32 031	21 355	53 200	36 056
1983	31 856	21 321	53 130	36 025
1984	31 775	21 212	52 990	35 967
1985	31 716	21 188	52 967	35 876
1986	31 588	20 934	52 787	35 839
1987	31 213	20 894	52 767	35 749
1988	31 189	20 836	52 562	35 751
1989	31 149	20 799	52 546	35 725
1990	31 130	20 793	52 542	35 441

GVRD: Greater Vancouver Regional District
DARD: Dewdney-Alouette Regional District
CFVRD: Central Fraser Valley Regional District
FCRD: Fraser-Cheam Regional District

SOURCE: B.C. Agricultural Land Commission 1990.

Soil Degradation

The sustainability of agriculture in the Lower Fraser River Basin depends upon maintaining soil quality and productivity. Soil degradation is primarily associated with erosion, acidification, compaction, and organic soil subsidence. A general decline in soil quality due to intensive agricultural production, heavy fertilization, and limited conservation practices has been observed in the Fraser Valley (Senate of Canada 1985).

Soil erosion and compaction are major problems. Water erosion can be particularly severe in the Fraser Valley due to the many wide-row crops such as corn, potatoes, and raspberries where, after harvesting, the soil is often left unprotected through the heavy fall and winter rains (Senate of Canada 1985). In addition to depositing sediments in fish habitat, erosion also reduces soil fertility, increases susceptibility to crusting, and reduces water holding capacity and soil rooting depth. The economic pressure to farm early in the spring, when wet conditions exist, further contributes to compaction and degradation of the soil structure.

The extensive use of nitrogen fertilizer to improve crop yields has contributed to increasing soil acidity. In the Lower Mainland, 84% of the soils are considered acidic, with an estimated 11 000 ha at pH less than 5.0 and 54 000 ha at pH 5.6 to 6.0. The trend data indicate an increase in acid soils. Studies of pH levels in soils show that land with pH less than 5.0 increased from 5.9% in 1967 to 13.9% in 1978 (Hoyt 1983). Commercial nitrogen fertilizer is presently applied at close to the maximum recommended rate of 140 kg/ha in the region. The addition of manure from livestock operations also adds an almost equal amount of nitrogen, resulting in levels which can far exceed the recommended rate (Kowalenko 1987). Intensive irrigation further increases soil acidity. Lime is often added to soils to maintain pH within the 5.0 to 6.0 range.

The subsidence of organic soils due to overintensive use is an additional problem which causes the emergence of subsurface mineral soils and reduced water-holding capacity, fertility, and nutrient balance.

Chemical and Waste Loadings

The use of fertilizers, pesticides, and animal manure is an integral part of the farming systems of the Lower Fraser River Basin. The high yields of intensive agriculture are particularly associated with increased use of agricultural chemicals and the production of large volumes of animal wastes in small areas.

Recent studies indicate that animal waste loadings from dairy, beef, pigs, and poultry significantly exceeded the capacity for disposal on agricultural land, causing local stream and groundwater degradation in some areas (Kowalenko 1987; Hutton 1987). Nutrient loadings from agriculture have created eutrophication, or enrichment, problems and fish kills in rivers such as the Serpentine, Nicomekl, and Sumas. In response to these problems, industry and government are developing a code of good practice to control nutrient inputs from agricultural activities.

Urban Development

There are distinct constraints to development in the Lower Fraser River Basin beyond which environmental quality becomes increasingly degraded. As population, land development, and transportation expand in the region, there are increasing demands upon the natural resource systems.

Population Growth

The estimated 1990 population of the Lower Fraser River Basin was 1 711 915 (B.C. Ministry of Finance and Corporate Relations 1990). Since 1976, population in the Basin has grown by an average of 2.4% per year. This rate is projected to decline to a rate of 1.8% to the year 2011 (due to changing age structure), by which time the population of the region will have increased to 2.27 million people (B.C. Ministry of Finance and Corporate Relations 1989). Almost two-thirds of the present growth in Greater Vancouver is attributable to people moving into the region and the remainder is due to natural population growth. The net immigration is expected to increase to 84% of total population growth by the year 2011 (Greater Vancouver Regional District 1988). Past and projected population of the Lower Fraser River Basin is shown in Figure 13.

The number of households in Greater Vancouver has increased from over 400 000 in 1976 to nearly 550 000 today and is projected to grow to 836 000 by the year 2011 (Figure 14). An increasing proportion of the population is being accommodated south of the Fraser River, often in close proximity to environmentally sensitive areas. Forty-five percent of the population growth is expected to occur in this area over the next two decades. Traditional industrial areas along the Fraser River are also being replaced with residential and commercial development.

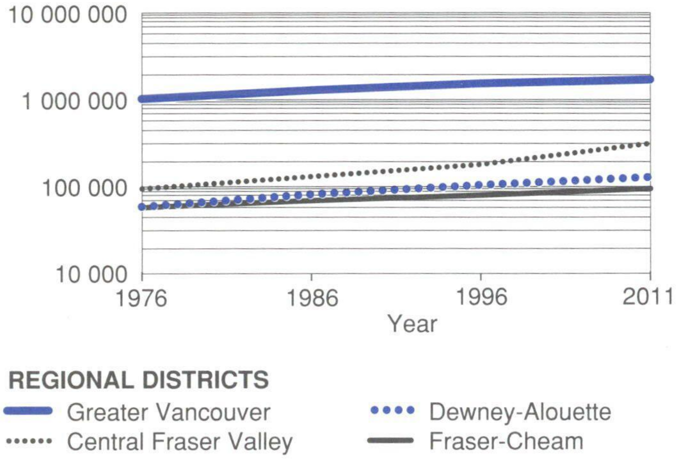
The distribution of population has changed significantly over the past two decades. In 1966, 40% of the Basin's population was located in the City of Vancouver and 87% in the GVRD. By 1988, Vancouver and the GVRD's share of the population had declined to 27% and 82%, respectively. Population growth is projected to double in the Central Fraser Valley Regional District, to increase by one-half in the Dewdney-Alouette Regional District, and to increase by one-quarter in the GVRD by the year 2011 (B.C. Ministry of Finance and Corporate Relations 1989). Figure 15 shows the current and projected population distribution in 1986 and 2001.

Urban Land Supply

There are both physical and political limitations to development in the Lower Fraser River Basin. Mountain slopes, the U.S. border, and the Strait of Georgia restrict the area in which development can occur. Between 1961 and 1981, the developed urban area within the Greater Vancouver Regional District expanded by about 18 000 ha, accommodating a population increase of nearly 380 000 (50 ha per 1 000 additional population) (Greater Vancouver Regional District 1982).

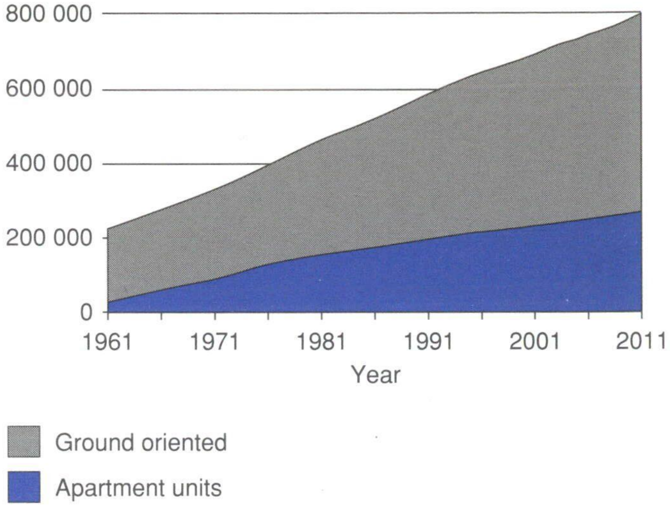
In 1981, nearly 24 000 ha of developable land was available for future growth, 3 200 ha of which was designated exclusively for industry. The 1982 Monitoring Report of the Official Regional Plan estimated that a total of 7 204 ha of

Figure 13
Population Growth, 1976–2011



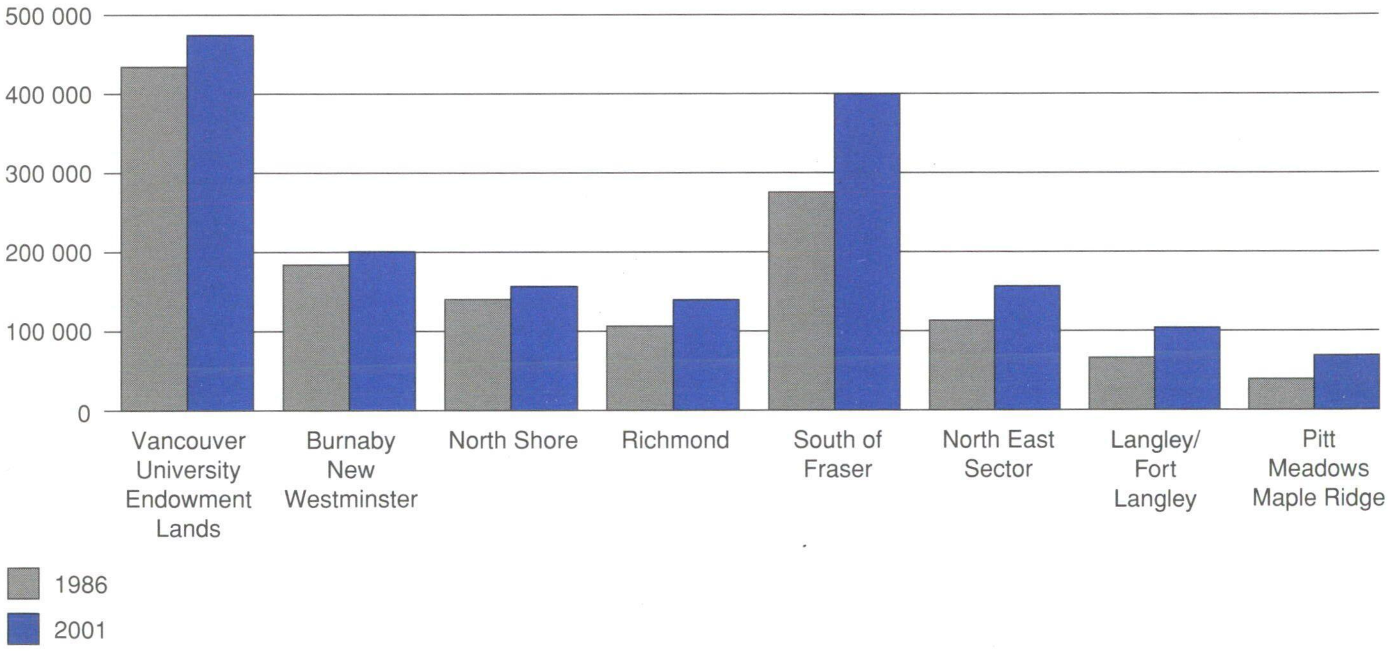
SOURCE: Greater Vancouver Regional District 1988.

Figure 14
Number of Households



SOURCE: Greater Vancouver Regional District 1989.

Figure 15
Greater Vancouver Population by Subregion, 1986 and 2001



SOURCE: Greater Vancouver Regional District 1989.

vacant land and 328 ha of agricultural land within the existing designated Urban area (47 000 ha), were potentially available for urban expansion (Greater Vancouver Regional District 1983). Outside of the urban area, another 13 000 ha of urban reserve was considered available for long-term growth in the GVRD.

Table 4 - 4 compares changes in urban land supply between 1981 and 1989. A 1989 survey of local governments indicated that the land supply designated or potentially designated for future urban expansion (non-industrial) in the GVRD is approximately 10 000 ha, a decline of one-half from 1981. A total of 15 800 ha was identified as potentially available for urban expansion, although other regional districts in the Fraser Valley significantly add to this estimate. The data reflect both increased land development and expanding boundaries of the designated urban area.

A recent study of urban land supply in Greater Vancouver indicates that the region has a short-term supply of 46 700 single family lots and potential long-term supply of 60 400 single family residential lots which, at the current take-up rate of 8 000 lots per year, should last 13.5 years (Coriolis Consulting Corp. 1990). Short and long-term multi-family unit capacity is approximately 199 400 units, which should last about 20 years. In the Fraser Valley, the short-term supply of 19 500 single family lots should last about 12.5 years, while the long-term supply of 18 300 lots should last about 11.5 years, based on 1990 estimates.

While there are other areas suited to future urban use in the Fraser Valley, there nevertheless exists a diminishing supply of developable land outside of the Agricultural Land Reserve. In addition to the physical limits to development imposed by the natural environment, local residents are becoming less willing to accept new developments where they are perceived to affect the quality of life, including open space, natural areas, and agricultural lands. The trend, therefore, is toward more intensive use of land and redevelopment of existing urban areas at higher densities.

Urban Development

Urban growth has clearly resulted in substantial conversion of rural resource lands to urban uses. A Canadian Mortgage and Housing Corporation (CMHC) study showed that between 1975 and 1981, land in the Vancouver urban region was developed for residential purposes at an average rate of 655 ha/yr, declining to 525 ha/yr by 1981 (Hamilton 1985). The future growth requirements (1987- 1992) were projected to be 934 ha/yr on an available inventory of 2 771 ha after 1987, although these trends have not been monitored.

In the Vancouver urban-centred region (comparable to the GVRD), the Canada Land Use Monitoring Program (Environment Canada) derived an annual estimate of 644 ha of land converted from rural to urban uses between 1982 and 1986 (Moore 1990). This represented a 3.7% expansion of the urban area. Table 4 - 5 summarizes the changes in proportions of land use types and the decline in the rate of urbanization between 1967 and 1986. The rate of land conversion from rural to urban has been declining: 2 600 ha annually between 1967 and 1971, 2 100 ha annually between 1971 and 1976, 1 200 ha annually between 1976 and 1982, and 600 ha annually between 1982 and 1986 (Redpath 1982; Environment Canada 1985; Moore 1990). This reflects the increasingly intensive use of land in the region.

The diminishing supply of new developable land in the face of population growth and development pressures raises major questions regarding the long-term form and density of urban development and the effects on resource lands and environmental quality. Proposals for the development of agricultural lands, wetlands, foreshore areas, forest lands, and mountain slopes will become increasingly prominent. The choices between urban growth and resource abundance and quality are already evident in many of the land use issues in the region.

In some cases, these land supply constraints and demand forces are requiring local governments to direct growth toward redevelopment of existing urban lands at higher densities of use, and to consider the options of controlled growth. The process of defining the appropriate structure and density of a "livable" urban region has important implications for the state of the environment in the Lower Fraser River Basin.

Transportation

Population growth and urbanization of the Fraser Valley have placed heavy demands on the transportation system. Figure 16 shows the major transportation network serving Greater Vancouver. The increased distance between work and home and the growth in vehicle ownership are reflected in the growing levels of traffic congestion. In 1987, peak rush hour automobile and transit trips were 168 900 and 37 500, respectively, and projections for the year 2001 indicate that auto peak-hour trips will increase 31% and transit trips 26% over present levels (Greater Vancouver Regional District 1989b). Figure 17 illustrates the increase in peak-hour person-trips for 1988 compared to estimates for 2001 for key transportation corridors in Greater Vancouver. The average trip distance is also projected to increase from 12.5 km to 13.2 km and average travel time from 18 to 22 minutes.

Table 4 - 4
Land Supply for Urban Development

	1981 (ha)			1989 (ha)		
Community	**Vacant Urban**[1]	**Urban Reserve**[2]	**Urban Expansion**[3]	**Urban Infill**[4]	**Industrial Expansion**	**Parks & Open Space**[5]
Vancouver	354	-	-	196	-	1 248
Burnaby	715	-	-	500	400	1 500
New Westminster	178	-	-	148	-	86
Coquitlam	1 322	828	1 510	nd	171	883
Port Coquitlam	271	-	121	nd	109	115
Richmond	405	-	405	nd	732	111
Delta	561	-	-	nd	1 500	511
Surrey	1 148	10 949	6 230	nd	769	1 340
N.Vancouver (District)	980	543	433	nd	240	1030
N.Vancouver (City)	134	-	43	nd	-	126
West Vancouver	939	124	730	130	-	435
Port Moody	488	-	528	nd	-	56
White Rock	19	-	1	nd	-	28
Subtotal	7 514	12 444	10 001		3 921	7 469
Maple Ridge	nd	nd	1 900	nd	570	641
Langley (District)	nd	nd	3 652	nd	562	401
Langley City	nd	nd	-	nd	5	130
Mission	nd	nd	242	nd	<304	253
Total			15 795		5 362	8 894

nd = No data

[1] Includes land designated Urban and Industrial in the 1981 Official Regional Plan, including some farmland.

[2] Consists of vacant or low density rural lands which could potentially be redesignated to urban density uses.

[3] Area currently designated for future urban expansion; includes approximately 5 000 ha in Surrey currently designated for low density suburban uses; much of which could be redesignated to urban density uses.

[4] Urban infill refers to major areas of urban redevelopment.

[5] Refers only to dedicated urban parks and open space; does not include regional parks or wilderness areas.

SOURCE: Greater Vancouver Regional District 1982, 1989a.

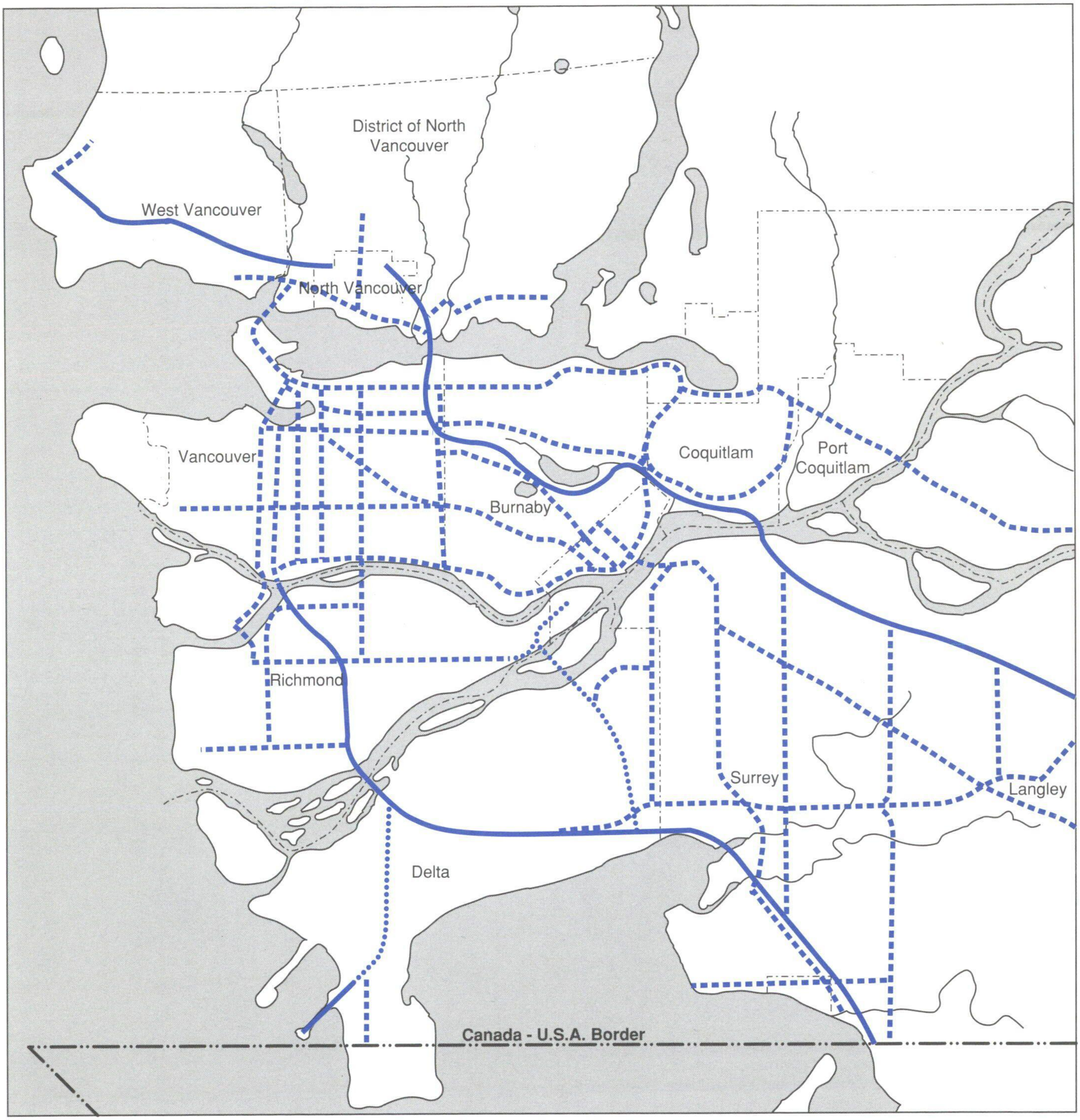
Table 4 - 5
Land Use Changes in the Vancouver Urban Region

Category	**1967**	**1971**	**1976**	**1982**	**1986**
Built-up	16%	20%	24%	39%	41%
Agriculture	24%	22%	19%	24%	24%
Outdoor Recreation	5%	6%	7%	—	—
Recreation/ Conservation	—	—	—	12%	13%
Vacant	—	—	—	22%	19%
Average Annual		1967-71	1971-76	1976-82	1982-86
Rate of Land Conversion to Built-up		2 600 ha	2 100 ha	1 200 ha	600 ha

Because of changes in classification method and boundaries, 1976-1986, data are approximate only.

SOURCE: Redpath 1982; Environment Canada 1985; Moore 1990.

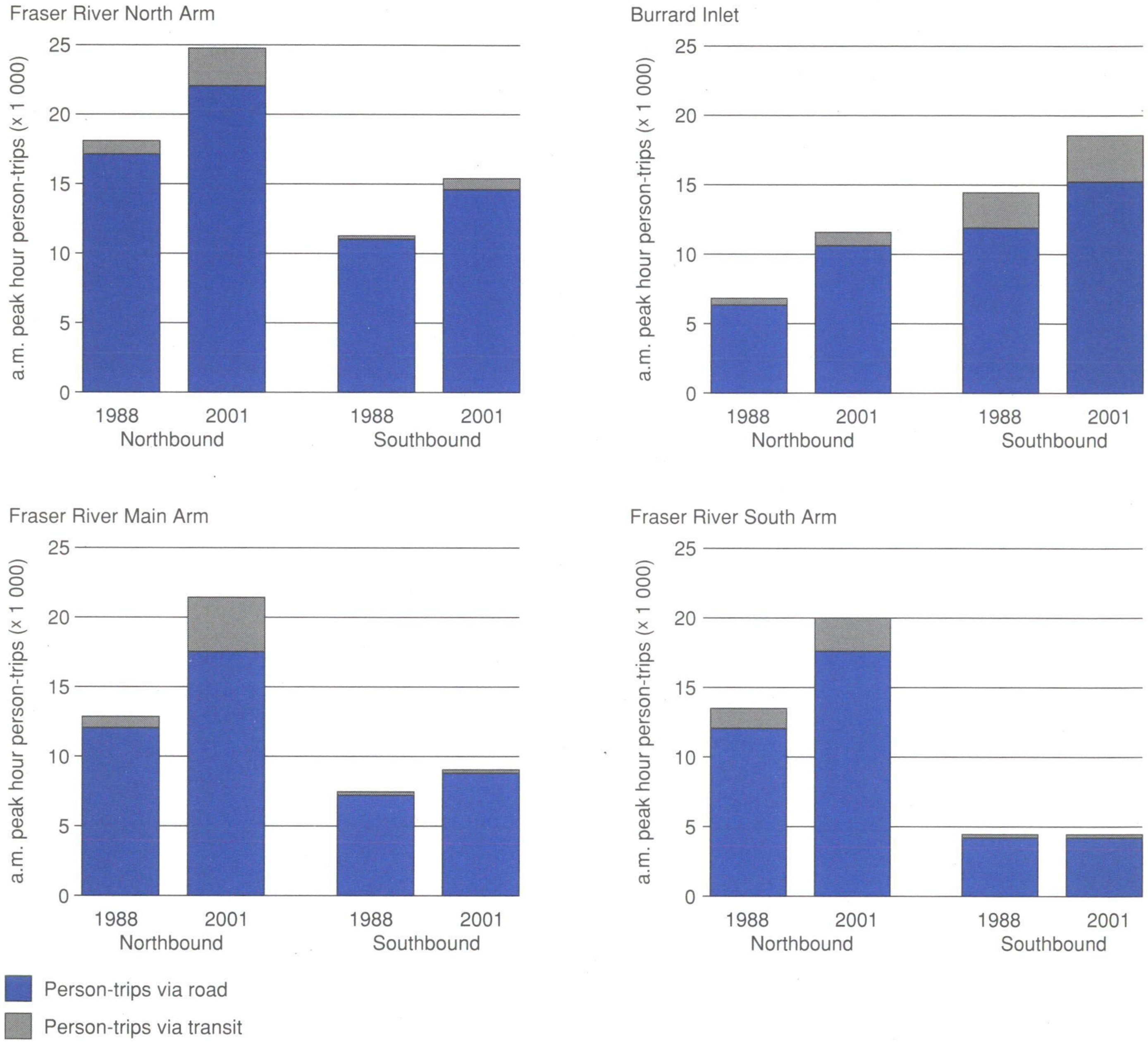
Figure 16
Greater Vancouver Road Transportation Network



- Freeways
- Expressways
- Regional Arterials

SOURCE: Greater Vancouver Transportation Task Force 1989.

Figure 17
Peak Hour Person-trips: 1988 vs. 2001 Projections



SOURCE: Greater Vancouver Transportation Task Force 1989.

The regional transportation program recognizes that to maintain the livability of the region as it grows and develops, we cannot merely respond to the travel demands occasioned by current travel habits and locational choices as if current habits and preferences are to be perpetuated into the future. The goals of protecting the environment and improving community life are central to the regional centres concept and public transit plans linking these centres.

The proposed addition of a third runway at Vancouver International Airport raises questions about growth, environment, and livability. The project has been referred to the Federal Minister of Environment for review by an Environmental Assessment Review Panel.

The lower Fraser River is used extensively for deep sea and coastal shipping, with the former being handled by facilities on the Main Arm (Fraser Port) and at Roberts Bank on the outer estuary (Vancouver Port Corporation). These facilities account for 30% of the international shipping volumes for the Lower Mainland (Kennett and McPhee 1988). Approximately 90% of this volume is coal which is exported through Roberts Bank. In the past ten years the export of coal through Roberts Bank has doubled. Eighty-five percent of the imports coming into Fraser Port are related to steel and automobiles. Exports include minerals, forest products, cement, fertilizer, machinery, fish products, and fruit. Coastal shipping involves primarily forest products (chip barges and logs). Shipping in the North Arm harbour is exclusively coastal shipping with the primary commodity being logs.

Port expansion has occurred at several sites over the past ten to fifteen years. Roberts Bank was expanded in the early 1980s and caused the destruction of large areas of intertidal habitat, while expansions of Fraser Port have occurred at Fraser Surrey and Fraser Richmond facilities. All these expansions have required habitat compensation programs as part of their development plans. While no major port expansions are planned in the immediate future, new terminal facilities have been considered in the Burns Bog area of Delta. Major environmental concerns were raised with this project when it was proposed, particularly the impacts on fish and wildlife.

Expansion of port facilities upstream of New Westminster is impeded by such factors as the New Westminster Railway Bridge, which limits the size of vessel able to navigate its swing-span. As a consequence, deep sea port facilities are not presently feasible upstream of the bridge (M. Presly, Transport Canada, pers. comm., June 28, 1990). In addition, the George Massey Tunnel under the Main Arm is a physical limitation to the deeper draft ships.

Solid and Special Wastes and Dangerous Goods

Solid Wastes

Generation

Solid wastes include residential, commercial, and industrial wastes which are managed or disposed of by regional or municipal solid waste facilities.

Other categories of solid wastes include sludge from municipal sewage treatment plants, woodwaste, and industrial refuse disposal sites. These are not discussed here but are recognized as contributing to the overall solid waste management issues facing the Basin. It is noted that in 1977, 1 million m^3 of woodwaste was landfilled and a further 2.5 million m^3 incinerated. A survey of the Fraser River estuary by Environment Canada showed that 35 woodwaste disposal sites (90% of which were along the banks of the Fraser River) encompassed an area of 130 hectares and contained an estimated 4.4 million m^3 of woodwaste (Fraser River Estuary Study Steering Committee 1979).

Another large volume of solid waste consists of debris from land clearing, construction, and demolition. Amounting to more than 500 000 tonnes per year, these wastes are recycled or disposed of by the private sector in private landfills, including the Richmond landfill and three industrial sites in Delta adjacent to the Fraser River Main Arm. This solid waste is not always benign. Gypsum board, for example, is responsible for creating significant leachate and odour problems and is no longer accepted for disposal in municipal landfills (Lower Mainland Refuse Project 1984). Currently this material is either recycled or disposed of by ocean dumping.

As shown in Table 4 - 6, the total volume of solid waste produced in the Lower Fraser River Basin in 1988 is estimated to be over 1.27 million tonnes. This is an increase of nearly 11% over the estimated 1.13 million tonnes in 1982. The annual volume of solid waste production of GVRD communities in 1978 was estimated to be about 800 000 tonnes (Lower Mainland Refuse Project 1984). About 800 kg of solid waste was produced per capita in 1982 compared to approximately 775 kg in 1988, which seems to be a positive trend. However, because solid waste volumes have not been rigorously measured until recently, it is not yet possible to accurately determine if per capita solid waste production is either rising or declining.

Disposal

The current system of solid waste management is characterized by a complex flow of solid wastes to and from various transfer stations, incinerators, resource recovery facilities, and landfills.

Table 4 - 7 shows the pattern of solid waste management in 1988, including the effects of recycling on disposal volumes. In 1988, 76% of the area's solid waste was disposed in landfills, 14% was incinerated and 10% was recycled. (The percentages refer to net volumes as some facilities, such as incinerators, generate substantial volumes of fly ash and bottom ash which must also be disposed of.)

Several distinct trends are evident from the data. In 1982, nearly 94% of all solid waste was disposed of in 12 municipal and regional landfills in the Lower Fraser River Basin. In 1988, only ten landfills were operating, including the Coquitlam landfill which was reactivated to accept residues from the Burnaby incinerator; these accommodated about 76% of the region's solid wastes. The opening of the Cache Creek landfill in 1989, located 340 km east of Vancouver, has further reduced the number of active landfills in the region to seven. In 1982, incineration handled a negligible volume of solid wastes; in 1988, nearly 14% of the waste stream was incinerated. Finally, the volumes of wastes recycled increased from 6% in 1982 to more than 10% in 1988.

Pressure on waste disposal capacity within the Lower Fraser River Basin has been reduced by the Cache Creek landfill and will be alleviated further if the privately owned Coquitlam Resource Recovery Plant reaches design capacity. With a 210 000 tonne/yr design capacity, this facility will produce a maximum of 70 000 tonnes of fibre-based fuel per year and will recover an estimated 11 000 tonnes per year of recyclable materials (T. Rattray, Wastech, pers. comm., November 7, 1989). An additional resource recovery facility had been proposed for downtown Vancouver but was defeated by Council. With its present service area and permitted capacity, Burns Bog landfill has the capacity to accommodate 50% of the Basin's total output of solid wastes until well into the 21st century. Nevertheless, projections of waste volumes suggest that the GVRD's solid waste management systems overall may only be able to handle 80% of the wastes by the late 1990s (Greater Vancouver Regional District 1989b). If the current per capita refuse disposal rate of 775 kilograms is applied to the projected Basin population of 2.27 million people in 2011, the region will have to manage 1.76 million tonnes of solid waste.

Table 4 - 6
Solid Waste Management Systems

Facility	1988 Tonnage	Design Capacity or Remaining Years
Landfills:		
Burns Bog	593 400	40 years
Port Mann	186 300	8 years
Coquitlam[1]	79 550	nd[6]
Minnies Pit	13 000	8 - 20 years
Chillwack	28 652	10 - 15 years
Kent[2]	469	10 years
Hope	4 500	0 years
Cottonwood[3]	24 486	closed in 1989
Jackman Pit[3]	4 091	closed in 1989
Valley[3]	36 888	closed in 1989
Cache Creek	n/a[6]	60 years @ 300 000 tonnes/year
Subtotal	971 336	
Incinerators:		
Burnaby[4]	171 680	235 000 tonnes/year
Kent[4]	7 830	7 830 tonnes/year
Subtotal	179 510	
Resource Recovery:		
Coquitlam	2 500[5]	225 000 tonnes/year
Recycling:	121 340	n/a[6]
Total	1 274 686	

[1] Handles ash from the Burnaby incinerator and transfer stations.
[2] Handles ash from the Kent incinerator.
[3] Closed in August 1989; refuse diverted to the Cache Creek Landfill.
[4] 1988 tonnage is the net weight of refuse incinerated; design capacity refers to delivered tonnage.
[5] Weight consists of recycled wastes; operations commenced in 1989.
[6] nd = no data; n/a = not applicable.

SOURCE: Greater Vancouver Regional District 1988a, 1988b.

The environmental acceptability of the current and planned waste disposal system is less clear. Both the active and the more than 40 inactive landfills in the Basin generate toxic leachates, which contribute loadings of BOD, metals, ammonia, organic compounds, and PCBs and which can be acutely toxic to fish. The active and inactive landfills also emit gases which consist of methane, carbon dioxide, organics, and sulphur compounds; active generation of gases can occur from 10 to 20 years following closure of a landfill (Lower Mainland Refuse Project 1984).

Table 4 - 7
Solid Waste Volumes: 1982 vs 1988

Regional District	Tonnage 1982	1988
GVRD	941 200	1 030 930
CFVRD	47 300	40 979
DARD	38 500	37 486
FCRD	36 000	41 451
Subtotal	1 063 000	1 150 846
Recycling/ Recovery	68 800	123 840
Total	1 131 800	1 274 686

GVRD: Greater Vancouver Regional District
DARD: Dewdney-Alouette Regional District
CFVRD: Central Fraser Valley Regional District
FCRD: Fraser-Cheam Regional District

SOURCE: Greater Vancouver Regional District 1988a; Lower Mainland Refuse Project 1985.

The GVRD's Burnaby refuse incinerator is equipped with state-of-the-art emission control technology, but concerns remain about the environmental and health impacts of incinerator emissions. Another concern is the more than 52 000 tonnes of fly and bottom ash residues produced annually by this incinerator. The ash contains lead and other heavy metals. The 7 000 tonnes/yr of fly ash captured in the air pollution control equipment is classified as a special waste by the provincial government. The 45 000 tonnes/yr of bottom ash consisting of uncombustible material is not considered a special waste. The fly ash is stored in lined and covered cells at the Coquitlam landfill. Leachate from these cells is collected and trucked off-site for treatment by a hazardous waste company. Bottom ash is utilized on the landfill surface to provide roadways and work surfaces. Leachate from the landfill area is directed to the regional sanitary sewer and monthly monitoring of the leachate does not reveal any contamination attributed to the bottom ash placement.

The existing and proposed resource recovery plants have several potential problems: the possibility that toxic substances will be burned; the relatively low net recovery of resources in relation to the total volume processed; the lack of markets for refuse-derived fuel; and the need to maintain high proportions of fibre material in the waste stream. One positive aspect of the resource recovery plant(s) is the potential substitution of waste-derived fuel for non-renewable fossil fuels. If the resulting fuel is used in cement plants, the high temperature incineration (1 550° C) would destroy most harmful substances and the ash would be used as a component of the cement (T. Rattray, Wastech, pers. comm., November 7, 1989).

Urban expansion, along with growing environmental awareness, has drastically reduced the range of available options for waste disposal. Public opposition has precluded the establishment of new major landfills in the Lower Fraser River Basin since the 1970s, when the Terra Nova landfill in Coquitlam was established on an emergency basis. As population and urban settlement increase, it appears unlikely that any new landfills will be developed within the Basin. Public opposition in other regions (e.g., Cache Creek) to landfills may also limit landfill options. Efforts to build refuse incinerators or resource recovery facilities face resistance, a fact already in evidence by the public opposition to resource recovery plants proposed in Vancouver and Delta.

Waste Reduction and Recycling

Public acceptance of waste reduction and recycling as an environmentally sustainable form of solid waste management has resulted in an increase of 80% in the volumes of recycled wastes between 1982 and 1988. As of 1988, most communities within the Lower Fraser River Basin had established some form of recycling program, involving either curbside pickup of recyclables, recycling depots, or both (Greater Vancouver Regional District 1988b).

Gains in the volume of solid wastes recycled have been largely due to efforts on the part of municipalities, non-profit organizations, and private industry. However, the capacity of the markets for recyclables presently limits recycling programs. Apart from being subject to cyclical price fluctuations for the major categories of recycled goods, including newsprint, glass, and metal, the increasing volumes of recylables have flooded the market, depressing prices and leading to more stringent quality specifications by buyers.

In 1989, the GVRD adopted a three phase Recycling Action Plan which established the goal of diverting a further 20% from the municipal waste stream by the mid-1990s. This action plan included measures to expand the availability of recycling programs to GVRD residents and the range of materials recycled; to increase efforts to develop and expand markets for recyclables; expand public awareness in the areas of waste reduction and recycling; and explore the use of both legislative and financial mechanisms to encourage more recycling (McLaren Engineers 1989). Recently, many communities have decided to follow the example set earlier by the District of Delta and establish curbside recycling programs.

In the near future, private sector initiatives may significantly increase the market for recycled products, particularly newsprint. In two years, it is projected that new de-inking plants will be constructed in British Columbia, Washington, and Oregon (T. Rattray, Wastech, pers. comm., November 7, 1989). A major stimulus for these plants is government legislation in jurisdictions such as California which require that newsprint contain a minimum quantity of recycled material. As the capacity of these plants will exceed the current supply of recycled newsprint, it is probable that market prices for recycled newsprint will rise, and hence encourage even more recycling effort.

Even if the goal of removing 25 to 30% of the waste stream is achieved through recycling, the region may still be confronted with over 1.4 million tonnes of solid waste to manage by the year 2011 due to population growth-induced volume increases. According to the design capacities of existing landfills, only Burns Bog and Cache Creek will remain usable by 2011. Assuming a net annual capacity of 900 000 tonnes/yr at these facilities, 170 000 tonnes/yr net capacity of the Burnaby incinerator, and 70 000 tonnes/yr at the Coquitlam Resource Recovery Plant, there will still be a shortfall in capacity of about 230 000 tonnes. This suggests that the future role of recycling will have to increase beyond the 30% level or that per capita waste production must decline. The only other apparent option to recycling and waste reduction is to develop additional landfill and incinerator disposal capacity along with existing and planned resource recovery facilities. This latter option appears to be less and less feasible given public opposition to such facilities. Clearly, solid waste management options are severely constrained.

Special Waste

Special waste refers to substances that may be poisonous, infectious, chemically reactive, corrosive, or flammable. These wastes can be carcinogenic or mutagenic. They can also accumulate in food chains and cause sublethal effects on all living things ingesting them. Special wastes originate from a wide range of industrial activities as well as from hospitals, commercial activities, and private households. As noted in the previous section, about 7 000 tonnes/yr of fly ash from the Burnaby incinerator is one of the largest sources of special waste in British Columbia. This ash is being handled subject to the requirements of a special waste storage permit from the B.C. Ministry of Environment.

In addition to the ash from the Burnaby incinerator, it is estimated that more than 74 000 tonnes of special wastes are produced annually in British Columbia, nearly 80% of which originate from the Lower Fraser River Basin (B.C. Ministry of Environment 1983). This is an increase from the widely used estimate of 60 000 tonnes/yr in the early 1980s; however, the types and sources of special waste are so diverse and widespread that it is extremely difficult to quantify the precise types and volumes. An estimated 385 companies in the region may have special waste management requirements and at least 26 priority sites were identified in 1985 as having special wastes which were damaging the environment (B.C. Ministry of Environment 1985).

Most special wastes are either placed in landfills, deposited in sewer systems; shipped to either the United States or Ontario for disposal; stored either at the point of origin or the B.C. Ministry of Environment facility in Surrey; or recycled. Spills of special waste are regular occurrences in the Lower Fraser River Basin, where the B.C. Ministry of Environment reports that its staff attends an average of one spill site per day (Vancouver Sun 1988).

During the 1980s two separate efforts on the part of the provincial government to establish a management program for special wastes, including a high-temperature incinerator, were not successful. Until such a plan is established and implemented, there will be ongoing threats to the environment of the Lower Fraser River Basin and the health of residents from the storage and disposal of special wastes.

Dangerous Goods

In 1986, a total of 11.65 million tonnes of dangerous goods were transported through the Lower Fraser River Basin by rail, marine, and road transport. Of the 6.335 million tonnes carried by road, more than 93% consisted of gasoline. Among the 3.578 million tonnes carried by deep sea shipping, coastal vessels, tugs and barges, and ferries, the principal commodities included gasoline (40%), caustic soda (sodium hydroxide) (16%), crude oil (12.5%), methanol (8%) and aviation fuel (6%). Rail transport handled 1.736 million tonnes of dangerous goods, primarily sodium hydroxide (30%), propane/butane (19%), methanol (16.3%), ethylene dichloride (10%), and styrenemonomer (10%) (Transportation of Dangerous Goods Study 1988).

Road and rail transportation networks are concentrated along the Fraser Valley, adjacent to the Fraser River. Marine shipment points occur in Burrard Inlet, the North Arm and Main Stem of the Fraser River, and at the B.C. Ferry Terminal in Delta. As these areas are either environmentally sensitive or are adjacent to large numbers of people, the shipment of dangerous goods presents an ever present threat to public safety and environmental quality. Table 4 - 8 summarizes statistics compiled for the period 1983 to 1986 and indicates that while accidents and spills involving the shipment of dangerous goods were relatively infrequent, they occurred among all three modes of transport.

Table 4 - 8
Reported Road, Rail, and Marine Accidents or Spills Involving Dangerous Goods

Year	Number of Accidents Reported Road	Rail	Marine	Total
1983	nd	7	4	11
1984	19	15	0	34
1985	20	17	3	40
1986	21	20	3	43

nd = no data

Source: Transportation of Dangerous Goods Study 1988a.

Qualitative information concerning the cause, nature, and effects of these spills are lacking except for incidents involving marine and marine intermodal facilities. There, the majority of incidents involved accidental spills of gasoline or sodium hydroxide and in five of ten reported accidents between 1983-1986, no discharge to water occurred (Transportation of Dangerous Goods Study 1988a).

In 1988, the Tri-Level Task Force on the Vancouver Area Transportation of Dangerous Goods conducted a comprehensive study of dangerous goods issues. In addition to examining intermodal issues, including the siting of dangerous goods facilities situated in high-risk areas such as the Fraser River, Roberts Bank, and Burrard Inlet, it provided recommendations to improve the operations, enforcement and compliance, training, and emergency response capability for all three transportation modes. Particular concerns exist with the condition and repair of railway tank car safety, especially when chlorine is being transported.

An environmental assessment was also undertaken on a proposed Sea Island fuel barge facility. The review panel recommended that the facility would pose unacceptably high risks of damage to valuable fish and wildlife resources.

Parks and Recreation

Parks and recreation are an important aspect of the quality of life in the Lower Fraser River Basin. Data on parks and recreation areas are presented in Table 4 - 9. In total, 7.7% (131 000 ha) of the region is allocated for park and recreation use, excluding nature conservation reserves. Between 1976 and 1987, total parkland area increased by 88% in the GVRD (Watmough 1987). The major parks and reserves provided for a total of 8.7 million visitor-days in 1988.

Table 4 - 9
Park and Recreation Areas and Visitations (1988)

Type	Number	Area (ha)	Visitations (1988)
Federal	1	8	83 758
Provincial Parks	16	114 364	5 433 995
Forest Rec. Areas	3	2 712	nd
Forest Rec. Sites	50	nd	38 000[1]
Regional Parks	20	9 137	2 813 791
B.C. Hydro Rec.Areas	4	420	397 369
Major Municipal Parks	nd	4 710[2]	nd
Total		131 351	8 766 913

[1] Refers to Satisfactory User-Day Opportunities.
[2] Includes only major municipal parks; does not include data for the Regional District of Fraser Cheam.
nd = no data

Source: B.C. Ministry of Parks 1988; Dewdney-Alouette Regional District 1983; B.C. Ministry of Forests 1990; B.C. Hydro files 1989; Greater Vancouver Regional District 1988c; Parks Canada files 1989.

The natural resources of the Lower Fraser River Basin also provide an important basis for outdoor recreation. The Fraser River alone supports a local sport fishing effort of 130 000 angler-days annually. The rivers and streams in total provide about 241 200 angler-days, while lakes contribute 308 000 angler-days of sport fishing activity (B.C. Ministry of Environment 1984).

In addition to parks, there are many other undesignated areas used for recreation. For example, dykes and causeways provide public access to the Fraser River. In the Fraser River estuary alone there are more than 30 fishing bars. Initiatives by the city of Richmond, which seeks to establish a complete dyke trail around Lulu and Sea Islands, demonstrate the growing importance of public waterfront access (Kennett and McPhee 1988).

Though comprehensive statistics on park attendance are difficult to obtain, available evidence suggests that public demand for recreation is growing rapidly. Annual attendance at Deas Island and Derby Reach Parks, for example, increased nearly five-fold between 1984 and 1987, from 80 000 to 352 000 (Kennett and McPhee 1989). Overall, attendance at regional parks was estimated at 3 000 000 in 1989, an increase of 11% over 1988 (Greater Vancouver Regional District 1989).

Sustaining the Land

Are land resources being adequately conserved to provide for sustained resource use and management? The land base necessary to maintain the production of forests, agriculture, recreation, fisheries, and wildlife is declining with expanding urbanization. The overall supply and distribution of resource lands can be a limiting factor in sustaining environmental quality unless appropriate management strategies are adopted.

Agricultural lands continue to decline, on average 368 ha annually, albeit at a slower rate than in earlier decades. Intensive farming and fertilization on smaller parcels have also degraded soil and water quality. Forest resources are increasingly being required to provide for a competing mix of resource and conservation uses on a smaller land base, while silviculture objectives have not been met. These pressures on resource lands are directly affected by urban expansion which has been converting rural lands to urban uses at a rate of over 600 ha annually in recent years.

The Lower Fraser River Basin is growing by over 45 000 new residents per year. There are critical choices to be made about the form of urban development, transport, waste disposal, resource development, and conservation which will determine the long-term ability to sustain the present level of environmental quality in the Lower Fraser River Basin.

Urban development will continue to expand into rural and agricultural lands as most vacant urban lands will be developed in 10 to 15 years. Urban and industrial development will especially increase in the Fraser Valley. Ports and waterways will also likely expand upstream of New Westminster and in other sections of the lower Fraser River, creating greater demand for dredging and river training.

While substantial increases in the volume of solid waste recycling are likely to occur, sheer population pressure threatens to outstrip the capacity of existing and planned solid waste systems as early as 1995. Further reductions in per capita waste production and even greater attention to recycling will be required to avoid the necessity of establishing extremely controversial and environmentally threatening waste disposal facilities in the future. In the meantime, there is no management or disposal plan in place to safely handle nearly 70 000 tonnes of special wastes generated in the Basin.

Dangerous goods are shipped through areas which are either environmentally sensitive or are adjacent to large numbers of people and are an ever present threat to public safety and environmental quality.

Park and recreation areas are critical to the quality of life in the Basin. Demand for more outdoor recreation opportunities will grow with the region's population. This suggests that, in the future, more park areas and recreation opportunities will have to be provided.

References

B.C. Agricultural Land Commission. 1989. Annual Agricultural Land Reserve Statistics to January 1, 1989.

B.C. Agricultural Land Commission. 1990. Annual Agricultural Land Reserve Statistics to January 1, 1990.

B.C. Ministry of Agriculture and Fisheries. 1989. Information on agricultural income.

B.C. Ministry of Environment. 1983. Special Waste Update.

B.C. Ministry of Environment. 1984. Lower Mainland Region Fisheries Management Plan.

B.C. Ministry of Environment. 1985. Fraser Delta Environmental Management Plan.

B.C. Ministry of Environment. 1989. Information on management issues with respect to forest harvest. Fish and Wildlife Management, Lower Mainland Region files.

B.C. Ministry of Finance and Corporate Relations. 1989. British Columbia Census Division Population Projections, 1989. Central Statistics Bureau.

B.C. Ministry of Finance and Corporate Relations. 1990. Municipal and Regional District Population Estimates, October, 1990. Central Statistics Bureau.

B.C. Ministry of Forests. 1979. Fraser Timber Supply Area Yield Analysis Report. Victoria: Planning Branch.

B.C. Ministry of Forests. 1985. Fraser Timber Supply Area - Management and Working Plans for Forest Land Holders.

B.C. Ministry of Forests. 1989. Fraser TSA Annual Reports (Combined 1986-88). Victoria.

B.C. Ministry of Forests. 1990. Fraser Timber Supply Area Plan, April 1985-March 1990. Victoria.

B.C. Ministry of Parks. 1988. Park Data Handbook, 1987 Summary Statistics.

Coriolis Consulting Corp. 1990. Evaluation of Greater Vancouver's Land Supply. Draft report for the Greater Vancouver Regional District. March 1990.

Dewdney Alouette Regional District. 1983. Official Regional Park Plan.

Environment Canada. 1985. Land Use Change in Canada - Vancouver Urban-Centred Region 1976-1982. Fact Sheet 85-5. Lands Directorate.

Fraser River Estuary Study Steering Committee. 1979. Summary Report of the Water Quality Work Group. Governments of Canada/Province of British Columbia.

Greater Vancouver Regional District. 1982. Greater Vancouver's Land Resource: Current Use and Land Supply. Burnaby.

Greater Vancouver Regional District. 1983. Official Regional Plan 1982 Monitoring Report. Burnaby.

Greater Vancouver Regional District. 1988. Vancouver Metropolitan Population Forecast 1986-2001. Regional Population. Burnaby.

Greater Vancouver Regional District. 1988a. Summary Report, Municipal Waste Flows for 1988. Burnaby.

Greater Vancouver Regional District. 1988b. Brief to the Ministry of Environment Task Force on Municipal Solid Waste Management. Burnaby.

Greater Vancouver Regional District. 1988c. Towards Year 2000. Appendix 1: Regional Park Visitation Estimates (1988 Final). Burnaby.

Greater Vancouver Regional District. 1989. The Livable Region, A Strategy for the 1990's. Burnaby: Development Service.

Greater Vancouver Regional District. 1989a. Questionnaire to local governments regarding land supply for urban development. Burnaby.

Greater Vancouver Regional District. 1989b. GVRD News. 1989 July/August. Burnaby.

Greater Vancouver Transportation Task Force. 1989. Summary Report. Greater Vancouver Regional District/Province of British Columbia.

Hamilton, S.W. 1985. Land and Infrastructure Mapping Program - Vancouver Region. Vancouver: Canada Mortgage and Housing Corporation.

Hoyt, P.B. 1983. Degradation Effects of Acidification. <u>In:</u> van Vliet, L.P.J., ed. Proceedings of the 8th Soil Science Workshop: Soil Degradation in British Columbia. Victoria: B.C. Ministry of Agriculture and Food.

Hutton, K. 1987. Lower Fraser Valley Waste Management Survey. Surrey: Minister of Environment and Parks. Unpublished manuscript.

Jacques, R. 1988. Impact of Forestry Activity on the Economy of Canada and its Provinces. Information Report E-X-39. Ottawa: Forestry Canada.

Kennett, K. and M. McPhee. 1988. The Fraser River Estuary: An Overview of Changing Conditions. New Westminster: Fraser River Estuary Management Program.

Krajina, V.J. and R.C. Brooke, eds. 1969. Ecology of Western North America 2(1). Vancouver: University of British Columbia, Department of Botany.

Kowalenko, C.G. 1987. An Evaluation of Nitrogen Use in British Columbia Agriculture. Agriculture Canada Technical Bulletin 1987-3E. Agassiz, B.C.

Lower Mainland Refuse Project. 1984. Landfills. Surrey: Landfills Committee.

Lower Mainland Refuse Project. 1985. Resource Recovery and Recycling.

McLaren Engineers. 1989. Waste Reduction and Recycling in the GVRD: A Blueprint for Comprehensive Resource Management. Burnaby: Greater Vancouver Regional District.

Moore, K.E. 1990. Urbanization in the Lower Fraser Valley, 1980-1987. Technical Reprot Series No. 120. Delta. Environment Canada, Canadian Wildlife Service.

Redpath, K. 1982. Canada Land Use Monitoring Program, total land use change in urban-centred regions: Vancouver 1967-76. Vancouver. Environment Canada, Lands Directorate.

Senate of Canada. 1985. Soil at Risk. Ottawa: Standing Committee on Agriculture, Fisheries and Forestry.

Statistics Canada. 1986. Census of Canada - Agriculture British Columbia.

Toews, D.A.A. and M.J. Brownlee. 1981. A Handbook for Fish Habitat Protection on Forest Lands in British Columbia. Fisheries and Oceans Canada.

Transportation of Dangerous Goods Study. 1988. Newsletter No. 3.

Transportation of Dangerous Goods Study. 1988a. Current Status Report. January.

Vancouver Sun. 1988. February 29; page B1.

Watmough, D. 1987. Background Information on the Natural Environment. Challenges for a Contemporary Statement of the Livable Region Strategy. Burnaby: Greater Vancouver Regional District.

Chapter 5

Fish and Wildlife Resources

The sustainability of fish and wildlife resources in the Lower Fraser River Basin is dependent upon the condition of the habitat, the productivity and robustness of the species populations which inhabit the Basin, and the level of harvest and conservation of these populations.

Ecosystems and Habitat

Aquatic Ecosystems

The freshwater, marine, and estuarine ecosystems support a rich variety of aquatic species of fish and wildlife. The condition of these ecosystems is reflected by indicators of heterotrophic activity (microorganisms), primary production (emergent vegetation, attached and benthic algae), invertebrates (crustaceans, insect larvae, mollusca[1], annelids[2], etc.), and by fish, aquatic mammals, and birds.

Human sources of organic carbon and nutrients have increased with urban development and overall heterotrophic production has also likely increased, although no trend data are available. Studies using different algal species in the early 1970s did not indicate high levels of pollution or nutrients in the Fraser River, but these data have never been updated (Northcote *et al.* 1975).

Invertebrates are especially important because they are the principal food source of many adult and most juvenile fish, and of many aquatic bird species. A decline in invertebrates can be directly linked to losses of habitat. Pollution-tolerant or sensitive indicator species have been used to identify contaminants within effluent dilution zones. For example, Dungeness crab sampled near the Iona sewage treatment plant were found to be contaminated with heavy metals and toxic organic compounds (Greater Vancouver Regional District 1988). Local effects of pollution are apparent in the benthic invertebrate community as changes in species diversity or shifts to more pollution-tolerant species. However, invertebrate species have not been monitored on a regular basis and only sporadic data are available.

Fish species diversity and abundance and the level of contaminants in fish are indicators of the health of aquatic ecosystems. Trend data on fish populations and catch are described below. Limited data are available on the levels of contaminants in fish. Recent studies show that pollutants, such as dioxins and furans from pulp mill effluent, discharged many hundreds of kilometres upstream are taken up via the food chain and accumulate in juvenile salmon in the lower Fraser River (Servizi *et al.* 1990). Some analysis has been made of contaminants in fish muscle tissues and livers over the last fifteen years (Swain and Walton 1989). While most contaminants are within accepted standards and no distinct changes have occurred in levels within sampled muscle tissue, some contaminants appear to be bioaccumulating in fish livers. However, there has not been a regular biomonitoring program to provide the necessary data from which to infer long-term trends.

Aquatic Habitat

The extent, distribution, and quality of habitat is critical to fish and wildlife resources in the Lower Fraser River Basin. The diversity of marine, intertidal, and riparian habitats provides spawning, rearing, and migratory habitat for fish and aquatic mammals, and feeding, resting, staging, and nesting sites for resident and migratory birds.

The aquatic habitats are characterized by high levels of heterotrophic activity, primary productivity, and invertebrate food sources important for fish. All five species of Pacific salmon, for example, depend upon the river and estuary for maintaining their life cycles. The river is used in varying degrees, depending upon the species, for migration (both upstream and downstream), spawning (particularly in the side channels and tributary streams), feeding, rearing, and resting and for migratory birds.

Table 5 - 1 indicates the change in habitat composition of lands in the Fraser River delta over the past century, an area which includes the present day municipalities of Delta

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[1] Mollusca are a large group of animals without backbones of which clams and snails are typical examples.

[2] Annelids are segmented worms including earthworms and many aquatic and marine species.

Table 5 - 1
Approximate Percentages of Lands in the Fraser River Delta Occupied by Various Habitat Types, 1880 and 1985[1]

Habitat	Area 1880	 1985
Seasonal Wet Meadows	43	<1
Bog	26	1
Trees and Shrubs	31	10
Cultivated Farmland	0	37
Urban/Industrial/Misc.	0	52

[1] Note that the 1880 data is based on legal surveys which generally did not include the intertidal areas.

SOURCE: adapted from Butler and Campbell 1987.

Table 5 - 2
Area of Marsh and Riparian Habitat on Foreshore of the Fraser River Estuary

Unit No.	Location	Marsh Area (ha)	Riparian (km)
7	Roberts Bank	1,042.0	5.0
6	Sturgeon Bank	649.0	0.2
9	Steveston to Deas Is.	606.0	39.0
15	Pitt River	447.0	29.9
8	Boundary Bay	177.0	10.3
4	Iona Island, North Arm	141.1	7.3
10	Deas to Annacis Is.	95.0	25.9
5	Middle Arm	68.3	2.2
14	Douglas Is. to Kanaka Ck.	19.0	38.7
11	Annacis Channel	9.0	7.0
2	Marpole Basin	7.4	6.5
3	Sea Island, North Arm	5.0	1.8
1	Burnaby Big Bend	3.9	7.2
12	Main Arm @ Annacis Is.	3.0	6.7
13	New West. to Douglas Is.	1.0	5.5
	Total	3 273.7	193.2

SOURCE: Williams 1986; Kistritz 1989.

and Richmond. Major losses have occurred to seasonal wet meadows, bog habitats, and riparian trees and shrubs (Butler and Campbell 1987). Studies of vegetation indicate that about 70% of the original wetland system has been altered, mostly by dyking and drainage schemes (Fraser River Estuary Study Steering Committee 1979). Substantial alienation of wetlands has also occurred upstream at the former Sumas Lake where 11 700 ha were drained in the 1920s, and at Pitt Polder, Cheam Lake, and along major sections of the Fraser River where dyking and drainage projects have occurred. The total area of wetlands in the south western portion of the Fraser lowland declined by 27% between 1967 and 1982 (Pilon and Kerr 1984).

Table 5 - 2 summarizes recent data on aquatic habitat in the Fraser River estuary. There is currently 3 273.7 ha of marsh habitat and 193.2 km of riparian habitat (Kistritz 1989; Williams 1986).

Long before land reclamation for agriculture, migratory waterbirds used all of the various habitats which occurred as a continuum from the open water to the upland areas. With dyking, that natural series of habitats was interrupted at the shoreline. Moreover, dyking altered the export of detritus (organic material) from the intertidal marshes of the outer estuary, reducing biological productivity of the area. Birds have, therefore, become increasingly dependent upon agricultural lands as a substitute for the natural habitats available prior to dyking.

Qualitative assessments of fish habitat have been made for 96 streams in six areas of the Lower Fraser River Basin: the Harrison River watershed; the Fraser River Main Stem - Hope to Mission; the Fraser River Main Stem - Mission to the mouth; the Chilliwack River Watershed; the Coquitlam River watershed; and Boundary Bay (Peterson and Lewynsky 1985). For each stream, the relative severity of impacts on fish habitat were evaluated and the source of each impact identified. Included among the impacts were blockage, pumps, dredging, water withdrawal, water contamination, forest removal, and landscaping. The sources of these various impacts included agriculture, forestry, hydro development, transportation, urban development, mining, and beaver dams. Severe or moderate impacts on productivity occurred on 62 of the 96 streams; in many cases from more than one impact source. Table 5 - 3 indicates, for each area, the most common problem activities and the source of the impact.

Upland Wildlife Habitat

The Lower Fraser River Basin's rich vegetation and wildlife resources have played an important role in the settlement of the area. Prior to permanent European settlement, the lowlands contained a mixture of alluvial and wetland forests, meadows, and riverine marshes. For thousands of years, Native Indians used these resources for food, clothing, and shelter. Early European settlers built an economy based on fur trade, and later on forestry and agriculture. Most of the lowland forest was cleared for urban development and agriculture. Much of the upland areas in the Basin have been logged over the past 100 years and there are few remaining stands of old growth timber. Dyking and drainage have altered an estimated 70% of the habitat in the Fraser River estuary. In the Fraser River delta, less than 1% of the original wet meadow areas remain (Butler and Campbell 1987).

Table 5 - 3
Stream Habitat Problems and Impact Sources — Lower Fraser River Basin

Area	Problems	Impact Sources
Harrison River	Forest Removal	Forestry
Fraser River Tributaries:		
Hope to Mission	Forest Removal; Pumps	Forestry; Agriculture
Mission to Mouth	Contamination; Water Withdrawal; Pumps	Agriculture; Urban Development
Chilliwack River	Forestry; Water Withdrawal	Agriculture; Forestry
Coquitlam River	Blockages; Forest Removal	Hydro; Urban Development
Boundary Bay	Contamination Blockages	Agriculture; Urban Development

SOURCE: Peterson and Lewynsky 1985.

The area and extent of habitat for birds and wildlife has progressively declined as urban development and resource use activities have increased; however, it is difficult to quantify the areal extent or the net impacts on original bird and wildlife populations. Some bird and wildlife species are flexible in terms of adapting to habitat created by human activity. Cultivated fields (particularly those which are periodically flooded) provide important habitat for many species of birds. Agricultural land in urban areas provides ideal habitat for those raptors which require open fields (Dave Dunbar, B.C. Ministry of Environment, pers. comm., August 1, 1989). Other species of wildlife, such as raccoons, thrive even in the presence of humans.

Based on written accounts of early explorers and on the presumed extent of habitat loss, historic populations of migratory birds were considerably larger than at present. Five native species of birds no longer breed here including the Yellow-billed Cuckoo, Purple Martin, Western Bluebird, Horned Lark, and Burrowing Owl (Butler and Campbell 1987). As well, the snowshoe hare has been eliminated from the delta, while the Roosevelt elk no longer inhabits the Basin.

The Lower Fraser River Basin still contains one of the richest and most diverse arrays of wildlife in Canada. These resources are a critical component of the Basin's ecosystem and play an important part in the quality of life for the 1.7 million residents. Nevertheless, as discussed in the following sections, many species of birds and wildlife today are considered to be threatened due to the continued loss of habitat.

Table 5 - 4
Wildlife Conservation Areas

Type	Area (ha)
Federal Migratory Bird Sanctuaries and Wildlife Areas	737
Provincial Ecological Reserves	616
Wildlife Management Areas	3 833
Crown Map Reserves and Notations of Interest	10 808
Total	15 994

SOURCE: Canadian Wildlife Service staff 1990; The Nature Trust of B.C. 1988; L. Foubister, B.C. Ministry of Environment, pers. comm., April 4, 1989.

Habitat Conservation and Restoration

As shown on Table 5 - 4, a total of 15 994 ha in the Lower Fraser River Basin, excluding parks, receive some degree of protection as wildlife conservation areas under initiatives by federal and provincial governments and private non-profit organizations such as the Nature Trust of B.C. The majority of wildlife conservation areas occur in the lowland areas of the Basin. Provincial Order-In-Council reserves account for 10 555 ha of conservation areas. While such reserves afford some degree of protection, they do not constitute permanent protection of fish and wildlife habitat.

Areas protected for the primary use of wildlife in the Fraser River delta area consist of 622 ha (Butler and Campbell 1987). Undeveloped urban areas and both unused and active agricultural lands provide important wildlife habitats which face continuous threats from urban encroachment. Within the upland forested areas about 77 km^2 have been identified as "environmentally sensitive" (B.C. Ministry of Forests 1985). In recent years, various habitat protection, enhancement, and restoration programs have been initiated. The "no net loss" policy of Fisheries and Oceans Canada has provided a means of limiting habitat destruction and providing for compensation. The Habitat Conservation Fund of the B.C. Ministry of Environment is also supporting fish and wildlife enhancement projects in the Lower Fraser River Basin.

Major federal/provincial wildlife management areas have been created at Westham Island, Sturgeon Bank, and Ladner Marsh. Several agencies are also cooperating in the reclamation of Cheam Lake near Chilliwack and in establishing wildlife management areas in the lower Pitt Lake area, Widgeon Slough, and elsewhere where important wetlands and other natural features occur. Other non-government organizations are directly involved in preserving, acquiring, and rehabilitating areas of ecological importance. Ducks

Table 5 - 5
Mean Numbers of Birds by Season

Group	Spring	Summer	Fall	Winter	Total
Geese	19 200	200	20 800	18 400	58 600
Ducks	29 200	17 900	86 100	58 100	191 300
Gulls	15 600	9 400	23 300	14 400	62 800
Shorebirds	90 500	12 300	47 100	44 000	193 900
Total	154 500	39 800	177 300	134 900	506 600

SOURCE: Butler and Campbell 1987.

Unlimited, The Nature Trust of B.C., and the Pacific Estuary Conservation Program have assisted in acquiring wildlife habitat at various locations.

Wildlife Species and Populations

More than 300 species of migratory and resident birds range throughout the Lower Fraser River Basin, including loons, grebes, cormorants, geese, dabblers, divers, mergansers, raptors, herons, coots, shorebirds, gulls, and passerines. The delta estuary portion of the Basin is a vital staging area on the Pacific Flyway and supports the highest density of wintering waterfowl, shorebirds, and raptors in Canada. The extensive marshes and mudflats attract birds migrating between their northern breeding grounds and southern wintering areas. During winter and migration periods, the area supports internationally significant populations of the Lesser Snow Goose, Green-winged Teal, Mallard, American Wigeon, Canvasback, Greater Scaup, Surf Scoter, White-winged Scoter, Black Scoter, Common Goldeneye, Bufflehead, Common Merganser, Ruddy Duck, Western Sandpiper, Dunlin, and Glaucus-winged Gull. Average monthly populations of these and other migratory birds total more than 0.5 million; during peak migration periods populations can reach 1.4 million birds (Butler and Campbell 1987).

In mountain areas, bird populations are comprised of a wide range of raptors, including eagles, hawks, and owls, as well as species such as the Ruffed and Blue Grouse and Quail. The Harrison River area, in particular, supports a large population of Bald Eagles during the autumn.

Table 5 - 5 shows maximum seasonal mean numbers for major aquatic bird groups in the Fraser River delta for the period 1966 to 1985. Population data for many species of birds frequenting the Fraser River delta are gathered annually in Christmas Bird Counts (CBCs). For example, between 1959 and 1986, an average of 124 Great Blue Herons, 61 Northern Harriers, 29 Short-eared Owls, and 13 Bald Eagles were sighted each year at Ladner.

Data regarding populations of terrestrial bird species of the upland and forested areas of the Basin are not as readily available as that for lowland bird species. However, of particular interest, due to its rapidly declining population, is the Spotted Owl which wholly relies on the availability of large tracts of old growth forest for its existence. Recent surveys indicate that approximately 100 Spotted Owls inhabit southwestern B.C. (Tom Burgess, B.C. Ministry of Environment, pers. comm., June 2, 1989). Other bird species which present management concerns include the Great Blue Heron; Green Backed Heron; Black-Crowned Night Heron; Turkey Vulture; Peregrine Falcon; Sandhill Crane; Common Barn Owl; Short-eared Owl; Horned Lark; and, the Yellow-headed Blackbird (B.C. Ministry of Environment n.d.).

The Basin's wildlife resources include more than 45 species of mammals, 11 species of amphibians and five species of reptiles. Native mammals in the valley include the black-tailed deer, black bear, red fox, coyote, and a number of furbearing aquatic species such as beaver and muskrat. Marine mammals, including harbour seals and sea lions, are common near the mouth of the Fraser River.

Wildlife inhabiting mountain areas includes such important species as mountain goats and cougar. Many of the species inhabiting the lowland areas are also found in the mountains. Estimates of wildlife populations in the Basin are mainly restricted to game species, large carnivores, and large mammals which are present in very low numbers. Estimated populations of these species and, where applicable, estimates of the maximum allowable harvest, hunter effort, and annual harvest are shown in Table 5 - 6.

Population estimates for other furbearing animals in the B.C. Ministry of Environment's Lower Mainland Region are presented in Table 5 - 7. While it is not possible to determine populations within the Basin, the relative abundance of each species is shown for the four planning units which contain the Lower Fraser River Basin.

Population estimates for many of the small non-game species and for all 16 species of reptiles and amphibians inhabiting the Basin are non-existent. However, 11 species have been identified by the B.C. Ministry of Environment as being of concern. These include the marsh shrew; Trowbridge's shrew; Townsend's vole; red bat; Keen's myotis; big free-tailed bat; mountain beaver; Townsend's chipmunk; creeping vole; Pacific jumping mouse; and the spotted skunk (B.C. Ministry of Environment n.d.).

Table 5 - 6
Estimated Population, Allowable Harvest, Hunter Effort, and Harvest of Important Game and Non-Game Wildlife - Lower Mainland Region[1]

Species	Maximum Estimated Population	Average[2] Hunter Harvest	Hunter Days	Annual Harvest
Black-tailed Deer	24 750	9 430	32 710	1 766
Mule Deer	6 650			
Mountain Goat	1 475	nd	291	17
Elk	20-30	0	0	0
Moose	85	0	0	0
Black Bear	6 300	504	3 426	274
Cougar	270	-	200	5
Wolf	90	-	-	very low

[1] Includes areas beyond the boundaries of the Lower Fraser River Basin.
[2] Average for the period 1948-1987; estimates do not include illegal hunting.
nd = no data.

SOURCE: B.C. Ministry of Environment, Fish and Wildlife Branch files.

Fish

The rivers, streams, and lakes of the Lower Fraser River Basin are inhabited by at least 87 species of resident, semi-resident, and migratory finfish (Birtwell *et al.* 1988) and shellfish. In addition to being an integral part of the aquatic ecosystem and an important indicator of environmental quality, many species have crucial commercial, recreational, and cultural value. In economic terms alone, the total wholesale value of the Fraser River's natural production of salmon was estimated to be nearly $260 million in 1987 ($85 million of which is attributed to production from within the Lower Fraser River Basin) and an additional $23 million resulting from enhancement facilities (Fisheries and Oceans Canada 1989).

In general, information about the population dynamics, life history characteristics, and utilization is available for the commercially and recreationally valuable salmonid and non-salmonid species. Little is known about factors affecting the distribution and abundance of many non-salmonid species. Similarly, information about the commercial utilization of shellfish is available, but there is little information as to whether or not current utilization patterns are sustainable or the extent to which degraded water quality and loss of habitat have adversely affected shellfish productivity. However, contamination by bacteriological pathogens have prohibited the commercial and recreational harvesting of bivalves such as clams in the Lower Fraser River Basin.

Table 5 - 7
Estimated Population of Furbearers and Relative Abundance in the Fraser-Skagit, Fraser Valley, Harrison, and Squamish-Pemberton Planning Units[1]

	Planning Units				
Species	Fraser-Skagit	Fraser Valley	Harrison	Squamish Pemberton	Est. Pop.
Beaver	c	d	c	d	8 000
Bobcat	c	b	c	c	600
Coyote	c	d	c	c	5 500
Fisher	b	a	b	b	500
Fox	a?	b	a?	b	600
Lynx	b?	a	b?	b?	50
Marten	c	b	c	b	3 000
Mink	c	c	c	c	5 000
Muskrat	b	d	b	d	100 000
Otter	c	c	c	c	1 500
Raccoon	c	d	c	c	16 000
Skunk	c	d	c	c	8 000
Squirrel	c	c	c	c	400 000
Weasel	c	c	c	c	24 000
Wolverine	b	b	b	b	250

a = absent, b = rare, c = moderate densities, d = abundant
[1] These planning units contain the Basin but extend beyond it. The Squamish-Pemberton planning unit is outside of the Lower Fraser River Basin.

SOURCE: B.C. Ministry of Environment, Fish and Wildlife Branch files.

The lower Fraser River is of critical importance as a corridor for all commercially valuable anadromous[4] salmonid species, including chinook, chum, coho, pink, and sockeye salmon, both for spawning adults and returning smolts. In an average year, more than 800 million juvenile salmonids migrate seaward through the lower Fraser River. Juveniles are present for much of the year, with peak concentrations in the lower Fraser occurring between March and July (Fisheries and Oceans Canada 1988). Degraded water quality and loss or degradation of habitat negatively affects all species. Particularly susceptible are species such as chinook and chum, which as smolts feed extensively on larvae, crustaceans, and plankton in the main stem, sloughs, and sidechannels of the Fraser River.

The lower Fraser River and its tributaries also provide critical spawning and rearing habitat for all five species and account for more than 50% of the total escapements of anadromous salmon to the entire Fraser River watershed. Virtually 100% of Fraser River chum salmon spawn

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[4] Anadromous – fish species that migrate up rivers or streams from the sea to spawn.

downstream of Hope. Since 1951, the average annual percentage of spawning escapements downstream of Hope has ranged from 68-76% for coho, 54-86% for pink, 20-35% for chinook and 10-15% for sockeye (Farwell *et al.* 1987). Recently, improved methods for estimating chinook escapements to the Harrison River system have resulted in substantial upward estimates of the proportion of chinook that spawn in the Lower Fraser River Basin (Bill Masse, Fisheries and Oceans Canada, pers. comm., November 24, 1989).

At least six species of non-salmonid finfish (dogfish, eulachons, herring, Pacific cod, sturgeon, and walleye pollock) and six species of shellfish (crabs, geoducks, shrimps, prawns, scallops and sea urchins) inhabit either the freshwater or marine aquatic environment of the Basin. Along with anadromous salmonids, eulachons and sturgeon are an important component of the Native food fishery. Crabs, in particular, are a highly valued recreational and commercial fishery in areas such as Burrard Inlet, Boundary Bay, and Roberts and Sturgeon Banks. One species of coarse fish, the Salish sucker, has been identified as rare and endangered (Williams *et al.* 1989).

Freshwater fish species with recreational values include salmonids (steelhead and rainbow trout, resident cutthroat, sea run cutthroat, Dolly Varden, and kokanee), non- salmonids (black crappie, bullheads, carp, sturgeon, and white fish), and one invertebrate - crayfish. All five salmonids inhabit various rivers, streams, and lakes throughout the area. Except for sturgeon, which occur in the entire length of the Fraser River and in large lakes such as the Harrison and Pitt, the non-salmonids are generally confined to the lower Fraser River. Both chinook and coho also contribute significantly to the in-river sport fishery.

Fish Production Trends

The most accurate measure of the health of the fisheries resource is gained by assessing fish production trends from the entire watershed. Estimates of anadromous salmon production, defined here as the sum of the commercial, recreational, and Native food catch plus escapements, indicates that total production of the Fraser River watershed averages about 24 million fish (Bill Masse, Fisheries and Oceans Canada, pers. comm., November 24, 1989).

Table 5 - 8 shows the average annual production for the five anadromous salmon species between 1981 and 1986 for the entire Fraser River system. Total production is defined as the sum of spawning escapements to the Fraser River system, hatchery rack returns, the U. S. and Canadian commercial catch, both the marine and freshwater sport catch, and Native food fishery.

Table 5 - 8
Average Catch and Escapements (x 10^3) of Fraser River Salmon 1981 - 1986

	Chinook	Coho	Sockeye	Pink[1]	Chum	Total
Commercial:						
Canadian	163.2	338.1	5 766.8	5 538.5	241.9	12 048.5
U.S.	0	0	1 989.8	1 578.8	45.0	3 613.6
Total	163.2	338.1	7 756.6	7 117.3	286.9	15 662.1
Sport	115.9	97.8	0	0	0	213.7
Native Food Fishery	19.4	29.8	434.0	81.3	14.5	579.0
Total Catch	298.5	465.7	8 190.6	7 198.6	301.4	16 454.8
Escapements[2]	106.4	58.2	1 902.6	5 139.5	511.0	7 717.7
Total Return	404.9	523.9	10 093.2	12 338.1	812.4	24 172.5

[1] Pink returns average based on odd-year returns.
[2] Escapements averaged over the period 1981 - 1985.

SOURCE: B. Masse, Fisheries and Oceans Canada, pers. comm., November 24, 1989; Farwell *et al.* 1987.

The data suggest that total returns to the Fraser River system have averaged more than 24 million fish since 1981 - counting the odd-year pink returns. The average annual production of both pink and sockeye salmon appears to have increased substantially since 1981; average annual chum production has shown a steady rise since 1951. On the other hand, production of both chinook and coho salmon have steadily declined. In addition to being commercially valuable, chinook and coho are also the target of in-river recreational fisheries.

Neither Burrard Inlet nor Boundary Bay are directly part of the Fraser River system but are included in the Lower Fraser River Basin. Tributaries to these areas support important populations of anadromous salmon (in addition to freshwater species). The pattern of escapements to these tributaries indicates that salmon escapements have either declined or at best remained stable. If hatchery rack returns are excluded, average annual escapements to Burrard Inlet streams have declined from 121 000 during 1951-60 to only 65 000 during 1981-86. Spawning escapements to Boundary Bay streams are principally coho, and average returns show no apparent patterns over time (Farwell *et al.* 1987).

It is difficult to speculate precisely on the overall health of anadromous salmonid stocks based on trends in overall production. Prior to 1951, data regarding catch and escapements are good for some species, such as sockeye and pink, but often incomplete for the other species. As well, methodologies to estimate fisheries catch and escapements have improved. Consequently, earlier estimates of production may be significantly underestimated. It is certain, however, that current production is far below the historical levels of 1913, when about 33 million sockeye alone were harvested (Fisheries and Oceans Canada 1989), and far below potential. Some streams, such as the Coquitlam River, have experienced a dramatic decline from historical fish populations.

Commercial Fisheries

As shown in Table 5 - 8, the average U.S. and Canadian commercial catch was over 15.6 million fish, more than 90% of which were pink and sockeye salmon. The average annual salmon catch is increasing; however, this rise is almost entirely attributable to increased harvests of pink and sockeye salmon; the commercial catch of coho, chum, and chinook salmon has declined steadily.

Table 5 - 9 shows trends in the commercial catch of non-salmonid finfish and shellfish in the Lower Fraser River Basin. The catch of these species in 1986 was 509 tonnes and 382 tonnes respectively. Dominated by crabs, prawns, and shrimp, the commercial harvest of shellfish has generally increased since 1981, along with the number of species harvested. By contrast, non-salmonid finfish harvests have declined since 1981 and the commercial harvests for most species can be extremely volatile from year to year. Walleye pollock and eulachons receive most of the fishing pressure.

Table 5 - 9
Annual Landings (tonnes) of Commercial Shellfish and Non-Salmonid Finfish in Department of Fisheries and Oceans' Statistical Areas 28 & 29

Species	1981	1982	1983	1984	1985	1986
Shellfish:						
Crabs	229.3	260.8	274.0	341.0	353.0	321.0
Geoducks	—	—	—	—	—	11.0
Prawn/Shrimp	136.0	171.1	233.0	240.0	201.0	161.0
Scallops	*	—	—	—	—	14.0
Sea Urchins	—	—	—	—	—	2.0
Total	365.3	431.9	507.0	581.0	554.0	509.0
Finfish:						
Pacific Cod	31.5	0.2	1.0	2.0	1.0	*
Eulachons	20.9	13.5	11.0	12.0	29.0	50.0
Sturgeon	4.6	3.8	2.0	4.0	8.0	6.0
Walleye	262.3	—	11.0	—	2.0	163.0
Dogfish	168.8	146.9	62.0	**	*	163.0
Herring	—	—	—	—	—	—
Total	488.1	164.4	87.0	18.0	40.0	382.0

* Reported landings of less than one tonne.
** Data not disaggregated on a district basis.

SOURCE: Ministry of Agriculture and Fisheries 1984, 1985 & 1986; Fisheries and Oceans Canada 1981, 1982 & 1983.

Recreational Fisheries

The recreational fishery has both a marine and freshwater component. Recreational fishing is an extremely popular activity in the Strait of Georgia. Strait of Georgia sport fishermen expended 621 000 angler-days; with a catch greater than 793 000 coho and chinook annually (Shardlaw and Collicutt 1989; Kennett and McPhee 1988). The in-river sport fishery for chinook and coho salmon accounted for an average annual harvest of 16 290 fish per year during the period 1961-70 (Fisheries and Oceans Canada n.d.). During 1986-88 in-river fisheries expended an average of 196 000 angler-days to catch more than 26 000 coho and chinook annually (N. Schubert, Department of Fisheries and Oceans, pers. comm., December 1989).

Table 5 - 10 provides estimates of catch, production, angler effort, maximum harvests, and projected demand for both salmonid and non-salmonid freshwater fish in the Lower Fraser River Basin. However, the data suggest that angler effort will have doubled between 1980 and 1990, with most activity directed at small, low elevation lakes, where natural production is augmented by fish stocking, and rivers and streams, where management activities continue to focus on habitat protection and enhancement and on the enforcement of strict catch restrictions. It is anticipated that salmonid freshwater species will continue to bear most of the angling demand.

With the exception of large lakes, both low and high projections of salmonid freshwater harvests cannot be sustained given current levels of management and minimum acceptable criteria for angler success rates as defined by the Ministry of Environment. These minimum criteria vary according to species and habitat type, but generally are 0.2 fish per angler-day for rivers and streams and 1.0 fish per day for lakes (B.C. Ministry of Environment 1985).

The critical situation facing salmonids in rivers and streams is partially obscured by the fact that nearly 80% of the maximum allowable harvest of 91 000 fish is based on the utilization of non-salmonids, which are currently not as desirable a sport fishery species.

Native Food Fisheries

Native Indians have been harvesting both salmonids and non-salmonids in the Lower Fraser River Basin for thousands of years. During the initial settlement of the Fraser

Table 5-10
Recreational Freshwater Fishery Catch, Effort, Production Estimates, and Projections for the Lower Fraser River Basin[1]

Habitat Type	Quantity	Production (1980)	Catch (1980)	Angler-Days (1980)	Maximum Harvest[2]	Projected Catch (1990)	Projected Angler-Days (1990)
Large Lakes	11	122 500	22 000	31 000	44 000	36 150 - 99 200	50 000
Small Lakes:							
Low Elevation	185	606 800	249 000	259 000	300 000	393 800 - 841 050	422 000
High Elevation	667	93 700	18 000	18 000	29 000	28 650 - 57 300	28 000
Rivers/Streams	847 km.	250 300	34 000	241 200	91 000[3]	43 545 - 61 700	440 000
Total		1 073 300	323 000	549 200	464 000	502 145 - 1 059 250	940 000

[1] Data pertain to the Fraser-Delta, Pitt, Lillooet, and Skagit Planning Units and include some areas beyond the Study Area boundaries.
[2] Maximum harvest refers to the number of fish that may be continuously harvested under existing conditions to maintain the same level of production into the future.
[3] Non-salmonid freshwater fish comprise 72 000 (80%) of the estimated maximum harvest of fish in river and stream habitat.

SOURCE: B.C. Ministry of Environment 1985.

Valley in the early 1800s, salmon played a major role in the trading relationship between Native Indians and fur traders. Since 1888, Native peoples in the Basin have been authorized to catch limited amounts of salmon for food and ceremonial purposes.

The average annual catch by the Native food fisheries has steadily increased, from an average of 116 737 per year during 1951-60 to 579 000 fish per year during the period 1981-86. While much of the fishing effort is directed at sockeye, the Native food fishery includes all five anadromous salmon species, as well as steelhead trout, eulachon, and sturgeon.

The traditional cultural and economic importance of salmon to Native people has made conflict over fisheries allocation and management a focal point for aboriginal land and sea claims. The inland Native food fishery occurs after exploitation by the commercial and saltwater recreational fisheries. Consequently, fisheries managers are faced with balancing continual pressures between the competing fisheries.

Sustaining Fish and Wildlife

Are fish and wildlife resources being sustained in the Lower Fraser River Basin? The data indicate that, since historical times, a significant decline has occurred in many fish stocks, such as anadromous salmon and sturgeon, and wildlife populations. This has been a result of both habitat destruction and degradation, and overharvesting of certain species. Moreover, the levels of contaminants which have acute and chronic effects on fish and wildlife are increasing as a result of urban and agricultural development. Some important habitat conservation programs have been undertaken to reduce this decline but there may also be distinct limits in the ability to accommodate both urbanization and abundant fish and wildlife populations in the area.

In addition to resident populations of fish and wildlife, the Lower Fraser River Basin provides critical habitat for major migratory fish and wildlife populations which utilize the Basin. The responsibility for protecting these populations and controlling the land uses which affect their well-being is dispersed among federal, provincial, and local government agencies throughout the Basin. Maintaining or enhancing fish and wildlife populations requires a committed effort at improving habitat protection and management within all levels of government.

Outlook for Wildlife

Urban and agricultural development in the lowlands and logging in the mountain areas have substantially altered natural habitat and have affected species abundance and diversity. In the lowlands, the continued reduction of riparian habitat and the intense development pressures on agricultural land are a primary concern. While the physical loss of habitat is a major problem, it is not necessarily more serious than the degradation of habitat quality. A 1977 study showed that concentrations of PCBs in eggs of the Great Blue Heron nesting in the Point Grey area were more than five times greater than eggs from Crescent Beach, possibly reflecting the effects of discharges from the Iona Island sewage treatment plant and industries along the Fraser River's North Arm. Also, the application of pesticides on farmland has been known to cause at least eight separate bird kills in recent years (Butler and Campbell 1987).

In the uplands, loss of old growth timber, which provides critical habitat for some species of both mammals and birds, is a vital issue for wildlife managers. Many remaining stands of old growth timber are contained in the cutting plans of forest companies. While some species may be more adaptable to habitat alterations, others, such as the Spotted Owl, may not be.

Due to the actions of government agencies and non-profit organizations, some bird and wildlife habitat has been protected. Despite these efforts, only a small percentage of the Lower Fraser River Basin is permanently reserved for wildlife uses. The past 25 years have seen a gradual erosion of the habitat base in lowland areas; more than 560 hectares has been lost to development, extractive, or agricultural uses due to infill and dyking. A continuation of this trend, particularly in the few remaining undeveloped areas in the Fraser delta, could have major effects on wetland birds, raptors, and other forms of wildlife.

Outlook for Fish

Fisheries resources of the Lower Fraser River Basin will continue to face growing demands from all sectors, including the commercial, recreational, and Native food fishery. Fisheries management agencies are confronted with the need to allocate fisheries resources among these competing uses and to expand and augment natural production where possible. They must not only address Fraser River fisheries allocation issues within the Basin, but also domestically and internationally.

It is clear that present harvesting trends in some freshwater sport fisheries are not sustainable given current estimates of maximum production, current angler preferences for salmonids, and minimum acceptable angler success rates. Sustaining current sport fishing levels will require increasing catch restrictions and continued reliance on artificial stocking to augment natural production.

Some fish populations face pressures due to habitat degradation and declining water quality. For pink and sockeye salmon, however, research provides no indication that the large volumes of industrial and sewage wastewater discharges into the Fraser River upstream of Hope have precluded successful production of these species (in fact, populations increased between 1965-1985) (Servizi 1989). For chum, chinook, and coho salmon it has not been possible to differentiate possible impacts of wastewater from other habitat or management problems; however, research indicates that salmon in small urban and rural streams, particularly coho, are at risk due to pollution and that there is a significant potential for negative impacts on chinook near dilution zones of wastewater discharges. It is also suggested that increased wastewater volumes, increased concentrations during low-flow periods, or reduced treatment standards could have serious consequences for juvenile salmonids resident in the Main Stem of the Fraser River (Servizi 1989).

Concerning habitat, two-thirds of the 96 streams surveyed in the Lower Fraser River Basin in 1985 were identified as suffering negative impacts from activities such as forestry, agriculture, urban development, hydro development, and transportation. The resulting impacts, including water withdrawal, blockages, water contamination, water pumping, and removal of streamside vegetation, are making the supply and quality of habitat an increasingly limiting factor in sustaining fish populations.

Throughout the Basin there are also external problems resulting from the threat of such factors as global warming, acid rain, incremental depletion of water flows through upstream diversions, and increasing consumptive water uses.

In summary, the increasing demand for fish in concert with ongoing degradation of fish habitat, both from within and beyond the Lower Fraser River Basin, does not bode well for sustainability of the fishery. Added to this scenario is the fact that the institutional framework for managing and allocating the fisheries resource and habitat is complex, multi-jurisdictional, and often conflicting.

References

B.C. Ministry of Agriculture and Fisheries. 1984, 1985, 1986. Fisheries Production Statistics of British Columbia.

B.C. Ministry of Environment. 1985. Lower Mainland Region Fisheries Management Plan, 1984. Surrey: Fish and Wildlife Management.

B.C. Ministry of Environment. n.d. Information on bird and mammal species needing special management, estimated populations, and harvest statistics. Fish and Wildlife Management, Lower Mainland Region.

B.C. Ministry of Forests. 1985 Fraser Timber Supply Area Plan, April 1985 - March 1990. Victoria.

Birtwell, I.K., C.D. Levings, J.S. Macdonald and I.H. Rogers. 1988. A Review of Fish Habitat Issues in the Fraser River System. Water Pollution Research Journal of Canada 23(1):1-30.

Butler, R.W. and R.W. Campbell. 1987. The Birds of the Fraser River Delta: Populations, Ecology and International Significance. Canadian Wildlife Serve Occasional Paper.

Farwell, M.K., N.D. Schubert, K.H. Wilson and C.R. Harrison. 1987. Salmon Escapements to Streams Entering Statistical Areas 28 and 29, 1951 to 1985. Canadian Data Report of Fisheries and Aquatic Sciences 601.

Fisheries and Oceans Canada. 1981, 1982, and 1983. British Columbia Catch Statistics.

Fisheries and Oceans Canada. n.d. Statistical summary of chinook adult, coho adult, chum, sockeye and pink returns to the Fraser, 1951-1986.

Fisheries and Oceans Canada. 1988. Submission to the Sea Island Jet Fuel Barge Federal Environmental Assessment Panel.

Fisheries and Oceans Canada. 1989. The Fraser: River of Opportunity. New Westminster. Unpublished manuscript.

Fraser River Estuary Study Steering Committee. 1979. Summary Report of the Habitat Work Group. Governments of Canada/Province of British Columbia.

Greater Vancouver Regional District. 1988. Greater Vancouver Liquid Management Plan - Stage 1. Report of the Combined Sewer Overflow and Urban Runoff Committee. Burnaby.

Kennett, K. and M. McPhee. 1988. The Fraser River Estuary: An Overview of Changing Conditions. New Westminster: Fraser River Estuary Management Program.

Kistritz, R.V. 1989. Habitat Inventory and Classification of Fraser River Main Arm, Pitt River, Delta Foreshore and Boundary Bay. New Westminster: Fraser River Estuary Management Program.

The Nature Trust of B.C. 1988. Project List, 1988. West Vancouver.

Northcote, T.G., G.L. Ennis and M. Anderson. 1975. Periphytic and Planktonic Algae of the Lower Fraser River in Relation to Water Quality Condition. Technical Report No. 8. Vancouver: Westwater Research Centre.

Peterson, G.R. and V.A. Lewynsky. 1985. Review of Lower Fraser System Salmon Escapements, Habitat Condition and Exploitation Rates. Howard Paish & Associates Ltd.

Pilon, P. and M.A. Kerr. 1984. Land Use Change on Wetlands in the Southwestern Fraser Lowland, B.C. Environment Canada.

Servizi, J.A. 1989. Protecting Fraser River Salmon (*Oncorhynchus* spp.) from Wastewaters: An Assessment. In: Levings, C.D., L.B. Holtby, and M.A. Henderson, eds. Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Can. Spec. Publ. Fish Aquatic Sciences 105.

Servizi, J.A. 1990. Effects of Bio-Treated Bleached Kraft Mill Effluent on Fingerling Chinook Salmon. In: Status Report on Water Quality in the Fraser River Estuary, 1990. New Westminster: Fraser River Estuary Management Program.

Shardlaw, T.F. and L.D. Collicutt. 1989. Strait of Georgia Sportfishery Creel Survey Statistics for Salmon and Groundfish. Fisheries and Aquatic Sciences manuscript 2036

Swain, L.G. and D.G. Walton. 1989. Report on the 1988 Fish Monitoring Program. Fraser River Harbour Commission/B.C. Ministry of Environment.

Williams, G.L. 1986. North Fraser Harbour Shoreline Habitat Inventory. North Fraser Harbour Commission.

Williams, J.E., J.E. Johnson, D.A. Hendrickson, S. Contreras-Baldaras, J.D. Williams, M. Navarro-Mendoza, D.E. McAllister and J.E. Deacon. 1989. Fishes of North America: Endangered, Threatened, or of Special Concern. Fisheries 14(6): 2-20.

Chapter 6
Conclusions

Major Issues in the State of the Environment

The current knowledge of the state of the environment of the Lower Fraser River Basin indicates a decline in the abundance and quality of natural resources since historical times. There are significant variations, however, in the condition of different components of the environment and areas of the region. For example, while water quality appears to be relatively good on the Main Stem of the Fraser River, there is evidence of degraded water quality and contaminated sediments and biota adjacent to major effluent outfalls and in the tidal lower estuary. For some environmental contaminants, such as airborne lead particulates, there have been significant reductions. Such improvements in environmental quality can be directly attributed to the application of better pollution control technology and resource management programs.

But there remain a series of indicators which reflect both declining environmental quality and increasing sources of stress on the environment. The growing pressures of urban development, particularly in the face of much uncertainty about the sublethal and additive effects of contaminants, are challenging our ability to maintain the quality of the natural environment. Most notably, the concept of a sustainable environment has yet to be fully adopted as a long-term goal in environmental and land use management practices.

The following is a list of environmental issues and concerns in the Lower Fraser River Basin.

Air

- Increased traffic volumes and congestion are contributing to greater air pollution and lower community "livability".
- Air pollutants such as sulphur oxides, nitrogen oxides, and suspended particulates are increasing due to greater vehicular traffic and industry.
- High ozone levels associated with vehicle emissions occur in localized areas of the region.
- Lakes and soils have high to moderate sensitivity to acid precipitation.
- Ecosystems in the Basin are vulnerable to changes from global warming and depletion of the ozone layer.

Water

- Increased industrial and municipal discharges and urban runoff are creating localized high levels of organic and metal contaminants, particularly in sediments and biota.
- Urban, agricultural, and industrial wastewater discharges are resulting in nutrient overloading and oxygen depletion on certain low-gradient streams, and sidechannels and sloughs of the Fraser River.
- Agricultural runoff is contributing to seasonally high levels of fecal coliforms at certain locations, such as streams draining into Boundary Bay.
- Leachate contamination of surface and groundwater is occurring at some landfill sites.
- Groundwater degradation associated with intensive agriculture in the Fraser Valley may be occurring at specific shallow aquifer sites.
- Increased demands for irrigation, fisheries, and recreational uses are resulting in water shortages and conflicting uses at certain times in the Fraser Valley.

Land

- Conflicts are occurring over the multiple use of forest lands and the environmental impacts of timber harvesting and processing.
- Growing urban development, utility corridors, and parks and recreation areas are resulting in a decline in the land base for forestry.
- Urban development is leading to ongoing decline in agricultural land supply.

- Agricultural soil overuse, overfertilization, and limited conservation practices are resulting in declining soil and water quality in certain areas.
- Population growth is resulting in increased solid waste and rapidly declining landfill capacity.
- Increased development, in general, is generating greater quantities of hazardous wastes while there is a lack of safe disposal facilities for such wastes.
- The extent of rural lands is declining while public demands for parks, recreation, and open space are growing.

Aquatic and Wildlife Resources

- Overfishing, coupled with complex fisheries management problems, are causing depleted salmon stocks, particularly chinook and coho.
- Urban expansion, flood protection, and drainage schemes are causing destruction of wetlands and other habitat important to fish and wildlife populations.
- At least five species of birds no longer breed in the Lower Fraser River Basin and one mammal no longer inhabits the region.
- Urban development and timber harvesting is resulting in declining forest habitat for wildlife populations, particularly Spotted Owls.

Management Challenges for a Sustainable Environment

The concerns described above present major challenges to the sustainability of a quality environment in the Lower Fraser River Basin. What, then, are the prospects that the current environmental management framework will be adequate to manage the pressures of increasing growth and declining environmental quality? Can the present state of the environment be maintained in the future? Several key issues to managing a sustainable environment in the Lower Fraser River Basin are examined below.

Multiple Jurisdictions

Over 75 agencies at the local, regional, provincial and federal levels are responsible for managing resources, resource use, and human activities which affect the environment. Each of these agencies has a specific mandate which can overlap or conflict with the responsibilities of other agencies. With so many stakeholders, it becomes difficult to coordinate and synchronize the decisions affecting the environment and to secure agreement on common goals by which to pursue sustainable development. New initiatives at an ecosystem and regional scale are needed to overcome the problem of multiple jurisdictions.

Scientific Uncertainty

Much of the data on the state of the environment are derived from interpreting short-term or site-specific studies of particular concerns. With some notable exceptions, such as the 1985 GVRD air emissions inventory, there are few examples of studies which have been designed to provide replicable data so that trend information on the state of the environment can be determined.

The lack of adequate data is apparent in the many uncertainties which surround decisions affecting the environment. Often the data cannot be reliably interpreted because little is known about background levels of contaminants in the environment and the significance of the samples often cannot be accurately evaluated. Furthermore, information is particularly lacking on the long-term and additive effects of sublethal levels of pollutants and the incremental losses of habitat on the natural productivity of fish and wildlife species. Nowhere is this problem of uncertainty more evident than in evaluating water quality. Despite the many measurements of water quality parameters in the Fraser River over the last decade, many scientists feel that there is inadequate statistical information upon which to draw firm conclusions about the overall state of water quality.

Management Philosophy

Some fundamental differences about the approach to management of the environment exist among government agencies and public groups in the Lower Fraser River Basin. One distinct contrast is between a focus on regulating effluent and emission discharge quality and related monitoring of the ambient conditions versus a focus on source control and treatment of pollutants prior to discharge. Regulating discharges and monitoring the ambient conditions concentrates on determining the fate of pollutants in the environment and setting environmental quality objectives and pollution control measures to ensure that these are not exceeded.

In contrast, the source control view advocates greater attention towards contaminant loadings, pretreatment, discharge treatment, and the elimination or reduction of pollution sources. This view questions the ability to adequately measure observable changes in the state of the environment when conditions are so variable in the natural state and when knowledge of long-term, chronic effects is so limited. While both approaches are necessary, there is increasing public demand for source control as a basis for sustaining the environment.

Growth Management

How can the growth in population and urban development, and the accompanying pressures on the environment be managed? The regional population is growing by over 45 000 per year. Agricultural land is declining by over 300 hectares per year. Since 1880, major areas of wetland have been lost or otherwise altered. Urban and agricultural runoff has made many small streams, as well as Boundary Bay, unsuitable for fish and certain recreational uses. Urban expansion and resource extraction is reducing the supply and quantity of fish and wildlife habitat. Air quality improvements will be outstripped by the increasing volume of automobile emissions. Water consumption and wastewater volumes are increasing. Except for Burns Bog, solid waste management systems (landfills, incinerators, resource recovery facilities) will probably reach capacity by the mid 1990s, even if an additional 20% of the refuse is recycled, as proposed by the GVRD.

Issues which are beyond the direct control or management of local management agencies, such as global warming and the international driftnet fishery, also affect the sustainability of resource uses in the Lower Fraser River Basin. As the profile of environmental issues expands, greater emphasis will be placed on controlling the use of lands and resources in a manner which contributes to "livable" communities and environmental quality.

Changing Environmental Values

Public awareness of and concern for the state of the environment in the Lower Fraser River Basin has never been higher. The public is demanding that the protection of the environment be explicitly recognized in resource use decisions and that higher levels of environmental standards be imposed and enforced. The public is also demanding a more visible role in the decision-making process.

This fact is readily apparent in public opinion surveys, where the environment ranks as one of the most important concerns and is reflected in the enormous media coverage now given to environmental matters. Moreover, it is becoming recognized that economic development in the region depends upon a healthy, sustainable environment.

The changes in environmental values have major implications for resource managers. Higher public expectations for environmental quality require that managers adopt more integrated, ecosystem approaches to regulating and allocating resource uses. Traditional pollution control standards and resource management practices are often unacceptable. At the political level, these changing values may prompt increased government expenditures in such areas as upgrading sewage treatment plants, for example, and higher budgetary allocations to monitoring, research, and enforcement.

Meeting the Challenges: Government and Public Responses

Over the past decade, resource management programs in the Lower Fraser River Basin have reflected a new emphasis on environmental protection. Some examples of the greater orientation towards environmental awareness and protection are described below.

Agencies are cooperating in joint resource management activities by establishing coordinated policies, programs, and planning mechanisms to protect environmental quality.

Most notably, the Fraser River Estuary Management Program (FREMP) administers programs for coordinated project review, area designation, water quality, waste management, fish and wildlife habitat, recreation, log management, navigation and dredging, and port and industrial development. A similar program is being developed for Burrard Inlet. Agencies are cooperating in the development of monitoring programs and in undertaking research related to environmental quality. Fisheries and Oceans Canada and the B.C. Ministry of Environment, for example, have established a fish habitat inventory and information system which integrates potentially useful management information on a watershed basis.

Resource management initiatives are cutting across political boundaries in favour of more regional and ecosystem approaches to problem solving.

The Greater Vancouver Regional District has initiated a Liquid Waste Management Plan to address the long-term problem of treating municipal wastes and urban runoff. A five-part solid waste management program is well underway. As noted earlier, an air management plan has also been established and may be extended up the Fraser Valley. The Livable Region Program has been updated for the 1990s to provide goals for urban planning and development in Greater Vancouver. Further up the valley, several agencies are co-operating in the reclamation of Cheam Lake near Chilliwack and in establishing Wildlife Management Areas in the lower Pitt Lake area, Widgeon Slough and elsewhere where important wetlands and other natural features occur.

Increasingly, agencies are accepting more responsibility for the design and implementation of policies and programs which lie beyond their traditional mandates and which include more consideration of environmental and social values.

In conjunction with Fisheries and Oceans Canada, the North Fraser Harbour Commission has established an Environmental Management Plan for the North Fraser Harbour, including an innovative fish habitat banking program; the Fraser River Harbour Commission will be implementing a similar program in the near future. The Vancouver Port Corporation has developed a marine recreation resource use plan for eastern Burrard Inlet and Indian Arm. Public Works Canada is sponsoring a habitat enhancement project using dredged material. Other examples include the environmental programs of the Transportation of Dangerous Goods Directorate of Transport Canada.

Local and regional governments are beginning to recognize the need to manage growth. The current emphasis is on controlling and directing development towards areas which are less environmentally sensitive and to structure the form and density of urban development in a manner which allows for greater conservation of natural resources. Individual municipalities have also established specific policies for environmental protection and natural drainage control, and have acquired parks and recreational corridors that focus on the river and estuary.

Innovative environmental designs are beginning to appear in specific development projects, recognizing environmental sensitivities and the need to protect and enhance the natural environment as a precondition to development.

In recent years, a new imperative has emerged, requiring that proposed land developments minimize impacts on and risks to the environment. In some cases, development has provided an opportunity to improve on the current state of the environment by rehabilitating previously degraded sites and by enhancing the natural biophysical productivity of sites. For example, new designs for incorporating an "ecostrip" into some types of dyke upgrading and maintenance programs have been developed. Preservation of the Tsawwassen salt marsh, the largest of its type in the estuary, was achieved through sensitive engineering design of flood protection works. The "no net loss" habitat policy of Fisheries and Oceans Canada has also inspired various marsh creation and wetland rehabilitation projects to offset the effects of proposed developments.

The role of public involvement in decision making is now formally acknowledged in most resource management initiatives and public interest organizations are showing increasing leadership and initiative in promoting environmental awareness and undertaking environmentally responsible resource management activities.

Special task forces and environmental review panels have been created in the past to deal with interagency review of large projects, including airport and port expansion, dredging and dyking, railway double tracking, jet fuel barge storage, and the transportation of dangerous goods. To varying degrees, these have included programs for public involvement.

The activities of environmental conservation organizations have increased public awareness of and interest in environmental management. The list of organizations is large; those consistently in the forefront in the Lower Fraser River Basin have included the West Coast Environmental Law Association, Society for the Promotion of Environmental Conservation, Fraser River Coalition, Greenpeace, United Fisherman and Allied Worker's Union, Outdoor Recreation Council of B.C., B.C. Wildlife Federation, and the Federation of British Columbia Naturalists.

While interest groups have played a key role in environmental quality, the public in general has not. This is rapidly changing as more information about the resources of the Fraser River is made available through the media and organizations such as FREMP. In recent years public access to the river has been improved as a result of new parks, commercial, and residential development, which has concurrently raised public use, awareness, and understanding of the importance of the river.

In the past 20 years, public interest groups have been active in promoting environmental protection and conservation. Community based recycling programs, for example, grew from the dedicated efforts of community volunteer groups. Other non-government organizations are directly involved in preserving, acquiring, and rehabilitating natural wetlands. Ducks Unlimited, the Nature Trust of B.C., and the Pacific Estuary Conservation Foundation have assisted in acquiring wildlife habitat at various locations. Many local fish and wildlife clubs, along with the B.C. Wildlife Federation, work closely with government programs such as the Federal Salmonid Enhancement Program. School groups are also active in salmon enhancement projects, storm drain marking programs, and other community initiatives.

Towards a Sustainable Environment

Despite the many uncertainties in determining the state of the environment in the Lower Fraser River Basin, it is apparent that urban growth and development are placing increasing stress on the natural environment and that the quality of the natural systems are unlikely to be sustainable under current management practices. There is a need to adopt a new perspective which explicitly recognizes the interdependencies and trade-offs between development and long-term environmental sustainability.

The concept of a sustainable environment can provide the focus for developing policies and programs directed at maintaining natural systems in the region. There is considerable scope for making significant improvements to the existing structures and processes of environmental management. The fundamental shortcoming of the present management framework is the lack of a long-term, integrated perspective which recognizes the cumulative effects of growth and development on the natural environment of the Lower Fraser River Basin.

Progress toward a sustainable environment will require changes to the current management institutions and practices. In the process of preparing this report some alarming problems were encountered concerning the present management framework: most environmental management programs are not geared to routinely monitor the condition of biophysical systems; many do not have clear objectives for anticipating the ongoing environmental stresses created by growth and development; and all too often, those responsible for guiding such growth and development are not sufficiently linked with those responsible for managing the effects on the environment.

There is an urgent need to develop long-term strategies which cut across traditional political, institutional, and community boundaries to integrated environmental management. In this regard, the Fraser River Action Plan, identified in the federal government Green Plan, provides an excellent opportunity to take steps towards sustainable management.

The following groups of actions are also recommended as a means of advancing the concept of a sustainable environment in the Lower Fraser River Basin.

Monitoring: measuring the health of the natural systems

Revised and expanded programs are needed to provide a comprehensive database on a selected number of key indicators of environmental quality in the region in order to enable timely state of the environment reporting.

Planning: setting objectives and policies based on a sustainable future

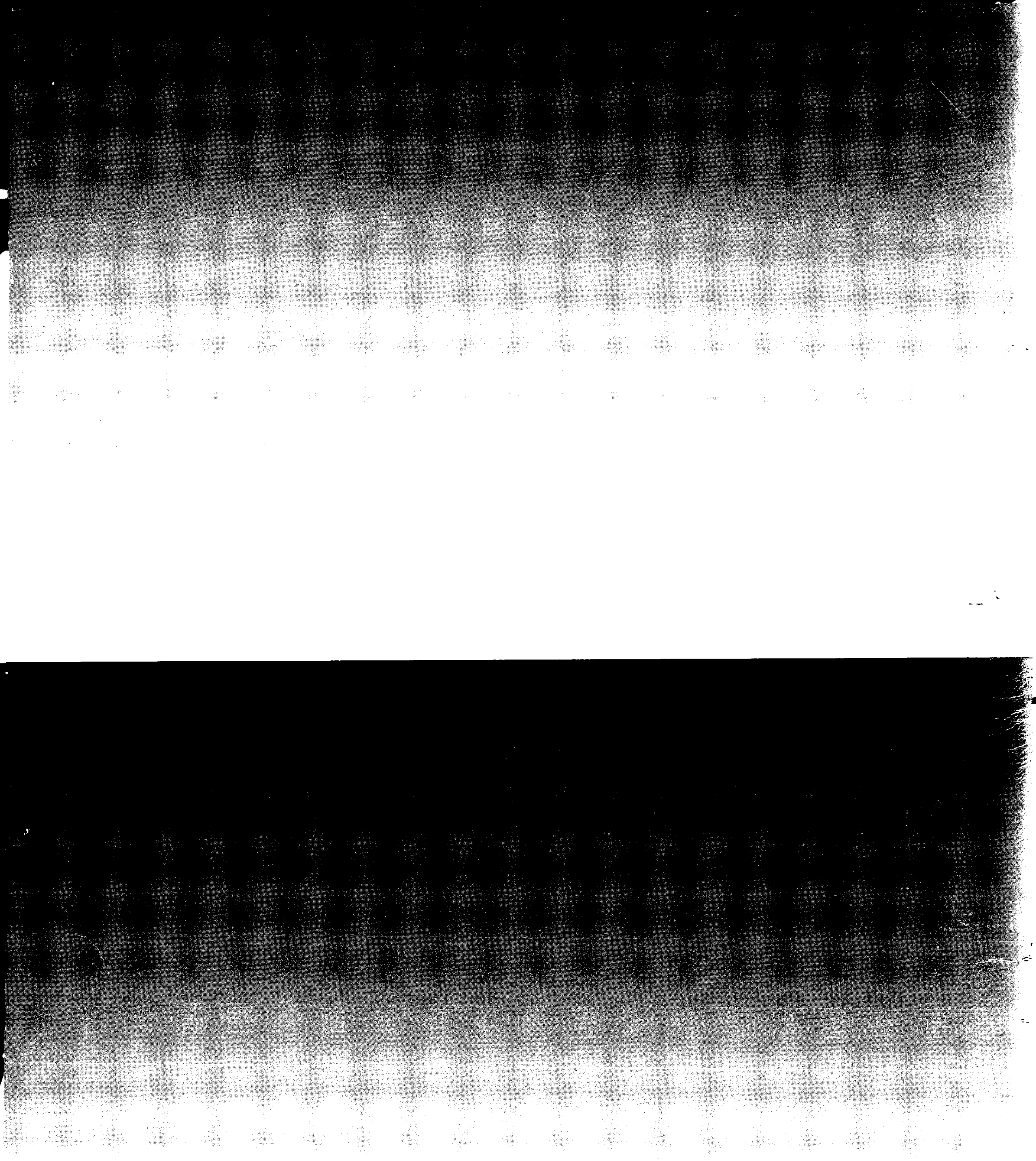
Integrated land and resource use policies should be formulated by all levels of government which provide environmental strategies for long-term development in the region, with the requirement of maintaining and, where possible, enhancing environmental quality.

Management: acting on the objectives and policies

A coordinated and mutually-supportive set of environmental conservation and management tools and programs should be developed among governments, community groups, and industry, within each environmental sector, to implement the goals of a sustainable environment.

Education: being informed and involved in environmental management

New initiatives are necessary to inform, educate, and involve the public in taking individual and community responsibility for environmental protection and resource conservation.



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