THE WESTWATER RESEARCH CENTRE

# WATER USE IN THE FRASER BASIN


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# TABLE OF CONTENTS

# TABLE OF CONTENTS (cont'd)

# LIST OF TABLES

# LIST OF FIGURES

# INTRODUCTION

The philosophy and the process of water management are undergoing great change in Canada and British Columbia. Since publication of the Pearse report (Pearse et al. 1985) on Federal Water Policy, the trend has been toward management of water resources on a watershed basis and toward recognition of water as a valuable asset rather than a free good. This latter change is reflected in a trend away from managing supply and toward managing demand for water and toward more realistic pricing of water use (Tate 1990). In British Columbia, the Provincial environmental legislation is being rewritten to reflect these new attitudes. Furthermore, the Province, the Federal government and the municipalities within the Fraser River basin have entered into an agreement to manage water resources in the Fraser basin according to principles of sustainable development (Agreement Respecting the Fraser Basin Management Program 1992). These changes in philosophy and approach to water resources management all require a firmer base of technical knowledge about how much water is available within a watershed and how much is being used. At present, neither the total supply, nor the current rate of use is known with any accuracy for Canada or the Fraser basin (Healey and Wallace 1985, Dorcey 1991).

In 1991, Westwater Research Centre published an extensive review of water use in the Fraser River basin as part of a larger study of water in sustainable development (Boeckh et al. 1991). This report builds on that work, updates and amends some of the data, expands the analysis of agricultural water use and adds an historical perspective. The three objectives of the present study were to update the existing data sources on water use within the Fraser Basin, to examine trends in water use over time and between regions, and to attempt a more comprehensive assessment of the use of water for agricultural purposes. Previous studies, including that by Westwater (Boeckh et al. 1991), have highlighted the need for better data on water use in the agricultural sector. In this study we compared two methods for estimating irrigation water use, an analysis based on license data and an analysis based on field surveys. Based on this comparison, we make recommendations about where future study and data collection efforts should be directed.

In Part One of this report we update the water use data for the Fraser Basin from the 1989 figures presented in Boeckh et al. (1991) to 1992 and we use historical data to identify trends in water use in 13 subbasins of the Fraser River. In Part Two we provide a more detailed analysis of water use in the Salmon, Bonaparte and Nechako watersheds. Methods for estimating water use for irrigation purposes are compared in these three watersheds.

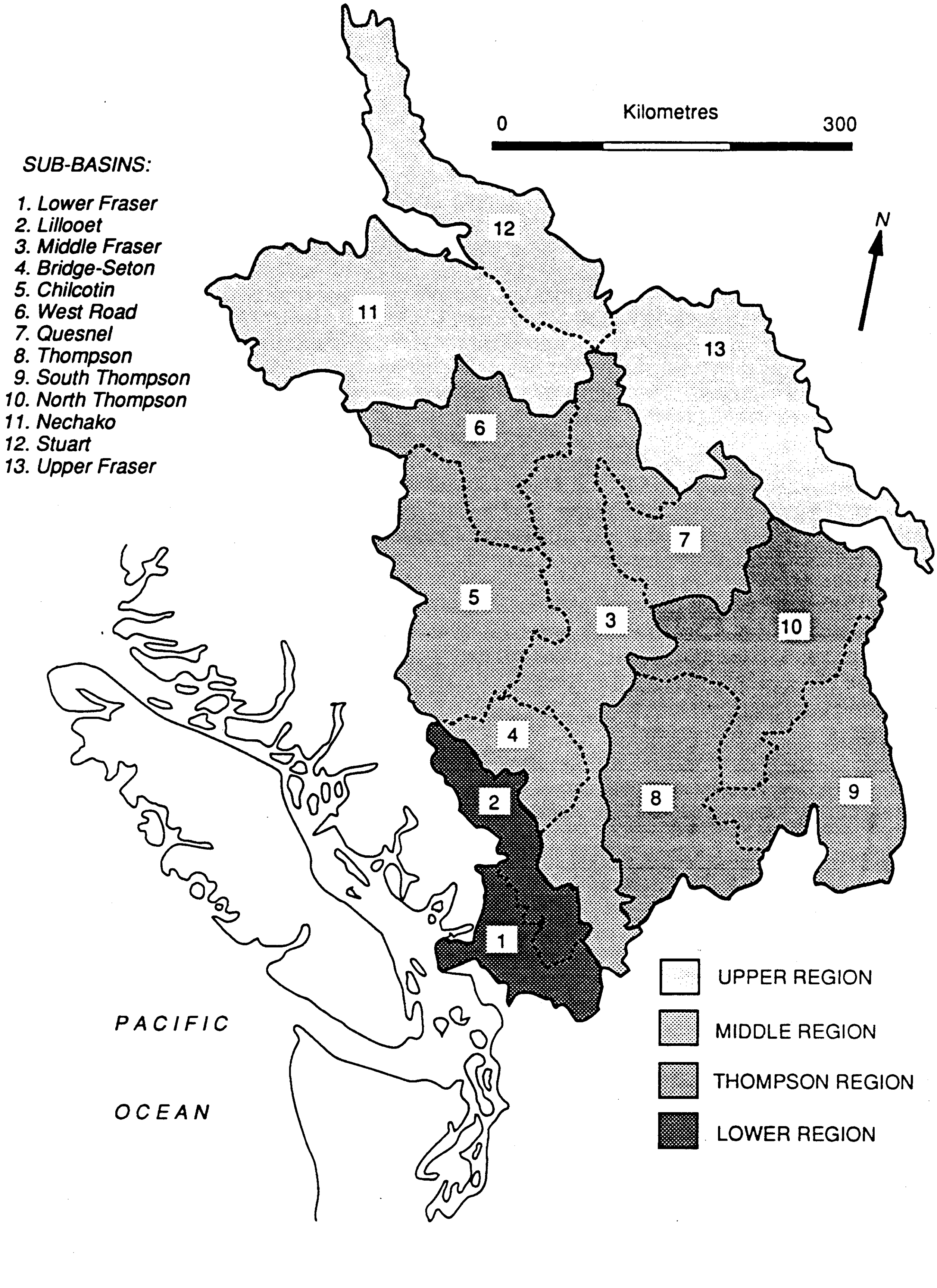


**Figure 1: Map of southern British Columbia and the Fraser River basin showing the 13 sub-basins used in this report.**

Westwater's previous water use study (Boeckh et al., 1991) used data defined by water precinct boundaries to determine water use within the 13 sub-basins. This approach required a great deal of approximation and interpolation as the precinct and sub-basin boundaries were seldom compatible. For example, if 30% of a water precinct fell within a sub-basin, 30% of the water use attributed to the precinct was applied to the sub-basin. This method is based on the assumption that water use is evenly distributed through the precincts. In areas where water use was evenly distributed this method was accurate; however, where water use was unevenly distributed, the method was inaccurate.

Since the time of this first study, the Water License Branch has switched to using watersheds as the basis for delineating sub-basin boundaries instead of using water precincts. The data collection for this study was, therefore, greatly simplified. The sub-basin boundaries matched up in all cases except the provincial government's 100-Fraser watershed. For our purposes, it was necessary to subdivide this large basin into the Salmon portion of the Stuart-Salmon drainage, the Bridge-Seton, and the Upper, Middle and Lower Fraser sub-basins by reference to detailed information on stream source and precinct. Details as to how the license data for the large 100-Fraser watershed were subdivided into the sub-basins defined by Westwater are included in Appendix B.

Detailed information on irrigation water licenses for three smaller basins was used to explore how licenses were issued over time, the average size of irrigated farms, and the conversion factors used to calculate water requirements for irrigation. These smaller basins were the Salmon River watershed in the Lower Fraser sub-basin, the Bonaparte River watershed in the Thompson sub-basin and the Nechako sub-basin (Figure 1).

### 1.1.2 Data Limitations

In working with the data base and the data itself, several constraints or limitations became apparent. The first practical obstacle to overcome was the conversion of the data into one common unit of measurement for water volume. Water was recorded in such units as acre feet, gallons, cubic feet and cubic metres for various time periods. All of these data were converted to cubic metres using the conversion factors shown in Appendix C. Converting all of the measurements not only took time, it also imposed a level of approximation, and thereby reduced the accuracy of the data.

Water Licenses can be obtained for over 45 different categories of water use. The distinction between the categories is often not readily apparent. Extra consultation with the License Branch staff was required in order to understand the categories contained in the data base. The definitions of the major categories are contained in Appendix A.

A water license can be granted in perpetuity if it is used according to the terms of the license and the Water Act. Some water licenses date back to 1865. As will be discussed in Part 2, it is difficult to determine whether or not the licenses are being used in the manner prescribed in the license or if the license is being used at all. In addition, the volume of water actually being used by the license holder is not usually measured or monitored in any way. Both of these factors limit the reliability of license data in estimating water use.

The volume of water licensed for use in irrigation is determined by the land area to be irrigated multiplied by a coefficient of water use for the crop to be irrigated. We discovered that the coefficients used to calculate the appropriate volume of water for an area of land have changed dramatically over time in some regions. For example, in the Bonaparte watershed an 1871 license granted 663 acre feet of water for 220 acres of land. In the same watershed a 1975 license granted 200 acre feet of water for 200 acres of land. The issuing of licenses in perpetuity reduces the ability to change the licensed volumes of water in light of increased knowledge and changing supply and demand patterns.

### 1.1.3 Opportunities For Improving Data

The following suggested changes in the data base would reduce, to some degree, the constraints noted above:

- sub-divide the 100-Fraser watershed into smaller units (e.g. Upper, Middle and Lower Fraser);
- make use of one standard metric unit for water volume measurement in the data base (e.g. cubic metres); and
- simplify and clearly define the categories of water use.

In addition, the value of license data as a means of estimating water use could be greatly enhanced if the licenses were monitored periodically, or issued for limited time periods to determine whether or not the licenses are being used as prescribed. Up to date addresses of license holders would be required to do this and, at present, this information is not current. The most significant improvement to this data set would come about through the use of water meters or some other reliable means of measuring water use by license holders and a corresponding water use reporting system. Further study would be required to determine the practicality and cost of implementing and maintaining a metering and monitoring system

### 1.1.4 Presentation of Data

As noted in Section 1.1.1, the data collected for this study is based on watershed boundaries rather than the precinct boundaries used to tabulate the 1989 data presented in Boeckh et al. (1991). Comparisons between the 1989 and 1992 sub-basin data sets cannot be made with any degree of certainty because of the different methods employed. The total figures and the use category data can be compared with confidence because they aggregate all sub-basin boundaries.

<u>Water Licenses by Sub-Basin</u>

Table 1 shows the total number of licenses in each sub-basin and the allocated volume. The Nechako watershed clearly has the highest volume of water allocated (53,623.5 cubic metres/yr.), reflecting the use of water for power generation at Alcan's Kenney Dam. The highest number of licenses are found in South Thompson (5,285 licenses) where irrigation is the main water use. The Lower Fraser has high values in both categories (24,269.1 cubic metres/yr. and 2,224 licenses), reflecting the concentration of population in this sub-basin. The greatest increase in the number of licenses from 1989 to 1992 was in the Nechako (270 to 623 licenses). The greatest decline in this period took place in West Road (316 to 87 licenses). The greatest increases in volume of water allocated between 1989 and 1992 were in the South Thompson and Chilcotin. Both regions experienced a 200% increase in volume. The Bridge Seton and the Middle Fraser both experienced 60% declines in volume of water allocated between 1989 and 1992. Overall, although licenses have increased in number by 319, volume allocated declined 4,157 cubic metres.

Table 1: Water Licenses in the Fraser Basin by Sub-basin, 1989 and 1992

| SUB-BASIN | NUMBER OF LICENSES | | VOLUME (million $m^3/yr$) | |
|---|---|---|---|---|
| | 1989 | 1992 | 1989 | 1992 |
| Upper Fraser | 601 | 688 | 139.5 | 317.9 |
| Stuart-Salmon | 163 | 56 | 38.1 | 6.6 |
| Nechako | 270 | 623 | 53,488.5 | 53,623.5 |
| West Road | 316 | 87 | 25.5 | 9.7 |
| Quesnel | 591 | 508 | 199.8 | 405.5 |
| Chilcotin | 536 | 342 | 160.8 | 471.5 |
| Bridge-Seton | 753 | 769 | 11,246.4 | 5,159.6 |
| Middle Fraser | 2,564 | 2,906 | 766.7 | 287.0 |
| North Thompson | 2,000 | 2,110 | 239.9 | 409.1 |
| South Thompson | 4,764 | 5,285 | 444.9 | 1,507.0 |
| Thompson | 2,499 | 2,438 | 604.9 | 816.4 |
| Lillooet | 339 | 281 | 167.8 | 152.6 |
| Lower Fraser | 2,602 | 2,224 | 24,269.1 | 24,468.8 |
| **TOTALS** | **17,998** | **18,317** | **91,791.9** | **87,635.2** |

*Source: B.C. Water License Data Base and Boeckh et. al., 1991*

## Water Licenses by Type of Use

Table 2 indicates the number and volume of licenses per use category. The licenses have been summarized into the major water use categories. Domestic use of water constitutes the highest number of licenses (8,389) but the lowest volume of water (12.1 million cubic metres/yr.). Although the number of licenses has increased slightly from 1989 to 1992, the volume has remained constant. The second highest water use category by number of licenses is irrigation (6,243 licenses). This figure has decreased slightly from the 1989 figure of 6,352. Power generation and storage account for the largest volume of water (35,754.3 and 45,993.3 million cubic metres/yr. respectively). Conservation is also a high volume water use at 3,736.2 cubic metres/yr.

The overall decline in volume of water used between 1992 and 1989 results primarily from a decline in the reported water use for power generation and pulp mills. The overall increase in licenses reflects increases in conservation and other industrial use.

Table 2: Water Licenses in the Fraser Basin by Category of Use, 1989 and 1992

| TYPE OF USE | NUMBER OF LICENSES | | VOLUME (million $m^3/yr$) | |
|---|---|---|---|---|
| | 1989 | 1992 | 1989 | 1992 |
| Waterworks | 380 | 365 | 322.2 | 323.7 |
| Domestic | 8,298 | 8,389 | 12.1 | 12.1 |
| Pulp Mills | 8 | 7 | 490.0 | 221.7 |
| Mining | 55 | 50 | 100.6 | 91.3 |
| Other Industrial | 895 | 1,251 | 168.0 | 341.0 |
| Irrigation | 6,352 | 6,243 | 693.6 | 681.1 |
| Land Improvement | 307 | 252 | 131.2 | 131.7 |
| Power generation | 128 | 132 | 40,762.2 | 35,754.3 |
| Storage (power) | 14 | 18 | 45,993.3 | 45,993.3 |
| Storage (other) | 1,249 | 1,283 | 340.4 | 348.8 |
| Conservation | 312 | 327 | 2,778.3 | 3,736.2 |
| **TOTALS** | **17,998** | **18,317** | **91,791.9** | **87,635.2** |

*Source: B.C. Water License Data Base and Boeckh et. al., 1991*

## 1.2 MUNICIPAL WATER USE DATA (MUD)

The Municipal Water Use Data (Environment Canada 1983, 1986, 1989, 1992) provides information on water used within municipal systems and includes data on the source of water supply, volume of water used, end use of water, and population served by the water source. These data compliment the license data by defining the source of water and, in particular, by including groundwater data. The volume and population data also allow for calculation of per capita water consumption.

### 1.2.1 Data Collection

Municipal Water Use Data (MUD) are collected every three years by Environment Canada (Inland Waters Directorate). The data collected refer to the previous years' water use and waste discharges; for example, 1992 data refer to 1991 measurements. Since MUD accounts for water withdrawal and waste discharge services supplied by the municipality to users within the municipal boundaries only, corrections need to be made for municipalities which supply services outside their boundaries. Environment Canada maintains municipal water use data in a computer data base.

MUD are collected by questionnaire. The questionnaire used is included in Appendix D. In 1992, questionnaires were mailed out by Environment Canada to municipalities with a population of 1,000 or more. Numerous follow-up phone calls, letters, and faxes increased the 1992 response rate to Environment Canada from approximately 75% to 100%. We obtained copies of these completed questionnaires for the purpose of this study. In addition, we made direct contact with municipalities having populations of 500 or more. Environment Canada provided 1983, 1986, and 1989 data on computer disks. Detailed summaries of the MUD data by municipality are provided for 1983 , 1986, 1989 and 1992 in Appendix E.

Information on category of water use, water source, daily flow at water plants and populations served (Questions 4, 7, 8, 10, and 11 from the MUD questionnaires) was used in this study. Data were summarized and grouped by sub-basins. The sub-basins of Quesnel, West Road, and the Chilcotin are not discussed in this section as they lacked municipalities with populations of over 500. Conversely, the Lower Fraser sub-basin, with its large urban population, dominates the final results.

This study was undertaken in a similar manner as Boeckh et al., (1991). Results in this section differ slightly from the earlier study due to differences in interpretation of 1989 raw data between this study and Boeckh et al.

### 1.2.2 Data Limitations

The 1992 data were not available from Environment Canada in their final form at the time of the study. Therefore, raw data needed to be interpreted and summarized in the tables below for the year 1992. Previous years' raw data were compiled by Environment Canada and were subject to slightly different interpretations and error corrections.

Municipalities do not always have easily accessible records of how much water is being used. In addition, municipalities report average daily flow rates in different units and raw data needed to be converted into cubic metres per day. The use of conversion factors may have added to inaccuracies.

Many municipalities do not keep accurate counts of numbers of people using their water supply. Information related to municipal populations and populations served by the municipal water supply is often taken from the most recent federal census and therefore may be several years out of date.

Many municipalities "had no idea" what percentage of their water went to Domestic, Commercial and Institutional, and Industrial uses in response to Question 4 on the MUD questionnaire. Municipalities do not keep track of these percentages nor do they necessarily classify the usage categories in the same manner as is used in the MUD questionnaire.

The quality of the data is limited by the person who fills in the form. Follow up phone calls with explanations of the purpose of this study (and other similar studies) increased the time and effort respondents put into filling in the 1992 MUD form accurately.

The subjective nature of much of the data reporting, particularly related to end use of water, reduces the accuracy and reliability of the municipal data.

### 1.2.3 Opportunities for Improving Data

The municipal data would be more reliable if accurate measurements of end use were taken by municipalities (particularly domestic use), if uniform units were applied, if population records were kept up to date, and if time were taken by qualified persons to ensure the accuracy of the forms.

### 1.2.4 Presentation of Data (1983, 1986, 1989, and 1992)

Source of Water Supply

Table 3 reveals that the Lower Fraser depends mostly on surface water for its water supply. The Greater Vancouver Water District (GVWD) supplies most of this surface water to its approximately 1.4 million users (1992) within the Lower Fraser sub-basin study area.[1] However, the percentage of water drawn from surface and groundwater not provided by the GVWD in the Lower Fraser has increased from 3% in 1983 to 8% in 1992 reflecting growth and increased demand in communities outside the GVWD.

In the Lillooet sub-basin, there has been a shift from surface water only (98% in 1983) to surface (84%) and groundwater (16%) in 1992. The resort municipality of Whistler accounts for most of this change. Whistler developed rapidly during this time period and switched from surface only to combined surface and groundwater in 1989.

The Thompson sub-basin also used primarily surface water until 1986 but now uses both surface and groundwater sources. Municipalities in the South Thompson sub-basin continue to rely mostly on surface water. However, there was a 20% increase since 1983 in users dependent on groundwater supply only.

The Middle Fraser continues to use groundwater only or a combination of surface and groundwater. Variations between years are most likely attributable to reporting errors. The municipality of Lillooet relies on surface and groundwater. The switch to surface only in Bridge Seton in 1989 could be a reporting error. Municipalities in the Nechako are increasingly relying on groundwater for their water source. The remaining three sub-basins show no change. Overall, their is a trend towards greater use of groundwater for municipal water supply, although surface water sources still predominate (Table 3).

Percentage of Water Used in Each Sub-basin

The Lower Fraser accounts for the majority of municipal water use in the entire Fraser Basin (85 to 87%). This figure is surprisingly stable given the high rate of population growth in the Lower Fraser. The Thompson's percentage of total water use is second highest in the Basin. This percentage has declined over time, (7 to 6%) although the actual water use in the sub-basin, measured in cubic meters per day, has increased. In the Lillooet sub-basin the percentage of total municipal water use has increased, reflecting growth in the municipality of Whistler. Summarized results for the entire Fraser basin are presented in Table 4 below.

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[1] This study used the same GVRD municipalities as Boeckh et al, 1991. The GVRD draws its water supply from three sources: the Capilano Reservoir, Seymour Falls and Coquitlam Reservoir. Only the Coquitlam is in the Basin and it provides only about 12% of the average daily flow to the GVRD. Municipalities on the North Shore of Burrard Inlet were not included.

## Table 3: Municipal Water Use - Populations Served and Water Source (1983 - 1992)

**POPULATION SERVED**

| SUB-BASIN | 1983 (No. of people) | 1986 (No. of people) | 1989 (No. of people) | 1992 (No. of people) |
|---|---|---|---|---|
| LOWER FRASER | 1,223,495 | 1,255,220 | 1,431,161 | 1,563,127 |
| LILLOOET | 1,598 | 2,691 | 2,773 | 5,440 |
| THOMPSON | 73,790 | 73,594 | 67,907 | 77,095 |
| SOUTH THOMPSON | 17,930 | 17,930 | 19,560 | 19,200 |
| NORTH THOMPSON | 1,925 | 1,925 | 1,692 | 1,692 |
| MIDDLE FRASER | 83,362 | 85,300 | 78,800 | 78,734 |
| BRIDGE-SETON | 1,604 | 1,604 | 1,635 | 2,500 |
| NECHAKO | 6,175 | 6,097 | 5,604 | 5,955 |
| STUART | 2,284 | 2,284 | 1,983 | 1,900 |
| UPPER FRASER | 1,893 | 1,841 | 1,819 | 1,825 |
| **TOTAL FRASER** | **1,414,056** | **1,448,486** | **1,612,934** | **1,757,468** |

**GROUNDWATER ONLY - AS A PERCENT OF ALL SOURCES**

| SUB-BASIN | 1983 % of Total | 1986 % of Total | 1989 % of Total | 1992 % of Total |
|---|---|---|---|---|
| LOWER FRASER | 3% | 4% | 2% | 2% |
| LILLOOET | 2% | 2% | 2% | 1% |
| THOMPSON | 14% | 14% | 14% | 13% |
| SOUTH THOMPSON | 7% | 7% | 16% | 27% |
| NORTH THOMPSON | 0% | 0% | 0% | 0% |
| MIDDLE FRASER | 90% | 100% | 76% | 100% |
| BRIDGE-SETON | 0% | 0% | 0% | 0% |
| NECHAKO | 38% | 38% | 69% | 73% |
| STUART | 100% | 100% | 100% | 100% |
| UPPER FRASER | 0% | 0% | 0% | 0% |

**SURFACE & GROUND WATER - AS A PERCENT OF ALL SOURCES**

| SUB-BASIN | 1983 % of Total | 1986 % of Total | 1989 % of Total | 1992 % of Total |
|---|---|---|---|---|
| LOWER FRASER | 3% | 4% | 5% | 8% |
| LILLOOET | 0% | 0% | 72% | 84% |
| THOMPSON | 0% | 0% | 81% | 83% |
| SOUTH THOMPSON | 11% | 11% | 51% | 0% |
| NORTH THOMPSON | 100% | 100% | 100% | 100% |
| MIDDLE FRASER | 10% | 0% | 22% | 0% |
| BRIDGE-SETON | 100% | 100% | 0% | 100% |
| NECHAKO | 0% | 0% | 0% | 0% |
| STUART | 0% | 0% | 0% | 0% |
| UPPER FRASER | 0% | 0% | 0% | 0% |

**SURFACE WATER ONLY - AS A PERCENT OF ALL SOURCES**

| SUB-BASIN | 1983 % of Total | 1986 % of Total | 1989 % of Total | 1992 % of Total |
|---|---|---|---|---|
| LOWER FRASER | 94% | 90% | 93% | 90% |
| LILLOOET | 98% | 98% | 26% | 15% |
| THOMPSON | 86% | 90% | 4% | 4% |
| SOUTH THOMPSON | 82% | 82% | 32% | 73% |
| NORTH THOMPSON | 0% | 0% | 0% | 0% |
| MIDDLE FRASER | 0% | 0% | 0% | 0% |
| BRIDGE-SETON | 0% | 0% | 100% | 0% |
| NECHAKO | 62% | 62% | 28% | 27% |
| STUART | 0% | 0% | 0% | 0% |
| UPPER FRASER | 100% | 100% | 100% | 100% |

*Source: Municipal Water Use Data Base, Inland Waters Directorate, Environment Canada*

## Table 4: Municipal Water Use By Sub-basin (1983 - 1992)

| SUB-BASIN | 1983 | | 1986 | | 1989 | | 1992 | |
|---|---|---|---|---|---|---|---|---|
| | Total Use ($m^3$/day) | % of Total Basin | Total Use ($m^3$/day) | % of Total Basin | Total Use ($m^3$/day) | % of Total Basin | Total Use ($m^3$/day) | % of Total Basin |
| LOWER FRASER | 829,278 | 85.01% | 928,527 | 86.17% | 954,955 | 87.64% | 1,030,241 | 85.54% |
| LILLOOET | 1,169 | 0.12% | 4,209 | 0.39% | 5,060 | 0.46% | 22,324 | 1.85% |
| THOMPSON | 70,535 | 7.23% | 67,104 | 6.23% | 66,048 | 6.06% | 71,334 | 5.92% |
| SOUTH THOMPSON | 13,676 | 1.40% | 13,676 | 1.27% | 15,308 | 1.40% | 16,409 | 1.36% |
| NORTH THOMPSON | 1,175 | 0.12% | 1,175 | 0.11% | 1,033 | 0.09% | 1,309 | 0.11% |
| MIDDLE FRASER | 51,507 | 5.28% | 53,486 | 4.96% | 38,802 | 3.56% | 52,989 | 4.40% |
| BRIDGE-SETON | 3,182 | 0.33% | 3,182 | 0.30% | 3,243 | 0.30% | 3,300 | 0.27% |
| NECHAKO | 3,642 | 0.37% | 4,167 | 0.39% | 3,917 | 0.36% | 4,362 | 0.36% |
| STUART | 158 | 0.02% | 1,402 | 0.13% | 200 | 0.02% | 1,000 | 0.08% |
| UPPER FRASER | 1,159 | 0.12% | 628 | 0.06% | 1,110 | 0.10% | 1,067 | 0.09% |
| **TOTAL FRASER** | **975,481** | **100.00%** | **1,077,556** | **100.00%** | **1,089,676** | **100.00%** | **1,204,335** | **100.00%** |

*Source: Municipal Water Use Data Base, Inland Waters Directorate, Environment Canada*

## End Use of Municipal Water

Domestic use represents the highest of all municipal uses and has increased from 54% to 68% since 1983. Industrial use has declined as a percentage of the total from 22% to 10%. Institutional and Commercial uses increased from 24% to 32% between 1983 and 1989 and then dropped to 21% in 1991.

Table 5 gives the estimates for percentage use in the categories of Domestic, Industrial, Commercial and Institutional, and Other. The Other category includes system losses and flows from municipalities that were unable to estimate the preceding user classes. The data are to be interpreted as estimations only and not exact measured units. Year to year variations depend, in part, on different individuals' opinions.

The percentage of water use unaccounted for likely varies depending on how much time and effort is expended by data collectors in confirming the figures with the municipalities. Data for 1989 stand out in this regard with a very low volume of water unaccounted for.

# Table 5: Municipal Water Use - End Use Estimates (1983 - 1992)

**DOMESTIC**

| SUB-BASIN | 1983 | | 1986 | | 1989 | | 1992 | |
|---|---|---|---|---|---|---|---|---|
| | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total |
| LOWER FRASER | 319,173 | 53% | 350,087 | 52% | 486,792 | 54% | 297,512 | 66% |
| LILLOOET | 8 | 10% | 9 | 10% | 9 | 10% | 598 | 64% |
| THOMPSON | 11,340 | 85% | 11,340 | 85% | 42,967 | 74% | 60,325 | 86% |
| SOUTH THOMPSON | 6,953 | 60% | 6,953 | 60% | 9,448 | 72% | 10,199 | 73% |
| NORTH THOMPSON | 705 | 60% | 705 | 60% | 620 | 60% | 838 | 100% |
| MIDDLE FRASER | 30,392 | 69% | 30,506 | 69% | 21,558 | 68% | 9,927 | 65% |
| BRIDGE-SETON | 0 | N/A | 0 | N/A | 0 | N/A | 2,475 | 75% |
| NECHAKO | 0 | N/A | 0 | N/A | 0 | N/A | 3,433 | 79% |
| STUART | 0 | N/A | 0 | N/A | 0 | N/A | 700 | 70% |
| UPPER FRASER | 0 | N/A | 0 | N/A | 0 | N/A | 382 | 63% |
| TOTAL | **368,571** | **54%** | **399,600** | **54%** | **561,394** | **56%** | **386,389** | **68%** |

**INDUSTRIAL**

| SUB-BASIN | 1983 | | 1986 | | 1989 | | 1992 | |
|---|---|---|---|---|---|---|---|---|
| | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total |
| LOWER FRASER | 143,926 | 24% | 156,586 | 23% | 109,001 | 12% | 49,079 | 11% |
| LILLOOET | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| THOMPSON | 293 | 2% | 293 | 2% | 7,103 | 12% | 6,152 | 9% |
| SOUTH THOMPSON | 995 | 9% | 994 | 9% | 704 | 5% | 780 | 6% |
| NORTH THOMPSON | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| MIDDLE FRASER | 2,672 | 6% | 3,076 | 7% | 2,427 | 8% | 1,365 | 9% |
| BRIDGE-SETON | 0 | N/A | 0 | N/A | 0 | N/A | 0 | 0% |
| NECHAKO | 0 | N/A | 0 | N/A | 0 | N/A | 61 | 1% |
| STUART | 0 | N/A | 0 | N/A | 0 | N/A | 100 | 10% |
| UPPER FRASER | 0 | N/A | 0 | N/A | 0 | N/A | 32 | 5% |
| TOTAL | **147,886** | **22%** | **160,949** | **22%** | **119,235** | **12%** | **57,569** | **10%** |

**INSTITUTIONAL AND COMMERCIAL**

| SUB-BASIN | 1983 | | 1986 | | 1989 | | 1992 | |
|---|---|---|---|---|---|---|---|---|
| | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total |
| LOWER FRASER | 143,812 | 24% | 166,929 | 25% | 300,243 | 34% | 107,362 | 24% |
| LILLOOET | 71 | 90% | 78 | 90% | 84 | 90% | 342 | 36% |
| THOMPSON | 1,652 | 12% | 1,651 | 12% | 8,240 | 14% | 3,865 | 5% |
| SOUTH THOMPSON | 3,729 | 32% | 3,729 | 32% | 3,045 | 23% | 3,008 | 22% |
| NORTH THOMPSON | 470 | 40% | 470 | 40% | 413 | 40% | 0 | 0% |
| MIDDLE FRASER | 10,849 | 25% | 10,754 | 24% | 7,512 | 24% | 3,996 | 26% |
| BRIDGE-SETON | 0 | N/A | 0 | N/A | 0 | N/A | 825 | 25% |
| NECHAKO | 0 | N/A | 0 | N/A | 0 | N/A | 838 | 19% |
| STUART | 0 | N/A | 0 | N/A | 0 | N/A | 200 | 20% |
| UPPER FRASER | 0 | N/A | 0 | N/A | 0 | N/A | 191 | 32% |
| TOTAL | **160,583** | **24%** | **183,611** | **25%** | **319,537** | **32%** | **120,627** | **21%** |

**UNACCOUNTED**

| SUB-BASIN | 1983 | | 1986 | | 1989 | | 1992 | |
|---|---|---|---|---|---|---|---|---|
| | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total | ($m^3$/day) | % of Total |
| LOWER FRASER | 219,236 | 30% | 255,075 | 25% | 58,919 | 6% | 575,142 | 60% |
| LILLOOET | 1,090 | 10% | 4,887 | 10% | 4,966 | 10% | 21,383 | 100% |
| THOMPSON | 57,252 | 80% | 54,784 | 80% | 7,737 | 7% | 992 | 1% |
| SOUTH THOMPSON | 2,000 | 14% | 2,000 | 15% | 2,111 | 13% | 3,702 | 25% |
| NORTH THOMPSON | 0 | 0% | 0 | 0% | 0 | 0% | 471 | 30% |
| MIDDLE FRASER | 7,593 | 14% | 8,500 | 70% | 7,305 | 20% | 37,700 | 75% |
| BRIDGE-SETON | 3,182 | 100% | 0 | 0% | 3,243 | 100% | 0 | 0% |
| NECHAKO | 3,642 | 100% | 0 | 0% | 3,917 | 100% | 31 | 0% |
| STUART | 158 | 100% | 158 | 100% | 200 | 100% | 0 | 0% |
| UPPER FRASER | 1,159 | 100% | 1,126 | 100% | 1,110 | 100% | 463 | 50% |
| TOTAL | **295,312** | | **326,530** | | **89,508** | | **639,884** | |

*Source: Municipal Water Use Data Base, Inland Waters Directorate, Environment Canada*

## Per Capita Consumption

Table 6 shows the total water use in each sub-basin divided by population to give a per capita water consumption rate. Due to the uncertainty of the end use data provided above, the total water use figures were thought to provide a more accurate representation of consumption than by using the domestic use figures.

The greatest increase in per capita water use over the years 1983 to 1992 occurred in the Lillooet sub-basin (4.1 $m^3$/day in 1992). The municipality of Whistler accounts for this high water consumption rate. While the permanent population of Whistler is now 4,590, the number of bed-units (hotel rooms and time-share condominiums) is presently 28,496 and is projected to increase to 52,500 by the year 2000. Most of these units are occupied 100% of the time reflecting Whistler's year round resort facilities (personal communication Joe Paul, Municipality of Whistler). Because the water volume estimate for the sub-basin is divided by the permanent population and does not incorporate the recreation and tourist population, the per capita consumption figure attributes all water use to the permanent population whereas much is used by the high transient population. Using the sum of the permanent and transient population for Whistler in the calculation, rather than the permanent population alone, reduces per capita consumption in the Lillooet sub-basin to 0.76 $m^3$/day, generally similar to other tabular values (Table 6).

The Bridge-Seton sub-basin has a consistently high per capita consumption (1.32 - 1.98 $m^3$/day), which is 2 - 3 times higher than most sub-basins. The Thompson and South Thompson also have above average per capita consumption rates. These consumption rates reflect the dry climate found within these sub-basins. The data for the Stuart-Salmon sub-basin reveals very low per capita consumption for the years 1983 and 1989. The reasons for this are unclear and are most likely recording errors. The Lower Fraser per capita use has declined from 0.68 $m^3$/day in 1983 to 0.66 $m^3$/day in 1992.

Table 6: Per Capita Water Consumption (1983 - 1992)

| SUB-BASIN | 1983 | | | 1986 | | | 1989 | | | 1992 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pop'n | Water Use ($m^3$/day) | Per Capita | Pop'n | Water Use ($m^3$/day) | Per Capita | Pop'n | Water Use ($m^3$/day) | Per Capita | Pop'n | Water Use ($m^3$/day) | Per Capita |
| LOWER FRASER | 1,223,495 | 829,278 | 0.68 | 1,255,220 | 928,527 | 0.74 | 1,431,161 | 954,955 | 0.67 | 1,563,127 | 1,030,241 | 0.66 |
| LILLOOET | 1,598 | 1,169 | 0.73 | 2,691 | 4,209 | 1.56 | 2,773 | 5,060 | 1.82 | 5,440 | 22,324 | 4.10 |
| THOMPSON | 73,790 | 70,535 | 0.96 | 73,594 | 67,104 | 0.91 | 67,907 | 66,048 | 0.97 | 77,095 | 71,334 | 0.93 |
| S. THOMPSON | 17,930 | 13,676 | 0.76 | 17,930 | 13,676 | 0.76 | 19,560 | 15,308 | 0.78 | 19,200 | 16,409 | 0.85 |
| N. THOMPSON | 1,925 | 1,175 | 0.61 | 1,925 | 1,175 | 0.61 | 1,692 | 1,033 | 0.61 | 1,692 | 1,309 | 0.77 |
| MIDDLE FRASER | 83,362 | 51,507 | 0.62 | 85,300 | 53,486 | 0.63 | 78,800 | 38,802 | 0.49 | 78,734 | 52,989 | 0.67 |
| BRIDGE-SETON | 1,604 | 3,182 | 1.98 | 1,604 | 3,182 | 1.98 | 1,635 | 3,243 | 1.98 | 2,500 | 3,300 | 1.32 |
| NECHAKO | 6,175 | 3,642 | 0.59 | 6,097 | 4,167 | 0.68 | 5,604 | 3,917 | 0.70 | 5,955 | 4,362 | 0.73 |
| STUART | 2,284 | 158 | 0.07 | 2,284 | 1,402 | 0.61 | 1,983 | 200 | 0.10 | 1,900 | 1,000 | 0.53 |
| UPPER FRASER | 1,893 | 1,159 | 0.61 | 1,841 | 628 | 0.34 | 1,819 | 1,110 | 0.61 | 1,825 | 1,067 | 0.58 |
| **TOTAL** | 1,414,056 | 975,481 | 0.69 | 1,448,486 | 1,077,556 | 0.74 | 1,612,934 | 1,089,676 | 0.68 | 1,757,468 | 1,204,335 | 0.69 |

*Source: Municipal Water Use Data Base, Inland Waters Directorate, Environment Canada*

## 1.3 INDUSTRIAL WATER USE DATA

The Industrial Water Use Data (Environment Canada 1981, 1986) provide information on the number of industrial operations making use of water and the amount of water being taken in by the industries. The data allow for comparison of water use between various industries. The industries are grouped into paper and allied, chemical, wood, food, mineral, thermal and other industrial categories. The breakdown by sub-basin also provides insight to the distribution of industries within the basin.

### 1.3.1 Data Collection

Information on water use in the industrial sector was obtained from the Industrial Water Use Data base (IWUD). This computerized data base was created in 1981 by Environment Canada to manage information regarding water use for manufacturing, mineral extraction and thermal power enterprises. This data base is updated through the use of questionnaires every five years.

The data are organized by hydrometric codes, sorted into sub-basins and then further organized in terms of SIC[1] codes (see Appendix F for hydrometric codes). The system of grouping industrial enterprises followed that used by Boeckh et. al. in 1991 (see Appendix G). Water intake and water consumption were then examined by industrial classification and geographic location. Spatial and temporal trends in industrial water use were identified by comparing the 1981 and 1986 data The 1991 IWUD were unavailable at the time of this study.

### 1.3.2 Data Limitations

The data base and the information it contains are limited by a number of constraints. These constraints are described below and include absence of information on small operations estimations used where data are missing double counting and missing data points with no estimations and boundary definitions. In most cases, it was possible to overcome the constraints and improve the accuracy of the data presented.

Small Operation Omissions

Small operations are not accounted for in IWUD. Consequently, those operations which were not among the highest water users (within the top 11 SIC groups in 1981 and the top 14 SIC groups in 1986) have been omitted from this analysis. In addition, those operations reporting less than 4500 cubic meters of annual water use have been excluded.

Data Estimations

The mailed survey questionnaires had a total response rate of 70% in 1981 and 71% in 1986. Estimations of water use by industries that failed to return a questionnaire were made by Environment Canada and included on the database (Tate and Scharf 1981, 1986).

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[1] Standard Industrial Classification (SIC) as defined by Statistics Canada, groups similar types of industrial operations such as pulp and allied products and assigns them a code (two digit level for a major division and a four digit level for the finest division).

Double Counting

Operations that include both thermal and manufacturing components are sent two separate questionnaires from Environment Canada. We found that some companies misunderstood the questionnaires and reported their total water use on both forms instead of separating the volumes (see Appendix H for questionnaires). This resulted in double counting large volumes of water. For, example, one company reported that their thermal operation had an annual water intake of 11, 949, 115 $m^3$. Exactly the same volume of annual water intake was reported for the manufacturing portion of this company. Clearly, this double counting will skew industry totals.

Missing Data

Another limitation encountered included missing data points. In 1981, a pulp and paper company (indicated by its SIC), reported its thermal intake but did not report its manufacturing intake. That same company in the 1986 survey; however, did report both intake volumes for the two operations of its plant. Thus, a volume of water, approximately 24 million cubic meters annually, was not recorded in 1981. Several other missing data points were found throughout the information for source of intake in the 1981 database.

Basin Boundaries

Only those operations that are physically located within the basin are included in our analysis. However, some operations lying outside of the basin boundaries draw their water from within the Fraser River Basin. For example, Alcan, which diverts a large volume of water from the Fraser Basin and discharges it into the Pacific Ocean, is not included in this analysis due to the physical location of the plant.

### 1.3.3 Opportunities for Improving Data

Consultation with IWUD analyst Dave Scharf of Environment Canada, allowed us to separate grouped totals and account for missed entries on the 1981 database. Furthermore, by supplying us with the names and locations of some of the industries, he made it possible for us to group some of the border operations into the appropriate sub-basin. These new volumes were then added to their respective industrial classifications and locations.

Without the names of the companies (1981) and with the changes in geographic codes and SIC codes from 1981 to 1986, it was difficult to match individual operations in the two surveys. Use of the data would be simplified if the codes remained constant. The reliability of the questionnaires themselves could be improved by conducting follow up telephone interviews. This may be especially beneficial in co-generating operations such as sawmills and pulp mills in which enormous volumes of water are used. Inclusion of all those who draw water from the Fraser River Basin regardless of the physical location of the plant would provide a better estimate of industrial water demand on the watershed. Finally, making the IWUD, MUD and census data collection periods consistent would greatly facilitate comparison among the data bases.

### 1.3.4 Presentation of Data

Figure 2 demonstrates the distribution of industrial operations by industry. This covers the entire Fraser Basin. There is an increase in most industrial sectors from 1981 to 1986, with slight declines in the mineral and thermal categories. The most dramatic increase took place in the "other" category.

Figure 3 illustrates industrial water intake by sub-basin. The Lower Fraser, Middle Fraser and Thompson account for the majority of industrial water use in the Fraser Basin. Of these three sub-basins, the Lower Fraser recorded the highest annual intake in 1986 (455 thousand cubic metres) and the lowest in 1981 (276 thousand cubic metres). The Middle Fraser was the highest in 1981 (402 thousand cubic metres) but second highest in 1986 (440 thousand cubic metres). The Thompson is the only sub-basin to show a decline from 1981 to 1986.

Figure 4 presents data on water intake by industrial category. The paper and allied category is clearly the dominant industrial use of water, using 624 thousand cubic metres in 1986. The next greatest user was the chemical industry, which also showed a notable increase in use from 46 thousand cubic metres in 1981 to 180 thousand cubic metres in 1986. The greatest use by this sector was still less than 1/3 that of the paper and allied users. Increases in water use also took place in the wood, food and other categories. Decreasing water use occurred in the mineral and thermal categories but total water use in these two sectors is very small.

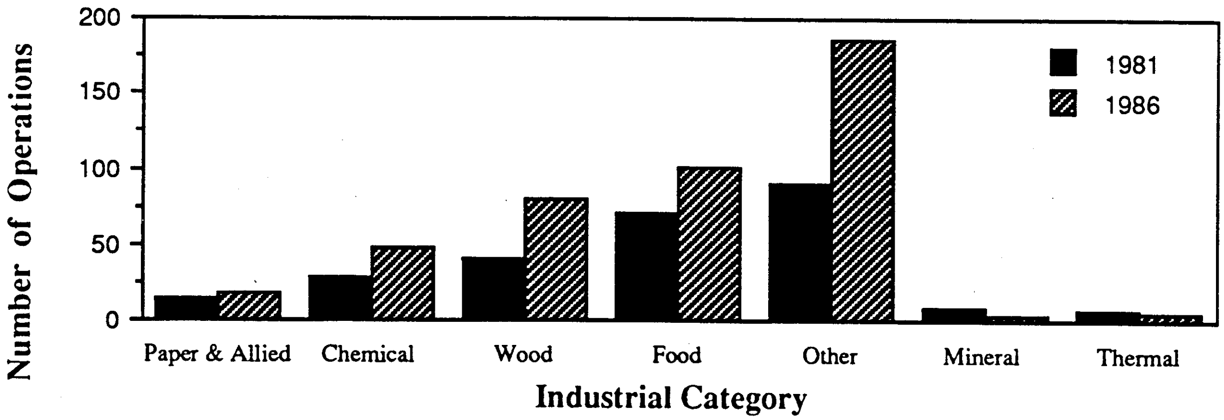



**Figure 2: Number of Industrial Operations, Fraser River Basin (1981 and 1986)**

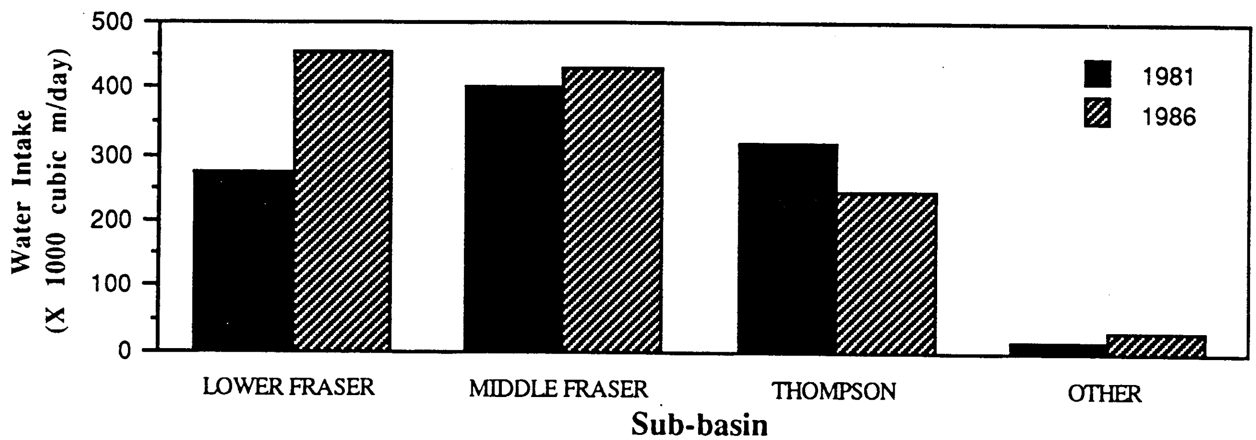



**Figure 3: Industrial Water Intake - by Sub-Basin (1981 and 1986)**

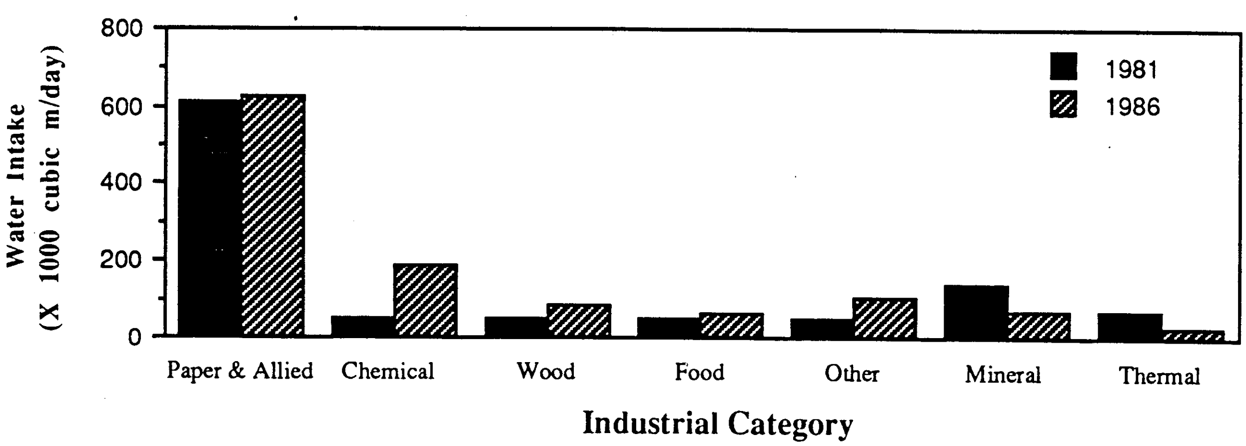



**Figure 4: Water Intake by Industrial Category (1981 and 1986)**

## 1.4 HYDRO-ELECTRIC POWER GENERATION

### 1.4.1 Data Collection

Data on water used for the purpose of power generation was collected from B.C. Hydro and from Alcan's Kenny Dam in Kitimat. B.C. Hydro provided summary records of recent and historical data.

The data included in Table 7 provide information on total storage, total live storage and average annual electricity generated. Live storage is the amount of water that can potentially run through the turbines. These figures represent the maximum volume of water that can be drawn annually from within the Fraser basin. The total storage column represents the total reservoir capacity, including live and dead storage. The volume of dead storage is "removed" from the Fraser system only once. The average electricity generated has been calculated over the period 1970 to 1991.

Table 7: Hydroelectric Generation Facilities

| SUB-BASIN | DAM | TOTAL STORAGE (mil. $m^3$/yr.) | LIVE STORAGE (mil. $m^3$/yr.) | AVG. ANNUAL ELECTRICITY GENERATED (Gw/h) |
|---|---|---|---|---|
| La Joie/ Bridge Seton | La Joie | 726.3 | 721.4 | 150 |
| | Terzaghi (Bridge River) | 1,025.7 | 1,013.9 | 2,420 |
| | Seton (1) | 21.0 | 21.0 | 300 |
| South Thompson | Sugar Lake (2) | 176.0 | 152.9 | N/A |
| | Shushwap Falls (1) | 0.0 | 0.0 | 40 |
| Lower Fraser | Wahleach | 63.6 | 61.0 | 250 |
| | Coquitlam (2) | 1,928.8 | 169.8 | N/A |
| | Buntzen | 7.1 | 5.5 | 190 |
| | Alouette | 210.1 | 209.9 | 30 |
| | Stave Falls | 579.4 | 155.9 | 280 |
| | Ruskin | 19.1 | 19.1 | 330 |
| SUB-TOTAL | | 4,049.9 | 1,828.1 | 4,320 |
| Nechako | Kenney (3) | 23,847.0 | 4,100.0 | 6,500 |
| **TOTAL** | | **28,604.1** | **6,630.4** | **10,490** |

*(1) Run of river plants with negligible storage*

*(2) Storage dams with no power producing facilities*

*(3) Data and conversion factors obtained from Alcan*

*Sources: Systems Operation, B.C. Hydro, Vancouver, B.C. and Kenney Dam, Alcan, Kitimat, B.C., 1992*

Table 8 records turbine discharge from 1984 to 1991. The total annual turbine discharge represents the amount of water required to generate electricity for that year plus the "leftover" water that was spilled. The turbine discharge data for the Kenney dam includes only the water that is returned back into the Fraser Basin. In addition to this volume is approximately 3375 million cubic metres of water required annually to generate electricity. This water does not re-enter the Fraser Basin; it is diverted via tunnel to Alcan's Kemano facility and then discharged into the Kemano River.

Table 8: Turbine Discharge (1984 - 1991)

| SUB-BASIN | DAM | 1984 (million $m^3$/yr) | 1985 (million $m^3$/yr) | 1986 (million $m^3$/yr) | 1987 (million $m^3$/yr) | 1988 (million $m^3$/yr) | 1989 (million $m^3$/yr) | 1990 (million $m^3$/yr) | 1991 (million $m^3$/yr) |
|---|---|---|---|---|---|---|---|---|---|
| La Joie/Bridge Seton | La Joie | 955.18 | 1,210.34 | 1,066.36 | 1,140.80 | 1,330.66 | 1,267.84 | 1,233.14 | 1,216.43 |
| | Terzaghi (Bridge River) | 2,362.33 | 3,026.85 | 2,349.19 | 2,992.58 | 2,823.18 | 2,496.55 | 2,669.96 | 3,725.60 |
| | Seton | 2,433.17 | 2,997.63 | 2,499.60 | 3,081.89 | 3,116.46 | 2,804.45 | 3,051.85 | 3,192.97 |
| South Thompson | Sugar Lake | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Shushwap Falls | 718.47 | 654.09 | 439.96 | 580.69 | 684.16 | 689.14 | 776.51 | 646.87 |
| Lower Fraser | Wahleach | 171.87 | 199.43 | 196.74 | 135.48 | 198.63 | 69.58 | 238.00 | 227.22 |
| | Coquitlam | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | Buntzen | 790.06 | 441.33 | 583.49 | 579.89 | 637.14 | 613.05 | 623.73 | 665.25 |
| | Alouette | 249.84 | 0.00 | 68.73 | 396.38 | 528.13 | 330.72 | 306.92 | 234.35 |
| | Stave Falls | 3,731.40 | 2,452.61 | 3,559.19 | 3,543.13 | 3,662.32 | 3,411.77 | 3,778.83 | 3,723.71 |
| | Ruskin | 4,665.66 | 3,318.80 | 3,869.37 | 3,896.39 | 4,299.94 | 4,204.64 | 4,436.32 | 4,151.52 |
| Nechako | Kenney* | 3,400.00 | 3,400.00 | 3,400.00 | 3,400.00 | 3,400.00 | 3,400.00 | 3,400.00 | 3,400.00 |
| TOTAL BASIN | | **19,477.98** | **17,701.08** | **18,032.63** | **19,747.23** | **20,680.62** | **19,287.74** | **20,515.26** | **21,183.92** |

* *approximated annual average - discharges to the Pacific Ocean via the Kemano River (does not flow to the Fraser)*

*Sources: Systems Operation, B.C. Hydro, Vancouver, B.C. and Kenney Dam, Alcan, Kitimat, B.C., 1992*

### 1.4.2 Data Presentation

The Kenney dam on the Nechako river has by far the largest total storage, representing almost 90% of the total storage for the Fraser Basin. It also produces the greatest annual amount of electricity (6500 GW/h). The Bridge River Dam generates 2420 GW/h making it the second highest generator of electricity in the Basin. The turbine discharge figures for each facility fluctuate over time, although there is an increase of less than 1% from 1984 to 1991.

# PART TWO: COMPARISON OF METHODS FOR ESTIMATING IRRIGATED AREA

## 2.0 INTRODUCTION

Three watersheds within the Fraser Basin were selected for more in-depth examination of agricultural water use. The main objective of this analysis was to compare two methods that have been applied in the past to estimate water use for irrigation purposes . The methods compared were air photo analysis with field surveys, and the use of water license data. Originally we had planned also to use information on agricultural water use from the most recent census; however, at the time of this study, the census data were not available in a form that would allow for this comparison. The three test watersheds were: the Bonaparte, located north of Cache Creek in the Thompson sub-basin; the Salmon, located south of Fort Langley in the lower Fraser sub-basin; and the Nechako sub-basin in the north eastern part of the Fraser basin (Figure 1).

After reviewing existing data sources and consulting with the contract authority, we decided to compare the methods in terms of their ability to estimate area of land irrigated. This unit of measurement was chosen rather than volume of water used in irrigation because almost all available volume data is derived through the use of area measurements multiplied by various water use coefficients.

The three watersheds were selected to represent different types of agricultural communities. The Salmon watershed is in the Municipality of Langley, located in the Lower Fraser sub-basin and has a west coast marine climate. The community in the Salmon River watershed has a rural tradition, although proximity to Vancouver is resulting in a shift towards suburban residential development. The farms in the Salmon are predominantly small commercial or hobby farm operations. The Bonaparte watershed is located in the dry southern interior of the province. The region is predominantly agricultural, with large farms growing hay and feed grains. Irrigation is used extensively in this basin. The Nechako is in the cool and dry central interior of the province. The major land use in the sub-basin is forestry. Farming in this area has been predominantly ranching but is now beginning to include crop production based on irrigation. Both agriculture and the use of irrigation are expanding in the Nechako sub-basin.

## 2.1 LICENSE DATA

### 2.1.1 Data Collection

The license data were obtained from the B.C. Water License Branch as outlined in Section 1.1.1. Detailed records for the three regions were sorted into various water use categories. The data were used to determine the number of licenses and volume of water used in each type of water use. Percentages of each total were calculated to determine the significance of each water use type in the three regions.

The irrigation licenses were further examined to determine the area of land to be irrigated by the allocated volume of water. The volume measurements noted in the licenses were calculated by using a water use coefficient multiplied by the area of land to be irrigated. The area of land was the original unit of measure.

For most licenses, the water license data base includes the date of issue, acreage to be irrigated, and a licensed water allocation in acre-feet/year. These records allowed us to calculate the conversion factor used to determine a water license allocation as the ratio of water allocation to acreage to be irrigated. We used these data to compare the history of license allocation, the size of irrigated acreages, and conversion factors used among basins.

In the Salmon watershed a more detailed examination of the water licenses was undertaken. A telephone survey was conducted of the irrigation water license holders. The license holders were asked whether or not they were making use of their licensed water allocation this year.

### 2.1.2 Data Limitations

At present, use of groundwater for the purpose of irrigation does not require a license. In areas such as the Nechako and Salmon, where the use of groundwater is common, the license data on their own do not represent the extent of water used for irrigation. This is significant in the Nechako, for instance, where groundwater is the source for 73% of municipal water (Municipal Water Use Data, presented in Table 3, Section 1.2.4).

As indicated in Section 1.1.2, Table 1, the Water License Data Base contains information on the amount of water allocated to the license holders. There is no system at present to monitor the use of the allocated water or even to ascertain that the allocated water is being "put to beneficial use" as required under the Water Act. Through the telephone survey conducted in the Salmon Watershed, we discovered that 18 of the 28 license holders who responded to our survey were not making use of their allocated water (see Table 9 below). This unused water accounted for over half of the water allocated for irrigation in the Salmon Watershed and 73% of water license holders who responded to our survey. In using the license data, recognition must be given to the fact that the data base includes both active and inactive licenses.

Table 9: Salmon Watershed Telephone Survey

| LICENSE IN USE 1992 | RESPONDENTS | % OF TOTAL LICENSES | VOLUME ($m^3/yr$) | % OF LICENSED IRRIGATION VOLUME |
|---|---|---|---|---|
| Yes | 10 | 24 | 107,495.80 | 21 |
| No | 18 | 44 | 285,393.95 | 54 |
| No Response | 13 | 32 | 133,050.71 | 25 |
| **TOTALS** | **41** | **100** | **525,940.46** | **100** |

Discussions with farmers in the Nechako watershed indicated that, in areas where irrigation was expanding, farmers applied for and received water licenses prior to putting irrigation equipment into operation. The lag time between receiving a license and beginning to irrigate may be several years. Therefore, the data base includes active, inactive and also potentially active irrigation operations.

### 2.1.3 Opportunities for Improving Data

Because groundwater use in not licensed, the license data base does not contain information on groundwater. This information could be added to the data base only if groundwater use required a license or if surveys were carried out and the results were provided to the Water License Branch. The licensing of groundwater is being considered for inclusion in the revisions to provincial water legislation.

In cases where one is interested in excluding the potential and inactive irrigation operations from the active ones, monitoring of the license holders would be required. This would be most beneficial to carry out in regions with changing land use patterns (i.e. either into or out of agriculture or irrigation).

### 2.1.4 Presentation of Data

Salmon Watershed

Irrigation accounts for 66% of the number of water licenses and 70% of the water volume allocated in the Salmon Watershed (Table 10). It is clearly the dominant licensed water use. The licensed volume of water (525,940.51 $m^3$/yr) corresponds to 183 hectares of land licensed for irrigation. These data have not been altered to reflect the occurrence of inactive licenses.

In the Salmon River watershed, most current licenses were issued in the 1950's, with smaller numbers issued in the 1940's and 1960's through 1980's (Figure 5). None of the current licenses was issued before 1940 and no new licenses have been issued in the 1990's. Thus, the development of irrigation agriculture in the Salmon River watershed was primarily a post-WW II phenomenon, although the region was cleared for farming much earlier. The development of irrigation after the War may reflect a shift from ranching and dairy farming to row cropping and fruit growing in the region.

As noted earlier, irrigation acreages in the Salmon River watershed tend to be small. Acreages licensed for irrigation were primarily less then 5 acres, although a few farms are in the size ranges 20-50 acres and 50-100 acres (Figure 6).

The conversion factor used to allocate water to irrigation acreage in the Salmon River watershed was 1 ft/ac in virtually all instances. In a few instances conversion factors of 1.5 and 0.5 ft/ac were also used (Figure 7).

Bonaparte Watershed

Irrigation is also the predominant licensed use of water in the Bonaparte (Table 11). Irrigation makes up 55.1% of the total number of licenses and 48% of the total licensed volume. Domestic use of water is the second highest in number of licenses (258), but an insignificant percentage of the total volume. Conservation is the second largest water use by volume (29%) but involves few licenses. The volume of irrigated water (34,076,230 $m^3$/yr) is based on a licensed area total of 4,634.62 hectares. About 13 million $m^3$/yr is licensed for storage in the basin. Most of this is probably used for irrigation.

Irrigation in the Bonaparte River watershed has a much longer history than in the Salmon. The earliest licenses were issued during the 1860's and a substantial number of licenses have been issued each decade from the 1860's to the present (Figure 5). The greatest number of licenses was issued during the decade 1910 to 1920 but the whole period from 1910 to 1980 was one of active irrigation development in the region.

In contrast to the Salmon River watershed, irrigation acreages in the Bonaparte tend to be large. Most farms are in the 20 to 50 acre size range and quite a few licenses are for acreages >100 acres (Figure 6). A substantial number of irrigation licenses are for acreages <5 acres, however, indicating a great diversity of irrigation activities within the watershed.

Not only are the acreages irrigated in the Bonaparte River watershed large, so are the conversion factors used to allocate water for irrigation. In recent years, conversion factors of 2, 2.5, and 3 ft/ac have been about equally common in the licenses, although in some instances conversions of 1 and 1.5 ft/ac were used (Figure 7). The license data give no indication as to why such a range of conversion factors was used in this basin or the basis on which a particular conversion was chosen. The Bonaparte watershed was by far the most variable in terms of conversion factors used. The relatively high conversion factors used in this basin presumably reflect the dry hot climate of the Thompson sub-basin.

Since licenses have been issued over such a long time in the Bonaparte watershed, we explored how the size of irrigated acreage and conversion factors have changed over time in this basin. A comparison of sizes of irrigated acreages before and since 1990 indicates no dramatic change in the distribution of acreages licensed for irrigation (Figure 8). More large acreages were licensed prior to 1900 and irrigated acreages are grouped more tightly into the 20 to 50 acre size range since 1900. These changes probably reflect the evolving technology of irrigation and the efficiency of different sized irrigation farming units.

Conversion factors for allocating water have also changed over time in the Bonaparte watershed. Conversion factors used have ranged from 0.5 ft/ac to 3.25 ft/ac. The average conversion factor used was more than 2.9 ft/ac in the 1860's and 1870's, declined to about 2 ft/ac during the 1920's and 1930's and then increased again to about 2.4 ft/ac in recent years (Figure 9). During the period 1860 to 1879, when the average conversion factor was high, only three conversion factors were used: 2.5, 3.0, and 3.25 ft/ac; and by far the majority of licenses were based on the 3 ft/ac conversion (Figure 10). During 1920 to 1939, when the average conversion factor was low, six different conversion factors were used and conversion factors of 1.0, 2.0, and 2.5 ft/ac were all commonly used (Figure 10). Variations of this magnitude in the conversion factors used to estimate irrigation water requirements impose an additional complication into the interpretation of the irrigation license data.

Nechako Watershed

Irrigation makes up 49% of the number of licenses and accounts for just over 40% of the licensed volume in the Nechako watershed (Table 12). Again, domestic use involves a high number of licenses but a negligible volume. The largest water use by volume (51.8%) is attributed to conservation. The volume of water allocated to irrigation (13,246,515.1 $m^3/yr$) corresponds to 4,115.3 hectares of licensed land.

The first irrigation licenses for the Nechako sub-basin were issued in the 1950's and most were issued in the 1980's, indicating the recent development of irrigation agriculture in the watershed (Figure 5). The Nechako watershed also has the largest acreages licensed for irrigation (Figure 6). The modal size of irrigation acreages is in the 50 to 100 acre size range but almost as many licensed acreages are greater than 200 acres. The conversion factors used to allocate water to irrigation acreage in the Nechako sub-basin are similar to the Salmon, most conversions being done at 1 ft/ac although a few were also done at 0.5, 1.5, or 2.0 ft/ac (Figure 7).

Proportion of River Flows Allocated

As shown in Tables 10-12, the total licensed allocation of water in the three watersheds is 752,973 $m^3$/yr for the Salmon, 70,963,979 $m^3$/yr for the Bonaparte, and 33,061,146 $m^3$/yr for the Nechako. Historical streamflow data for these rivers suggests annual discharges ranging from 31 to 63 million $m^3$ for the Salmon (average 46 million $m^3$), ranging from 77 to 264 million $m^3$ for the Bonaparte (average 159 million $m^3$), and averaging about 10,000 million $m^3$ for the lower Nechako (The Nechako flow is regulated by Alcan Ltd. for power generation.). With the completion of the Kemano project (Alcan Ltd.), the flow in the lower Nechako would be further reduced. For the Salmon, therefore, the licensed allocation is only about 1.6% of the average flow of the river and only 2.4% of the lowest flow recorded. This is a small allocation of total flow. If one assumes, however, that the irrigation volume, which is the majority of the allocation, is all taken during the summer period (July to September), then the licensed water removals during the summer amount to more than 25% of the summer flow. For the Bonaparte, the licensed volume amounts to 44.6% of the average flow of the river and is 92% of the lowest flow recorded. This is a very large allocation of river flow. Twenty-nine percent of the licensed allocation is for conservation purposes, however, so that if this is subtracted from the licensed allocation, the licensed allocation (presumably for off channel uses) drops to 32% of the average river flow. Again, if we assume that irrigation takes all its allocation during the summer months, then the presently licensed allocation in the Bonaparte is more than 90% of the summer flow of the river. The presently licensed allocation of the Nechako is less than 1% of the river flow and will still be less than 1% even after completion of the Kemano project, provided more licenses are not issued. If one assumes that the majority of the removals of water from the Nechako will occur in the summer months, the amount presently licensed for removal is still less than 1% of the flow during July to September.

In terms of total river flow, therefore, only the Bonaparte is very heavily subscribed. Water allocations from the Salmon could have a significant effect on low summer flows if all license holders were to begin using their licensed allocation. The amount licensed from the Nechako is, at present, a very small proportion of the flow of the river. Not all licenses are for removal of water from the main stem of these rivers, however, nor are the removals from the main stem necessarily near the gauging station. Even though the licensed allocations may be a small percentage of the whole river, there may still be problems with excessive removal from local tributaries. Furthermore, without better information on the amounts of water actually being used rather than the amounts licensed for use it is impossible to make any determination of the actual impact of the licensed water allocations on the hydrology and ecology of the river systems. It is worth noting, however, that evidence suggests that removals of 30% or more of river flow have a very high probability of adversely affecting fishery resources (Mundie and Bell-Irving 1986).

## Table 10: Salmon River Watershed License Summary, 1991

| USE TYPE | NO. OF LICENSES | % OF TOTAL | VOLUME $m^3/yr$ | % OF TOTAL |
|---|---|---|---|---|
| Domestic | 8 | 13 | 10,777 | 1 |
| Industrial | 2 | 3 | 28,568 | 4 |
| Irrigation | 41 | 66 | 525,940 | 70 |
| Land Improvement | 8 | 13 | 117,385 | 16 |
| Storage (other) | 1 | 2 | 61,638 | 8 |
| Conservation | 2 | 3 | 8,629 | 1 |
| **TOTALS** | **62** | **100** | **752,937** | **100** |

*Source: B.C. Water Data Base, 1991*

## Table 11: Bonaparte River Watershed License Summary, 1991

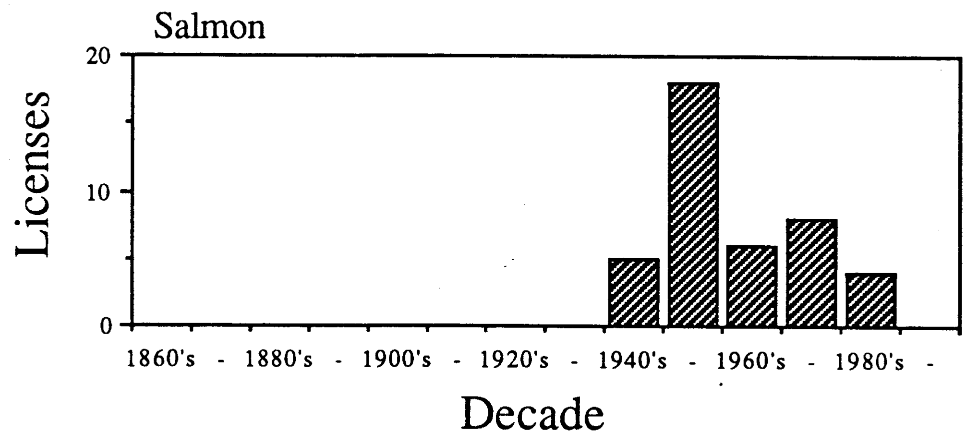
| USE TYPE | NO. OF LICENSES | % OF TOTAL | VOLUME $m^3/yr$ | % OF TOTAL |
|---|---|---|---|---|
| Domestic | 128 | 28 | 174,753 | 0 |
| Industrial | 23 | 5 | 3,554,215 | 5 |
| Irrigation | 253 | 55 | 34,076,230 | 48 |
| Storage (other) | 43 | 9 | 12,814,461 | 18 |
| Conservation | 16 | 4 | 20,344,320 | 29 |
| **TOTALS** | **463** | **100** | **70,963,979** | **100** |

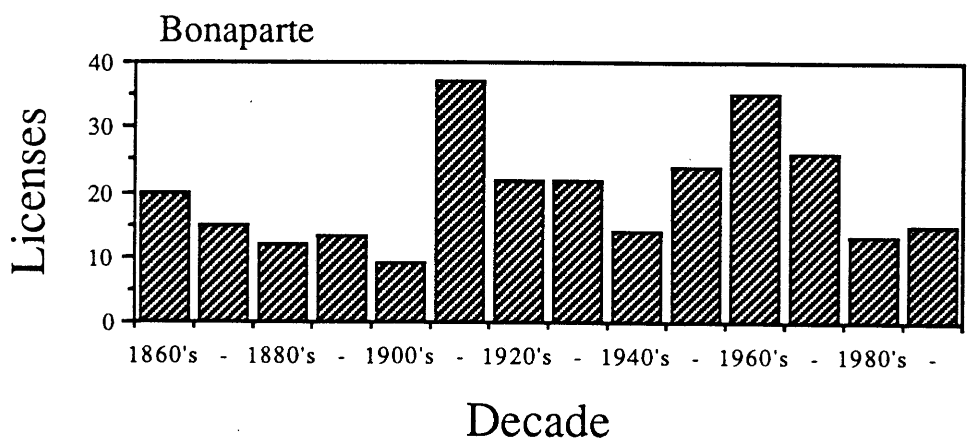
*Source: B.C. Water License Data Base, 1991*

## Table 12: Nechako River Watershed License Summary, 1991

| USE TYPE | NO. OF LICENSES | % OF TOTAL | VOLUME $m^3/yr$ | % OF TOTAL |
|---|---|---|---|---|
| Domestic | 49 | 27 | 82,071 | 0 |
| Industrial | 15 | 8 | 1,805,392 | 6 |
| Irrigation | 89 | 49 | 13,246,515 | 40 |
| Storage (other) | 14 | 8 | 772,527 | 2 |
| Conservation | 15 | 8 | 17,154,641 | 52 |
| **TOTALS** | **182** | **100** | **33,061,146** | **100** |

*Source: B.C. Water License Data Base, 1991*



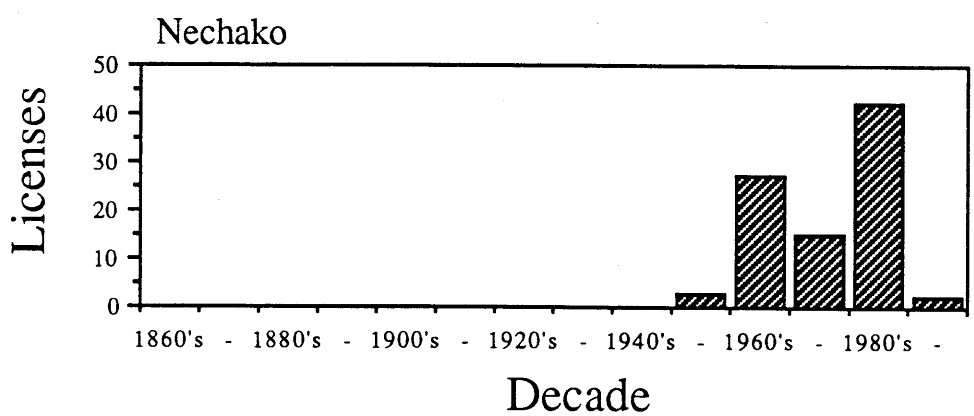




**Figure 5: Licenses Issued Per Period in the Salmon, Bonaparte and Nechako Watersheds**

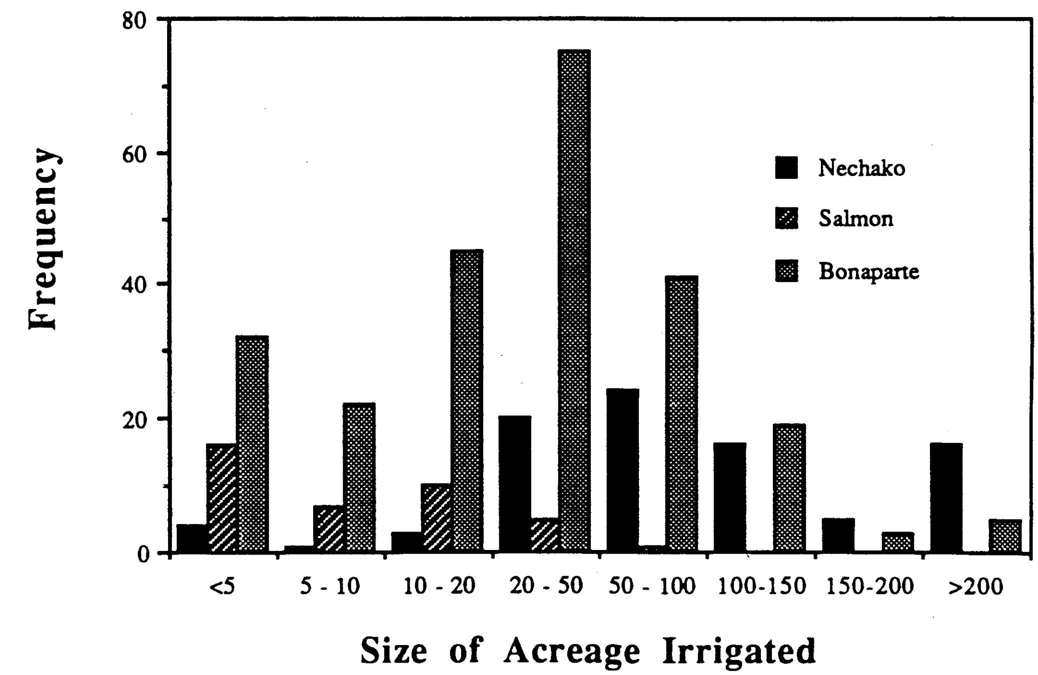



**Figure 6: Comparison of Acreage/License in the Salmon, Bonaparte and Nechako Watersheds**

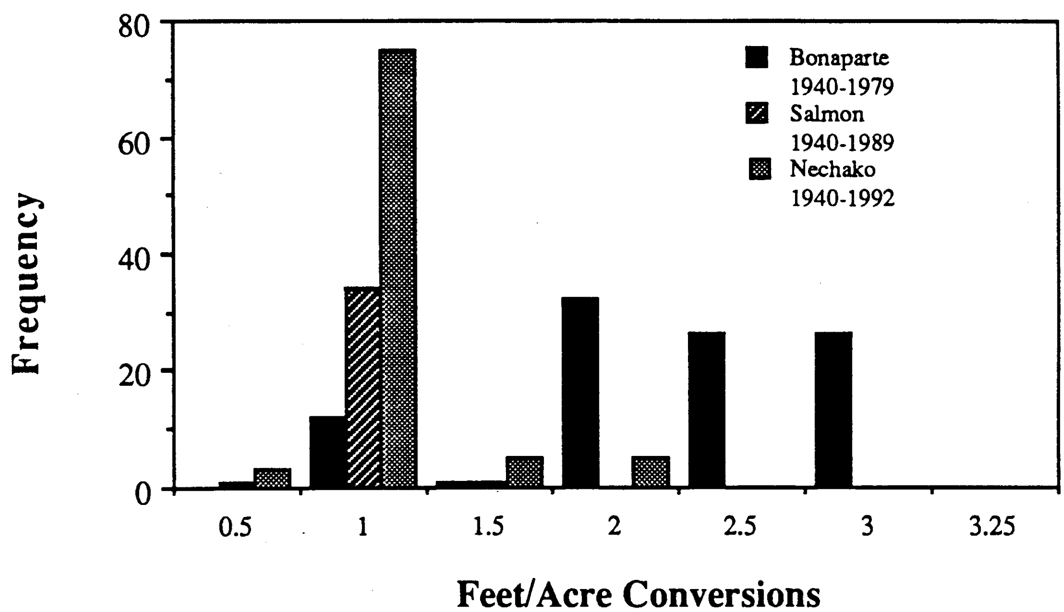



**Figure 7: Comparison of Conversion Factors Recently Used to Determine Water Allocations in the Three Watersheds**

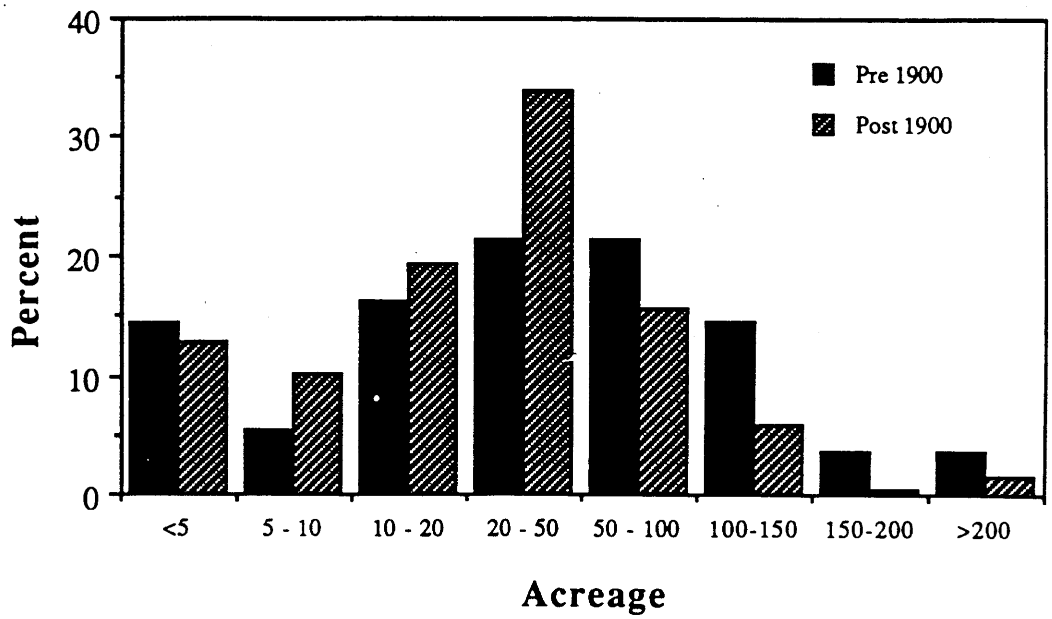



**Figure 8: Comparison of Acreage/License Prior to and Since 1900 in the Bonaparte Watershed**

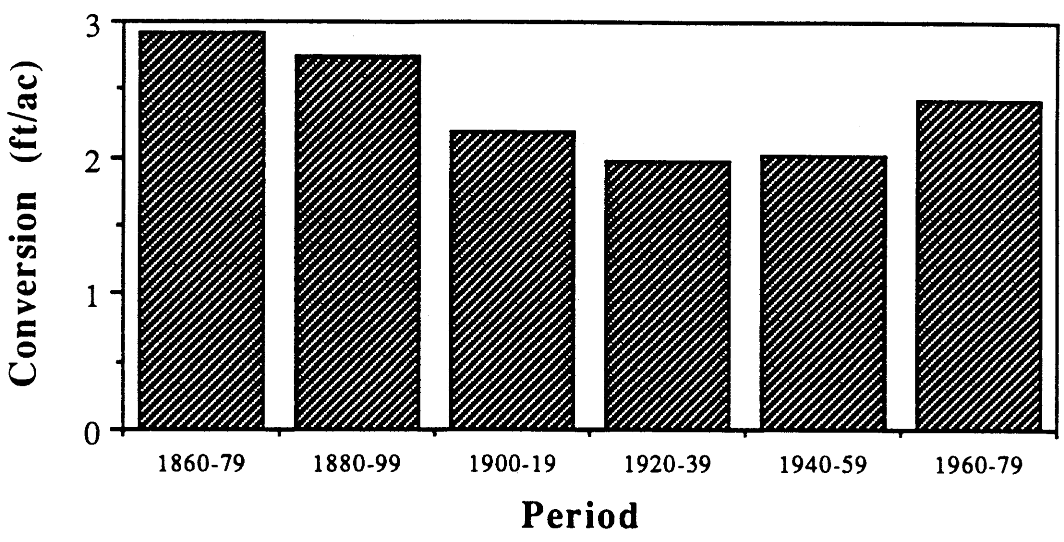



**Figure 9: Changes in Average Conversion Factor Used in the Bonaparte Watershed, 1860-present**

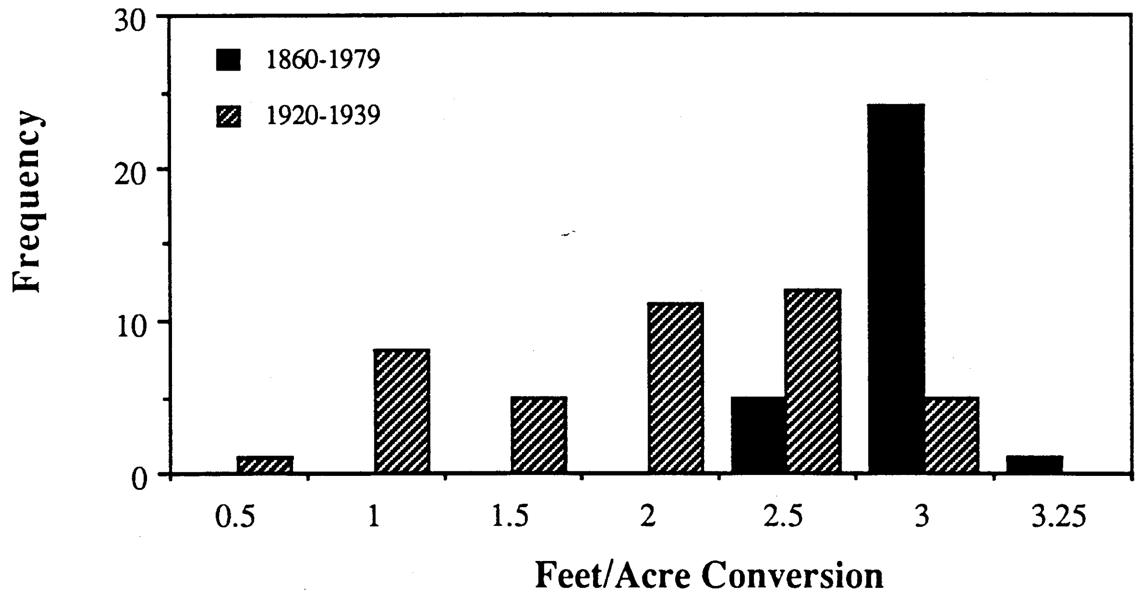



**Figure 10: Conversion Factors Used in the Bonaparte Watershed During Two Time Periods**

## 2.2 AIR PHOTO INTERPRETATION AND FIELD SURVEY

The air photo interpretation method was chosen to estimate area irrigated because this method was used in several recent water use studies carried out for Environment Canada (e.g. in the Lower Kootenay River Basin (Fisher and Wipond 1987), Kettle-Granby Basin (Betkowski and Fisher 1986) and the Upper Kootenay River Basin (Brownlee and Sherwood 1989)). These studies made use of 1:20,000 air photos to plot irrigated land onto 1:20,000 cadastral maps. Field surveys were carried out to confirm the results of the air photo interpretation. The irrigated area identified on the maps was then planimetered to determine irrigated hectares. An outline of the application of the air photo method in our three test watersheds follows. Discussion of this method is divided into four sections: selecting photos, selecting maps, mapping from air photos, and field surveying.

### 2.2.1 Data Collection

SELECTING PHOTOS

When selecting photos for interpretation, several factors must be taken into consideration. These include: the type (satellite, colour or black and white); time (in relation to growing season); scale (large or small); and date (year) of the photos.

<u>Types of Photos</u>

Three types of photos were available: black and white air photos; colour air photos; and land satellite photos. These were compared for their ability to illustrate irrigation, availability and cost. In terms of ease in identifying irrigated plots from photos, it was determined through observation and discussion with remote sensing experts (personal communication with Dr. Peter Murther and associates, Dept. of Forestry, U.B.C.) that no particular type of photo is better than another. The variations in shades of red (satellite), green (colour) and grey (black and white) were found to be fairly similar as indicators of irrigated plots.

Availability of photos for the areas under investigation varied for each type of photo. Coverage by satellite photos is most limited and although some areas have been photographed by the Ministry of Forests, this ministry only releases photos for projects conducted with the Ministry (pers. comm. Dr. Peter Murther). Coverage by colour photos was also very limited, with only small areas covered during a short time period. Black and white photos were by far the most readily available in terms of area covered, dates covered and scales produced. In fact, a set of black and white photos were the only ones that provided fairly recent coverage of the three test areas.

The cost of photos was taken into consideration. The costs for development of images from film to print are as follows:

| | |
|---|---|
| Satellite | $ 500.00 per image (approximately) |
| Colour | $ 8.00 per image |
| Black and White | $ 4.00 per image |

The decision to use black and white photos was arrived at primarily by the availability of photos but was supported by our conclusion that the photo types are equal in terms of accuracy and by the relative cost of the photos.

Time of Photos

The time the photos were taken in relation to the growing season is another consideration in air photo interpretation. Unfortunately, photo series are not so frequently taken that this factor can be seriously considered in choosing photos. Fortunately, the majority of the photos used for this study were taken in July and August. Because this is the driest time of the growing season and before harvest time, one would expect the photos to reflect the greatest contrast between irrigated crops and non-irrigated fields. Luckily, this timing coincides with optimal conditions for taking air photos (i.e. clear skies).

Scale and Date of Photos

In selecting the scale of photos used, it was important to consider the size of the areas to be surveyed, cost, type of farming and the most recent date of photo coverage. Large scale photos (1:5,000 to 1:25,000) provide a greater amount of detail, while small scale photos (1:50,000 to 1:70,000) provide a greater amount of coverage.

Large scale photos are appropriate for small areas of study, but the number of photos to interpret becomes unmanageable for large study areas. For example, approximately 4,000 large scale photos would have been needed to cover the Bonaparte watershed (5,100 $km^2$). The handling time and cost make using large scale photos for large areas such as the Bonaparte impractical.

The predominant type of farming in an area is also important in selecting a scale. Where cultivated plots are small or where land use patterns are not clear, more detailed (large scale) photos are required. For example, in the Salmon watershed, most of the farms are small hobby farms of less than 5 acres. Even using 1:20,000 photos these plots were difficult to interpret as irrigated or non-irrigated.

We expected that large scale photos would also provide detail that would make identifying distinctive irrigation patterns easier. However, the only distinctive irrigation pattern visible in the three study areas was the *centre pivot system* for irrigation which creates large circular patches. These patterns were visible at both large and small scales so there was no advantage in using large scale photos.

Using the most recent air photos available is particularly important in areas where land uses are changing either into or out of agriculture and where irrigation is gradually being introduced. Because small scale photos are more widely available, they are also likely to be more recent. By using small scale photos, we were able to get photos dating 1986 to 1989 for the Bonaparte and Nechako basins. Because the Salmon watershed is relatively small, large scale photos were available for 1988.

In the end, we chose large scale photos from 1988 for the Salmon, and small scale photos dating mostly from 1988 for the Bonaparte and Nechako. The photos for the Bonaparte and Nechako were not all of uniform scale.

## SELECTING MAPS

Complete 1:20,000 map coverage of the three study areas was gradually pieced together from maps available through Maps B.C. and the B.C. Ministry of Forests. The maps are cadastral or planimetric maps which allow for accurate area measurements. Topographic maps would also allow the relief of an area to be accounted for. However, these maps are not yet available at 1:20,000 for the study areas. Apparently the Terrain Resource Information Management (T.R.I.M.) project will produce these maps for the entire province in the future.

## MAPPING FROM AIR PHOTOS

In transferring information from air photos to maps, consideration must be given to several potential sources of error. These include air photo distortion, different scales, replication of information and interpretation of features. These potential sources of error were largely overcome by making use of an imagery analysis instrument called a Zoom Transfer Scope (ZTS). This instrument has been used primarily by planners to update maps from air photos. The ZTS matches the two scales and superimposes the image taken from the air photo directly onto the map.

### Photo Distortion

Areas shown on air photos are distorted to varying degrees. Distortion increases with distance from the centre of all types of air photos, depending on the flight angle when the photo was taken. Distortion is also created in topographically diverse areas. At the outer edges of photos in topographically diverse areas, area estimates can be off by 30% (pers. comm. Hans Schrier, 1992). The ZTS compensates for distortion by adjusting the direction and intensity of stretch required to match a photo to a map. This matching of photo to map does not completely eliminate errors due to distortion, however.

### Different Scales

Because we wanted to reduce the number of photos viewed by using small scale photos in the Bonaparte and Nechako watersheds, the photos and the maps were in different scales. In past uses of the air photo method, the air photos and maps have been of the same scale to avoid the problem of scale adjustment. The ZTS has the ability either to magnify or reduce the image projected from the air photo to match the scale of the map. The initial set up of the ZTS for a particular scale adjustment may take 15 minutes. Once set for a scale, however, each photo takes 1 - 3 minutes to line up on the map.

### Mapping Features

When an irrigated plot was identified on an air photo, the area had to be drawn on to the map in the correct location and representing the correct size. This was straightforward with the ZTS because the image of the photo was projected directly on the map. The feature, in this case an irrigated plot, was then traced on to the map. In past studies, this transfer was made by spotting a plot on a photo and then *eye-balling* the plot onto the map. This method left room for error in locating the plot and accurately defining the area of the plot.

### Interpretation

One of the most subjective elements of air photo interpretation involves the determination of irrigated plots of land. In mapping the three test areas, all cultivated land was mapped and those plots thought to be irrigated were shaded in. By using the magnification function of the ZTS, we were able to observe details not obvious to the naked eye. In the Salmon watershed, this aided in mapping the small plots, and in the Nechako and Bonaparte it helped to distinguish between cultivated plots and clear cuts where plant succession had taken place. By using the stereoscopic image function, we were also able to view areas in three dimension.

As noted earlier, irrigated plots were identified by observing variations in shading and distinctive patterns. In most cases, however, the shading method was not very helpful. Although a darker shade of grey does indicate a darker green field, the tone also reflects the crop type and the crop height. For instance, some fields may have been irrigated, but had been recently harvested at the time the photo was taken. These fields would not appear irrigated in the photo. In areas where there was a great diversity of crops the photos showed so many shades of grey, it was difficult to note a distinctive pattern in the shading. The centre pivot irrigation was the only distinctive pattern found in our test watersheds.

Because the distinction between irrigated and non-irrigated plots was not obvious, all cultivated land was mapped. Although estimations were made of what plots were irrigated, it was clear that the determination of irrigated plots would have to be made in the field.

Mapping of the three watersheds took 10 person-days for the Salmon, 10 person-days for the Bonaparte and 6 person-days for the Nechako. As the operators became familiar with the equipment and technique, mapping time was significantly reduced.

## FIELD SURVEYING

Field surveys were carried out in all three test watersheds during the month of July. This was chosen as the time when the conditions were dry enough that irrigation would be taking place and early enough in the growing season that most crops were not yet being harvested. Precipitation was also unusually low during this time period, providing optimum conditions for determining irrigated areas.

Two field investigators carried out the field work; one drove the vehicle and the other worked with the maps. The maps delineated all plots of cultivated land and indicated those plots thought to be irrigated. On the basis of their observations and discussions with farmers, the field investigators marked the irrigated plots on the maps. The irrigated area was calculated from the maps through the use of a planimeter. Each parcel was measured three times and then an average of the readings was taken to represent the area. Each test watershed took five days of surveying and mapping and half a day calculating the areas irrigated (with a two-person crew). This included time the field crew spent orienting themselves on the maps and determining their routes.

### The Salmon Watershed

In the Salmon watershed the water table is very high, making the contrast between irrigated and non-irrigated land unclear. Through discussions with farmers, it was discovered that irrigation was used primarily for berries, turf and nurseries. This information guided the field investigators to areas where these crops were grown. Irrigation equipment of various sorts (e.g. sprinklers, hoses and drip irrigation) was identified in the fields. Land use patterns had also changed since the time of the air photos; subdivision of farms into residential lots had taken place in several cases.

The field surveys in the Salmon watershed demonstrated very clearly that the estimations from the air photos were highly inaccurate. Of the 97 plots thought to be under irrigation (on the basis of air photos), only 37 were found to be irrigating (on the basis of the field survey). Also, an additional 85 plots were found to be irrigating that had not been identified through the air photo interpretation.

The Bonaparte Watershed

Field investigations in the Bonaparte watershed were much more straightforward. Almost all cultivated land was being irrigated and the contrast between irrigated and non-irrigated land was obvious in both the photos and the field surveys. The only areas where the irrigation was difficult to ascertain was in the valley floors where the water table was high. In some cases, field investigators found new areas of cultivated land that were not indicated on the maps. These were added to the maps using roads and other landmarks as guides. The identification of irrigated plots was far more accurate in this area, where the farms tended to be much larger than in the Salmon watershed and where the distinctive centre pivot irrigation pattern was quite common.

The Nechako Watershed

Surveys in the Nechako watershed once again relied greatly on discussions with local farmers. After identifying that hay and barley were the principle crops being irrigated, the field work focused on these areas. Visual identification of equipment was then used to locate the farms that were irrigating.

The size of the Nechako watershed precluded a complete survey of the watershed. Instead, we surveyed that portion of the watershed in the lower Nechako River between the settlements of Fort Fraser and Isle Pierre (Figure 11). This portion of the watershed includes the majority of the irrigation licenses and is relatively accessible by vehicle.

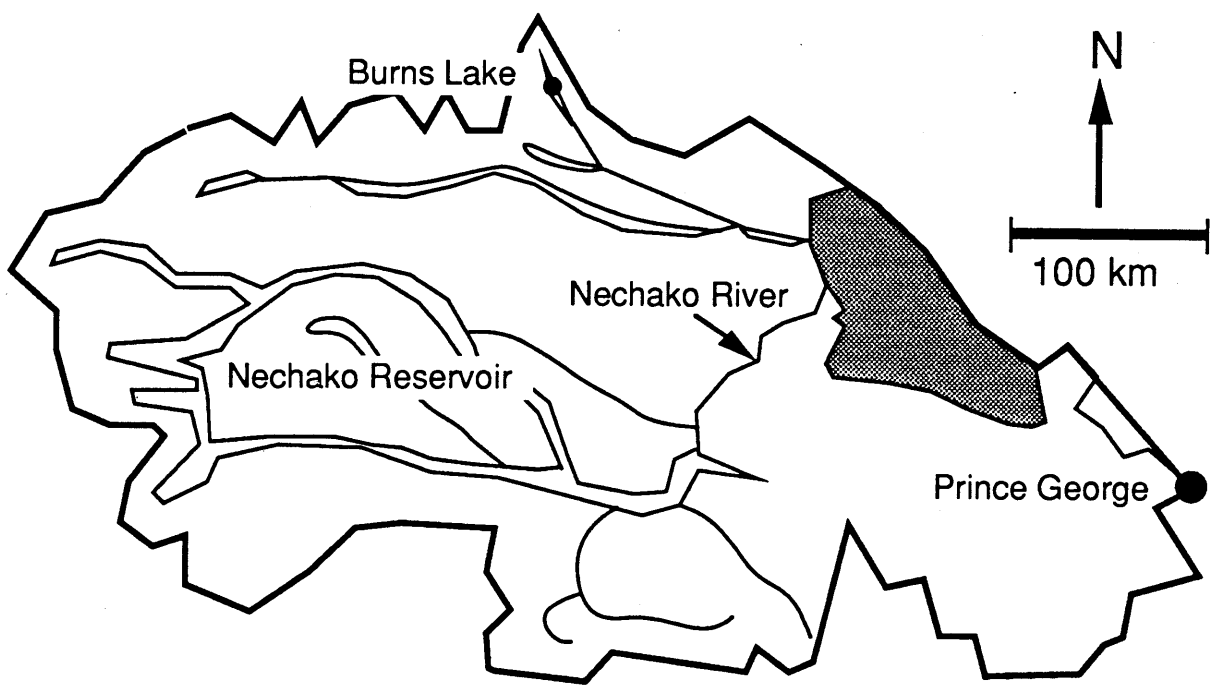



**Figure 11. Map of the Nechako Watershed Showing the Area Surveyed by the Field Crew in July 1992.**

### 2.2.2 Data Limitations

The accuracy of the air photos for identifying irrigated crops was limited by the following factors:

- the date of the photos - in some cases land use changes had occurred since the time of the photos;
- where irrigated crops had been recently harvested, they appeared not to be irrigated;
- where the contrast between irrigated and non-irrigated plots was low, irrigation was difficult to detect;
- small cultivated plots (under 5 acres) are easily missed in small scale photos;
- patterns created by forest harvesting sometimes were difficult to distinguish from cultivated plots; and
- mechanical error in estimating the area of small plots with a planimeter.

The accuracy of the field surveys in locating irrigated plots was limited by the following factors:

- road access was difficult in rural and wilderness areas, particularly the Bonaparte and Nechako;
- the visual contrast between irrigated and non-irrigated land was small to non-existent in the Salmon where the water table was very high;
- not all farmers could be located to confirm the use of irrigation;
- some types of irrigation equipment, such as drip or trickle irrigation, were difficult to see in the plots; and
- if an irrigated plot was found in the field that was not mapped from the air photos, the area had to be estimated using landmarks for spatial reference.

### 2.2.3 Opportunities for Improving Data

The accuracy of the air photos is increased by using very recent photos and by using the largest scale that is reasonable. Air photo use is also more applicable to areas with large size farms and a high degree of contrast between irrigated and non-irrigated land. In any case, the air photo interpretation should always be followed up with ground proofing in the field. The more time spent in the field, the more accurate the results will be.

### 2.2.4 Presentation of Data

Once the field work was completed, the maps delineating irrigated plots were planimetered to determine the area of land irrigated in each of the three watersheds. Estimates of area under irrigation were also obtained from the analysis of license data. The results are shown below in Table 13

Table 13: Estimates of Area Under Irrigation in the Salmon, Bonaparte and Nechako Watersheds

| WATERSHED | AIR PHOTO/ FIELD DATA (Hectares) | LICENSE DATA (Hectares) |
|---|---|---|
| Salmon | 360.2 | 183.0 |
| Bonaparte | 2553.2 | 4634.6 |
| Nechako | 1707.8 | 4115.3 |

## 2.3 COMPARISON OF RESULTS AND METHODS

The two approaches to estimating area under irrigation (and by inference, the amount of water used for irrigation) give quite different results. This section includes some possible explanations for these differences and recommendations for future work.

### 2.3.1 Salmon Watershed

In the Salmon watershed, the area derived through the air photo/field method (360.2 hectares) is almost double that obtained from the license data (183.0 hectares). This discrepancy most likely results from the fact that a great deal of irrigation water in the Salmon is drawn from groundwater, which does not require a license. The high figure for the air photo method is particularly surprising given that over half of the land licensed for irrigation was not being irrigated at the time of this study and would, therefore, not be included in the air photo/field data. Because of the small plot size in the Salmon, it is also possible that the results from planimetering are inaccurate.

### 2.3.2 Bonaparte Watershed

In the Bonaparte watershed, the license results (4,634.6 hectares) are much higher than the air photo/field results (2,553.3 hectares). Additional research was not conducted to explain the discrepancy or to give more confidence to one set of data over the other. Both methods have limitations in this region. The irrigated plots were easily detected from air photos, but the photos dated in some cases from 1986. The plots were readily detected from the field surveys as the contrast of irrigated to non-irrigated was great. There may have been irrigated land that had been developed since the time of the photos in areas that are not adjacent to the mapped plots. The field surveys stayed fairly close to the mapped cultivated areas and may have missed irrigation development in new areas. The license data may be high due to the existence of inactive licenses as we found in the Salmon. In particular, as so many licenses in the Bonaparte watershed date from long ago, it seems likely that some licenses, although never cancelled, are inactive.

### 2.3.3 Nechako Watershed

In the Nechako watershed, the results from the license data (4,115.3 hectares) are more than double those derived through the air photo and field data (1,707.8 hectares). The primary factor in this difference is likely the occurrence of license holders who are not yet equipped to irrigate. Some farmers who hold irrigation licenses in the Nechako said they were waiting for financing before purchasing irrigation equipment. The licenses of those planning to irrigate in the future would appear in the license data but not the air photo/field data. A quick scan of the licenses in the Nechako revealed that a high percentage of the licenses have been granted in the past five years. The limitations on the air photo/field data in the Nechako included the date of the photos and limited road access. Because irrigation is expanding in this region, recent air photos would have helped greatly. Many plots not shown on the air photos were visually estimated and added to the maps in the field.

## 2.4 CONCLUSIONS

An integrated approach to managing resources within the Fraser River basin, such as is envisioned in the Fraser River Action Plan (1992) and the Agreement Respecting the Fraser Basin Management Program (1992) will require good technical information on water supply and water use. At present the information on both supply and use are inadequate. Among water uses, agricultural water use is the second largest (in terms of volume) and the least well documented water use. Accurate and cost efficient methods to measure or estimate agricultural water use are required.

The comparison in three watersheds of methods that have been used in the past for estimating irrigation water use illuminated several limitations of the methods.

The method of air photo interpretation combined with field surveys proved most useful in the dry Bonaparte region where the contrast between irrigated and non-irrigated land was obvious on the air photos and the farms were large. In the Salmon and Nechako watersheds, the air photo interpretation could only be used as a guide to map cultivated land, both irrigated and non-irrigated. The field surveys were essential in all cases to identify and verify the occurrence of irrigated plots. Time spent mapping could have been eliminated by using survey maps that outline the cultivated plots. These maps could then be used as a basis for the field surveys. Extra time could be taken in the field to talk to farmers and verify the results.

When using license data, it is important to recognize that it records the area of land that is licensed for irrigation. The farmer may be irrigating more, less, or no land at all. As we found in the Salmon and Nechako watersheds, not all license holders are making use of their allocated water, and this was probably true in the Bonaparte as well. This is an important consideration in water management because if all licensed irrigation water users began to use their allocated water, water supply may become a problem. In the Salmon River watershed, for example, water use could double if all license holders began to exercise their right to draw water from the river.

The license data provide only a general indication of irrigation trends and patterns. The comparisons between regions and over time may be limited by the fact that the accuracy of the data will depend on the degree and rate of land use change (i.e. change into or out of irrigation). The license data in some regions such as the Nechako and the Salmon, where irrigation is intermittent or in a rapid phase of growth, may be less accurate than in a well established agricultural area with a fairly constant use of irrigation. On the other hand, in an area with a long history of irrigation licensing, like the Bonaparte watershed, the license data may contain many anachronisms unless it is reviewed and kept up to date.

This comparison was based on area irrigated rather than volumes of water used for irrigation. The results of the comparison show that one cannot rely on the area data with much confidence. Because the volume data in the literature is based on area estimations multiplied by water use coefficients, it too is limited by the factors discussed above. The coefficients themselves attempt to incorporate a variety of complex factors (e.g. crop type, soil type, micro-climate, etc.), are based on a series of assumptions, and are considered by many to be inaccurate. Because the volume of water being used is of primary interest, rather than area of land irrigated, means of estimating volumes without basing them on area estimates should be explored further.

Several approaches might be taken to improve the information on water use by agriculture. The first is to improve the existing water license system in British Columbia. The license system provides the basis for obtaining good information on potential and actual levels of water use. For the license data base to serve this function, however, it needs to be updated so that inactive license holders are removed from the system. Furthermore, there should be a requirement that license holders renew their licenses at some reasonable interval (e.g. every 5 years). At each renewal the license holder should be required to show that the license has been used as intended, not simply held in anticipation of use, or because the licensee thinks it may have future value. Licensee's could also be required to keep records of acreages and crops irrigated on an annual basis. Finally, use of groundwater for irrigation should be licensed. We understand that licensing of groundwater use is contemplated for the revised B.C. Water Act. The addition of groundwater to the licensing program would provide an opportunity to restructure the whole licensing system to provide better information on water use.

In our view, an effective and efficient licensing system is the key to having good information on water use in the long term. In the short term, however, better information on irrigation water use could be obtained for selected regions by a number of techniques. For example, a questionnaire, similar to that used for collecting MUD and IWUD could be sent to irrigation farmers at the end of the growing season. While it is doubtful that farmers will know exactly how much water they used, water use data that is considerably better than that which is now available could be obtained through careful questionnaire design, with questions that could be cross-referenced to provide accuracy checks. This approach could be applied to the Fraser River basin as a whole.

A second approach would be to enlist the assistance of a subset of interested farmers and have them keep log books of their irrigation activities. Daily log entries on irrigation activities combined with weather information, crop types, etc. would provide detailed information for a sample of irrigation farmers that could be expanded to provide estimates for all irrigation farmers. We have used this technique successfully in the fishing industry to obtain data on catch rates and fishing effort and we see no reason why it could not be applied in agriculture. Our experience with fishermen was that many were very interested in such projects and willingly participated, provided they were convinced that the results were not going to be used to sanction them. This approach could be applied to smaller sub-basins or individual watersheds on the order of the size of the Bonaparte. Details of the log book design might differ between regions with different approaches or styles of farming. The success of this methodology depends on the technician developing rapport with the farmer and providing feedback to the farmer on results of the program and its implications.

A third approach would be to conduct more detailed field surveys than we were able to do in this project and to incorporate the collection of information on rates of water use together with area of land under irrigation and crop types. The field technician would make regular visits to irrigation farms noting when irrigation equipment was operating, type of equipment and its water delivery specifications, area and crop under irrigation. A Doppler acoustic flow metre could also be used to record flow in the main irrigation delivery line to provide a direct estimate of short term water use. As with the log book approach, the success of this kind of intensive data gathering would depend on the field technician obtaining the cooperation and assistance of the farmers in the region.

The three approaches described above are not mutually exclusive. All three might be applied in the same region, or they might be combined in various ways depending on the characteristics of a region and its accessibility.

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# APPENDIX A

HOW TO OBTAIN A WATER LICENSE IN BRITISH COLUMBIA

APPENDICES
NOT INCLUDED