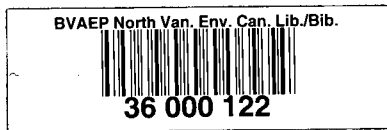


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NITRATES AND PESTICIDES
IN THE
ABBOTSFORD AQUIFER
SOUTHWESTERN BRITISH COLUMBIA

by

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ABSTRACT

The Abbotsford aquifer is comprised of extensive surficial sand and gravel deposits located in southwestern British Columbia and extending across the international boundary into northwestern Washington State. The aquifer is an important source of water for domestic, municipal, agricultural, and other industrial users in both countries. Ground water flow in the southern part of the aquifer is primarily south into the United States. Locally, land use practices have caused deterioration of ground water quality in the aquifer by nitrate and pesticide contamination.

Sampling of ground water in the Abbotsford aquifer specifically for nitrates and pesticides has been focused in the south Matsqui area, where local ground waters appear to have been most severely impacted. Monitoring of water wells and piezometers has shown that both pesticide and nitrate concentrations are generally site specific and fluctuate seasonally. Elevated nitrate concentrations also signal the potential for contamination from other pollutants.

Approximately 60% of the samples collected from the south Matsqui study area have nitrate - nitrogen concentrations that exceed the 10 mg/L maximum acceptable concentration for drinking water as defined in the Health and Welfare Canada Canadian Drinking Water Quality Guidelines.

Twelve of 23 targeted pesticides have been detected in local ground waters. Concentrations of 10 of the pesticides detected are within established Canadian drinking water guidelines. Two pesticides, 1,2 dichloropropane and 1,3, dichloropropene, for which there are no Canadian Drinking Water Guidelines, have been detected in concentrations that exceed the Washington State water quality standards for ground water.

Improved farming practices, enhanced septic field design and maintenance, modified land use activities, and additional research followed by appropriate provincial legislation, if implemented, would assist in minimizing ground water contamination and improve ground water quality within the Abbotsford Aquifer.

Afin de diminuer la pollution de l'eau souterraine de la formation aquifère d'Abbotsford et de restaurer sa qualité, il faut améliorer les pratiques agricoles ainsi que la construction et l'entretien des fosses septiques, modifier les autres activités terrestres, poursuivre les recherches et promulguer des lois appropriées.

RESUME

La formation aquifère d'Abbotsford est un important dépôt de sable et de gravier que est situé dans le sud-ouest de la Colombie-Britannique et le nord-ouest de l'Etat de Washington, à cheval sur la frontière internationale. Cet aquifère est un important réservoir d'eau pour usages domestique, municipal, agricole et industriel dans les deux pays. L'écoulement d'eau souterraine dans la partie sud de l'aquifère se fait généralement en direction sud, vers les Etats-Unis. En certains endroits, diverses activités terrestres ont amené une contamination de l'eau souterraine de l'aquifère par le nitrate et les pesticides.

Un échantillonnage de l'eau souterraine de cet aquifère pour mesurer le nitrate et les pesticides a été effectué dans la partie sud de Matsqui, là où l'eau souterraine local semble être plus sévèrement affecté. La surveillance continue des puits et des piézomètres a montré que les concentrations de nitrate et de pesticides varient selon l'emplacement et les saisons. De plus, des niveaux élevés de nitrate peuvent indiquer la présence possible d'autre polluants.

Environ 60% des échantillons prélevés dans la partie de l'étude au sud de Matsqui contenaient de l'azote de nitrates à des niveaux excédant la concentration maximale de 10 mg/L pour l'eau potable fixée par Santé et Bien-Etre Social Canada.

Douze des vingt-trois pesticides visés ont été décelés dans les eaux souterraines locales. Pour dix des pesticides décelés les concentrations mesurées sont inférieures aux niveaux recommandés pour l'eau potable au Canada. Cependant, deux pesticides, le 1,2-dichloropopane et le 1,3-dichloroporpène, pour lesquels il n'existe aucune norme canadienne pour l'eau potable, ont été décelés à des niveaux qui excèdent les normes de qualité de l'eau souterraine de l'Etat de Washington.

ACKNOWLEDGEMENTS

The National Hydrology Research Institute (NHRI) provided initial funding and staff for ground water research and monitoring in the Lower Fraser Valley. They remain involved in ground water research of the Abbotsford aquifer with the regional Environment Canada office and a federal multi-agency research investigation.

The authors are indebted to a large number of individuals who have contributed to this report. In particular they would to thank Dr. C. H. Pharo, Mr. G. Derksen, Dr. V.G. Bartnik and NHRI staff who provided detailed reviews of the report.

Ms. Lidia Mozetic and Ms. Shain Amershi spent many hours revising drafts. We sincerely thank them for their hours of commitment.

FREQUENTLY USED TERMS

The term **aquifer** as used in this report describes a geological unit that will economically yield significant quantities of ground water to springs and wells. Relatively impervious geologic units that are incapable of transmitting significant quantities of water under ordinary hydraulic conditions are referred to as **aquicludes**. Aquifers such as the Abbotsford aquifer, which are exposed at land surface, are called **unconfined** or water table aquifers. Aquifers that occur between aquicludes, such as clays and glacial tills, are described as **confined aquifers**.

When wells are drilled through a confined aquifer, the water level will frequently rise above the top of the aquifer, and the well is said to exist under **artesian** conditions. In some artesian areas where water levels rise above the land surface, the well is defined as a **flowing artesian** well.

Piezometers are monitoring wells which are used for collecting ground water at specific depths in the aquifer and are also used for calculating ground water flow directions.

Static level is the distance from land surface to water in a well or piezometer. Water table elevations are calculated by subtracting the static levels from the land elevations. **Equipotential lines** are points of equal hydraulic head, which are plotted from a number of water table elevations in an aquifer.

1.0 INTRODUCTION

Approximately 16,000 wells have been drilled into aquifers in the lower Fraser River Valley to provide ground water for individual homes, municipalities, industries, commercial use, and high capacity farm irrigation. Ample supplies of generally excellent quality water have been drawn from these wells since the early 1920's.

There are approximately 200 aquifers in the lower Fraser River valley, of which the Abbotsford aquifer is the largest. The areal extent of the aquifer is approximately 100 square km in British Columbia, and about 100 square km in Washington State.

The Abbotsford aquifer is an extensive sand and gravel deposit located in the lower Fraser River Valley in south-western British Columbia and northwestern Washington State (See Figure 1 Section 2.1) This aquifer is largely unconfined, and most of the water extracted from it comes from relatively shallow depths. Because the aquifer is unconfined it is susceptible to contamination from activities on the land surface.

Over time, the area covered by the aquifer has been subjected to increasing pressures of population growth and industrial, commercial, and agricultural development. Urban development is spreading over parts of the aquifer recharge areas. Most houses outside the city limits of Clearbrook and Abbotsford have septic tanks and septic fields for waste disposal rather than municipal sewerage services. In many places the septic effluent drainage systems have been installed below the soils in the permeable sands and gravels.

Increased urbanisation and related development has also raised the demand for landfill sites. Concurrently, there has also been a steady increase in the intensity of various agricultural and animal husbandry activities in the area. This plethora of activities has resulted in a gradual but steady decline locally in ground water quality.

The objective of this report is to review concentrations of nitrates and selected pesticides detected in ground waters in the south Matsqui and Abbotsford municipalities. These substances are applied over a wide area and generally constitute a series of multiple point sources of contamination. Other sources of contamination, such as septic fields, landfill leachates, leaking underground storage tanks, and accidental spills of chemicals, also have an impact on ground water quality.

The data presented in this report have been collected between 1955 and 1990 from a steadily increasing number of ground water monitoring locations. In the early period, chemical analyses were confined to traditional inorganic constituents. Between 1970 and 1983, focus shifted to measuring nitrates in response to the recognition that nitrate levels seemed to be increasing locally. Analysis of pesticides in ground water was started in 1984 by Environment Canada. Areas close to raspberry fields were deemed to be at greatest risk from contamination by pesticides, and ground water pesticide sampling was concentrated at these sites.

Samples were collected and analysed from a large number of wells and piezometers over extended, and often irregular, time intervals.

Physical and chemical data on ground water from the Abbotsford aquifer collected since the mid 1950's have been compiled by the National Hydrology Research Institute (NHRI), and by the B.C. Ministry of Environment, Lands and Parks (BCMOEL&P). Data have also been compiled by staff at the regional office of Inland Waters, Agriculture Canada, B.C. Ministry of Health and local municipalities. Almost all these data focused on major inorganic constituents, including nitrate.

Pesticides are being detected in an increasing number of piezometers and wells, but it is evident that a more rigorous study of pesticide occurrence in ground water, and the persistence over time, has to be developed.

In 1990 two Agriculture Canada research stations, the National Hydrology Research Institute, and the regional office of Inland Waters, Environment Canada, developed and implemented the first phase of a four year study to evaluate the impact of specific pesticides on ground water in relation to rates and time of application, weather patterns, soil types and conditions, and ground water levels and flow rates. The regular collection and analysis of samples for pesticides in the aquifer began in March 1991.

2. THE ABBOTSFORD AQUIFER

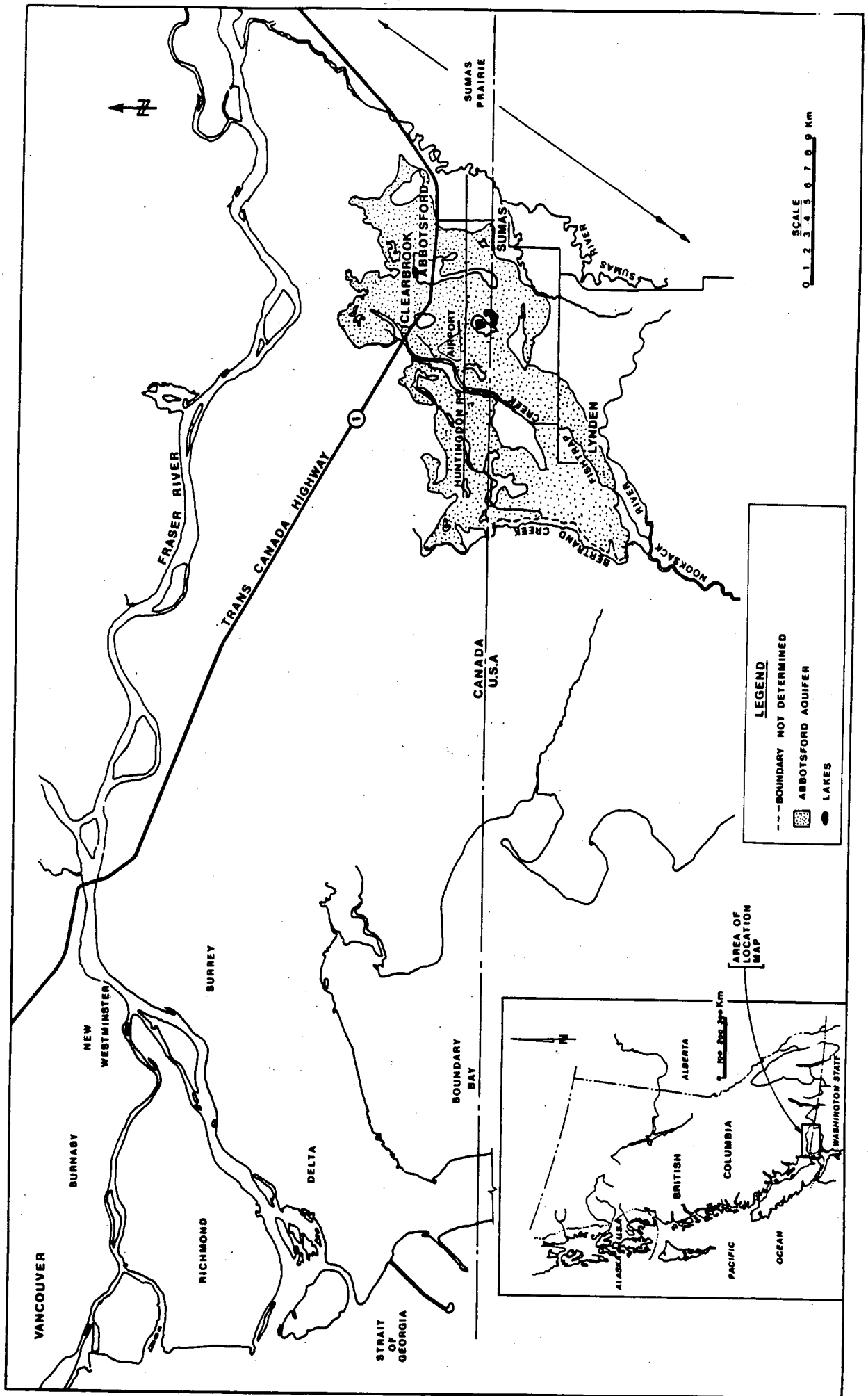
2.1 Geographic Setting

The Abbotsford aquifer lies in the Fraser Lowland in southwestern British Columbia and Washington State in the U.S.A. (Figure 1). The Lowland is part of the lower Fraser River valley, and lies between the Coast Mountains to the north, and the Cascade Mountains to the south. The aquifer extends south of Abbotsford into Washington State, west of Sumas, Washington, and north of the Nooksack River.

The topography over most of the aquifer is primarily flat. To the east, where the sands and gravels of the aquifer were deposited against an old ice mass that lay in the area of what is now Sumas Prairie, the edge of the aquifer forms an escarpment. On its north side, the sands and gravels butt against an upland composed of low permeable clays. A small stream, Fishtrap Creek, flows from the clay uplands across the surface of the aquifer southwards into the United States, into the Nooksack River drainage.

Precipitation during the winter months is the major source of ground water recharge. Thus climate and weather are significant in maintaining adequate ground water supplies. In the Fraser Lowland, winters are warm and wet, in response to a steady succession of low pressure systems moving eastward from the Pacific Ocean. Average annual precipitation is about 1500 mm per year (at Abbotsford Airport: Halstead 1986), of which about 75% falls between October and March. Summers, in contrast, have frequent long periods of sunny weather; temperatures are generally warm, and rainfall is low.

FIG.1 ABBOTSFORD AQUIFER - LOCATION MAP



2.2 Geologic Setting

The general physiography, geology, and ground water resources of the Fraser Lowland have been described by Armstrong et al. (1965), Halstead (1986), and Kohut (1987), and summarised in Atwater et al. (1991).

The geologic setting of the Fraser Lowland is that of a major structural trough that has subsided repeatedly since the last great local episode of mountain building in Late Cretaceous time. The trough was continually filled by sediments eroded from the adjacent mountain ranges which included a succession of sediments of marine, fluvial, and glacial origin. The late glacial and inter-glacial sediments are the aquifers most commonly developed south of the Fraser River.

Quaternary deposits, formed during the glacioclimatic period of the last 2 million years, are locally over 300 m thick. The repeated advance and retreat of glaciers during this period, and the deposits associated with the different stages of glacial development, form a highly complex sequence of sediments of diverse origins and varying permeabilities.

The Abbotsford aquifer is a unit within this complex sequence. It is composed of a succession of stratified, permeable, glaciofluvial sands and gravels interspersed with minor till and clayey silt lenses, collectively called the Sumas Drift (Armstrong et al. 1965). The base of the aquifer has not been completely defined but the aquifer is known to reach 70 m in thickness locally (Dakin, in Atwater et al., 1991). Drilling records indicate that the aquifer is underlain by low permeability glaciomarine and marine clays (Halstead 1986).

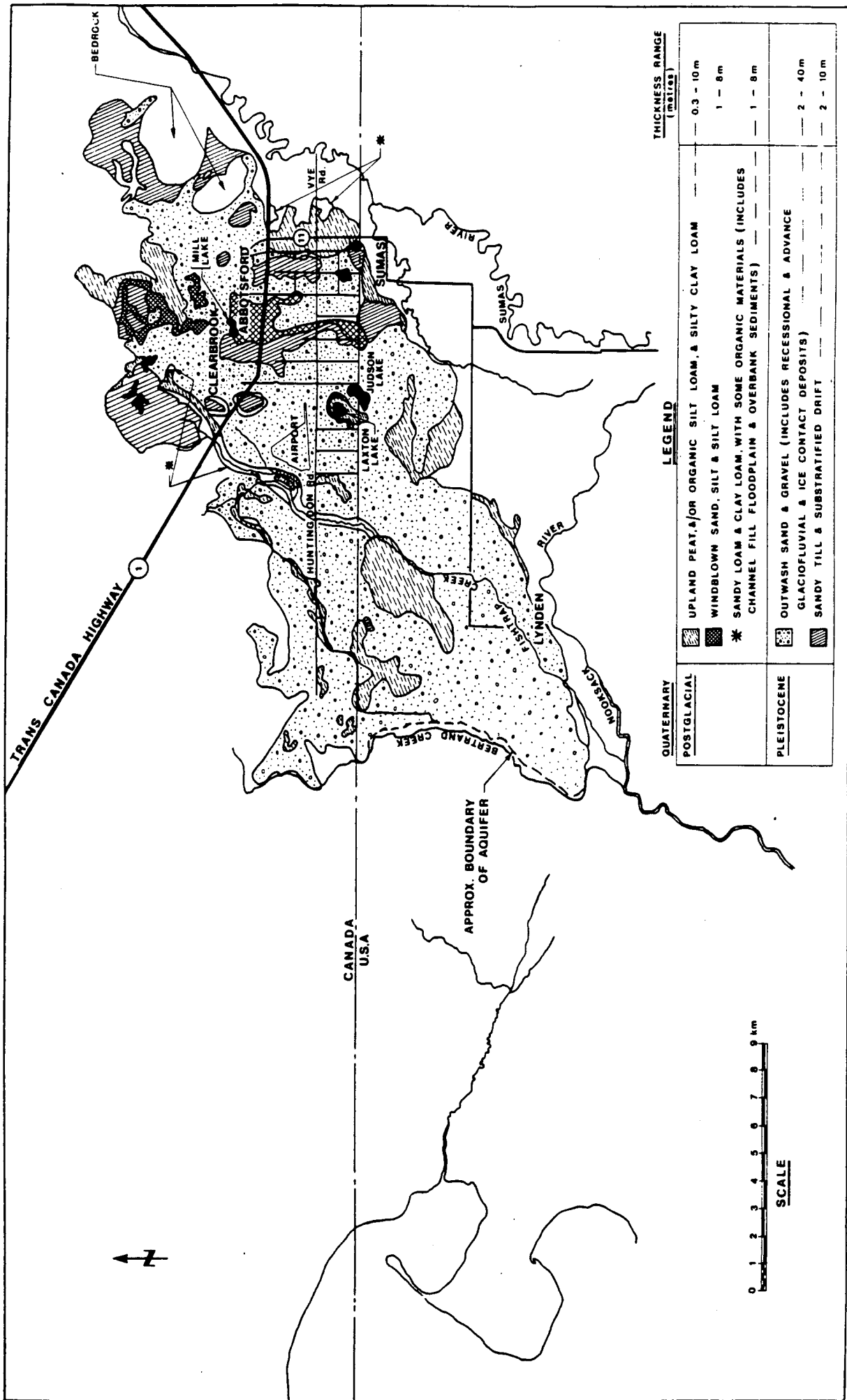
The glacial till and clay components of the aquifer are more common in the eastern parts of the aquifer while the western section of the aquifer is characterised by cleaner sands and gravels. Figures 2 and 3 show the distribution of the surficial materials that form the aquifer and the aquicludes north of the international border. Piezometer bore hole logs are listed in Appendix A. The aquifer extends 20 km along the international boundary, and ranges between 5 and 30 m in thickness. The same unit in the United States, north and north-east of Lynden and extending to Sumas, averages less than 30 m in thickness although locally the thickness may exceed 60 m (Easterbrook 1976). West of Lynden, near Bertrand Creek (Figure 1), the sediments are predominantly sands with thin layers of silt and clay (Creahan and Kelsey 1988). Less stratified sands and gravels with till lenses are found at the southeastern edge of the aquifer just west of Sumas.

2.3 Hydrogeology

The hydrogeology of the Fraser Lowland is discussed in Halstead (1986) and is summarised in Atwater et al (1991). Water table monitoring in the Abbotsford aquifer is part of an on-going program conducted by Environment Canada. The data show that seasonal fluctuation of the water table is directly correlated to precipitation between November and March (Figures 4a & 4b). Ground water in the Abbotsford aquifer is recharged annually, by three mechanisms: direct infiltration from rain or snow melt during winter months, runoff from the clay uplands to the north, and seasonal recharge from Fishtrap Creek.

Precipitation on the clay uplands north of the aquifer results in runoff into local ditches and to Fishtrap Creek which flows south across the aquifer. Water seeps from these channels into the sands and gravels of the aquifer. To the north of the drainage divide, surface water flows to the Matsqui Lowland and into the Fraser River.

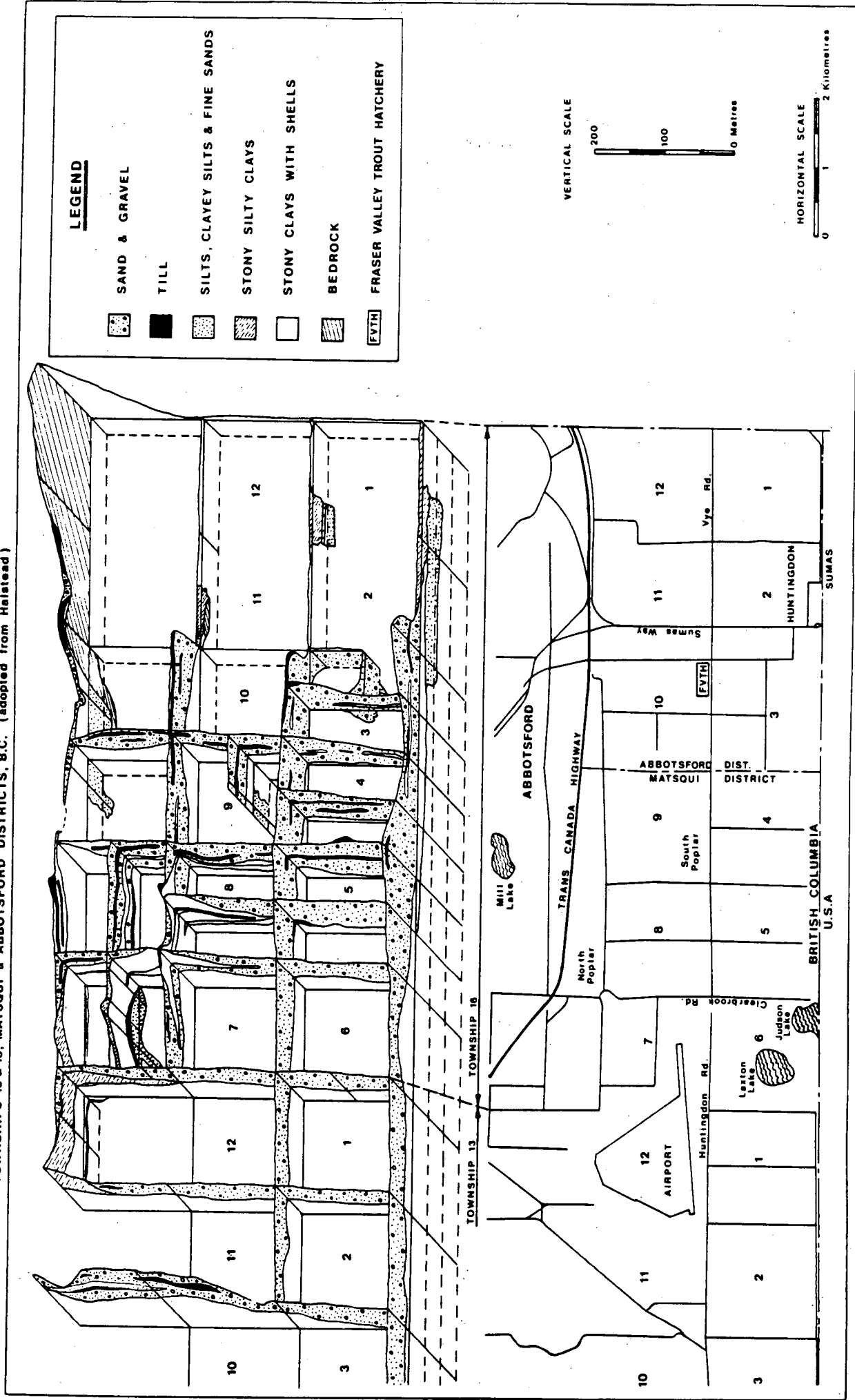
FIG.2 SURFICIAL GEOLOGY



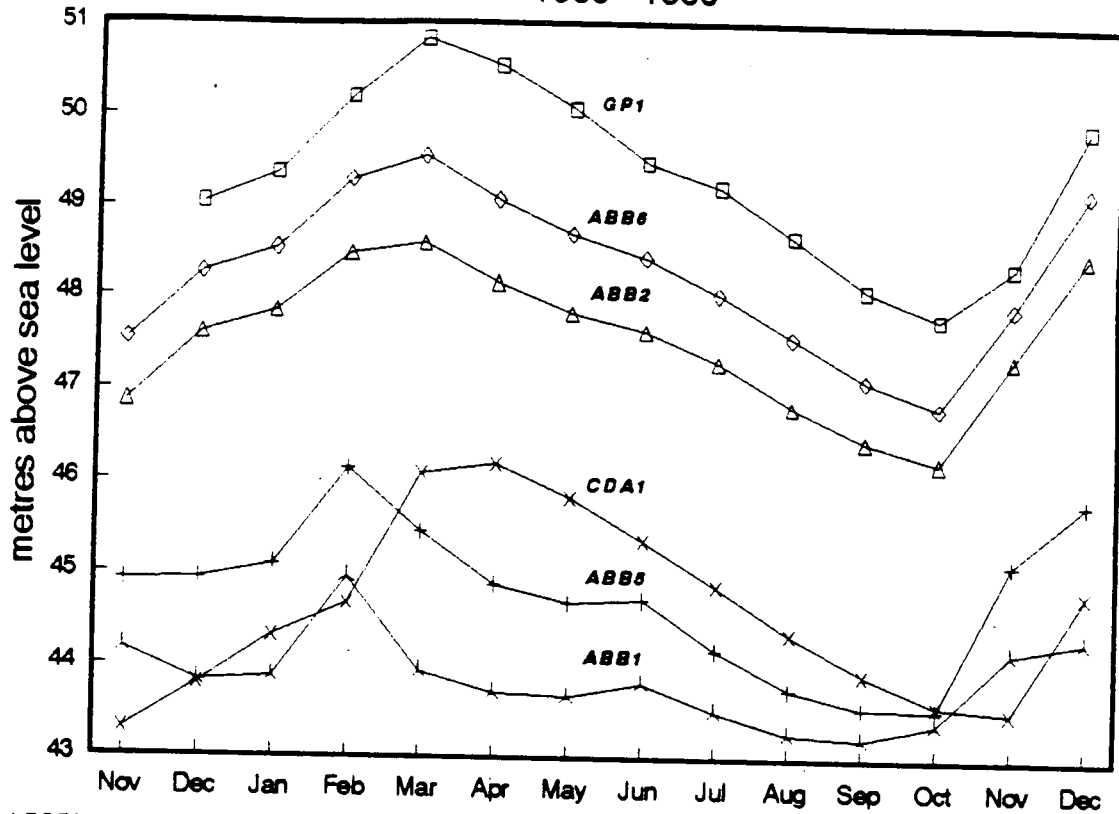
QUATERNARY		THICKNESS RANGE (metres)	
POSTGLACIAL	UPLAND PEAT, &/OR ORGANIC SILT LOAM, & SILTY CLAY LOAM	---	0.3 - 10 m
	WINDBLOWN SAND, SILT & SILT LOAM	---	1 - 8 m
	* SANDY LOAM & CLAY LOAM, WITH SOME ORGANIC MATERIALS (INCLUDES CHANNEL FILL FLOODPLAIN & OVERBANK SEDIMENTS)	---	1 - 8 m
PLEISTOCENE	OUTWASH SAND & GRAVEL (INCLUDES RECESSIONAL & ADVANCE GLACIOFLUVIAL & ICE CONTACT DEPOSITS)	---	2 - 40 m
	SANDY TILL & SUBSTRATIFIED DRIFT	---	2 - 10 m



FIG.3 — GEOLOGICAL FENCE DIAGRAM
 TOWNSHIPS 13 & 16, MATSQUI & ABBOTSFORD DISTRICTS, B.C. (adopted from Halstead)



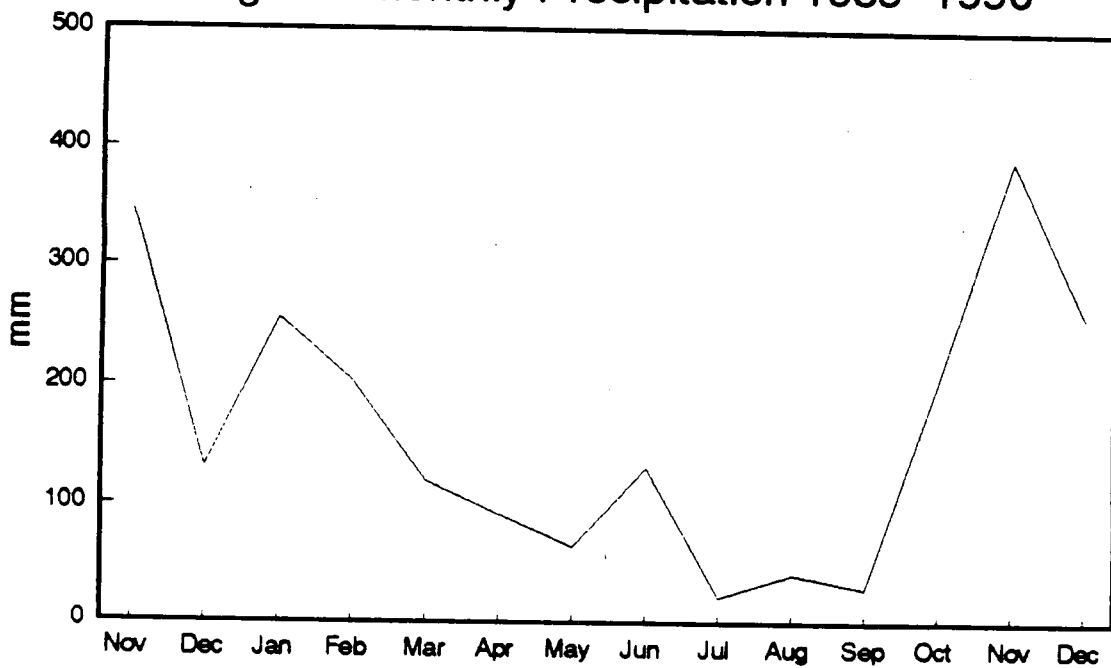
**Fig. 4a Hydrographs - Abbotsford Aquifer
1989 - 1990**



LEGEND

- | | | | |
|------|-------------------------------------|------|----------------------------------|
| GP1 | GRAVEL PIT AT VRMIX ON VEMSLY ROAD | CDA1 | CDA STN 500 CLEARBROOK |
| ABB6 | 1.25 Km S OF HUNTINGDON ON TOWNLINE | ABB5 | 0.75 Km FROM ROSS ON BOUNDARY RD |
| ABB2 | 1.25 Km S OF HUNTINGDON ON TOWNLINE | ABB1 | 1.0 Km S OF HUNTINGDON ON ROSS |

Fig. 4b Monthly Precipitation 1989 -1990



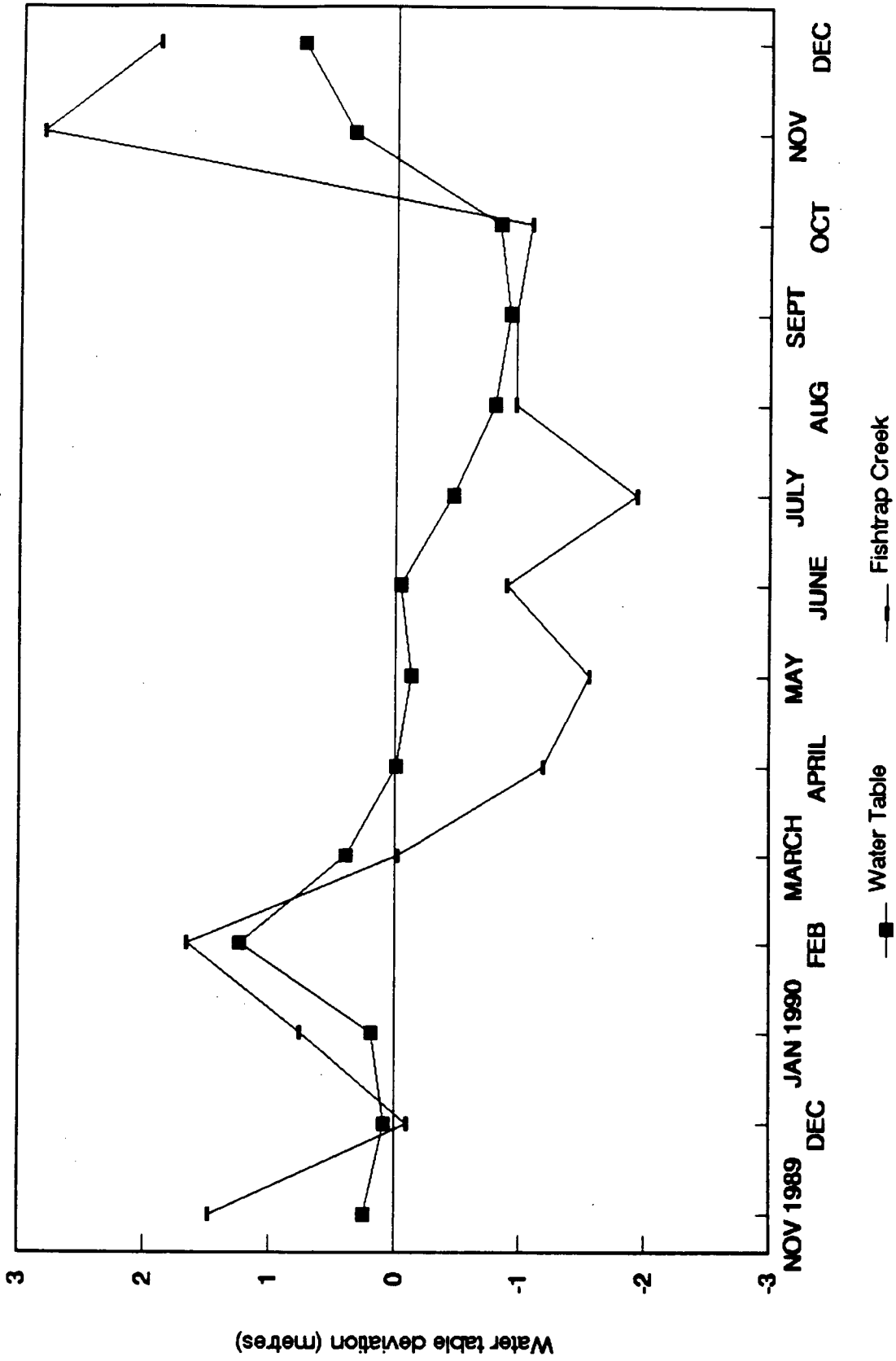
Fishtrap Creek, located 1 km west of the airport, drains part of the clay upland and flows south across the aquifer and into Washington State. For six months of the year the creek's water level lies above local ground waters and during this period the creek flows into, or recharges, the aquifer (Figure 5). During the other six months, when the creek level lies below local ground water levels, the ground waters flow into or under the creek.

The water table in the aquifer is highest in March and is lowest in late October. This dynamic change is site specific, with an average 3 m seasonal fluctuation of the water table. This degree of fluctuation is common on both sides of the international boundary. (S. Cox, USGS, unpublished data).

Ground water flow directions in the Abbotsford aquifer can be interpreted from equipotential lines within the aquifer (Figure 6) that was compiled from well data and piezometers. Water levels south of the international boundary are documented in Creahan and Kelsey (1988), Kahle (1990), and Cox (USGS, unpublished data). Static levels recorded from water well drillers' well logs which have been adjusted for seasonal fluctuations of the water table by using correction factors derived from water-table hydrographs.

Regional ground water flow in the southern part of the aquifer is primarily southwards, with local variations controlled by subsurface hydraulic conductivities, ground water recharge, water withdrawal, and natural discharge zones. Local flow directions south of the international boundary are southeast in the "Upland Unconfined aquifer" (Kahle 1990) and southerly in the Lynden and Bertrand Creek areas (Creahan and Kelsey 1988). North of the international boundary, local flow directions are south around Laxton Lake, southwest at Abbotsford Airport, and southeast at Farmer Road. Environment Canada has not monitored the northern section of the aquifer underlying Clearbrook and Abbotsford. Interpretations of land contours from topographic maps suggests ground water underlying these urban areas flows northerly into the Matsqui Lowland lying within the Fraser Basin.

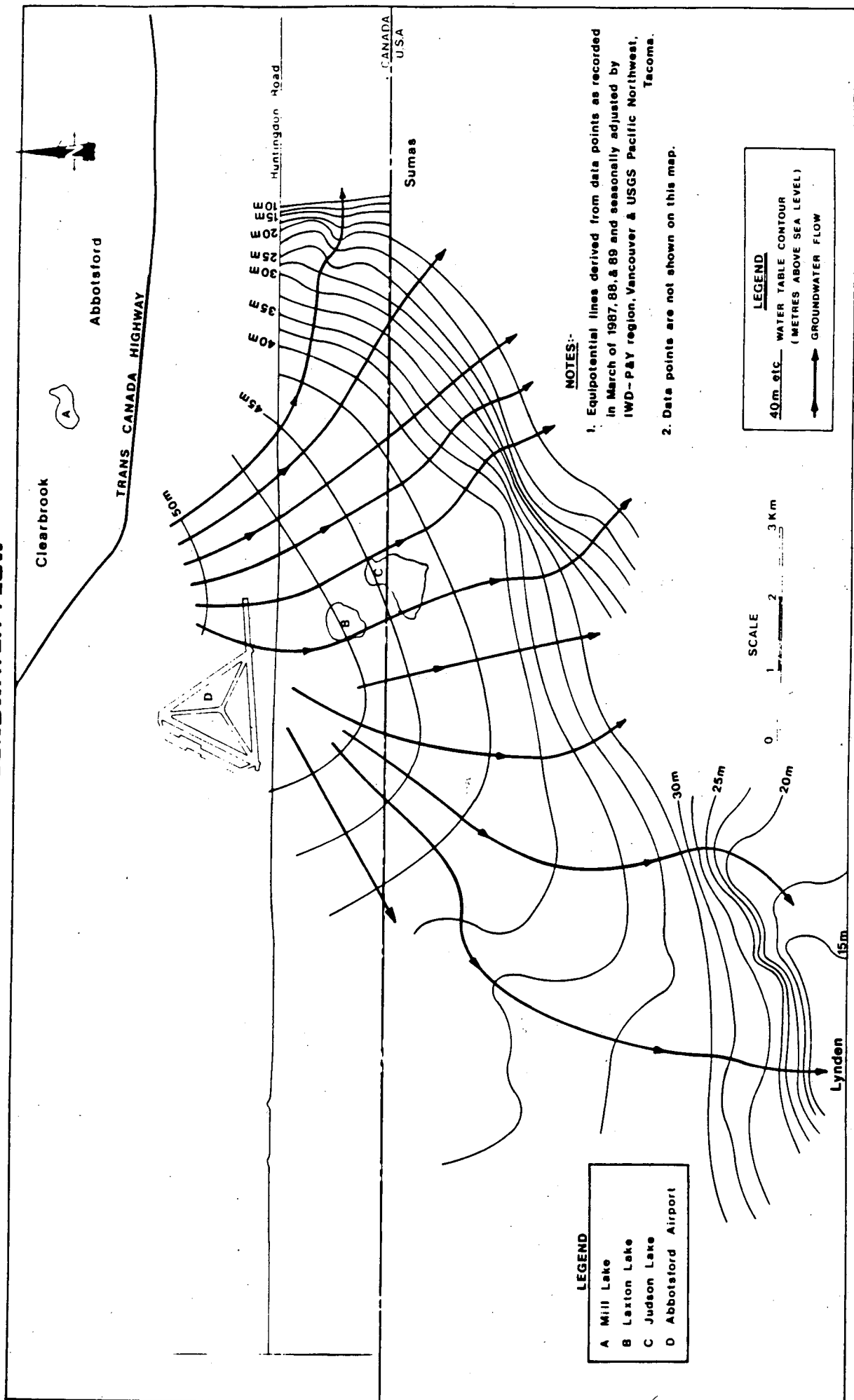
Fig.5 Water Table and Fishtrap Creek



Fishtrap Creek mean discharge deviation (cu m/s X 2.0)

measurements from gauge at International Border & nearby piezometers

FIG. 6 GROUNDWATER FLOW



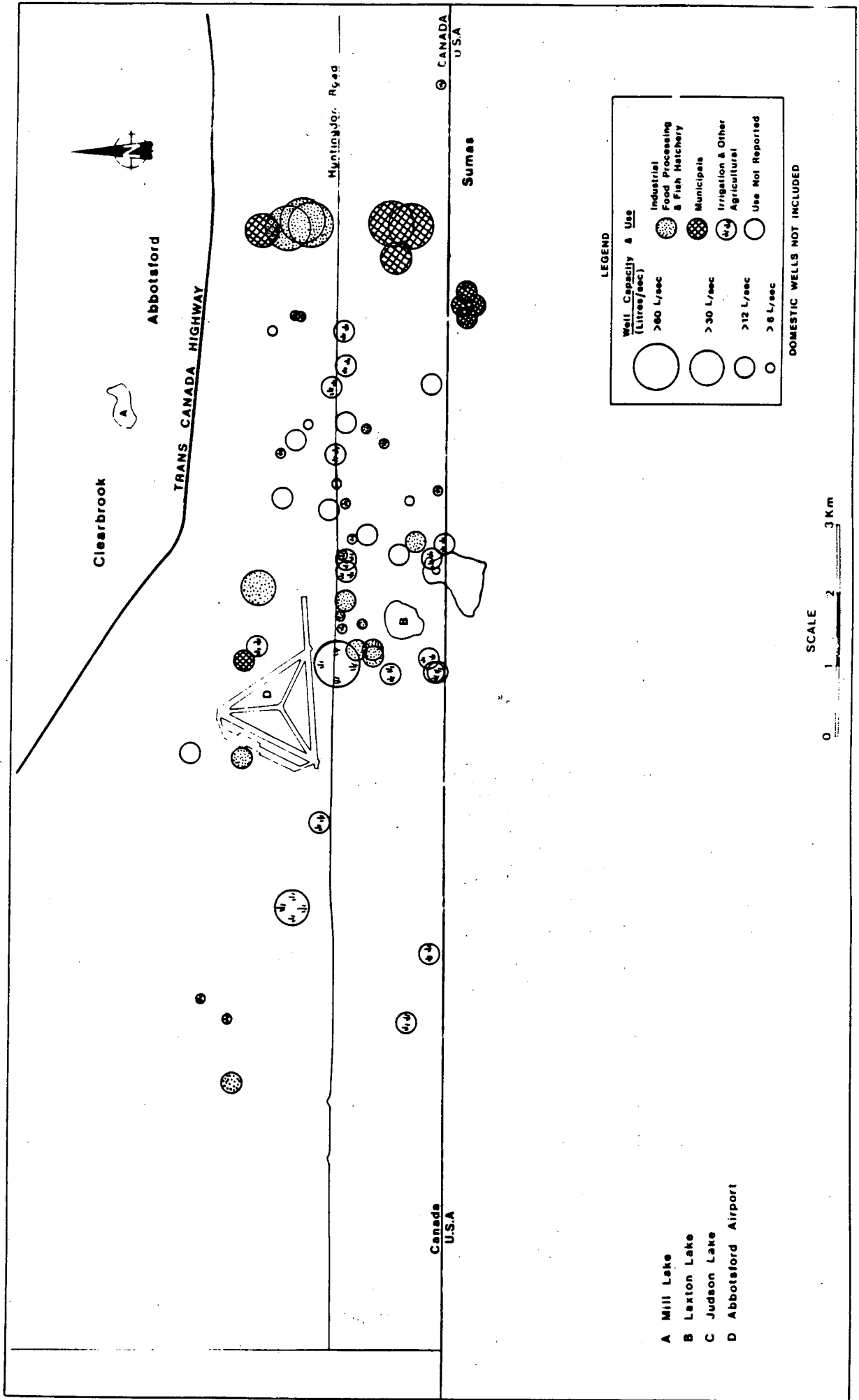
The ground water flow directions at the southeast corner of the Canadian portion of the aquifer is primarily toward the "radii of influence" of the high capacity pumps that withdraw water for the Fraser Valley Trout Hatchery and the Abbotsford municipal production well field. Interference effects from the high capacity production wells at the hatchery, together with below average precipitation recharge between 1976 and 1979, caused the water table at the hatchery to temporarily decline at an average annual rate of approximately 1 m per year (Zubel 1979). Observation wells near the hatchery show that, beginning in 1977, high capacity withdrawals at the hatchery have influenced local ground water flow directions to the degree that the resultant local flow is now more towards the east than the south. Ground water level monitoring in a number of places in the aquifer has not shown any persistent ground water level decline (Dakin, in Atwater et al. 1991).

Hydraulic gradients, hydraulic conductivities, and local porosities are the main controlling variables of ground water flow rate. Average linear velocities of ground water have been calculated using a modification of Darcy's equation. Calculated flows range between 5 and 450 m per year, depending on the real and assumed values of site-specific variables controlling flow rates.

2.4 Ground Water Development

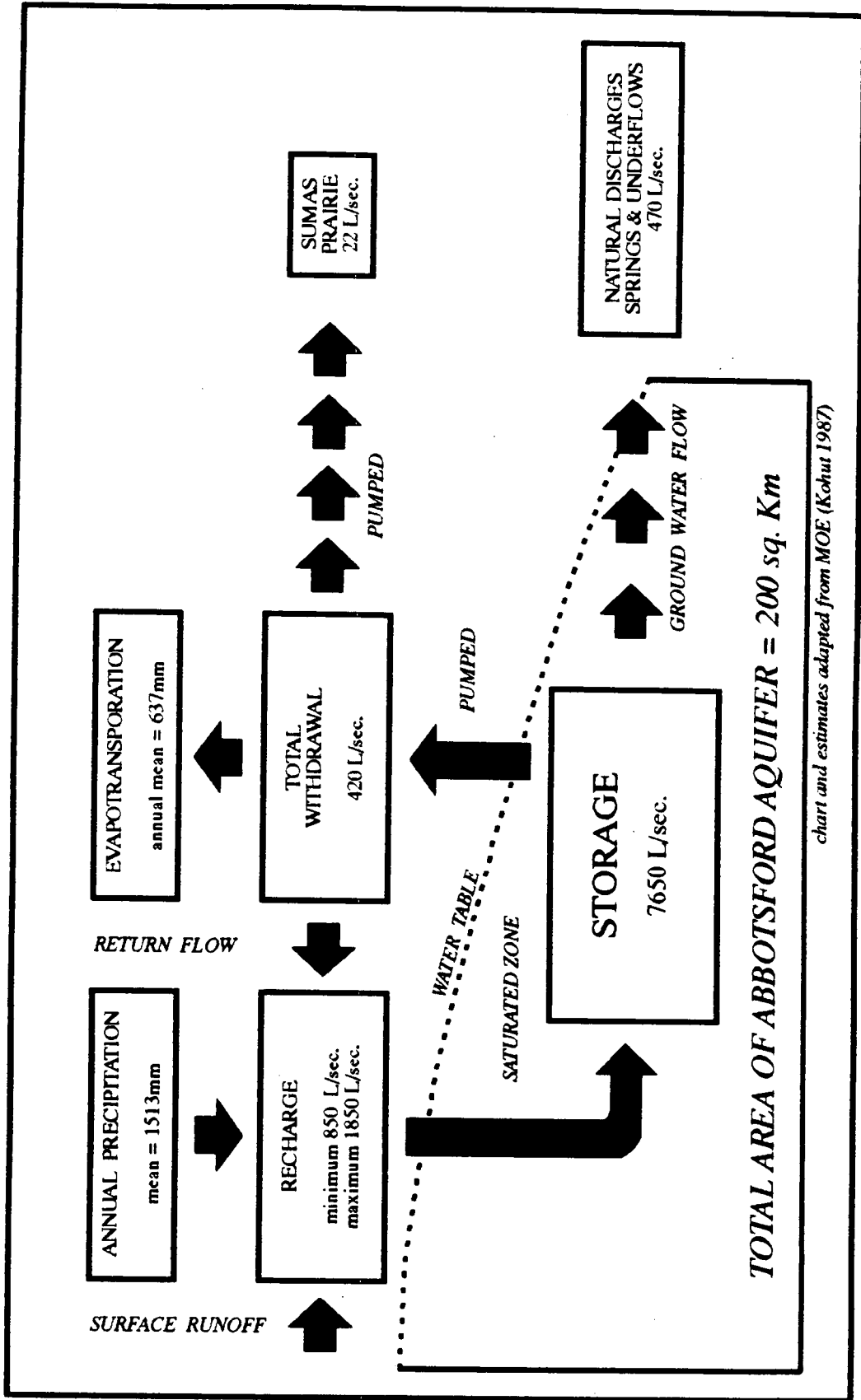
Major ground water users of the Abbotsford aquifer in Canada are the Fraser Valley Trout Hatchery, industries, the municipalities of Abbotsford and Matsqui, irrigation wells with high capacity sprayers, and domestic wells. High capacity municipal production wells are located primarily in the south east part of the aquifer (Figure 7) and, along with the trout hatchery, account for approximately two-thirds of the total ground water withdrawal north of the international boundary.

FIG. 7. HIGH CAPACITY WELLS



- A Mill Lake
- B Lexton Lake
- C Judson Lake
- D Abbotsford Airport

Fig. 8 Ground Water Budget for Abbotsford Aquifer



Kohut (1987) estimated that, in 1985, the total amount of water withdrawn by all wells was about 12 M cu.m per year. The approximate breakdown is: industrial 41%, municipal 34%, irrigation 21%, and domestic 4%. These observations support the ground water budget, shown in Figure 8, with use estimated at 420 L per sec., and recharge at between 1850 and 850 L per sec.

The extent of ground water withdrawal is controlled by the number of wells, their locations, well capacities and natural discharge zones. There are about 500 wells in a 6 square km area between Abbotsford and the international boundary. More than half of these wells are located in the unconfined sands and gravels. The others, primarily on the east side, develop ground water from the confined and semi-confined sands and gravels underlying till and clay lenses.

The ease of development of ground water supplies from the Abbotsford aquifer is controlled by the specific details of the geology and hydrogeology at each site. Where till lenses or clays are close to the surface, as is the case around Mill Lake, most wells in the area must be drilled through to the permeable sands and gravels.

In the southeast part of the aquifer where the sands and gravels are interspersed with till or clay layers, all the wells are drilled and most are over 30 m deep. Some wells, such as the Fraser Valley Trout Hatchery production wells, draw water from a confined zone of the aquifer.

Springs on the Canadian side of the international boundary are found along the eastern escarpment of the aquifer. This is the area where flowing artesian wells have been drilled. Major springs also discharge at the southern edge of the aquifer north east of Lynden, Washington. The Sumas well field consists of 4 flowing artesian wells and 2 springs located west of Sumas near the eastern escarpment, close to the international boundary (see Figure 7).

2.5 Ground Water Quality

Ground water sampling and analysis in the lower Fraser River Valley commenced in 1955 by E.C. Halstead (Geological Survey of Canada) and was focused on inorganic constituents. Ground water quality data from the Abbotsford aquifer are given in Appendix B. The predominant natural constituents are calcium and magnesium bicarbonate, with total dissolved solids concentrations ranging between less than 100 mg/L at shallow depths, to over 300 mg/L where water-bearing sands and gravels are confined or partly confined by till and clay lenses. In general the quality of water in this aquifer has been regarded as good.

The infiltration of nitrates and pesticides from the land surface into the aquifer has caused local deterioration of the quality of water in the aquifer. These topics are dealt with separately in Sections 3 and 4.

With the advancement of field sampling equipment and the improvements in laboratory methods, field sampling methods, analytical procedures and detection levels have changed and improved with time. Field sampling methods for inorganic constituents, including nitrates and pesticides are summarized in Appendix C.

2.6 Land Use Activities

Activities on the land surface have a significant impact on the quality of water in an unconfined aquifer. In the area covered by the Abbotsford aquifer, in Canada, the trend has been the loss of agricultural land to urban expansion. About 20% of the aquifer's surface is covered by urban areas.

Recent surveys by the provincial Ministry of Agriculture, Fisheries and Food (BC MAFF) and aerial photographs from the Canada Land Use Monitoring Program, identify the main agricultural activities on the Canadian part of the aquifer as row crops, poultry breeding and production, and pasture. About 60% of the agricultural lands are raspberry farms. Large greenhouse operations have been expanding in recent years. Approximately 60% of poultry production in B.C. is on, or in close vicinity of the Abbotsford aquifer.

Poultry manure is frequently applied on raspberry fields as both a fertilizer and to enhance the soils. Application rates are highly variable and have been estimated to be in excess of 200 kg nitrate - nitrogen per ha (B. Zearth, Agriculture Canada, pers comm.). Manures destined for spreading and incorporation into the raspberry farms are frequently left in exposed stockpiles and spread on the land during the winter months.

Land use activities south of the international boundary are less intensive than on the Canadian side. They include dairy, raspberry, corn and potato farming and residential development. Satellite imagery reveals less cultivation, extensive dairy farming, and more woodlands.

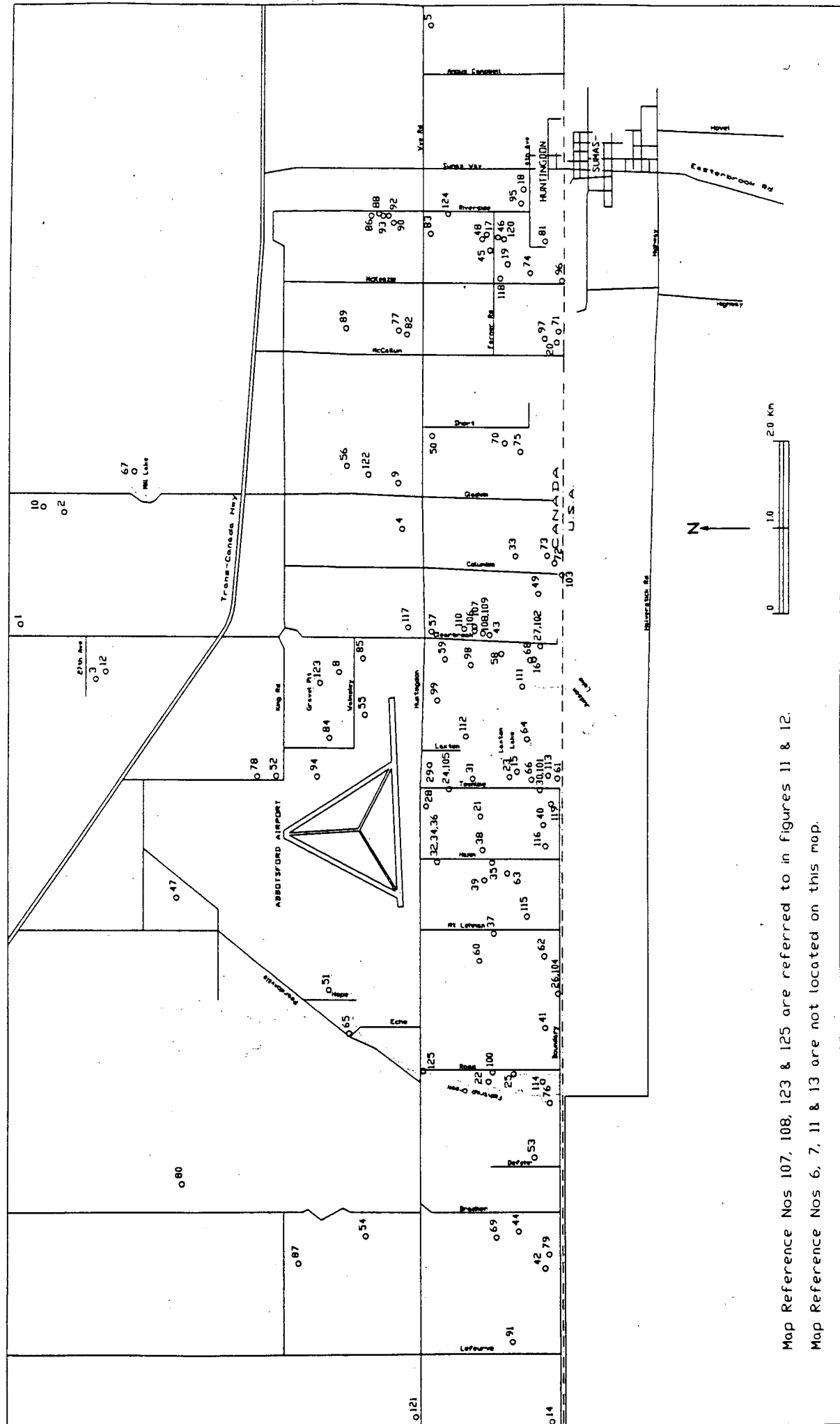
3.0 NITRATES

Nitrates are highly soluble, easily incorporated into local surface and ground waters and, where found in significant concentrations, can be used as an indicator of contamination from local land use activities. Unconfined aquifers are particularly vulnerable to contamination by nitrates.

Since 1955, over 450 ground water samples have been collected from domestic wells and piezometers, and analyzed for nitrates (Table 1 and Figure 9). The sampling site locations and concentrations of nitrates measured are discussed in the following sections. Municipal wells were not included in the federal sampling programs.

Sampling locations were initially on a large grid. Later sampling became more focused towards areas of higher nitrate concentrations in south Matsqui Municipality. Sampling frequencies were highly variable. The location of wells and piezometers sampled are shown in Figure 9.

Fig.9 Nitrate Sampling Locations
using Map Reference No. as shown in Table 1.



Map Reference Nos 107, 108, 123 & 125 are referred to in figures 11 & 12.
Map Reference Nos 6, 7, 11 & 13 are not located on this map.

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
1	16-29-41	16	29	21-Oct-55	0.60
2	16-29-51	16	29	21-Oct-55	4.00
3	16-19-42	16	19	21-Oct-55	0.60
4	16-5-043	16	5	21-Oct-55	12.00
5	16-1-36	16	1	21-Oct-55	3.60
6	16-21-50	16	21	21-Oct-55	2.40
7	16-14-34	16	14	21-Oct-55	0.60
8	16-7-52	16	7	21-Oct-55	10.00
9	16-9-45	16	9	21-Oct-55	10.00
10	16-29-49	16	29	22-Oct-55	1.20
11	16-33-02	16	33	01-Oct-57	0.10
12	16-19-78	16	19	01-Sep-66	<0.05
13	AL51	13	20	30-Nov-81	7.78
14	AL52	13	5	08-Mar-84	5.21
15	I03	16	6	14-Dec-84	20.81
16	S2	16	6	15-Feb-88	0.14
17	16-3-12	16	3	16-Feb-88	3.02
18	16-3-15	16	3	16-Feb-88	0.01
19	16-3-10	16	3	16-Feb-88	14.00
20	16-3-39	16	3	18-Feb-88	11.00
21	13-1-11	13	1	19-Feb-88	8.58
22	D11	13	3	23-Jan-89	12.70
23	D17	16	6	23-Jan-89	34.20
24	F03	13	1	23-Jan-89	10.30
25	D12	13	3	23-Jan-89	15.40
26	F05	13	2	23-Jan-89	18.70
27	F02	16	6	26-Jan-89	10.20
28	D08	13	1	26-Jan-89	3.10
29	D06	16	6	26-Jan-89	2.90
30	F04	13	1	26-Jan-89	22.40

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
31	D09	16	6	26-Jan-89	10.80
32	P-A-55	13	1	06-Feb-89	4.00
33	D22	16	5	06-Feb-89	16.80
34	P-A-35	13	1	06-Feb-89	5.40
35	P-C-20	13	1	06-Feb-89	17.60
36	P-A-25	13	1	06-Feb-89	6.40
37	P-B-20	13	2	06-Feb-89	28.70
38	D21	13	1	09-Feb-89	13.50
39	D20	13	1	09-Feb-89	11.50
40	D18	13	1	09-Feb-89	0.00
41	D14	13	2	13-Feb-89	0.39
42	D41	13	4	13-Feb-89	19.90
43	D02	16	5	13-Feb-89	15.00
44	D24	13	4	13-Feb-89	16.50
45	FARMER#3	16	3	22-Feb-89	5.32
46	FARMER#2	16	3	22-Feb-89	5.62
47	D39	13	14	23-Feb-89	13.00
48	D40	16	3	23-Feb-89	6.42
49	D34	16	5	23-Feb-89	16.00
50	D46	16	4	23-Feb-89	16.10
51	D38	13	11	23-Feb-89	19.60
52	D43	16	18	27-Feb-89	0.01
53	D45	13	4	27-Feb-89	0.21
54	D3A	13	9	27-Feb-89	5.08
55	D47	16	7	27-Feb-89	14.30
56	D48	16	9	27-Feb-89	0.05
57	N1	16	5	01-Nov-89	11.40
58	C10	16	6	01-Nov-89	0.24
59	16-6-3	16	6	01-Nov-89	11.15
60	BC67	13	1	02-Nov-89	7.30

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
61	16-6-1	16	6	02-Nov-89	9.25
62	I02	13	2	02-Nov-89	28.65
63	BC66	13	1	02-Nov-89	20.80
64	LAXTON	16	6	17-May-90	1.60
65	FISHTRAP	13	13	17-May-90	0.76
66	16-6-99	16	6	17-May-90	5.16
67	MILL	16	16	17-May-90	0.07
68	JUDSON	16	6	17-May-90	0.03
69	13-4-009	13	4	04-Jun-90	1.50
70	16-4-63	16	4	18-Jul-90	15.80
71	16-3-38	16	3	18-Jul-90	14.00
72	BC78	16	5	18-Jul-90	25.70
73	ABB34	16	5	18-Jul-90	26.30
74	16-3-3	16	3	18-Jul-90	6.83
75	16-4-63A	16	4	18-Jul-90	18.70
76	13-3-010	13	3	21-Sep-90	<0.01
77	16-10-41	16	0	21-Sep-90	4.93
78	MA2	16	7	21-Sep-90	17.20
79	13-4-025	13	4	21-Sep-90	13.00
80	13-15-008	13	15	21-Sep-90	7.94
81	16-3-A	16	3	21-Sep-90	12.60
82	16-10-43	16	10	21-Sep-90	0.01
83	16-3-59	16	3	21-Sep-90	18.40
84	16-7-47	16	7	21-Sep-90	15.20
85	16-7-64	16	7	21-Sep-90	15.50
86	FVTH1	16	10	21-Sep-90	7.34
87	13-9-013	13	9	21-Sep-90	<0.01
88	FVTH_R	16	10	21-Sep-90	7.12
89	16-10-2	16	10	21-Sep-90	0.78
90	FVTH2	16	10	21-Sep-90	6.54

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
91	13-4-11	13	4	21-Sep-90	10.40
92	FVTH4	16	10	21-Sep-90	11.00
93	FVTH3	16	10	21-Sep-90	3.35
94	16-7-60	16	7	21-Sep-90	30.50
95	16-3-49	16	3	21-Sep-90	5.48
96	16-3-34	16	3	16-Feb-88	0.07
	16-3-34	16	3	18-Jul-90	22.70
97	16-3-380	16	3	02-Nov-89	5.10
	16-3-380	16	3	17-May-90	6.17
98	16-6-37	16	6	19-Feb-88	17.80
	16-6-37	16	6	01-Nov-89	22.25
99	16-6-5	16	6	19-Feb-88	8.63
	16-6-5	16	6	01-Nov-89	24.30
100	ABB1	13	3	15-Nov-89	5.85
	ABB1	13	3	19-Jan-90	10.50
	ABB1	13	3	20-Mar-90	15.15
	ABB1	13	3	17-May-90	13.85
	ABB1	13	3	18-Jul-90	9.90
	ABB1	13	3	14-Aug-90	8.71
	ABB1	13	3	19-Sep-90	9.82
	ABB1	13	3	18-Oct-90	11.40
	ABB1	13	3	22-Nov-90	9.51
	ABB1	13	3	18-Dec-90	9.09
101	ABB2	13	1	19-Jan-90	14.50

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
	ABB2	13	1	20-Mar-90	14.10
	ABB2	13	1	17-May-90	14.30
	ABB2	13	1	18-Jul-90	9.65
	ABB2	13	1	14-Aug-90	8.13
	ABB2	13	1	19-Sep-90	9.35
	ABB2	13	1	18-Oct-90	10.45
	ABB2	13	1	22-Nov-90	8.62
	ABB2	13	1	18-Dec-90	10.10
102	ABB3	16	6	15-Nov-89	21.00
	ABB3	16	6	19-Jan-90	26.30
	ABB3	16	6	20-Mar-90	11.05
	ABB3	16	6	17-May-90	11.60
	ABB3	16	6	18-Jul-90	21.10
	ABB3	16	6	14-Aug-90	20.60
	ABB3	16	6	19-Sep-90	21.10
	ABB3	16	6	18-Oct-90	21.20
	ABB3	16	6	22-Nov-90	19.30
	ABB3	16	6	18-Dec-90	26.90
103	ABB4	16	5	19-Jan-90	35.65
	ABB4	16	5	20-Mar-90	26.85
	ABB4	16	5	17-May-90	25.75
	ABB4	16	5	18-Jul-90	22.80
	ABB4	16	5	14-Aug-90	23.50
	ABB4	16	5	19-Sep-90	24.90
	ABB4	16	5	18-Oct-90	29.35
	ABB4	16	5	22-Nov-90	28.85
	ABB4	16	5	18-Dec-90	28.50

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
104	ABB5	13	2	15-Nov-89	17.30
	ABB5	13	2	19-Jan-90	20.50
	ABB5	13	2	20-Mar-90	15.50
	ABB5	13	2	17-May-90	16.50
	ABB5	13	2	18-Jul-90	16.20
	ABB5	13	2	14-Aug-90	16.05
	ABB5	13	2	19-Sep-90	17.00
	ABB5	13	2	18-Oct-90	22.75
	ABB5	13	2	22-Nov-90	20.35
	ABB5	13	2	18-Dec-90	20.40
105	ABB6	13	1	15-Nov-89	13.50
	ABB6	13	1	19-Jan-90	15.00
	ABB6	13	1	20-Mar-90	14.37
	ABB6	13	1	17-May-90	13.50
	ABB6	13	1	18-Jul-90	10.25
	ABB6	13	1	14-Aug-90	9.67
	ABB6	13	1	19-Sep-90	10.70
	ABB6	13	1	18-Oct-90	11.00
	ABB6	13	1	22-Nov-90	10.60
	ABB6	13	1	18-Dec-90	11.40
106	CDA1	16	5	19-Sep-90	19.10
	CDA1	16	5	24-Oct-90	18.10
	CDA1	16	5	22-Nov-90	16.20
	CDA1	16	5	18-Dec-90	16.90
107	CDA2	16	5	19-Jan-90	42.30
	CDA2	16	5	20-Mar-90	34.25
	CDA2	16	5	17-May-90	33.50

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
	CDA2	16	5	18-Jul-90	36.25
	CDA2	16	5	14-Aug-90	24.70
	CDA2	16	5	19-Sep-90	23.20
	CDA2	16	5	24-Oct-90	22.55
	CDA2	16	5	22-Nov-90	23.30
	CDA2	16	5	18-Dec-90	10.50
108	D01	16	5	07-Mar-70	8.85
	D01	16	5	17-Jul-73	9.69
	D01	16	5	05-Sep-73	9.06
	D01	16	5	15-Oct-73	9.40
	D01	16	5	21-Nov-73	8.40
	D01	16	5	24-Jan-74	9.00
	D01	16	5	10-Apr-74	9.13
	D01	16	5	04-Jun-74	10.93
	D01	16	5	01-Aug-74	15.20
	D01	16	5	24-Oct-74	11.30
	D01	16	5	07-Jan-75	14.20
	D01	16	5	02-Apr-75	15.20
	D01	16	5	21-May-75	14.60
	D01	16	5	15-Jul-75	14.90
	D01	16	5	10-Sep-75	14.50
	D01	16	5	13-Nov-75	14.80
	D01	16	5	12-Feb-76	15.10
	D01	16	5	08-Apr-76	15.30
	D01	16	5	27-May-76	15.90
	D01	16	5	22-Jul-76	16.70
	D01	16	5	16-Sep-76	17.40
	D01	16	5	18-Nov-76	17.30
	D01	16	5	13-Jan-77	16.00

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
	D01	16	5	21-Feb-77	16.40
	D01	16	5	31-Mar-77	16.80
	D01	16	5	13-May-77	16.00
	D01	16	5	23-Jun-77	15.80
	D01	16	5	11-Aug-77	16.00
	D01	16	5	22-Sep-77	15.00
	D01	16	5	03-Nov-77	16.00
	D01	16	5	12-Jan-78	15.00
	D01	16	5	23-Feb-78	14.00
	D01	16	5	06-Apr-78	13.00
	D01	16	5	25-May-78	13.00
	D01	16	5	20-Jul-78	14.00
	D01	16	5	30-Aug-78	14.00
	D01	16	5	19-Oct-78	14.00
	D01	16	5	05-Dec-78	15.00
	D01	16	5	14-Jan-81	18.40
	D01	16	5	25-Feb-81	15.80
	D01	16	5	28-May-81	17.00
	D01	16	5	24-Sep-81	20.80
	D01	16	5	10-Dec-81	22.00
	D01	16	5	11-Mar-82	21.30
	D01	16	5	17-Feb-88	18.13
	D01	16	5	13-Feb-89	13.30
	D01	16	5	01-Nov-89	23.60
	D01	16	5	17-May-90	19.90
	D01	16	5	18-Jul-90	19.95
	D01	16	5	19-Sep-90	21.00
	D01	16	5	24-Oct-90	21.80
	D01	16	5	22-Nov-90	22.60
	D01	16	5	18-Dec-90	22.10

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
109	D01A	16	5	18-Jul-90	24.90
	D01A	16	5	24-Oct-90	26.40
	D01A	16	5	22-Nov-90	25.10
	D01A	16	5	18-Dec-90	22.60
110	D03	16	6	30-Jan-89	13.50
	D03	16	6	01-Nov-89	19.10
111	D04	16	6	30-Jan-89	6.30
	D04	16	6	01-Nov-89	2.15
	D04	16	6	17-May-90	7.91
112	D05	16	6	30-Jan-89	16.20
	D05	16	6	01-Nov-89	19.90
113	D10	16	6	11-Mar-82	11.80
	D10	16	6	26-Jan-89	13.10
	D10	16	6	02-Nov-89	24.20
114	D13	13	3	23-Jan-89	14.60
	D13	13	3	02-Nov-89	8.40
115	D15	13	1	09-Feb-89	27.50
	D15	13	1	02-Nov-89	23.85
116	D19	13	1	09-Feb-89	41.50
	D19	13	1	02-Nov-89	23.05
117	D25	16	8	13-Feb-89	7.75

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
	D25	16	8	01-Nov-89	4.60
118	D5A	16	3	23-Feb-89	6.75
	D5A	16	3	17-May-90	7.64
119	D99	13	1	09-Feb-89	4.60
	D99	13	1	02-Nov-89	13.85
120	FARMER#1	16	3	22-Feb-89	10.60
	FARMER#1	16	3	24-May-89	7.46
121	FOSTER	13	5	06-Oct-71	6.20
	FOSTER	13	5	06-Oct-71	6.20
	FOSTER	13	5	14-Jan-81	22.70
	FOSTER	13	5	14-Jan-81	22.70
	FOSTER	13	5	25-Feb-81	32.20
	FOSTER	13	5	25-Feb-81	32.20
	FOSTER	13	5	28-May-81	16.00
	FOSTER	13	5	28-May-81	16.00
	FOSTER	13	5	24-Sep-81	14.60
	FOSTER	13	5	24-Sep-81	14.60
	FOSTER	13	5	10-Dec-81	12.50
	FOSTER	13	5	10-Dec-81	12.50
	FOSTER	13	5	11-Mar-82	19.00
	FOSTER	13	5	11-Mar-82	19.00
122	G10	16	9	30-Sep-71	7.94
	G10	16	9	18-Mar-73	6.60
	G10	16	9	17-Jul-73	6.48
	G10	16	9	05-Sep-73	6.63

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
	G10	16	9	16-Nov-73	7.16
	G10	16	9	24-Jan-74	7.70
	G10	16	9	10-Apr-74	8.13
	G10	16	9	04-Jun-74	8.80
	G10	16	9	01-Aug-74	8.45
	G10	16	9	24-Oct-74	7.80
	G10	16	9	07-Jan-75	8.20
	G10	16	9	02-Apr-75	9.30
	G10	16	9	21-May-75	9.10
	G10	16	9	15-Jul-75	9.90
	G10	16	9	10-Sep-75	10.40
	G10	16	9	13-Nov-75	10.50
	G10	16	9	12-Feb-76	9.40
	G10	16	9	08-Apr-76	8.00
	G10	16	9	27-May-76	7.10
	G10	16	9	22-Jul-76	6.75
	G10	16	9	16-Sep-76	6.30
	G10	16	9	18-Nov-76	5.90
	G10	16	9	13-Jan-77	5.00
	G10	16	9	21-Feb-77	5.60
	G10	16	9	31-Mar-77	6.30
	G10	16	9	13-May-77	5.75
	G10	16	9	23-Jun-77	6.60
	G10	16	9	11-Aug-77	6.90
	G10	16	9	22-Sep-77	6.80
	G10	16	9	03-Nov-77	6.80
	G10	16	9	12-Jan-78	6.40
	G10	16	9	23-Feb-78	6.10
	G10	16	9	06-Apr-78	6.60
	G10	16	9	25-May-78	6.60

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
	G10	16	9	20-Jul-78	6.50
	G10	16	9	30-Aug-78	6.50
	G10	16	9	19-Oct-78	6.00
	G10	16	9	06-Dec-78	7.00
	G10	16	9	14-Jan-81	5.75
	G10	16	9	25-Feb-81	5.75
	G10	16	9	28-May-81	6.20
	G10	16	9	03-Sep-81	6.60
	G10	16	9	24-Sep-81	6.60
	G10	16	9	10-Dec-81	8.25
	G10	16	9	11-Mar-82	7.70
	G10	16	9	01-Nov-89	12.70
123	GP1	16	7	19-Jan-90	21.00
	GP1	16	7	20-Mar-90	18.70
	GP1	16	7	17-May-90	18.03
	GP1	16	7	18-Jul-90	18.45
	GP1	16	7	14-Aug-90	18.20
	GP1	16	7	19-Sep-90	18.80
	GP1	16	7	18-Oct-90	16.75
	GP1	16	7	22-Nov-90	16.00
	GP1	16	7	18-Dec-90	16.40
124	S1	16	3	15-Feb-88	7.48
	S1	16	3	18-Jul-90	9.59
125	S3	13	2	20-Aug-73	1.21
	S3	13	2	05-Sep-73	2.00
	S3	13	2	15-Oct-73	0.16
	S3	13	2	15-Nov-73	3.52

Table 1 Nitrate as Nitrogen Concentrations from wells sampled within the Abbotsford Aquifer (1955 - 1990)

Map Reference No.	Locator Code	Township	Section	Sampled Date	Nitrate (mg/L)
	S3	13	2	10-Apr-74	2.66
	S3	13	2	01-Aug-74	3.08
	S3	13	2	07-Jan-75	3.00
	S3	13	2	21-May-75	3.30
	S3	13	2	15-Jul-75	2.50
	S3	13	2	10-Sep-75	2.50
	S3	13	2	13-Nov-75	2.40
	S3	13	2	08-Apr-76	2.80
	S3	13	2	27-May-76	2.14
	S3	13	2	22-Jul-76	3.10
	S3	13	2	16-Sep-76	1.65
	S3	13	2	18-Nov-76	2.50
	S3	13	2	13-Jan-77	1.20
	S3	13	2	21-Feb-77	2.00
	S3	13	2	31-Mar-77	2.60
	S3	13	2	11-Aug-77	4.60
	S3	13	2	15-Feb-88	4.18
	S3	13	2	16-Feb-88	4.20
	S3	13	2	18-Jul-90	6.17

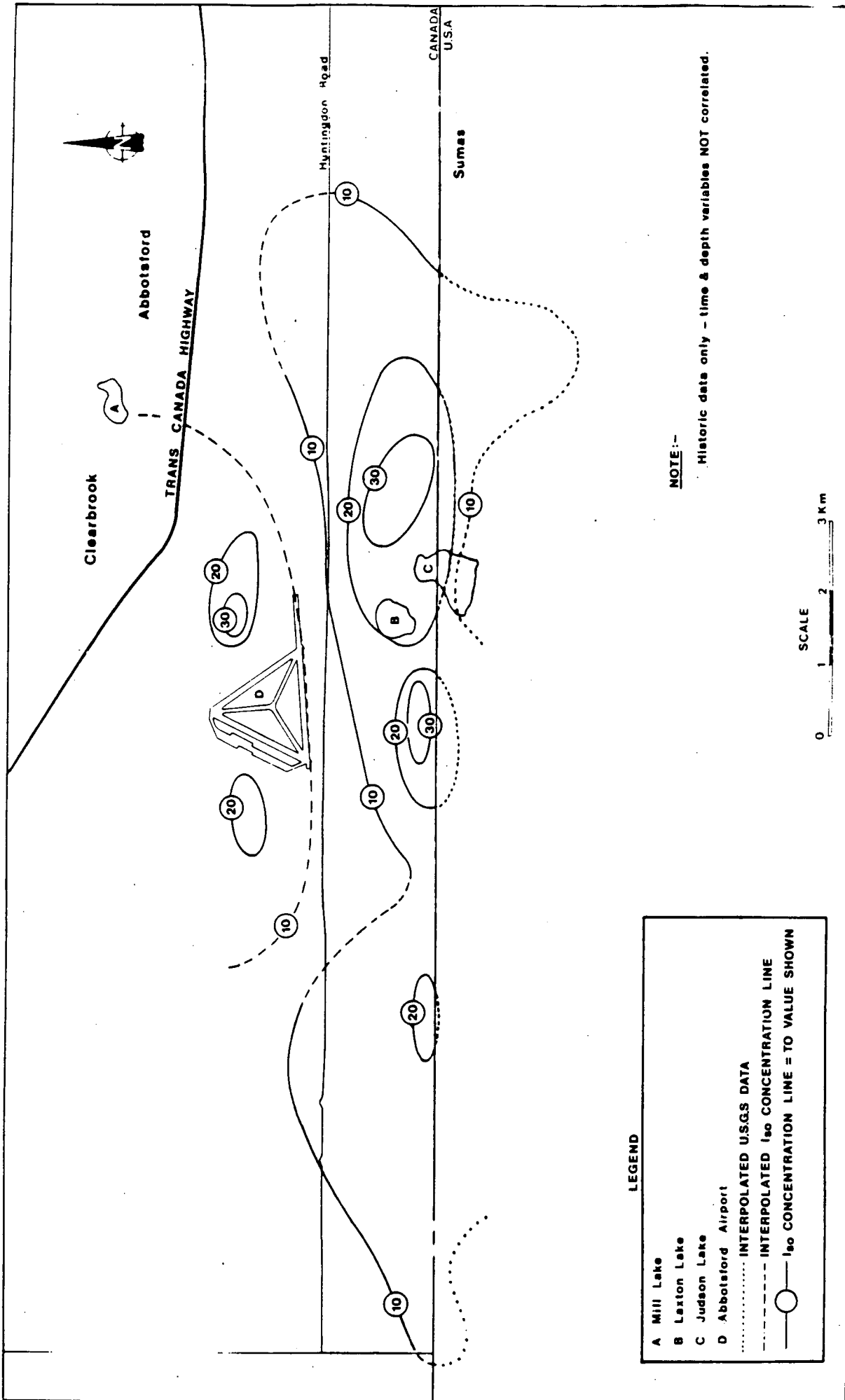
3.1 Nitrate Concentrations

Since 1984 sampling of ground waters specifically for nitrates in the Abbotsford aquifer has been focused on those areas of the aquifer that appear to be most severely impacted. Consequently, the results reported here in are representative of the most severely impacted parts of the aquifer.

Kwong (1986) conducted a data review and a field sampling study in the South Matsqui and South Abbotsford area to investigate nitrates in the aquifer. He reported that much of the ground water in this area, including parts of the confined and partly confined aquifer, are contaminated with nitrates. Environment Canada's 1989 sampling results from the same general area found 46 out of 73 sample sites with nitrate as nitrogen concentrations greater than 10 mg/L, the maximum acceptable concentration set by federal drinking water guidelines. The mean for these samples was 13.08 mg/L, with 0.0 mg/L and 41.5 mg/L as minimum and maximum concentrations detected.

There are 5 areas in the mid and western sections of the aquifer where nitrate concentrations have exceeded 20 mg/L (Figure 10). Ground water quality in the eastern portion of the aquifer, where the aquifer is generally confined or semi-confined, and is thus partially protected from direct surface contamination, show the presence of nitrates but in lower concentrations than those found to the west.

FIG.10 NITRATE AS NITROGEN CONCENTRATIONS FROM TABLE 1 & INTERPOLATED U.S.G.S DATA



3.2 Nitrate Trends

Nitrate concentrations within the study area appear to be increasing at some long term monitoring stations (Figures 11a & 11b) and several sites monitored over a short time period (one year), suggest local decreasing trends (Figures 12a & 12b). Nitrate data in Table 1 have been grouped by monitoring station and are listed in chronological order. Meaningful mathematical correlations are difficult to present, in part because of the size of the data base, the irregular sampling frequency, the sampling bias toward highly impacted areas, depth below water table, seasonal fluctuations, and changing land use practices.

A compilation of all available nitrate data (Figure 13) shows an increasing spread in the range of concentrations over time. The plot of annual means shown on the same figure suggests that the trend is to progressively higher ground water nitrate concentrations over time.

3.3 Discussion - Nitrates

Exposed manure stockpiles (Gilmour et al., 1987; Ritter et al, 1984), manure soil enhancement, septic effluent discharges (Canter and Knox 1986), airport de-icing urea formaldehyde, soil nitrate mineralization and manure and chemical fertilizers, are believed to be sources of nitrate contamination to Abbotsford aquifer ground waters. The degree of contamination from each of these sources remains unknown.

Manures destined for spreading and incorporation onto the raspberry farms are sometimes left in exposed stockpiles or spread on land during the winter months. Rain and snow melt percolating through these materials solubilize selected nitrogen compounds and carry them down into the aquifer.

Fig. 11a Increasing Nitrate Concentrations
From Sample Location D01 - Map Ref. No. 108 in Table 1

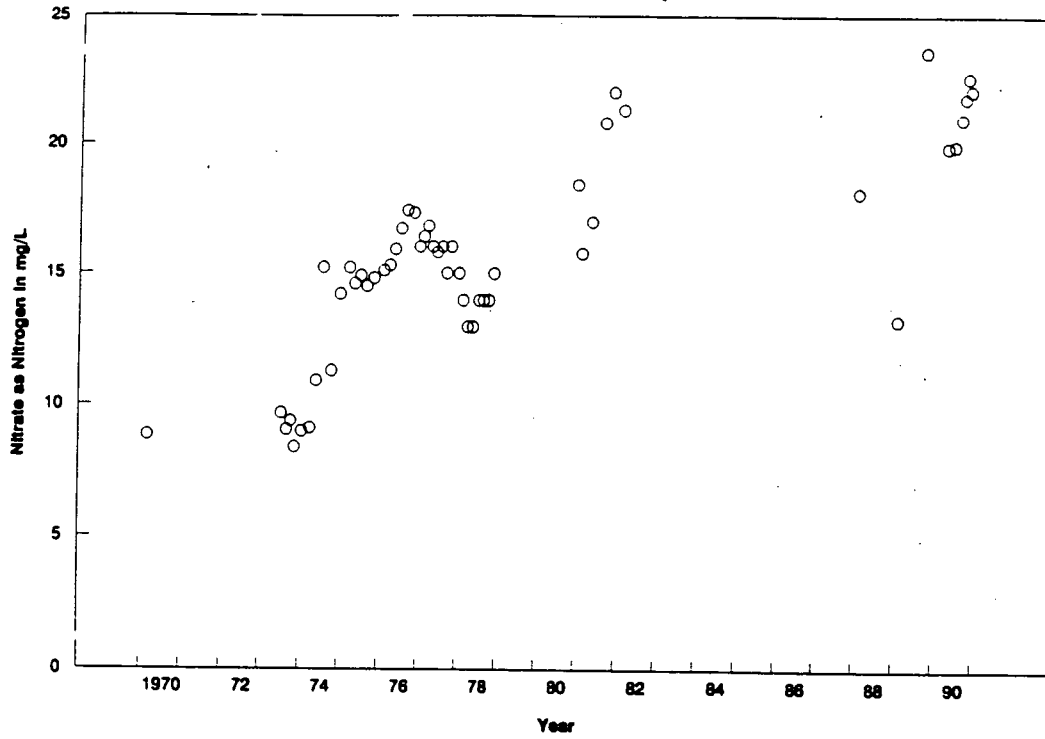


Fig. 11b Increasing Nitrate Concentrations
From Sample Location S3 - Map Ref. No. 125 in Table 1

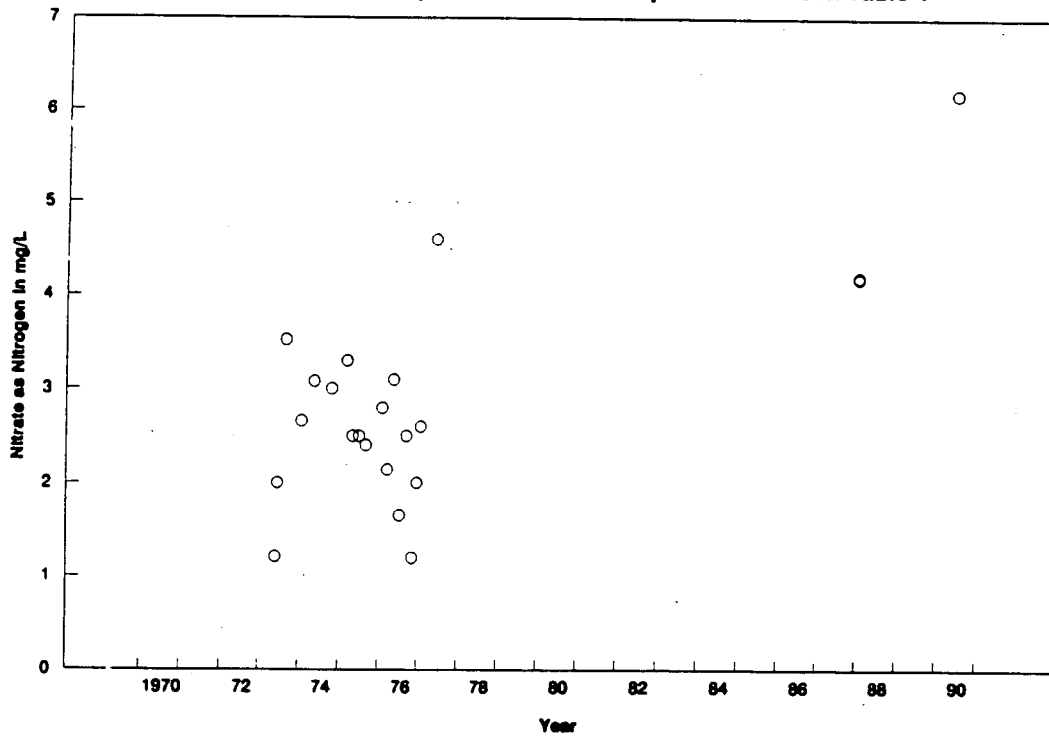


Fig. 12a Decreasing Nitrate Concentrations
From Sample Location CDA2 - Map Ref. No. 107 In Table 1

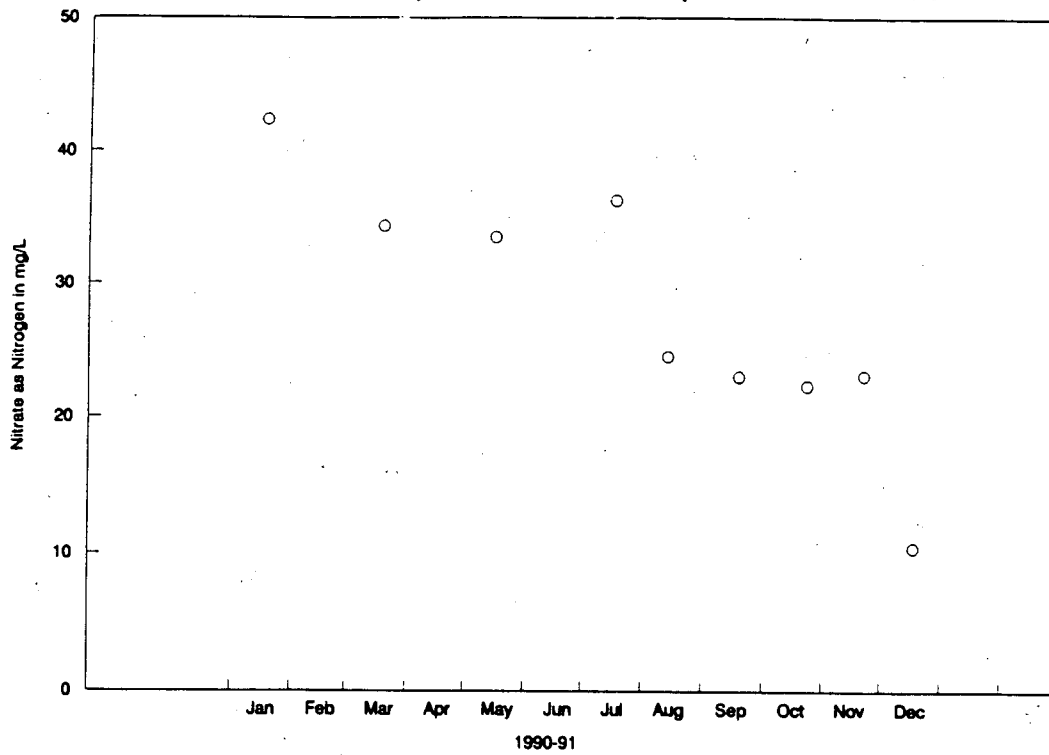


Fig. 12b Decreasing Nitrate Concentrations
From Sample Location GP1 - Map Ref. No. 123 In Table 1

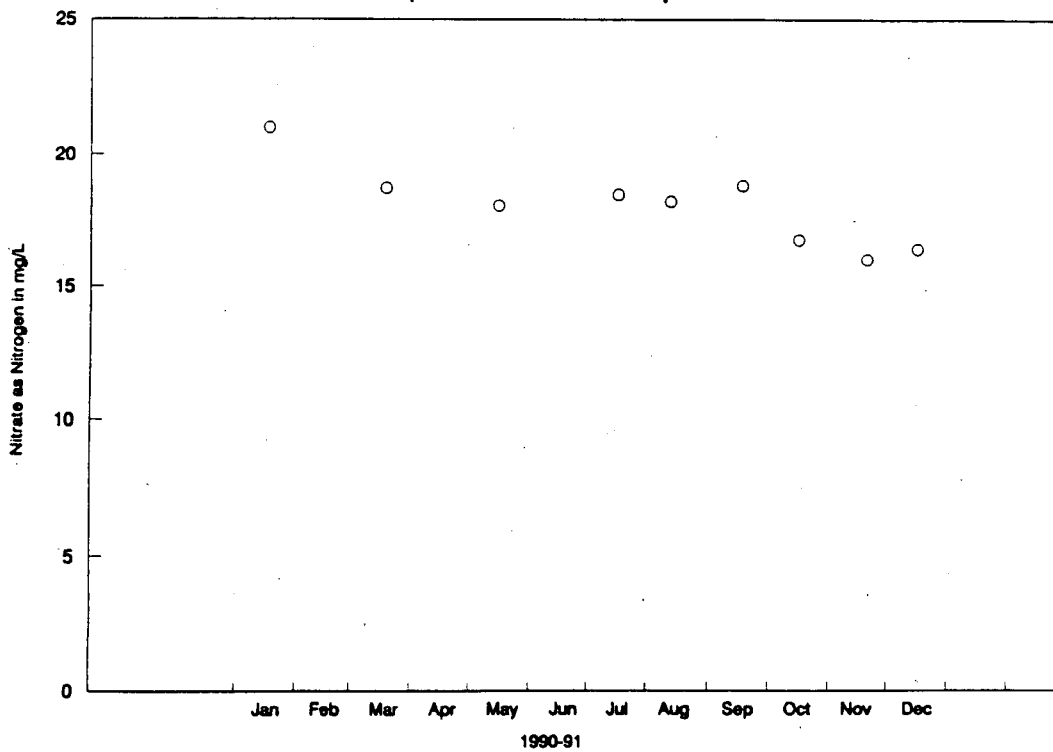
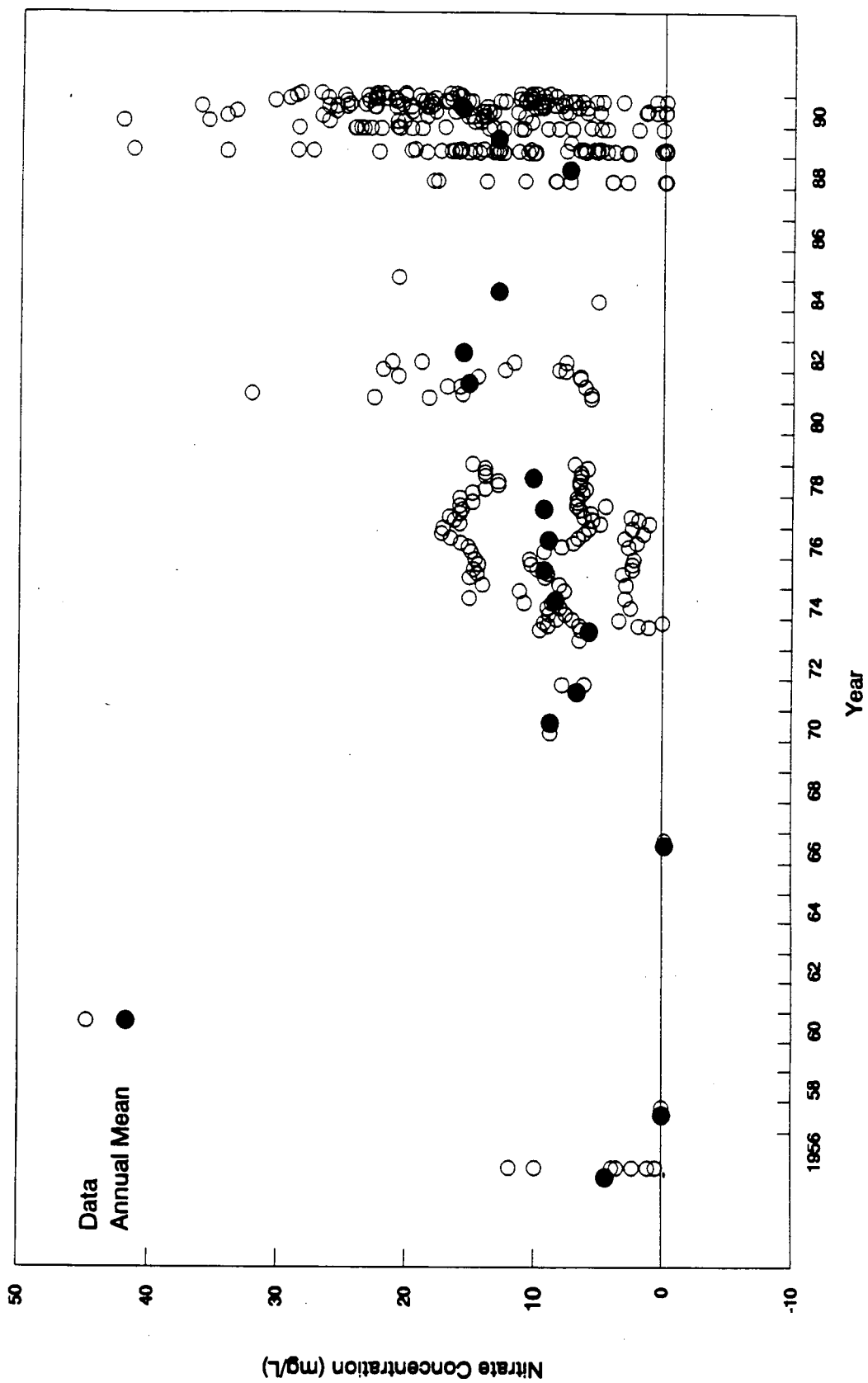


Fig. 13 Nitrate as Nitrogen Concentration
All samples as in Table 1



Manure fertilizer application to fields during the winter months provides very little, if any, benefit to crops but provides a source of nitrate contamination to the underlying ground waters. Similarly, the heavy loading of poultry manures to fields specifically for soil enhancement causes similar degradation of ground water supplies, particularly during the winter months.

Septic effluent drain fields located within or below shallow soils can be considered a nitrate source to ground water contamination because the underlying coarse sands and gravels provide very little attenuation of sewage effluent.

Malfunctioning and poorly designed septic fields, outdoor manure stockpiling, soil nitrate mineralization, and other land use practices in the adjoining low hydraulic conductivity (clay) upland areas are also sources of nitrate contributing to ground water contamination in both the aquifer and Matsqui Lowland.

4.0 PESTICIDES

4.1 Use

The first pesticide investigation by Environment Canada involved a small ground water sampling project in 1984, in which several domestic wells south of the Abbotsford Airport were sampled and analyzed for the then most commonly used pesticide, a nematocide, 1,2 dichloropropane. Subsequently, more extensive sampling was carried out with an expanded list of pesticides (Table 2) with sampling emphasis focused in areas of initial detection. The expanded survey has evolved into a monitoring and research program. Data are being provided to both federal and provincial toxicologists on a regular basis. Data summaries will be published at 1 year intervals. Research papers will be published as results warrant.

4.2 Pesticide Detections

The chemistry of pesticides in soil is complex. The potential for a pesticide to contaminate groundwater is determined by the mobility of the pesticide in soil, the persistence of the pesticide, climatic conditions, and soil properties. Pesticide leaching will be enhanced with increasing pesticide mobility, increasing persistence in soil, and increasing rate and frequency of application. The potential for pesticide leaching is increased with increasing precipitation, particularly when the precipitation occurs shortly after pesticide application and when the precipitation occurs as an intense rainfall event. In general, pesticide mobility and persistence is increased in soils which are coarse textured and are low in organic matter.

During initial pesticide sampling in 1984, the National Hydrology Research Institute (NHRI) collected 21 ground water samples from domestic and irrigation wells located between Fishtrap Creek and Clearbrook Road (Figure 9). Three piezometers were installed and sampled at the Agriculture Canada Agassiz Research Substation on Clearbrook Road.

Additional drilling and sampling programs were later conducted in the study area and expanded eastward to Mackenzie Road and westward to Bradner Road. These studies concentrated on domestic and irrigation supply wells, and piezometers. Target compounds, listed in Table 2, were selected on the basis of a pesticide use survey conducted in the Abbotsford area.

Table 2 List of Targeted Pesticides

Pesticide Group	Pesticide	Detected
Organophosphorus	EPTC	No
	Dimethoate	Yes
	Diazinon	Yes
	Malathion	No
	Guthion	No
Organonitrogen	Atrazine	Yes
	Simazine	Yes
Carbamate	Carbaryl	No
	Carbofuran	Yes
Phenoxy-acid	Dichlobenil	No
	Dicamba	No
	MCPA	No
	2,4-D	No
Dinitrophenol	Dinoseb	Yes
Organochlorine	Endosulfans	Yes
	O,P'-DDT	Yes
	P,P'-DDT	No
	P,P'-DDE	No
	P,P'-DDD	No
	1,2 dichloropropane	Yes
	1,3 dichloropropene	Yes
	Chlordane	Yes
Acetamide	Alachlor	Yes

Field sampling methods are listed in Appendix B. The analyzing laboratories included National Hydrology Research Institute (Ottawa), B.C. Research (Vancouver), and Envirotest Laboratories (Edmonton).

Most of the pesticide detections were found in the coarse sands and gravels south of the airport in South Matsqui, (Figure 14). Tables 3 and 4 list the analytical results (ug/L) for the twelve pesticides detected in the ground waters of the Abbotsford aquifer. Table 4 lists the analytical results for 1,2 dichloropropane. Table 5 summarises the drinking water guidelines, criteria, and standards for Canada, US EPA, and Washington State. The detection limits for pesticides varied depending on the analytical methods used and on the laboratory doing the analyses (Table 6).

Because relatively little research has been done on pesticide leaching in soil under lower Fraser Valley conditions, and because relatively little is known about some of the pesticide compounds mentioned in the report, particularly 1,2-DCP, it is difficult to comment further on the pesticide results.

Table 3 Pesticide Detections for Locations shown in Figure 14.

Map Ref. No.	Locator Code	Township	Section	Sampled Date	Dinoseb (ppb)	Simazine (ppb)	Alachlor (ppb)	Atrazine (ppb)	Dimethoate (ppb)	Diazinon (ppb)	Chlordane (ppb)	Endosulfan (ppb)	1,3 DCP (ppb)	DDT (ppb)	Carbofuran (ppb)
1	BC71	16	5	12-Feb-85				0.01							
2	D34	16	5	12-Feb-85				1.20		0.70					
3	BC73	16	6	12-Feb-85				0.03							
4	ABB10	16	5	26-Aug-87											0.19
5	ABB1	13	3	26-Aug-87					0.24	0.05					
6	ABB37	16	5	26-Aug-87				0.01							
7	ABB21	16	4	26-Aug-87										0.01	
8	BC65	13	11	21-Oct-87											
9	F03	13	1	23-Jan-89	0.02										
10	D09	16	6	26-Jan-89	0.06						0.03				0.40
11	D10	16	6	26-Jan-89		0.10									
12	D04	16	6	30-Jan-89		0.10									
13	F03	13	2	06-Feb-89		0.10									
14	F01-35	13	1	06-Feb-89				0.20							
15	F01-25	13	1	06-Feb-89		0.10		0.20							

1,2 DCP data are presented in Table 4
 Samples having less than detection limits of pesticides are not included in this table.
 Refer to Table 6 for different detection limits.

Table 3 Pesticide Detections for Locations shown in Figure 14.

Map Ref. No.	Locator Code	Township	Section	Sampled Date	Dinoseb (ppb)	Simazine (ppb)	Alachlor (ppb)	Atrazine (ppb)	Dimethoate (ppb)	Diazinon (ppb)	Chlordane (ppb)	Endosulfan (ppb)	1,3 DCP (ppb)	DDT (ppb)	Carbofuran (ppb)
16	D18	13	1	09-Feb-89	0.02										
17	D02	16	5	13-Feb-89	0.09					0.05					
18	D01	16	5	13-Feb-89	0.02					0.05					
19	D41	13	4	13-Feb-89	0.10			0.20							
20	D29	7	26	20-Feb-89						0.30					
21	D32	10	34	20-Feb-89						0.05					
22	D26	7	24	20-Feb-89	0.02							0.13			
23	D43	16	18	27-Feb-89						2.00					
24	P-A-35	13	1	04-Apr-89				0.16							
25	P-A-25	13	1	04-Apr-89				0.14							
26	CDA1	16	5	04-Apr-89			1.00								
27	P-C-25	13	1	04-Apr-89											0.50
28	I02	13	2	16-Mar-90	1.72										
29	D15	13	1	16-Mar-90		0.10		0.20				0.02			
30	D05	16	6	16-Mar-90								0.02			

1,2 DCP data are presented in Table 4
 Samples having less than detection limits of pesticides are not included in this table.
 Refer to Table 6 for different detection limits.

Table 3 Pesticide Detections for Locations shown in Figure 14.

Map Ref. No.	Locator Code	Township	Section	Sampled Date	Dioxeb (ppb)	Simazine (ppb)	Alachlor (ppb)	Atrazine (ppb)	Dimethoate (ppb)	Diazinon (ppb)	Chlordane (ppb)	Endosulfan (ppb)	1,3 DCP (ppb)	DDT (ppb)	Carbofuran (ppb)
31	D19	13	1	09-Feb-89					0.05						
	D19	13	1	16-Mar-90		0.10									
32	D24	13	4	13-Feb-89	0.85								3.50		
	D24	13	4	16-Mar-90	1.95										
33	BC66	13	1	17-Nov-86											0.40
	BC66	13	1	05-Jan-87											1.40
34	BC67	13	1	17-Nov-86											0.40
	BC67	13	1	30-Dec-86											0.50
35	BC68	13	1	17-Nov-86											0.10
	BC68	13	1	30-Dec-86											0.07
36	BC69	13	13	17-Nov-86											0.20

1,2 DCP data are presented in Table 4
 Samples having less than detection limits of pesticides are not included in this table.
 Refer to Table 6 for different detection limits.

Table 3 Pesticide Detections for Locations shown in Figure 14.

Map Ref. No.	Locator Code	Town ship	Section	Sampled Date	Dinoseb (ppb)	Simazine (ppb)	Alechlor (ppb)	Atrazine (ppb)	Dimethoate (ppb)	Diazinon (ppb)	Chlordane (ppb)	Endosulfan (ppb)	1,3 DCP (ppb)	DDT (ppb)	Carbofuran (ppb)
	BC69	13	13	30-Dec-86											0.20
37	BC72	16	6	12-Feb-85				4.00							
	BC72	16	6	16-Mar-90	0.12			0.30	0.05						
38	BC75	16	6	04-Mar-85		0.17									
	BC75	16	6	22-May-85		0.70									
	BC75	16	6	10-Jul-85		1.25									
	BC75	16	6	29-Jul-85		0.89									
39	BC94	13	4	12-Dec-86											2.00
	BC94	13	4	22-Dec-86											0.60
	BC94	13	4	21-Jan-87											3.00
	BC94	13	4	19-Mar-87											12.00
	BC94	13	4	25-Mar-87											5.00
	BC94	13	4	16-Apr-87											9.00

1,2 DCP data are presented in Table 4
 Samples having less than detection limits of pesticides are not included in this table.
 Refer to Table 6 for different detection limits.

Table 3 Pesticide Detections for Locations shown in Figure 14.

Map Ref. No.	Locator Code	Town ship	Section	Sampled Date	Dimethob	Simazine	Alachlor	Atrazine	Dimethoate	Diazinon	Chlordane	Endosulfan	1,3 DCP	DDT	Carbo furan
	BC94	13	4	14-May-87											5.00
	BC94	13	4	17-Jul-87											1.50
	BC94	13	4	14-Oct-87											4.00
	BC94	13	4	16-Mar-90				0.20							

1,2 DCP data are presented in Table 4
 Samples having less than detection limits of pesticides are not included in this table.
 Refer to Table 6 for different detection limits.

Table 4 1,2 Dichloropropane (DCP) Concentrations for Locations shown in Figure 15.

Map Reference No.	Locator Code	Township	Section	Sampled Date	1,2 DCP (ppb)	Well Depth (m)	Static Level (m)
1	I04	13	1	30-Aug-84	0.00		
2	I05	13	1	30-Aug-84	3.54		3.66
3	I06	13	1	30-Aug-84	0.00	8.53	
4	BC81	16		11-Feb-85	0.00		
5	BC80	16	5	11-Feb-85	0.00	51.51	27.74
6	BC84	16	5	11-Feb-85	0.00	39.32	21.95
7	BC83	16	5	11-Feb-85	0.00	29.26	
8	BC82	16	5	11-Feb-85	0.00	41.15	29.57
9	BC79	16	5	11-Feb-85	0.00		
10	BC78	16	5	11-Feb-85	0.00		
11	BC89	16	5	12-Feb-85	0.00	33.53	21.95
12	BC73	16	6	12-Feb-85	0.00	12.80	4.57
13	BC87	16	6	12-Feb-85	0.00	18.29	
14	BC86	16	5	12-Feb-85	0.00	0.00	
15	BC76	16	5	12-Feb-85	0.00	31.40	
16	BC85	16	5	12-Feb-85	0.00	30.48	
17	BC92	13	1	13-Feb-85	0.00	27.43	
18	BC91	13	1	13-Feb-85	0.00		
19	BC70	13	1	13-Feb-85	<0.10		
20	BC90	16	6	13-Feb-85	0.00	10.67	1.53
21	BC68	13	1	13-Feb-85	0.00	25.60	
22	BC74	13	1	13-Feb-85	<0.10		
23	BC93	13	1	13-Feb-85	0.00	7.62	
24	BC77	16	5	04-Mar-85	0.00	46.32	26.21
25	BC75	16	6	04-Mar-85	0.00	18.29	
26	BC88	16	6	04-Mar-85	0.00	10.67	
27	ABB1	13	3	29-Jun-87	0.00		
28	CDA4	16	5	29-Jun-87	4.00		
29	ABB11	16	5	30-Jun-87	4.00		
30	ABB15	16	10	30-Jun-87	0.00	65.84	7.92
31	ABB27	16	4	30-Jun-87	0.00		

Table 4 1,2 Dichloropropane (DCP) Concentrations for Locations shown in Figure 15.

Map Reference No.	Locator Code	Township	Section	Sampled Date	1,2 DCP (ppb)	Well Depth (m)	Static Level (m)
32	ABB24	16	4	30-Jun-87	0.00	26.00	16.80
33	ABB30	16	4	30-Jun-87	0.00		
34	ABB21	16	4	30-Jun-87	0.00		
35	ABB18	16	4	30-Jun-87	0.00		
36	ABB7	16	5	30-Jun-87	11.00*	24.69	15.24
37	ABB13	16	5	30-Jun-87	0.00		
38	ABB41	16	5	01-Jul-87	0.00		
39	ABB33	16	4	01-Jul-87	0.00		
40	F05	13	2	23-Jan-89	0.00	4.23	1.42
41	F03	13	1	23-Jan-89	0.00	9.65	4.83
42	F02	16	6	26-Jan-89	0.00	16.27	12.10
43	P01-25	13	1	06-Feb-89	0.00	8.25	3.20
44	P01-35	13	1	06-Feb-89	0.00	11.30	3.02
45	P01-50	13	1	06-Feb-89	0.00	17.57	3.04
46	P02	13	1	06-Feb-89	0.00	7.98	3.16
47	P03	13	2	06-Feb-89	0.20	6.39	2.87
48	D22	16	5	06-Feb-89	0.00	40.23	27.43
49	D18	13	1	09-Feb-89	0.00	15.20	
50	D21	13	1	09-Feb-89	0.00	12.80	10.70
51	D41	13	4	13-Feb-89	0.00		
52	D25	16	8	13-Feb-89	0.00	36.60	
53	D28	7	13	20-Feb-89	0.00	18.30	
54	D29	7	26	20-Feb-89	0.00	45.70	
55	D31	11	3	20-Feb-89	0.00	4.60	
56	D26	7	24	20-Feb-89	0.00	9.80	
57	D32	10	34	20-Feb-89	0.00	33.50	
58	D30	10	34	20-Feb-89	0.00	6.10	3.10
59	D5A	16	3	23-Feb-89	0.00	18.30	12.20
60	D38	13	11	23-Feb-89	0.00		
61	D40	16	3	23-Feb-89	0.00		

* Included in the table but not in discussion because of suspected sampling or analytical error.

Table 4 1,2 Dichloropropane (DCP) Concentrations for Locations shown in Figure 15.

Map Reference No.	Locator Code	Township	Section	Sampled Date	1,2 DCP (ppb)	Well Depth (m)	Static Level (m)
62	D39	13	14	23-Feb-89	0.00	7.30	
63	D46	16	4	23-Feb-89	0.00	26.00	12.20
64	D45	13	4	27-Feb-89	0.00		
65	D3A	13	9	27-Feb-89	0.00		
66	D50	11	3	27-Feb-89	0.20	36.60	
67	D43	16	18	27-Feb-89	0.00		
68	D48	16	9	27-Feb-89	0.00	15.00	
69	D47	16	7	27-Feb-89	0.00	18.30	11.00
70	G10	16	9	16-Mar-90	0.00	49.68	27.43
71	BC66	13	1	16-Mar-90	0.00	4.57	
72	BC94	13	4	16-Mar-90	0.00		
73	ABB1	13	3	01-Apr-90	0.00		
74	ABB2	13	1	01-Apr-90	4.00		
75	ABB6	13	1	01-Apr-90	4.00		
76	P-B-25			01-Apr-90	1.00		
77	P-B-35			01-Apr-90	4.00		
78	P-B-55			01-Apr-90	1.00		
79	CDA2			01-Apr-90	1.00		
80	ABB10	16	5	30-Aug-84	5.52	24.69	15.24
	ABB10	16	5	30-Jun-87	0.00*	24.69	
81	ABB37	16	5	01-Jul-87	0.00	40.23	
	ABB37	16	5	16-Mar-90	<0.10	40.23	27.43
82	BC71	16	5	12-Feb-85	0.00	41.75	28.04
	BC71	16	5	16-Mar-90	0.00	41.75	
83	BC72	16	6	12-Feb-85	0.00	15.85	
	BC72	16	6	16-Mar-90	0.00	15.85	

* Included in the table but not in discussion because of suspected sampling or analytical error.

Table 4 1,2 Dichloropropane (DCP) Concentrations for Locations shown in Figure 15.

Map Reference No.	Locator Code	Township	Section	Sampled Date	1,2 DCP (ppb)	Well Depth (m)	Static Level (m)
84	D01	16	5	13-Feb-89	0.60	24.69	
	D01	16	5	16-Mar-90	0.60	24.69	15.24
85	D02	16	5	30-Aug-84	0.74		
	D02	16	5	13-Feb-89	0.20		
86	D03	16	6	30-Aug-84	0.00		
	D03	16	6	30-Jan-89	0.00		
87	D04	16	6	30-Aug-84	0.00		
	D04	16	6	30-Jan-89	0.00		
88	D05	16	6	30-Aug-84	0.79	12.50	3.66
	D05	16	6	30-Jan-89	0.50	12.50	
	D05	16	6	16-Mar-90	0.10	12.50	
89	D06	16	6	30-Aug-84	0.00		
	D06	16	6	26-Jan-89	0.00		
90	D08	13	1	30-Aug-84	0.00		
	D08	13	1	26-Jan-89	0.00		
91	D09	16	6	30-Aug-84	1.91	50.29	
	D09	16	6	12-Feb-85	<0.10	50.29	
	D09	16	6	26-Jan-89	0.80	50.29	5.49
	D09	16	6	16-Mar-90	0.60	50.29	
92	D10	16	6	30-Aug-84	0.15	11.00	
	D10	16	6	13-Feb-85	0.00	11.00	
	D10	16	6	26-Jan-89	0.10	11.00	

Table 4 1,2 Dichloropropane (DCP) Concentrations for Locations shown in Figure 15.

Map Reference No.	Locator Code	Township	Section	Sampled Date	1,2 DCP (ppb)	Well Depth (m)	Static Level (m)
93	D11	13	3	30-Aug-84	0.00	7.60	
	D11	13	3	23-Jan-89	0.00	7.60	
94	D12	13	3	30-Aug-84	0.00	30.00	
	D12	13	3	23-Jan-89	0.00	30.00	
95	D13	13	3	30-Aug-84	0.00	9.10	
	D13	13	3	23-Jan-89	0.00	9.10	4.60
96	D14	13	2	30-Aug-84	0.00	12.20	
	D14	13	2	13-Feb-89	0.00	12.20	
97	D15	13	1	30-Aug-84	1.22	9.10	
	D15	13	1	09-Feb-89	0.40	9.10	
	D15	13	1	16-Mar-90	0.10	9.10	
98	D17	16	6	13-Feb-85	0.00	12.19	4.27
	D17	16	6	23-Jan-89	0.00	12.19	
99	D19	13	1	09-Feb-89	0.40		
	D19	13	1	16-Mar-90	0.10		
100	D20	13	1	30-Aug-84	0.00	6.00	
	D20	13	1	09-Feb-89	0.00	6.00	
101	D24	13	4	13-Feb-89	1.30		
	D24	13	4	16-Mar-90	<0.10		
102	D34	16	5	12-Feb-85	0.00	45.70	
	D34	16	5	23-Feb-89	0.00	45.70	

Table 4 1,2 Dichloropropane (DCP) Concentrations for Locations shown in Figure 15.

Map Reference No.	Locator Code	Township	Section	Sampled Date	1,2 DCP (ppb)	Well Depth (m)	Static Level (m)
103	D99	13	1	13-Feb-85	0.00		
	D99	13	1	09-Feb-89	0.00		
104	F04	13	1	26-Jan-89	4.60	8.00	
	F04	13	1	06-Sep-89	0.00	8.00	1.44
105	I01	16	6	30-Aug-84	0.42		6.10
	I01	16	6	16-Mar-90	0.10		
106	I02	13	2	30-Aug-84	0.38	12.19	
	I02	13	2	16-Mar-90	0.10	12.19	3.66
107	I03	16	6	30-Aug-84	0.00		
	I03	16	6	16-Mar-90	0.00		

TABLE 5 CANADIAN, U.S. ENVIRONMENTAL PROTECTION AGENCY AND WASHINGTON STATE WATER QUALITY GUIDELINES, STANDARDS, AND CRITERIA

	CONCENTRATION (ppb)											Reference
	Dinoseb	Birmaxine	Alachlor	Alazine	Dimethoate	Diazinon	Chlordane	Endosulfen	1,3-Dichloropropene	1,2-Dichloropropene	DDT	
CANADIAN DRINKING WATER GUIDELINES												
Interim Maximum Acceptable Concentration	10.0	10.0	NRG	60.0	20.0	20.0	7.0*	NRG	NRG	NRG	30.0*	90.0
Maximum Acceptable Concentration (MAC)												
CANADIAN WATER QUALITY GUIDELINES												
Agricultural Uses												
- livestock watering	150.0	10.0 interim	CDWG	60 interim	4.9	CDWG	CDWG	CDWG	CDWG	CDWG	CDWG	45.0
- irrigation	18.0	0.5 interim	NRG	10 interim	NRG	NRG	NRG	NRG	NRG	NRG	NRG	NRG
Protection of Freshwater Aquatic Life	0.05	10.0	NRG	2.0	0.8 interim	NRG	0.005	0.02	NRG	NRG	0.001	1.7
U.S. ENVIRONMENTAL PROTECTION AGENCY												
a. DRINKING WATER STANDARDS												
status #	P	P	F	F	NR	NRS	F	NR	L	F	NR	F
MCLG	7.0	1.0	zero	3.0		NRS	zero		NRS	zero		40
MCL	7.0	1.0	2.0	3.0		NRS	2.0		NRS	5.0		40
For 10-kg child												
1-day	300	70	100	100		20	60		30			50
10-day	300	70	100	100		20	60		30			50
longer term	10	70	NRS	50		5.0	NRS		30			50
For 70-kg adult												
longer term	40	70	NRS	200		20	NRS		100			200
DWEL	40	200	400	200		3.0	2.0		10			200
Lifetime	7.0	NRS	40	3.0		0.8	NRS		NRS			40
cancer risk at 10-4	NRS	NRS	40	NRS		3.0	5.0		20			50
cancer group	D	C	B2	C		E	B2		B2			NRS
c. FRESHWATER AQUATIC LIFE CRITERIA												
								0.22		1.1		E
WASHINGTON STATE WATER QUALITY STANDARDS												
a. Drinking Waters	EPA	EPA	EPA	EPA	EPA	EPA	EPA	EPA	EPA	EPA	EPA	12, 13, 14, 16, 18
b. Ground Waters												
c. Surface Waters												

FOOTNOTES

DDT - parts per billion equals micrograms per liter.

DDT - DDT, DDE, DDD, and DDE.

NRG - No Recommended Guideline.

CDWG - Canadian Drinking Water Guidelines. CORM recommends the adoption of the Canadian guidelines for pesticides in drinking water as the maximum limits of pesticides in livestock drinking water as a means of providing a margin of safety for livestock and preventing unacceptable residues in animal products.

- under review.

EPA - U.S. Environmental Protection Agency. No State Drinking Water Standards for these pesticides.

NRS - No Recommended Standard.

NRG and status NA - P=final, P=proposed, L=listed for regulation.

MCLG - Maximum Contaminant Level Goal. A non-enforceable concentration of a drinking water contaminant that is protective of adverse human health effects and allows an adequate margin of safety.

MCL - Maximum Contaminant Level. Maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

DWEL - Drinking Water Equivalent Level. A lifetime exposure concentration protective of adverse, non-cancer health effects, that assumes all of the exposure to a contaminant is from a drinking water source.

NR - Not regulated.

* - An instantaneous concentration not to be exceeded at any time.

† - A 24 hour average not to be exceeded.

B2 - probable human carcinogen

C - possible human carcinogen

D - not classifiable

E - evidence of non-carcinogenicity

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Table 6 Laboratory Detection Limits

Pesticide	Detection Limit (ppb)				
	August 1984	June/July 1987	Jan/Feb 1989	April/May 1989	March 1990
Alachlor			0.10	0.50	
Atrazine		0.50	0.20	0.05	0.20
Azinphosmethyl			0.20		
BHC's			0.004		
Captan			0.10		
Carbaryl		0.50	1.00	0.05	1.00
Chlorothalonil			0.10		
Dazomet			0.10		
Diazinon		0.20	0.05	1.00	0.05
Dimethoate		0.20	0.05	0.50	0.05
Endosulfans		0.10	0.02		0.02
Folpet			0.10		
Malathion		0.20	0.10		
Metolachlor			0.50		
Parathion			0.10		
Phosmet			0.10		
Simazine		0.50	0.10	0.05	0.10
DDT		0.01	0.02	0.01	
DDE			0.01		
DDD			0.02		
Chlordane			0.02		0.02
Lindane			0.001		
Dinoseb			0.02	0.20	0.02
Glyphosate			5.00		
1,2 Dichloropropane	1.00	1.00	0.10	1.00	0.10
1,3 Dichloropropene			0.05		
Carbofuran		0.50		0.05	
EPTC		0.50			
Guthion		0.50		0.10	

1,2 dichloropropane

1,2 dichloropropane (1,2 DCP), a pesticide used for controlling nematodes in raspberry fields, was the most commonly used pesticide up to and including 1985 when its use as an active ingredient was discontinued by its manufacturers. Approximately 10,000 kg of 1,2 DCP was sold in the Abbotsford area in 1984. 1,3 dichloropropene (1,3 DCP) was used as a replacement for 1,2 DCP as the active ingredient for nematode control. It is reported that a cheaper nematocide, Vapam, is locally replacing 1,3 DCP (B. Peters, BCMOA, pers.com). Most of the nematocides are applied to nematode infested fields in the fall following raspberry cane removal. They are applied to each field at 8 to 10 year intervals depending upon degree of infestation.

1,2 DCP was detected in 40 of 139 samples in concentrations that range between <0.01 and 5.52 ppb (Table 4). The distribution of sample sites from which 1,2 DCP has been detected is shown in Figure 15.

The data show that 1,2 DCP has been detected in the south Matsqui area, and has persisted in local ground waters despite its use having been discontinued in 1987 when local supplies are believed to have been used up. There are no Canadian drinking water guidelines for this compound. Washington State ground water quality standards have been set at 0.6 ppb (Table 5).

1,3 dichloropropene

1,3 dichloropropene (1,3 DCP) was detected in 1 ground water sample with a concentration of 3.5 ppb. 1,3 DCP is a pesticide used for controlling nematodes in raspberry fields. There are no Canadian drinking water guidelines for this compound. Washington State ground water quality standards have been set at 0.2 ppb (Table 5).

Dinoseb

Dinoseb was detected in 11 of 58 ground water samples collected between 1985 and 1990, with concentrations ranging from 0.02 to 1.95 ppb (Table 3). Dinoseb is listed as a herbicide, desiccant and dormant fruit spray. Canadian Drinking Water Guidelines (CDWG) (1989) have a Maximum Acceptable Concentration (MAC) of 10.0 ppb (Table 5).

Simazine

Simazine was detected in 11 of 58 ground water samples collected between 1985 and 1990, with concentrations ranging from <0.01 to 1.25 ppb. Simazine is listed as a herbicide for weed control. Canadian Drinking Water Guidelines (1989) have set an interim MAC at 10.0 ppb.

Alachlor

Alachlor was detected in 1 of 58 ground water sample, with a concentration of 1.0 ppb. Alachlor is listed as a pre-emergence herbicide for controlling annual grasses and certain broadleaf weeds. There are no Canadian recommended drinking water guidelines for alachlor.

Atrazine

Atrazine was detected in 13 of 58 ground water samples collected between 1985 and 1990, with concentrations ranging from 0.01 to 4 ppb. Atrazine is listed as a selective and non-selective herbicide for season-long weed control. Canadian Drinking Water Guidelines (CDWG) have set an interim MAC at 60.0 ppb.

Dimethoate

Dimethoate was detected in 3 of 58 ground water samples collected between 1985 and 1990, with concentrations ranging from 0.05 to 0.24 ppb. Dimethoate is listed as a systemic insecticide - acaricide and is used as a residual wall spray in farm buildings for controlling flies and for controlling insects and mites on ornamental plants and crops. The CDWG has an interim MAC of 20.0 ppb.

Diazinon

Diazinon was detected in 7 of 58 ground water samples collected between 1985 and 1990, with concentrations ranging from 0.05 to 2.0 ppb. Diazinon is listed as an insecticide and nematocide. CDWG have set a MAC of 20.0 ppb.

Chlordane

Chlordane was detected in 1 of 58 ground water sample, collected in 1989, with a concentration of 0.03 ppb. Chlordane is listed as a contact insecticide. The CDWG lists a MAC of 7.0 ppb, which is currently under review.

Endosulfan

Endosulfan was detected in 3 of 58 ground water samples collected between 1985 and 1990, with concentrations ranging from 0.02 to 0.13 ppb. Endosulfan is listed as an insecticide and acaricide. The CDWG have no recent guideline for endosulfan.

DDT

O,P' - DDT was detected in 1 of 58 ground water samples, with a concentration of 0.01 ppb. DDT was once used as an insecticide. The CDWG lists a MAC of 30.0 ppb, which is currently under review.

Carbofuran

Carbofuran was detected in 20 of 58 ground water samples collected between 1985 and 1990, with concentrations ranging from 0.10 to 12 ppb. Carbofuran is listed as a broad spectrum insecticide, nematocide, and miticide. The CDWG MAC is 90.0 ppb.

4.3 Discussion

1,2 DCP is a commonly occurring, and the most persistent, pesticide identified in local ground waters in the south Matsqui area of the Abbotsford aquifer. There are no Canadian recommended drinking water guidelines for 1,2 DCP, but 19 of 139 samples analysed equaled or exceeded the Washington State ground water quality standard of 0.6 ppb (Table 5).

Currently, 1,2 DCP is applied in much smaller concentrations as a byproduct, of less than 0.5%, with the nematocide 1,3 dichloropropene. 1,2 DCP was not re-registered by the three manufacturers in 1985, and old stocks are believed by the manufacturers to have been used up by 1987.

1,3 dichloropropene (1,3 DCP) was detected in one sample, at 3.5 ppb, which exceeds Washington State ground water quality standards of 0.2 ppb. There are no Canadian drinking water quality guidelines for 1,3 DCP.

The ten other pesticides detected in the ground waters were dinoseb, simazine, alachlor, atrazine, dimethoate, diazinon, chlordane, endosulfan, DDT, and carbofuran. All were found in concentrations below Maximum Acceptable Concentrations listed in the Canadian Drinking Water Guidelines.

Freshwater aquatic guidelines for dinoseb, atrazine, endosulfan and carbofuran are much lower than CDWG MACs. A number of detections of all four pesticides exceeded the freshwater aquatic guidelines (Table 5). Ground water from the aquifer provides significant base flow to fish rearing creeks on both sides of the border and ground water is the sole source of water for the Fraser Valley Trout Hatchery.

5.0 CONCLUSIONS

The central and western sections of the Abbotsford aquifer comprise clean sands and gravels with very few lenses of clays. Consequently, contaminants from the land surface can migrate vertically downwards to the water table with minimum attenuation or dispersion. This has resulted in higher contaminant concentrations than in the eastern part of the aquifer.

The infiltration of nitrates from the land surface into the aquifer has resulted in nitrate concentrations, in parts of the aquifer, exceeding the maximum acceptable concentrations set under the Canadian Drinking Water Quality Guidelines (Health and Welfare Canada, 1989). There is an apparent trend that nitrate concentrations in the South Matsqui groundwaters are gradually increasing with time.

Ground water nitrate contamination is believed to originate from land use activities including exposed manure stockpiles, septic effluent fields, manures applied as fertilizers and soil enhancers during the winter months, chemical fertilizer application to cultivated lands and urea based deicing compounds. Similar activities in the adjacent clay uplands contribute contaminants in runoff to the aquifer following rainfalls.

Elevated nitrates are a sign of ground water contamination from local land use practices and can be used as a relatively low-cost indicator of both point source and non point source pollution. Elevated nitrate concentrations in a given area can be a signal that the potential for ground water contamination by fecal coliforms, solvents, pesticides and other liquids may also be possible.

Twelve different pesticides were detected between 1984 and 1990 in measurable concentrations in samples from wells and piezometers from the south Matsqui area. Two of the pesticides, 1,2 DCP and 1,3 DCP, for which there are no Canadian drinking water guidelines, equal or exceed the Washington State ground water quality standard. 1,2 dichloropropane was detected in 40 of 139 samples analysed, and is persistent at many sampling locations in South Matsqui despite not having been applied since 1987.

Dinoseb, simazine, alachlor, atrazine, dimethoate, diazinon, chlordane, endosulfan, DDT and carbofuran were detected in ground waters in concentrations well below established Canadian drinking water guidelines.

The sources of ground water contamination of the Abbotsford aquifer, as with most unconfined aquifers, are reasonably well understood. The mechanisms and degree of contamination from these contaminant sources are poorly understood. Improving existing legislation, screening pesticide use in high risk areas, research, implementing aquifer protection plans, evaluating application practices and educating local farmers to improve land use practices, would result in improvement of ground water quality in this aquifer. It would also provide long term protection of the resource, and would minimize the risks of contamination from other pollutants.

6.0 RECOMMENDATIONS

The following recommendations are presented to improve the quality of local ground water in affected areas of the Abbotsford aquifer, and would provide better ground water protection. Some of these recommendations have been initiated by other federal and provincial agencies.

1. Minimize nitrate contamination of the aquifer by improving manure management practices such as:
 - * discouraging uncovered manure stockpiling during fall and winter months;
 - * discouraging manure application during fall and winter months;
 - * restricting manure application rates and timing to appropriate nitrate consumption capabilities of crops; and
 - * eliminating soil enhancement practices whereby excessive manures are applied to the soils.
2. Encourage research into development of alternative manure handling practices such as composting wastes in excess of agricultural needs.
3. Evaluate septic effluent impacts on ground water by examining existing septic fields within the sands and gravels and adjoining clay uplands for efficiency and for local subsurface attenuation capabilities. Promote improvements to septic system design guidelines in areas where such systems are contributing contaminants to ground water.

4. Minimize pesticide contamination of the aquifer by:
 - * better screening of pesticides, particularly when used above unconfined aquifers to examine persistence, solubilities, and potential to be leached to local ground waters; and
 - * promote the use of alternative pesticides that are less soluble, have shorter half-lives, and are less susceptible to contaminating local ground waters. A recent model has been developed by Crowe and Mutch (1991) that examines pesticide leachabilities in the subsurface environment.
 - * development of improved management systems which reduce the dependency of agricultural production on conventional pest control products.

5. Enact legislation to regulate the use of ground water, and to control the methods of developing ground water resources (e.g. by regulating the placing, construction, and abandonment of wells).

6. Develop and implement policies and regulations to influence or control the agricultural activities on unconfined aquifers.

7. Develop and implement a regional ground water quality monitoring program for unconfined aquifers that are deemed to be at high risk of contamination and are used as drinking water sources.

8. Compile existing and historic land use practices on the aquifer which would examine population growth, soil management practices, poultry, production and crop production.

9. In view of the high nitrate concentrations at the Provincial Trout hatchery which utilizes local ground water, it is recommended that the pesticides dinoseb, atrazine, endosulfan and carbofuran (which locally exceed freshwater aquatic guidelines), be monitored on a regular basis.

Similarly, local fish rearing streams and tributaries which are fed by ground water discharge from the Abbotsford aquifer should also be monitored.

10. Develop a long term multi-agency ground water protection strategy for the aquifer. This might be included in a detailed land use investigation using GIS or similar investigative tools.
11. Develop drinking water guidelines for all pesticides used on unconfined aquifers. This should include 1,2 DCP, 1,3 DCP and Vapam.
12. Assess ground water quality in other areas of the aquifer. Expand the current monitoring and research programs to include other high risk unconfined aquifers in the region.
13. Conduct further research on nitrogen cycling in the soils overlying the Abbotsford Aquifer. In particular, research is required to obtain estimates of the various components of the nitrogen cycle under different soil and crop management systems, different climatic conditions, and different soil properties. Of particular interest are the rate of mineralization, the rate of denitrification, the addition of nitrogen to soil by precipitation and dry deposition, the nitrogen requirement of raspberries and resulting impacts on local ground water quality.
14. That research efforts on the development of integrated pest management systems be intensified, in order to reduce pesticide use, and therefore reduce the potential for ground water contamination by pesticides.

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APPENDIX A
BORE HOLE LITHOLOGIES

APPENDIX A

LITHOLOGIC LOGS OF NHRI PIEZOMETERS, ABBOTSFORD

Piezometer: ABB1

Date of completion: March 1988

Depth Interval Metres		Lithological Description
0.00	0.61	coarse sand & gravel; oxidized
0.61	1.52	coarse sand & gravel; unoxidized
1.52	2.44	sand & gravel with silt
2.44	3.20	silty clayey sand with some pebbles
3.20	3.66	silty sand with some pebbles
3.66	3.96	silty sand , medium pebbles
3.96	7.92	sand & gravel, coarser pebbles
6.92	7.92	#10 slot screens

Piezometer: ABB2

Date of completion: March 1988

Depth Interval Metres		Lithological Description
0.00	1.83	sand & fine to medium gravel
1.83	2.90	sand & coarse gravel
2.90	3.66	grey sand & cobbles (2.5 cm dia.)
3.66	5.79	grey sand; fine to medium gravel
5.79	7.01	grey sand; coarse gravel
7.01	7.62	sand less silt; cobbles
6.62	7.62	#10 slot screens

APPENDIX A
LITHOLOGIC LOGS OF NHRI PIEZOMETERS, ABBOTSFORD

Piezometer: ABB3

Date of completion: March 1988

Depth Interval Metres		Lithological Description
0.00	1.52	sand & coarse gravel; oxidized
1.52	3.35	grey sand & medium to coarse gravel
3.35	7.62	grey sand & coarse gravel
7.62	8.23	grey sand; very fine to coarse gravel
8.23	9.14	grey sand; sorted coarser gravel
9.14	10.06	grey sand; fine to medium gravel
10.06	17.07	interbedded fine to medium gravel & grey sand
17.07	17.37	grey sand & gravel with cobbles
17.37	17.68	grey sand & coarse gravel
16.68	17.68	#10 slot screens

Piezometer: ABB4

Date of completion: March 1988

Depth Interval Metres		Lithological Description
0.00	0.91	sand & coarse gravel; oxidized
0.91	6.86	grey sand & very coarse gravel
6.86	10.97	grey sand; fine to coarse gravel
10.97	14.48	sand; very fine gravel
14.48	14.63	sand; coarse gravel
14.63	17.22	silty sand & fine gravel
17.22	17.37	silty sand & very fine gravel
17.37	19.35	grey sand & coarse gravel
19.35	20.27	grey sand; very fine gravel
20.27	24.54	grey sand; fine to coarse gravel
24.54	24.84	sand & gravel; cobbles
24.84	26.21	sand & fine to coarse gravel
26.21	28.50	sand & coarse gravel
28.50	29.26	sand & gravel; some cobbles
28.26	29.26	#10 slot screens

APPENDIX A
LITHOLOGIC LOGS OF NHRI PIEZOMETERS, ABBOTSFORD

Piezometer: ABB5

Date of completion: March 1988

Depth Interval Metres		Lithological Description
0.00	3.66	clayey sand & gravel; oxidized
3.66	5.33	silty brown sand; slight clay
5.33	6.40	grey sand & coarse gravel
6.40	7.62	grey sand & fine gravel; cobbles
7.62	7.92	grey sand & pea gravel
7.92	8.53	sand & coarser gravel; cobbles
8.53	8.84	grey sand & gravel; no pebbles
7.84	8.84	#10 slot screen

Piezometer: ABB6

Date of completion: March 1988

Depth Interval Metres		Lithological Description
0.00	0.61	silty sand with some clay; oxidized
0.61	2.13	silty sand; some clay; some pebbles
2.13	9.14	silty sand; very fine gravel; cobbles
8.14	9.14	#10 slot screens

APPENDIX A
LITHOLOGIC LOGS OF NHRI PIEZOMETERS, ABBOTSFORD

Piezometer: CDA1

Date of completion: November 1984

Depth Interval Metres		Lithological Description
0.00	0.61	top soil
0.61	0.91	brown silt & sand
0.91	9.45	interbedded sands & gravels
9.45	14.33	coarse gravels
14.33	18.29	boulders
18.29	20.73	sands & gravels
20.12	20.73	#10 slot screens

Piezometer: CDA2

Date of completion: November 1984

Depth Interval Metres		Lithological Description
0.00	1.52	brown silt & sand
1.52	10.36	sand with less gravel
10.36	18.90	gravel with sand lenses
18.90	20.73	sand & gravel lenses
20.12	20.73	#10 slot screen

APPENDIX B
INORGANIC CONSTITUENTS

INORGANIC CHEMICAL ANALYSIS OF GROUND WATERS FROM THE ABBOTSFORD
AQUIFER (mg/L)

ANALYTE	CODE	CDA-2	BC-C-35	BC-C-55	BC-C-75	BC-B-55
MAJOR CONSTITUENTS						
Ca	20101L	43	39	27	31	26
Cl	17209L	10	10	4.1	7	4.4
HCO3	06202L	30	15	61	75	49
K	19103L	1.1	1	1.2	1.7	1.1
Mg	12103L	8	6	5	5	6
Na	11101L	6.3	5.6	4.8	7.1	3.9
SO4	16301L	12	16	13	25	7.4
Sum of Ions	00223L	212	186	132	153	132
Tot. Alkalinity	10109L	24	13	50	61	40
Tot. Hardness	10602L	141	122	89	98	87
NUTRIENTS						
C, tot, inorg.	06051	5.9	3	12	15	9.6
C, tot, org.	06017P	0.2	1	1.1	1.5	0.6
C, total	06006	6.1	4	13	17	10
N, NO2 only	07206P	0.01	0.06	0.03	0.01	0.02
N, NO2+NO3	07110P	23	21	3.7	0.19	7.8
N, NO3 only	07110P	23	21	3.7	0.18	7.8
PO4, ortho as P	15206P	<0.01	<0.01	<0.01	<0.01	<0.01
TRACE METALS						
Fe, ICP-AES	26451P	0.04	0.04	0.02	0.02	0.02
Mn, ICP-AES	25451	<0.01	0.02	<0.01	<0.01	<0.01
PHYSICAL PROPERTIES						
Sp. conduct.						
umho/cm	02041L	268	280	185	180	187
Ph of water						
Ph units	10301L	6.88	6.8	7.54	7.85	7.24

ANALYTE	UNITS	CODE	BC-B-75	BC-C-25	BC-A-75	BC-B-25	BC-B-35
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MAJOR CONSTITUENTS

Ca	mg/L	20101L	34	31	36	34	31
Cl	mg/L	17209L	4.1	7.2	4.7	11	7.7
HCO3	mg/L	06202L	81	12	76	12	17
K	mg/L	19103L	1.9	1.1	1.8	5.6	2.2
Mg	mg/L	12103L	6	6	7	6	5
Na	mg/L	11101L	4.6	5.7	4.1	4.8	4.8
SO4	mg/L	16301L	19	14	18	7.9	9.2
Sum of Ions	mg/L	00223L	160	157	172	179	157
Tot. Alkalinity	mg/L	10109L	66	10	62	10	14
Tot. Hardness	mg/L	10602L	107	100	118	108	100

NUTRIENTS

C, tot, inorg.	mg/L	06051	16	2.4	15	2.4	3.3
C, tot, org.	mg/L	06017P	0.6	0.9	0.8	1.1	1.6
C, total	mg/L	06006	17	3.3	16	3.5	4.9
N, NO2 only	mg/L	07206P	0.02	0.01	0.1	0.06	0.07
N, NO2+NO3	mg/L	07110P	2.1	18	5.4	22	18
N, NO3 only	mg/L	07110P	2.1	18	5.3	22	17
PO4, ortho as P	mg/L	15206P	<0.01	<0.01	<0.01	<0.01	<0.01

TRACE METALS

Fe, ICP-AES	mg/L	26451P	0.02	0.05	0.01	23	0.03
Mn, ICP-AES	mg/L	25451	<0.01	0.02	0.02	0.03	<0.01

PHYSICAL PROPERTIES

Sp. conduct.	umho/cm	02041L	216	236	198	269	199
Ph of water	Ph units	10301L	7.92	6.21	7.95	6.58	6.59

ANALYTE	UNITS	CODE	BC-A-35	BC-A-55	ABB-88-4	ABB-88-5	ABB-88-6
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MAJOR CONSTITUENTS

Ca	mg/L	20101L	14	20	52	35	27
Cl	mg/L	17209L	2.5	1.8	12	9.3	13
HCO3	mg/L	06202L	26	55	58	23	17
K	mg/L	19103L	0.7	0.9	1.8	1	1.2
Mg	mg/L	12103L	2	5	14	6	5
Na	mg/L	11101L	3	3.3	7.9	4.9	5.2
SO4	mg/L	16301L	2.3	2.6	20	2.5	14

Sum of Ions	mg/L	00223L	7.1	104	281	179	131
Tot. Alkalinity	mg/L	10109L	22	45	48	19	14
Tot. Hardness	mg/L	10602L	45	71	186	113	88

NUTRIENTS

C, tot, inorg.	mg/L	06051	5.1	11	11	4.5	3.3
C, tot, org.	mg/L	06017P	0.4	0.8	1.1	1	2.6
C, total	mg/L	06006	5.5	12	12	5.5	5.9
N, NO2 only	mg/L	07206P	0.02	0.01	0.02	0.02	0.04
N, NO2+NO3	mg/L	07110P	4.7	3.6	26	22	11
N, NO3 only	mg/L	07110P	4.7	3.6	26	22	11
PO4, ortho as P	mg/L	15206P	<0.01	<0.01	<0.01	<0.01	<0.01

TRACE METALS

Fe, ICP-AES	mg/L	26451P	0.03	0.01	0.02	0.03	0.03
Mn, ICP-AES	mg/L	25451	<0.01	<0.01	0.06	0.05	0.08

PHYSICAL PROPERTIES

Sp. conduct.	umho/cm	02041L	83	118	337	218	177
Ph of water	Ph units	10301L	6.59	7.09	7.03	6.7	

ANALYTE	UNITS	CODE	BC-A-25	ABB-88-1	ABB-88-2	ABB-88-3
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MAJOR CONSTITUENTS

Ca	mg/L	20101L	15	44	23	26
Cl	mg/L	17209L	3.8	14	4.8	9.6
HCO3	mg/L	06202L	22	10	20	32
K	mg/L	19103L	0.6	2.5	0.7	1.3
Mg	mg/L	12103L	2	8	3	7
Na	mg/L	11101L	2.9	8.5	5.5	7.5
SO4	mg/L	16301L	2.3	61	3.5	21
Sum of Ions	mg/L	00223L	72	214	122	148
Tot. Alkalinity	mg/L	10109L	18	8	16	26
Tot. Hardness	mg/L	10602L	48	143	71	94

NUTRIENTS

C, tot, inorg.	mg/L	06051	4.3	1.9	3.9	6.3
C, tot, org.	mg/L	06017P	0.8	1.2	0.9	1.1
C, total	mg/L	06006	5.1	3.1	4.8	7.4
N, NO2 only	mg/L	07206P	0.04	0.03	0.01	0.02
N, NO2+NO3	mg/L	07110P	5.2	15	14	9.8
N, NO3 only	mg/L	07110P	5.2	15	14	

PO4, ortho as P	mg/L	15206P	<0.01	<0.01	<0.01	<0.01
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TRACE METALS

Fe, ICP-AES	mg/L	26451P	0.14	2.4	0.05	0.04
Mn, ICP-AES	mg/L	25451	0.01	0.26	0.01	0.05

PHYSICAL PROPERTIES

Sp. conduct.	umho/cm	02041L	89	334	150	190
pH of water	pH units	10301L	6.49	5.84	6.44	6.83

APPENDIX C
FIELD SAMPLING METHODS

Most of the early (1955 - 1985) ground water samples were collected by NHRI staff from the pressure systems of domestic wells. The sample was collected following a 3 to 5 minute flushing period from the well pressure system. A peristaltic pump equipped with teflon tubing was used for sampling piezometers which had shallow static water levels. Bailers or an air-driven bladder pump were used to lift water to the surface in piezometers with water levels below the limit of peristaltic suction lift.

Water samples were collected and stored using standard methods recommended by the laboratory.