Groundwater Conditions
of the
Columbia Valley Aquifer
Cultus Lake, British Columbia

Marc Zubel, P.Eng.
Regional Hydrogeologist

BRITISH COLUMBIA

Ministry Of Environment, Lands & Parks
Water Management
Lower Mainland Region, Surrey BC
January, 2000

Canadian Cataloguing in Publication Data
Zubel, Marc.
Groundwater conditions of the Columbia Valley aquifer, Cultus Lake, British Columbia

Includes bibliographical references: p.
ISBN 0-7726-4149-8

1. Groundwater - British Columbia - Chilliwack Region - Quality. 2. Groundwater - Pollution - British Columbia - Chilliwack Region. 3. Drinking water - British Columbia - Chilliwack Region.
4. Nitrates - Environmental aspects - British Columbia - Chilliwack Region. I. British Columbia. Water Management Branch. II. Title.

TD227.B7Z82 2000 363.739'42'0971137C00-960062-0

Executive Summary

Columbia Valley is a rural-agricultural area south-west of Chilliwack, British Columbia, nestled between two mountain formations south-west of Cultus Lake. Homeowners in the valley rely predominantly upon very abundant good quality groundwater for their drinking water supply and other uses. During the past several years, some residents in the valley have complained of serious deterioration of their groundwater quality due to nitrate contamination and have blamed local agricultural activities. At the request of the Concerned Citizens of Columbia Valley, through their elected MLA, John van Dongen, the Ministry Of Environment, Lands & Parks (Lower Mainland Region) has completed an investigation of the groundwater resources (quantity and quality) and land use activities in the area and completed the following report.

The study area is underlain by very permeable glacial outwash sand and gravel deposits. Groundwater is present within an extensive unconfined aquifer to a depth of at least 100 metres. There are 56 known wells ranging in depth from about 48 metres to 105 metres. These wells are used for domestic needs, serving approximately 130 out of about 200 residents, as well as for irrigation and stock watering purposes. Along with an office review of available technical information, a site investigation was conducted in 1997 consisting of a geodetic survey of well locations and depths to water levels in selected wells, water quality sampling and analyses, and a land use survey. Groundwater flow directions and quantities were determined and several hydrogeologic cross-sectional views were constructed. Water quality analyses showed that groundwater had nitrate-nitrogen concentrations below the Guidelines for Canadian Drinking Water Quality (10 mg/L NO3-N) and according to the Fraser Valley Health Region there is presently no risk to health. However, there are two areas within the aquifer where nitrate-nitrogen concentrations are above background levels of 3 mg/L NO3-N, confirming that nitrate contamination exists. Groundwater flow directions in these areas and evaluation of land use indicate that agricultural activities are the most likely sources. Calculations of the estimated amount of nitrate-nitrogen in these two areas indicate that the quantity of nitrogen loading from agricultural activities is not an overly excessive amount and that minor adjustment of manure management activities will ensure excess nutrients applied to the soil will not leach into the groundwater.

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1. Introduction

1.1 Purpose and Scope

Residents of Columbia Valley, south-west of Cultus Lake, British Columbia, who obtain their drinking water from groundwater wells have expressed concerns at the elevated concentrations of nitrate-nitrogen in their drinking water supply. Reported chemical analyses of groundwater from some wells have shown nitrate-nitrogen values in excess of the Guidelines for Canadian Drinking Water Quality (GCDWQ) maximum acceptable concentration (MAC) of 10 mg/L NO_3-N. The residents, dependent upon well water as their sole source of drinking water, have organized themselves as the Concerned Citizens' Group of Columbia Valley. This group has met on several occasions to discuss groundwater quality issues and concerns about local manure management practices and to determine how the polluting sources may be stopped. A common perception is that the land is underlain by very porous sediments, that a significant amount of liquid manure is applied frequently to the land, and that this manure is somehow ending up as nitrate in the groundwater below, and into their well water.

On March 12, 1997 the Concerned Citizen's Group held a local meeting in Columbia Valley including the MLA for Abbotsford, John Van Dongen; Ministry of Environment, Lands & Parks regional staff; local Regional Health representative; and a representative from the Fraser Valley Regional District. The residents voiced their concerns and requested the government take action to identify the source(s) of the apparent contamination and provide remedies so that residents in the area could again have acceptable drinking water quality. In response, the Ministry of Environment, Lands & Parks (MELP) indicated that additional information on the groundwater conditions in the valley was needed to address the above concerns. MELP agreed to undertake a hydrogeologic investigation and evaluation of the Columbia Valley area and to provide recommendations. The following hydrogeologic report is based on an office review and evaluation of available information, and an on-site investigation including measurements, testing and data collection.

1.2 Acknowledgements

Site inventory of land uses, elevation survey of well heads and groundwater levels, streamflow measurements, percolation test, soil sampling and water quality sampling were carried out at different times by college co-op students: Natasha Silva, Joe Serna, Senja Kylmala, Canisius Chan and Regan Olson. Bev Locken also assisted with various site investigations. Special thanks to all the residents of Columbia Valley who supported the collection of data and provided valuable information.

Editing and technical reviews were performed by various government personnel, including Rick Van Kleek and Geoff Hughes-Games of the Ministry of Agriculture and Food (MAF); Mike Wei, Alan Kohut and Ross Kreye of Ministry Of Environment, Lands & Parks (MELP), and George Rice of the Fraser Valley Health Region.

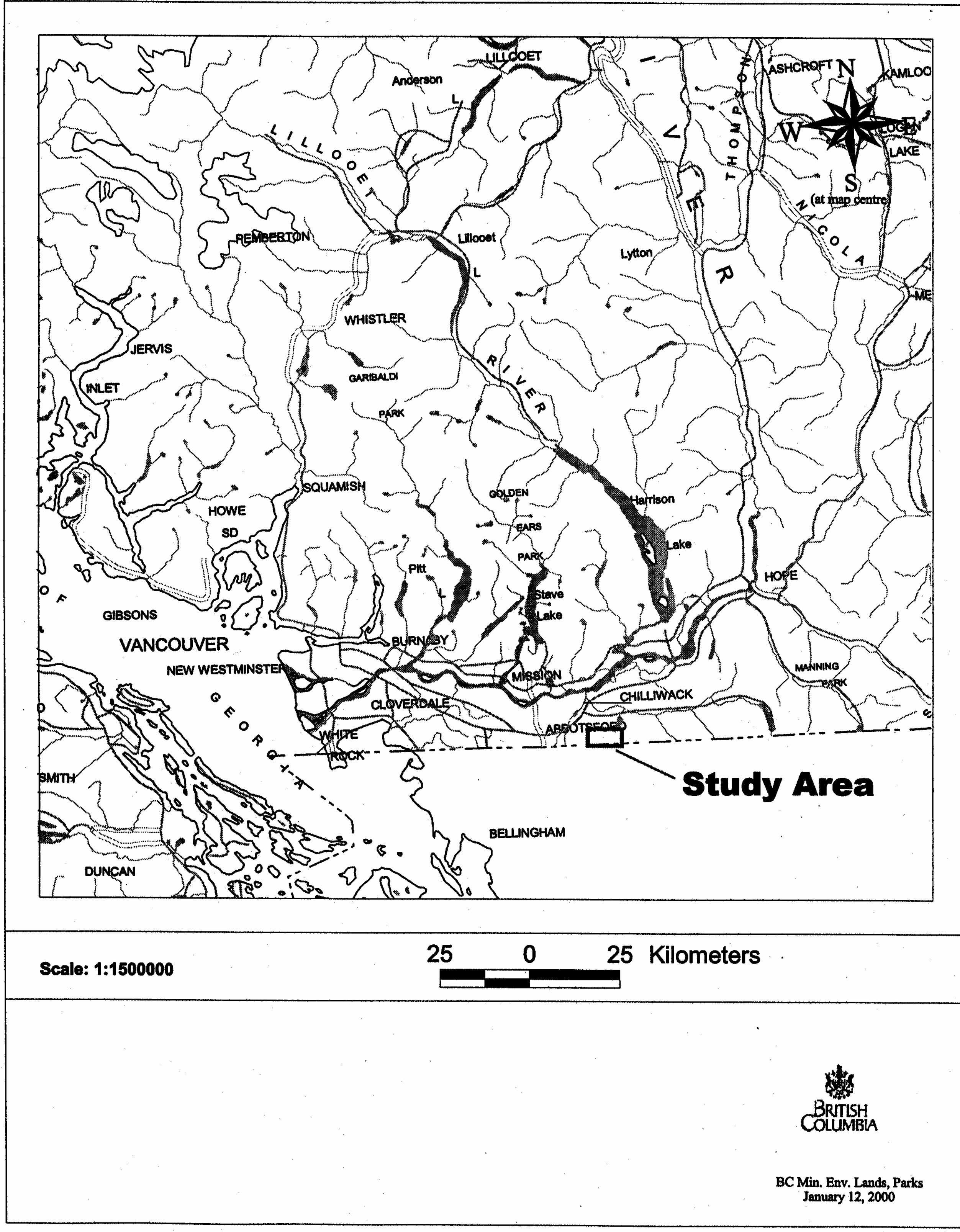
1.3 Location and Extent of Study Area

Columbia Valley, as shown in **Figure 1**, is located south-west of Cultus Lake and about 16 km south-west of Chilliwack in south-western British Columbia. The Study Area, as outlined in **Figure 2**, occupies an area of about 9 km^2, and lies within the Agricultural Land Reserve and within the jurisdiction of the Fraser Valley Regional District. It is bounded on the north-west by Mount Vedder, the International Ridge on the south-east, Frosst Creek on the east, and the Canada - U.S. border on the south. The area east of Frosst Creek was not included in this study due to time and resource constraints.

1.4 Data Inventory

An office inventory of groundwater data resulted in the collection of available sources of information including: published geologic, hydrogeologic and other technical reports, soils maps, geologic maps, aquifer classification maps, aerial photographs, meteorologic data, water well records, and water chemistry data. Additional information was collected from field inventories including: laboratory chemical analyses of water quality samples obtained from water wells, springs and creeks; measurements of depths to water levels in wells; surveyed elevations of well locations; and a resident survey of land use practices and domestic water source.

FIGURE 1: Location of Study Area, Columbia Valley, BC



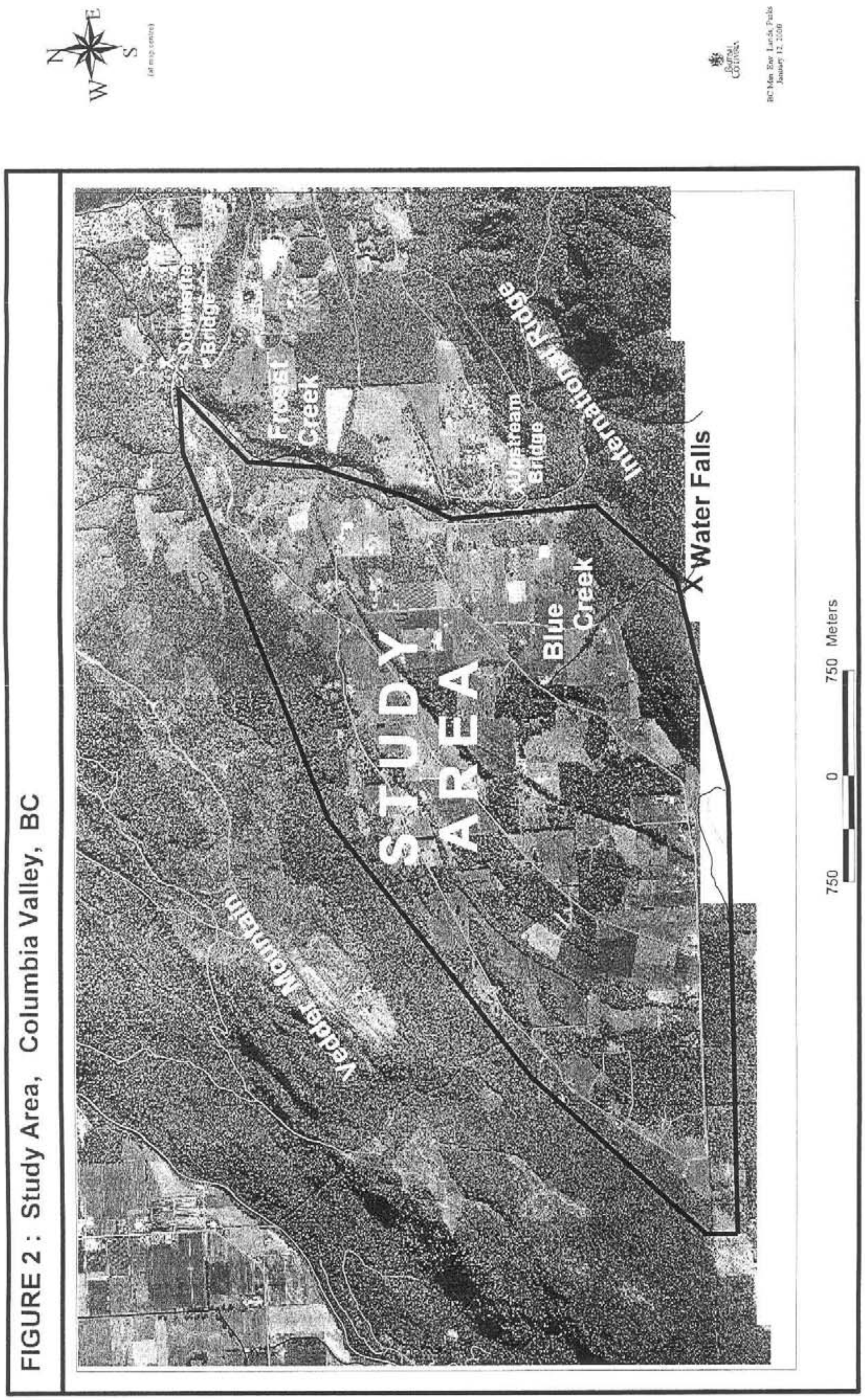


FIGURE 2 : Study Area, Columbia Valley, BC

1.5 Summary of Previous Studies

The following is a summary of pertinent information from previous relevant technical studies conducted in the Columbia Valley area.

- **"The Columbia Valley Aquifer, British Columbia: Groundwater Analysis for Nitrate"** B.C. Ministry of Health report for Project Enviro-Health; Steven M. Caine, Ruth Cridland, Ph.D., August 1995:

Groundwater samples obtained in November 1994 and April 1995 from 26 water wells were analyzed for nitrate-nitrogen. None of the samples had reported nitrate-nitrogen concentrations above the GCDWQ's maximum acceptable concentration of 10 mg/L NO_3-N. Groundwater from only two wells had nitrate-nitrogen concentrations above 3.0 mg/L. These values (3.77 mg/L and 7.95 mg/L) indicate that nitrogen contamination sources do exist locally. Manure was the suspected source of the higher nitrate concentration, but identification of the exact origin was not possible from this study. The study suggested that determination of water infiltration rates and groundwater migration characteristics would likely assist in locating the source(s), and that land-use activities which minimize nitrate leaching must be encouraged to prevent contamination of this unconfined aquifer.

- **"Columbia Valley Irrigation - ARDSA BC #734"** B.C. Ministry of Environment internal memorandum report, Mike Wei, May 1983.

An office study of available geologic, hydrogeologic (mainly water well record) data and air photos was conducted to assess the groundwater potential for irrigation and domestic needs within the valley. The report concluded that the valley is underlain mainly with highly permeable shaly gravel and sand with minor till lenses. The underlying aquifer is unconfined with a relatively deep water table, generally about 180 feet (54.9m) below ground. Based on well record data and composition of underlying sediments, the groundwater potential for irrigation and domestic use was considered to be good. Recharge to the aquifer comes mainly from infiltration of precipitation falling on the valley floor, runoff from the valley sides and seepage along parts of some of the creeks in the valley. Groundwater quality appears to be good with low overall mineralization, moderate hardness, and negligible iron and manganese.

- **"Columbia Valley Study"** B.C. Ministry of Agriculture report to the Provincial Agricultural Land Commission, Gary A. Mosher, PAg, July 1980.

This study examined existing agricultural land uses, potentially arable lands and lands unsuitable for agricultural production. At the time of the study, of the total 3,792 acres (1535 ha) in the Columbia Valley, 39% was cultivated, 31% was arable and useful for agricultural purposes, and the remainder was considered non-arable. Major land uses included forage production, and livestock operations such as beef and swine. From a land use viewpoint, swine operations were considered well suited for the Columbia Valley; however, the then current BC Ministry of Agriculture environmental guideline, printed in 1978, needed to be followed to minimize environmental impacts. There were reported problems with manure management, including the absence of a developed land base for disposal, unlined lagoons, frequent spreading leading to odour problems and cracked cement manure troughs, resulting in the release of raw manure effluent. The availability of water for domestic and agricultural uses was considered limited to three main creeks (Frosst, Watt, Dorko), some springs and minor creeks sufficient for domestic needs, and a limited number of deep water wells.

- **"Geology and Groundwater Conditions of Leisure Valley Holiday Park, Columbia Valley."** BC Ministry of Environment, Internal Memo Report, Groundwater Section NTS File 92G/1, A.P. Kohut, July, 1979.

This internal memorandum report provided an independent evaluation of the geology and groundwater conditions in the Leisure Valley Holiday Park area and the suitability of a proposed sewage disposal system. Conclusions in the report indicated that the area was underlain by glacial-fluvial outwash deposits; that groundwater levels are below the level of Frosst Creek; that groundwater levels along Janovick Road in the upland area are higher than Frosst Creek to the east; the gravel deposits in the floodplain are highly permeable and effluent (*editor's note: the soluble material*) from septic systems would reach the water table within a relatively short time.

- **"Investigation of Subsurface Geology and Groundwater Conditions of Leisure Valley Holiday Park, Columbia Valley, British Columbia"** McElhanney Surveying & Engineering Ltd., Report No. C326, R.H. Blunden, May, 1979.

This study investigated the geologic and hydrogeologic conditions of the Leisure Valley Holiday Park area. Conclusions in the report included: that the soils in the area below the proposed septic sewage disposal systems were very permeable; that the measured depths to the groundwater table in a well 23 m from Frosst Creek was between 19.2m and 26.2m; that Frosst Creek flows upon a groundwater mound and recharges the groundwater system; that the groundwater resource can sustain a yield of 400 L/min to wells; that percolation rates in test pits ranged between 0.04 to >25 $L/m^2/min.$; Frosst Creek has a gradient of approximately 12%.

2. Physio/Geographic Description of Study Area

2.1 Soils Morphology

Table 1 outlines a list of soil types in Columbia Valley, their drainage characteristics and the relative percentages of their abundance throughout the valley. **Figure 3** shows the aerial extent of the various soil types. Most soils in the valley are well to rapidly drained and pervious, with low water holding capacity.

2.2 Climate and Precipitation

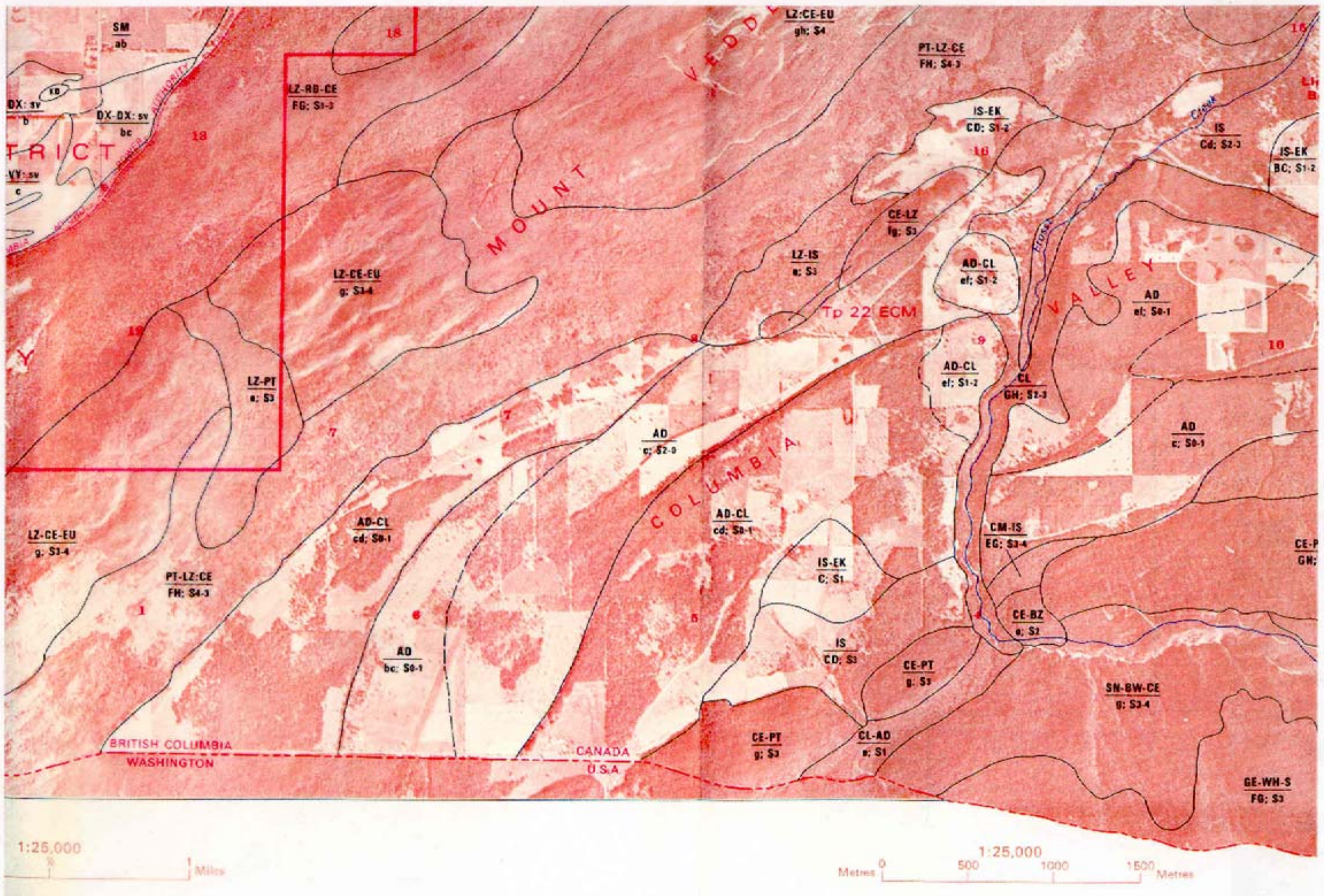
The climate of the Lower Fraser Valley can be characterized as having warm, rainy winters, resulting from frequent low pressure systems moving eastward from the Pacific Ocean, and relatively cool dry summers with frequent long periods of sunny weather.

Table 1: Soil types and Abundance, Columbia Valley, BC

Soil Name & Map symbol	Abundance	*Classification* & Description
Abbotsford (AD)	40%	*Orthic Humo-Ferric Podzol*. Eolian deposits over gravelly glacial outwash. Rapidly drained; rapid to moderately pervious; slow runoff; low water holding capacity in gravelly subsoil; tend to be droughty; irrigation usually required for good production; potential for groundwater contamination from septic tank effluent due to low filtration capacity of subsoil gravel and coarse sand.
Columbia (CL)	45% (AD-CL)	*Orthic Humo-Ferric Podzol.* Gravelly glacial outwash deposits. Well to rapidly drained; rapidly pervious; slow surface runoff and water holding capacity; limited agricultural use due to low water holding capacity, low fertility and stoniness; effluent from numerous septic tanks can potentially contaminate groundwater through incomplete filtration in the coarse textured, gravelly subsoil.
Isar (IS)	4%	*Orthic Regosol*. Coarse alluvial fan deposits. Rapid to well drained; rapidly pervious; low water holding capacity; slow surface runoff; poorly suited for agricultural use due to low moisture holding capacity and high stone contents; septic tank effluent disposal is efficient although incomplete filtration through coarse textured soils may lead to groundwater contamination.
Elk (EK)	4% (IS-EK)	*Rego Humic Gleysol.* Coarse alluvial fan deposits. Poorly drained and rapidly to moderately pervious; moderate to slow surface runoff; moderate water holding capacity; moderate flooding sometimes during heavy, prolonged rains; mainly used for forage and pasture; generally poorly suited for urban and related uses; potential for groundwater contamination exists due to incomplete filtration of effluent through coarse subsoil.
Lonzo Ck. (LZ)	3% (LZ-IS)	*Orthic Humo-Ferric Podzol.* Eolian deposits over moderately coarse glacial till. Well to moderately well drained; moderate water holding capacity; slow to moderate surface runoff; suited for agricultural crops although adverse topography limits some areas; relatively low permeability limits septic tank effluent disposal.
Cannel (CE)	4% (CE-LZ)	*Orthic Humo-Ferric Podzol (lithic phase).* Glacial till or colluvium over bedrock. Well to rapidly drained and pervious; low to moderate water holding capacity; generally not suited for agricultural crops because of shallowness to bedrock, steep slopes and stoniness. Septic tanks are unsuitable because of the lack soil depth for effluent disposal, and steep slopes.

(after Luttmerding, 1981, Soils of the Langley – Vancouver Map Area, Vol 3)

FIGURE 3: Soil Types, Columbia Valley, BC



AD - Abbotsford   CL - Columbia   IS - Isar   EK - Elk   LZ - Lonzo Creek   CE - Cannel

(scanned image from Soils of the Langley-Vancouver Map Area, Report No. 15, BC Soil Survey, 1980)

Precipitation in the Columbia Valley occurs mainly as rainfall and averages about 1,533 mm per year. **Table 2** shows the mean monthly precipitation data from Environment-Canada's Cultus Lake, BC station (I.D. 1102220) between 1962 and 1992, and evaporation data from Agriculture and Agrifood Canada, Pacific Agriculture Research Centre's Agassiz CDA site between 1951 and 1980. This data indicates that of the total annual precipitation approximately 70% of it occurs during the period October to March. During this period, when precipitation is greatest, evaporation is at its lowest and infiltration of precipitation into the soils is at its peak. Infiltration of precipitation will eventually reach the water table and recharge or replenish the underlying aquifer. **Figure 4** shows the average monthly precipitation and evaporation patterns. It is evident from this figure that precipitation significantly exceeds evaporation for eight out of twelve months.

2.3 Physiography, Topography and Drainage

Columbia Valley is in the Northern Cascade Mountains and begins at Lindell Beach, on the south-west shore of Cultus Lake, and extends approximately 6 km in a north-east to south-west direction to the Canada /U.S. border. It is approximately 3 km in width and is bounded on the north-west by Mount Vedder and on the south-east by the International Ridge.

Within a kilometre of Lindell Beach the valley topography rises gently from an elevation of about 43 m to 76 m. At a further 500 to 600 metres, the topography rises almost abruptly to an elevation of about 152 m, eventually reaching an elevation of about 230 m at the mountain edges. Some notable topographic features flanking the main valley floor are the relatively flat terraces. The main valley floor, about 15 m below the terraces, appears to be a remnant of a glacial meltwater channel.

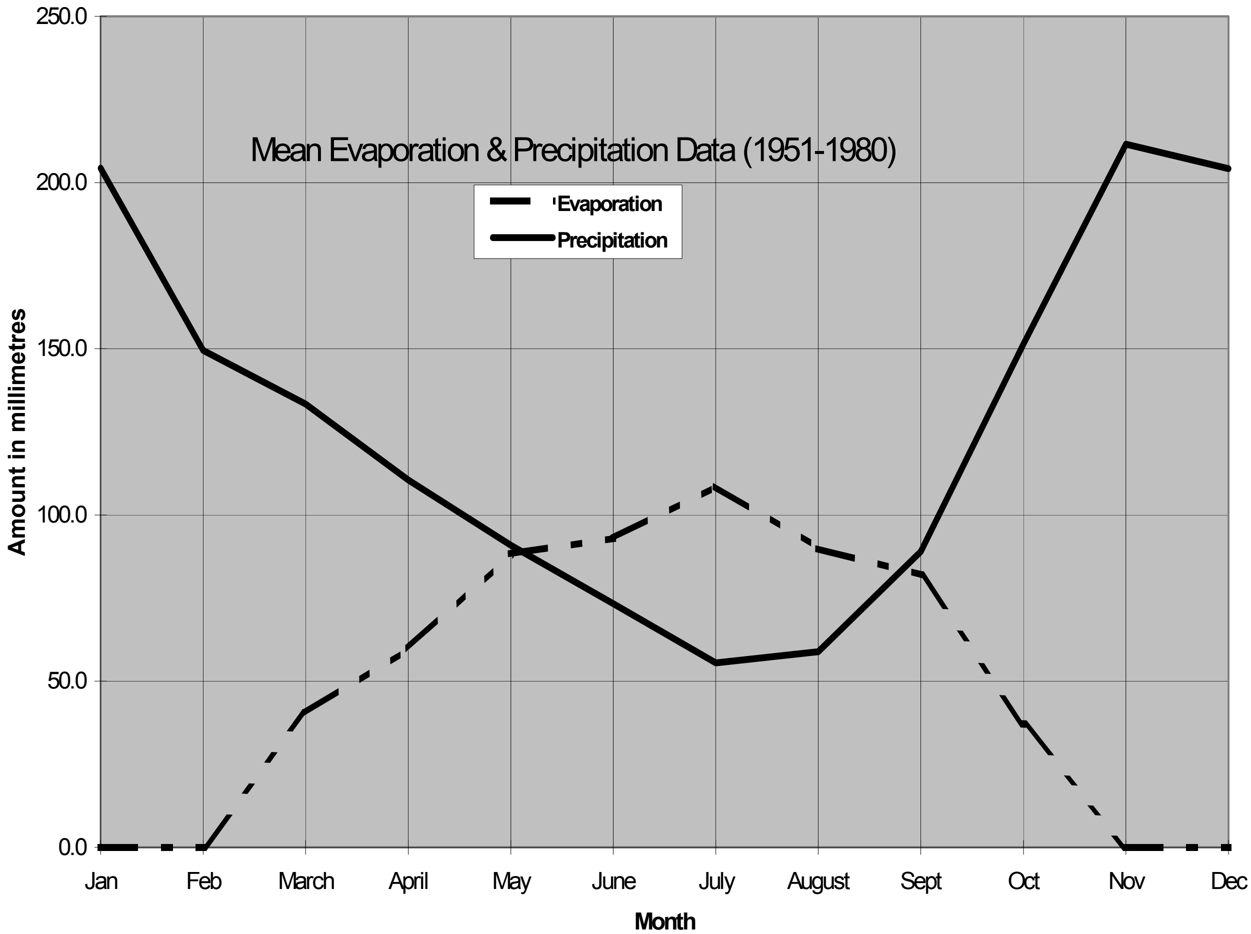
With the exception of Frosst Creek, there are no surface water-courses draining out of the valley. Most of the brooks and creeks flowing down the mountain sides discharge and disappear into the valley floor which is underlain predominantly with very permeable sediments.

Table 2: Precipitation and Evaporation Data, Columbia Valley BC

Month	Average Monthly Precipitation, mm (1961 - 1992)	No of Years	Calculated Lake Evaporation, mm (1951 - 1980)
January	204.3	29	0
February	149.5	30	0
March	133.4	29	40.4
April	110.5	29	59.8
May	90.9	29	88.3
June	73.3	31	93
July	55.5	29	108.6
August	58.9	31	89.9
September	89	29	61.9
October	151.5	31	37.1
November	211.5	29	0
December	204.2	27	0
Total Annual	**1532.6**		**579.0**

Precipitation data from Environment Canada, Cultus Lake, BC station (I.D. 1102220)
Evaporation data from Environment Canada, Agassiz, BC station (CDA)

FIGURE 4: Precipitation vs. Evaporation, Columbia Valley BC



Note: Evaporation data from Agriculture-Canada's Agassiz Station;
Precipitation data from Environment-Canada's Cultus Lake Station

2.4 Surficial Geology

The top 30 to 45 cm of soil at the surface of the valley is comprised predominantly of well to rapidly drained sandy eolian loam. Below this, the valley floor is underlain by glaciofluvial outwash sediments comprised mainly of sand, shaly gravel, and cobbles with minor till and/or clay lenses. These outwash sediments were deposited during the last glacial period less than about 11,000 years ago as local ice retreated (Armstrong, 1960; Halstead, 1961). The maximum thickness of these unconsolidated sediments is not known; however, water well records indicate they are at least 120 m thick. Based on the glacial history of the Fraser Lowland area (Armstrong, 1960) it is likely that this outwash deposit is underlain by Sumas till or glacial deposits related to valley glaciers.

A predominant glacial feature in the valley is a remnant meltwater channel down the central part of the valley from Frosst Creek to the international border. The terraces at the base of the mountains are approximately 15 m above the main valley floor. Other glacial features include several kettle holes that are readily visible on aerial photographs.

2.5 Bedrock Geology

According to Roddick (1965) Mount Vedder, to the north-west of the valley, is comprised predominantly of Cretaceous metavolcanic and metasedimentary rocks (sandstone, conglomerate, shale). To the south-east, International Ridge is comprised predominantly of Jurassic slaty argillite (a compact rock derived from mudstone or shale) and minor shale type rocks. There are no bedrock outcrops within the study area.

2.6 Surface Water Hydrology

There are two main surface water courses within the study area: Frosst Creek and Blue Creek. There are also numerous small springs, minor creeks and brooks.

Frosst Creek flows from the mountains on the south-east side of the valley and has cut through glacial outwash deposits to form a gorge-like (about 50 m high) steep-sided stream valley. Between the upstream and downstream bridges approximately 3000 m apart, the creek drops approximately 120 m, which results in a gradient of about 4%. Streamflow measurements of Frosst Creek were taken in September 1997 near the upstream and downstream bridges using a mini streamflow meter. An average discharge of 2.1 m^3/sec was calculated at the upstream site and only 2.0 m^3/sec at the downstream site. The downstream site measurement includes some minor flow from a small tributary creek flowing into Frosst Creek about 100 m upstream of the downstream bridge site. The decreased amount of discharge at the downstream site is attributed mainly to seepage into the groundwater regime under the 3000 m length of the creek. Part of this decreased amount may also be due to degree of equipment and measurement accuracy or slight evaporation losses. This data supports Blunden's (1979) conclusion that Frosst Creek flows upon a groundwater mound and recharges the groundwater regime.

In addition to the above streamflow measurements a site reconnaissance of Frosst Creek between the two bridges was conducted in September 1997 to further assess surface water and groundwater interaction. The investigation did not find any groundwater discharges (upwellings or springs) into the creek. A measurement of the groundwater level in the Leisure Valley Trailer Park well located approximately 10 m from Frosst Creek was taken and showed that the groundwater level was almost 20 m below the creek level. This information further supports the fact that groundwater from the study area does not discharge into Frosst Creek, but flows beneath the creek, towards Cultus Lake.

Blue Creek also flows from the mountains on the south-east side of the valley, down some cascading falls (about 30 m high) at the international border. Just below the falls, it is joined by a minor tributary creek, called Dorko Creek, and then flows into a pond just north-west of Maple Falls Road. The area of the pond varies in extent depending upon creek inflow, but during a site investigation on April 29, 1998, it was approximately 30 m in diameter and of unknown depth. This pond is likely within a glacial kettle hole, many of which are prevalent in the valley elsewhere. As there are no surface water outlets from the pond and no apparent water withdrawals, the pond water naturally seeps into the permeable ground, eventually reaching the groundwater table approximately 50 m below. Evaporation may also account for some loss from the pond, but this would be very minor.

During the site reconnaissance of Blue Creek in April 1998, the amount of flow downstream of the cascading water falls (see Figure 2) was estimated at about 0.5 m^3/sec. At the culvert under Maple Falls Road, the flow was roughly estimated at about 0.3 m^3/sec. There are some domestic water licences on this creek which could account for some surface water withdrawals between these sites. The most likely cause of loss of water loss however is seepage below the creek bottom into the ground and recharging the groundwater regime. This is further substantiated by the fact that towards late summer, this creek often dries up for most of its course in the study area, even though there is still a significant amount of flow in the creek immediately downstream of the falls.

2.7 Land Use

Approximately 85% of Columbia Valley is in the Provincial Agricultural Land Reserve. Zoning and land use is regulated by the Fraser Valley Regional District and is described in the Official Settlement Plan for Electoral Area E. The Valley is primarily zoned as “Rural-Agricultural” in the central portion and “Rural” near the south-eastern and north-western mountains. Land uses include livestock production (cattle, swine, poultry and deer) and horticultural production (nurseries, tree farms and raspberries).

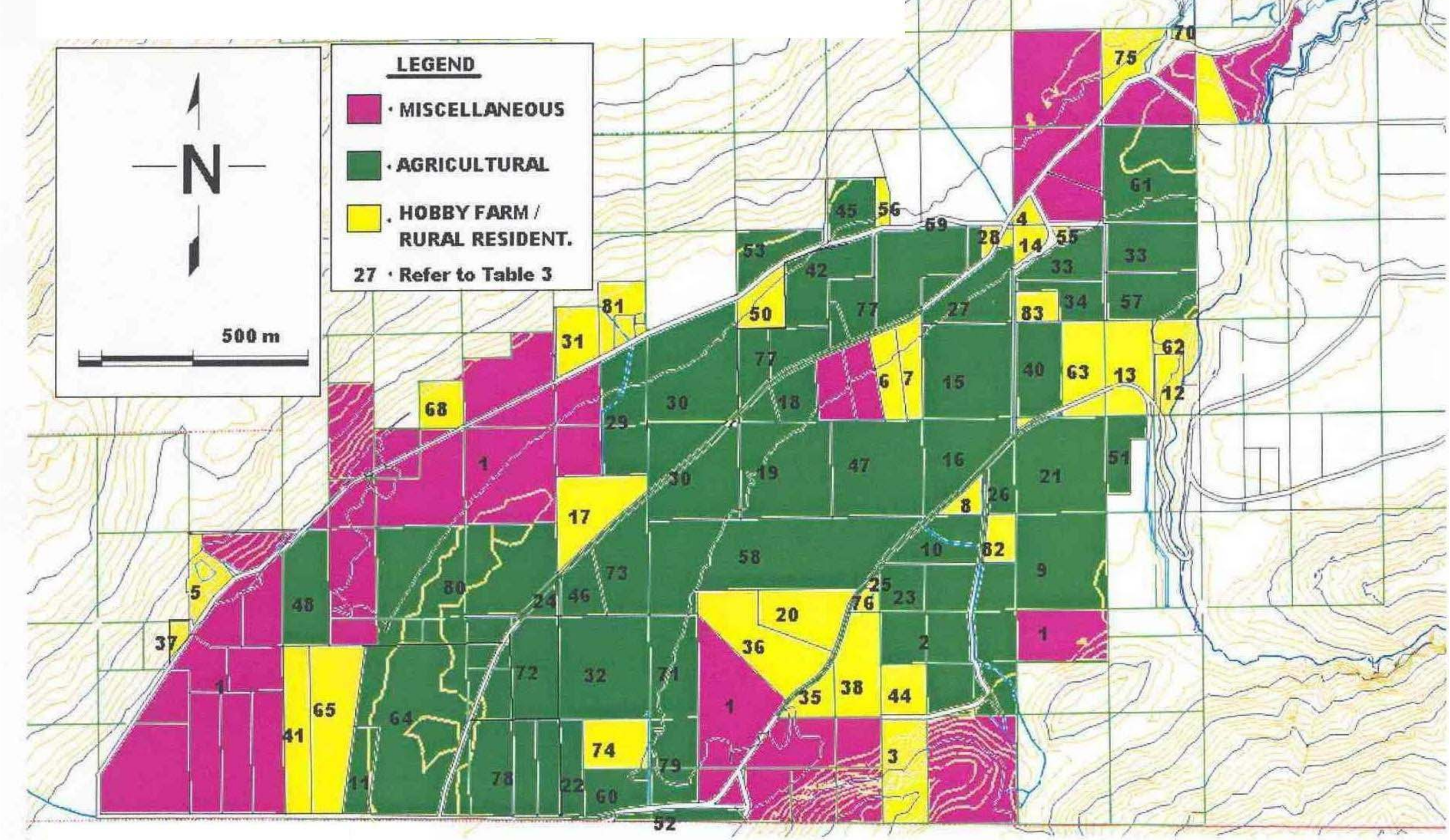
During the summer of 1997, a land use survey was conducted in the study area to identify the types of existing land use activities. A land use survey form (**Appendix 1**) was used to record residents’ general comments about the current type of land use activities, including the size of properties, chemical fertilizer and/or manure use and management practices, and use of pesticides. **Table 3** provides a summary of what individual land owners identified, while **Figure 5** shows the distribution of land uses in the valley grouped into three main categories: miscellaneous (mainly forested or undeveloped), agricultural and rural residential or hobby farms.

According to the data collected, of the approximately 978 hectares of surveyed land in the study area, approximately 27% or 260 hectares is forested or undeveloped (non-arable), approximately 21% or 122 hectares is used as rural residential or hobby farm, and 52% or 506 hectares is used for agricultural purposes. This generally agrees with the results of the 1980 land use study of the Columbia Valley by Mosher. In the Mosher report, of 1517 ha of land, 30% was considered non-arable while 70% was either cultivated or useful for agricultural purposes. The limited information from the 1997 survey indicates that agriculture is still the predominant land use activity in the study area.

Table 3: 1997 Land Use Survey, Columbia Valley BC

Site No.	Land Use	Area, ha	Site No.	Land Use	Area, ha
1	Miscellaneous	260.0	43	Rural Residential	3.5
2	Agricultural	29.1	44	Hobby Farm	4.0
3	Hobby Farm	8.5	45	Hobby Farm	4.5
4	Rural Residential	1.2	46	Hobby Farm	4.0
5	Rural Residential	5.3	47	Agricultural	16.2
6	Hobby Farm	4.0	48	Agricultural	9.3
7	Hobby Farm	4.0	49	Hobby Farm	16.2
8	Rural Residential	2.0	50	Rural Residential	4.0
9	Agricultural	16.2	51	Hobby Farm	4.0
10	Agricultural	6.5	52	Hobby Farm	2.8
11	Agricultural	4.0	53	Hobby Farm	5.3
12	Rural Residential	4.0	54	Agricultural	16.2
13	Agricultural	16.2	55	Rural Residential	0.4
14	Rural Residential	2.0	56	Hobby Farm	6.0
15	Agricultural	16.2	57	Agricultural	7.8
16	Agricultural	10.9	58	Agricultural	34.0
17	Hobby Farm	9.3	59	Rural Residential	0.3
18	Agricultural	4.0	60	Agricultural	5.3
19	Agricultural	17.4	61	Agricultural	16.2
20	Rural Residential	8.1	62	Hobby Farm	4.0
21	Agricultural	16.2	63	Rural Residential	8.1
22	Agricultural	4.0	64	Agricultural	29.5
23	Agricultural	4.0	65	Hobby Farm	13.8
24	Hobby Farm	1.0	66	Agricultural	2.0
25	Hobby Farm	1.4	67	Rural Residential	7.9
26	Agricultural	3.0	68	Hobby Farm	4.0
27	Agricultural	22.5	69	Hobby Farm	6.0
28	Rural Residential	0.8	70	Rural Residential	0.4
29	Agricultural	10.5	71	Agricultural	10.1
30	Agricultural	24.3	72	Agricultural	8.1
31	Rural Residential	5.1	73	Agricultural	9.3
32	Agricultural	16.2	74	Hobby Farm	6.5
33	Agricultural	8.1	75	Hobby Farm	5.1
34	Agricultural	4.0	76	Rural Residential	1.0
35	Hobby Farm	2.8	77	Agricultural	24.5
36	Hobby Farm	12.1	78	Agricultural	16.0
37	Hobby Farm	3.0	79	Agricultural	7.0
38	Rural Residential	8.1	80	Agricultural	32.0
39	Rural Residential	0.2	81	Hobby Farm	5.0
40	Agricultural	8.0	82	Hobby Farm	2.0
41	Rural Residential	8.1	83	Hobby Farm	2.0

FIGURE 5: Land Use, Columbia Valley, BC



3. Hydrogeology

3.1 Groundwater Wells and Use

There have been 56 water wells reportedly drilled in the study area since 1970. Well depths vary from about 41 m (136 ft.) to about 105 m (345 ft.) with an average depth of about 66 m (216 ft.). The depths to the water table are relatively deep, generally between about 30 m (100 ft.) and 50 m (165 ft.). According to the well drilling contractors' reports, estimated well yields vary from 0.4 Litres per second (L/s) or 5 imperial gallons per minute (igpm) to as much as 76 L/s (1000 igpm). Groundwater is used mainly for domestic purposes, serving approximately 130 out of about 200 residents in the study area. Other well uses include irrigation and agricultural purposes such as livestock watering.

In conjunction with the land use survey, a water well inventory (see **Appendix 1**) was conducted to locate and identify the 56 water wells. A summary of information about these wells is found in **Table 4**, and the location of these wells is shown in **Figure 6**.

3.2 Hydrogeologic Cross-sections

Hydrogeologic cross-sections provide a unique two-dimensional representation of the underlying unconsolidated sediments. The purpose of these cross-sections is to visualize the orientation of the topography; variations in geologic sediments with depth; groundwater level conditions; groundwater flow direction; and the extent and nature of any aquifers. Figure 6 shows the locations of four cross-sections. **Figure 7A** showing cross-section A-A'**,** **Figure 7B** showing cross-section A'-A", **Figure 8** showing cross-section B-B', and **Figure 9** showing cross-section C-C', have been drawn on the basis of water well information reported by well drilling contractors, and includes the lithologic log of the hole drilled and surveyed elevations of the groundwater table and well locations.

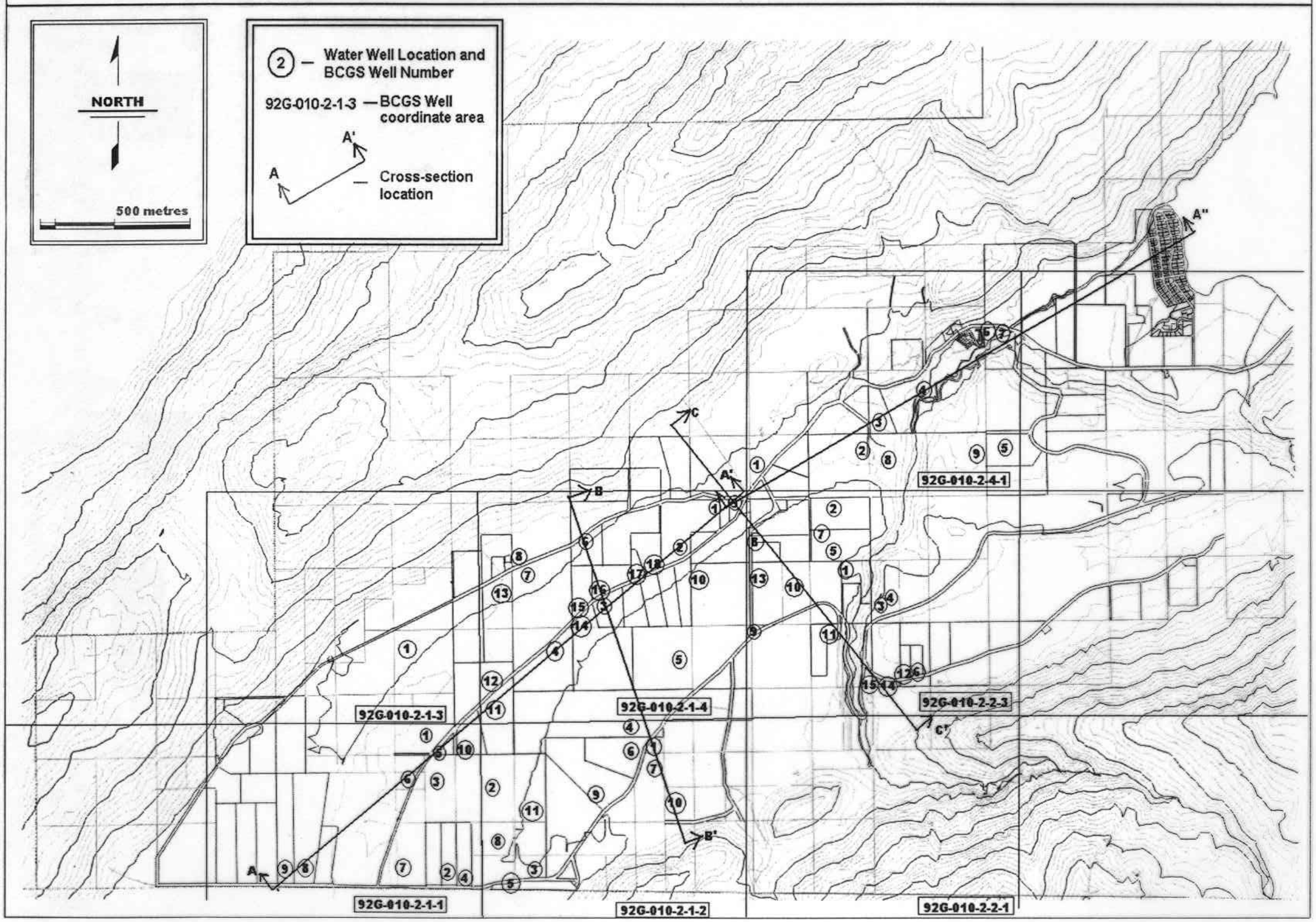
Table 4: Summary of Water Well Data, Columbia Valley, BC

BCGS Well No.	Well Site Address	Well Tag #	Year Drilled	Depth of Well, mbg	Depth to Water, mbg	Estimated Yield, L/s
092G-010-2-1-1 # 1	361 Columbia Valley Rd	x	1993	54.9	30.5 +	3.8
092G-010-2-1-1 # 2	41381 Henderson Rd	39175	1978	54.9	42.7	1.3
092G-010-2-1-1 # 3	280 Columbia Valley Rd	46793	1980	47.5	36.6	0.6
092G-010-2-1-1 # 4	41421 Henderson Rd	38257	1977	61.0	43.3	2.5
092G-010-2-1-1 # 5	360 Columbia Valley Rd	6233	1983	50.3	x	1.9
092G-010-2-1-1 # 6	231 Columbia Valley Rd	x	1995	54.9	30.5	6.3
092G-010-2-1-1 # 7	c.100 Columbia Valley Rd	x	1995	57.9	x	18.9
092G-010-2-1-1 # 8	40895 Henderson Rd	x	c.1995	c.61.0	45.0	x
092G-010-2-1-1 # 9	40835 Henderson Rd	x	1995	67.4	54.9	1.9
092G-010-2-1-1 # 10	540 Columbia Valley Rd	x	1983	48.8	38.1	3.2
092G-010-2-1-2 # 1	422 Maple Falls Rd	34341	1976	61.0	46.9	2.5
092G-010-2-1-2 # 2	290 Colter Rd	x	1994	54.9	47.9	0.6
092G-010-2-1-2 # 3	41621 Henderson Rd	36554	1977	105.2	54.9	1.6
092G-010-2-1-2 # 4	525 Maple Falls Rd	33969	1975	68.6	55.5	1.3
092G-010-2-1-2 # 5	41632 Henderson Rd	x	1995	60.4	51.8	0.5
092G-010-2-1-2 # 6	397 Maple Falls Rd	53025	1983	65.5	61.3	0.3
092G-010-2-1-2 # 7	402 Maple Falls Rd	57184	1989	68.3	57.9	0.9

BCGS Well No.	Well Site Address	Well Tag #	Year Drilled	Depth of Well, mbg	Depth to Water, mbg	Estimated Yield, L/s
092G-010-2-1-2 # 8	41525 Henderson Rd	59109	1994	62.5	47.2	3.8
092G-010-2-1-2 # 9	267 Maple Falls Rd	x	1972	78.0	61.6	1.9
092G-010-2-1-2 # 10	280 Kosikar Rd	x	1994	66.4	x	0.3
092G-010-2-1-2 # 11	41627 Henderson Rd	x	x	85.3	x	x
092G-010-2-1-3 # 1	c.810 Iverson Rd	x	1998	91.4	54.9	1.3
092G-010-2-1-4 # 1	40860 Iverson Rd	19428	1965	15.2	7.3	0.1
092G-010-2-1-4 # 2	40730 Iverson Rd	23338	1970	60.4	30.2	0.9
092G-010-2-1-4 # 3	910 Columbia Valley Rd	28694	1973	54.9	35.1	1.9
092G-010-2-1-4 # 4	700 Columbia Valley Rd	27354	1972	67.1	33.5	12.6
092G-010-2-1-4 # 5	601 Maple Falls	34242	1976	67.7	54.9	1.3
092G-010-2-1-4 # 6	1070 Iverson Rd	53471	1984	62.5	48.8	0.4
092G-010-2-1-4 # 7	1060 Iverson Rd	45039	1980	81.7	54.9	18.9
092G-010-2-1-4 # 8	1045 Iverson Rd	44993	1980	73.8	54.9	12.6
092G-010-2-1-4 # 9	1185 Columbia Valley Rd	62635	1994	51.5	35.7	2.2
092G-010-2-1-4 # 10	995 Kosikar Rd	62636	1987	92.0	61.0	25.2
092G-010-2-1-4 # 11	570 Columbia Valley Rd	39195	1978	48.8	30.5	x
092G-010-2-1-4 # 12	575 Columbia Valley Rd	57301	1987	77.4	60.0	1.3
092G-010-2-1-4 # 13	960 Iverson Rd	62634	1994	93.3	61.0	0.9
092G-010-2-1-4 # 14	800 Columbia Valley Rd	75302	1995	70.1	33.5	18.9
092G-010-2-1-4 # 15	1172 Iverson Rd	x	1996	61.3	29.9	1.3

BCGS Well No.	Well Site Address	Well Tag #	Year Drilled	Depth of Well, mbg	Depth to Water, mbg	Estimated Yield, L/s
092G-010-2-1-4 # 16	1172 Iverson Rd	x	1996	80.8	29.0	3.8
092G-010-2-1-4 # 17	1172 Iverson Rd	x	1996	73.8	28.0	4.4
092G-010-2-1-4 # 18	1172 Iverson Rd	x	1996	55.5	28.0	3.8
092G-010-2-2-3 # 1	42651 Canyon Rd	32126	1975	74.1	45.4	3.2
092G-010-2-2-3 # 2	42590 Erho Rd	53455	1984	78.6	63.1	7.9
092G-010-2-2-3 # 5	1010 Erho Rd	43433	1979	73.2	57.3	1.6
092G-010-2-2-3 # 7	1010 Erho Rd	43970	1979	17.7	DRY	x
092G-010-2-2-3 # 8	1072 Kosikar Rd	62637	1985	82.3	62.2	1.9
092G-010-2-2-3 # 9	790 Kosikar Rd	62638	1994	75.0	61.6	7 GPM
092G-010-2-2-3 # 10	42621 Canyon Rd	62639	1994	81.4	57.9	1.6
092G-010-2-2-3 # 11	781 Blatchford Rd	62640	1991	72.5	64.0	0.4
092G-010-2-2-3 # 13	982 Kosikar Rd	62642	1994	90.5	54.9	63.1
092G-010-2-4-1 # 1	1291 Columbia Valley Rd	6776	1950	9.1	DRY	x
092G-010-2-4-1 # 2	1331 Janovick Rd	33983	1975	43.9	32.0	0.8
092G-010-2-4-1 # 3	1420 Janovick Rd	36864	1977	73.5	x	1.9
092G-010-2-4-1 # 4	1650 Columbia Valley Rd	21187	1968	41.5	21.0	6.0
092G-010-2-4-1 # 6	1680 Columbia Valley Rd	48841	1981	18.0	8.5	1.3
092G-010-2-4-1 # 7	1680 Columbia Valley hwy	35307	1976	25.0	x	2.5
092G-010-2-4-1 # 8	1320 Janovick Rd	62643	1990	76.8	57.9	1.9

FIGURE 6: Locations of Water Wells, Columbia Valley BC



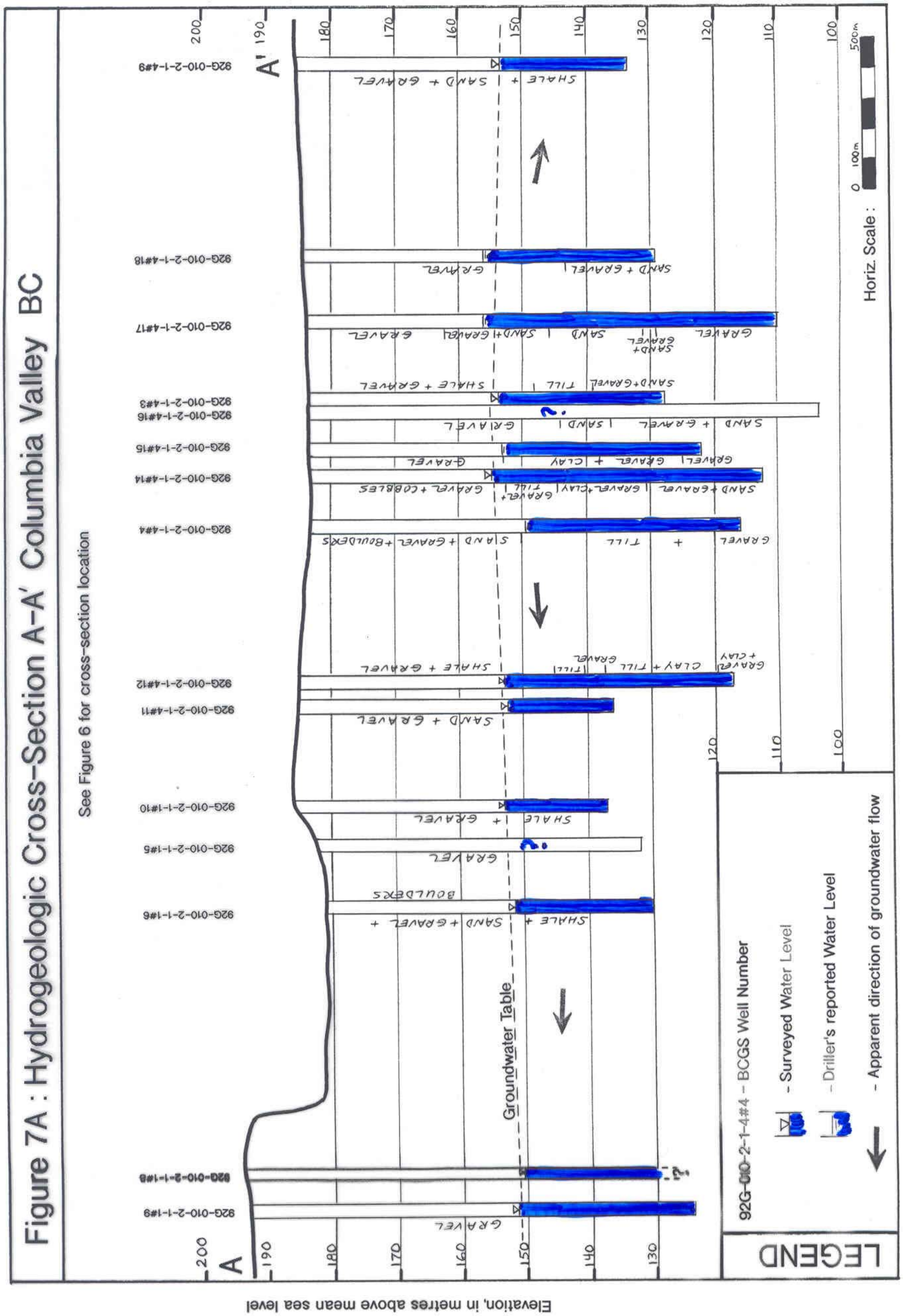


Figure 7A : Hydrogeologic Cross-Section A-A' Columbia Valley BC
See Figure 6 for cross-section location
A
A'
Groundwater Table
Elevation, in metres above mean sea level
Horiz. Scale :
0
100m
500m
LEGEND
92G-010-2-1-4#4 - BCGS Well Number
- Surveyed Water Level
- Driller's reported Water Level
- Apparent direction of groundwater flow

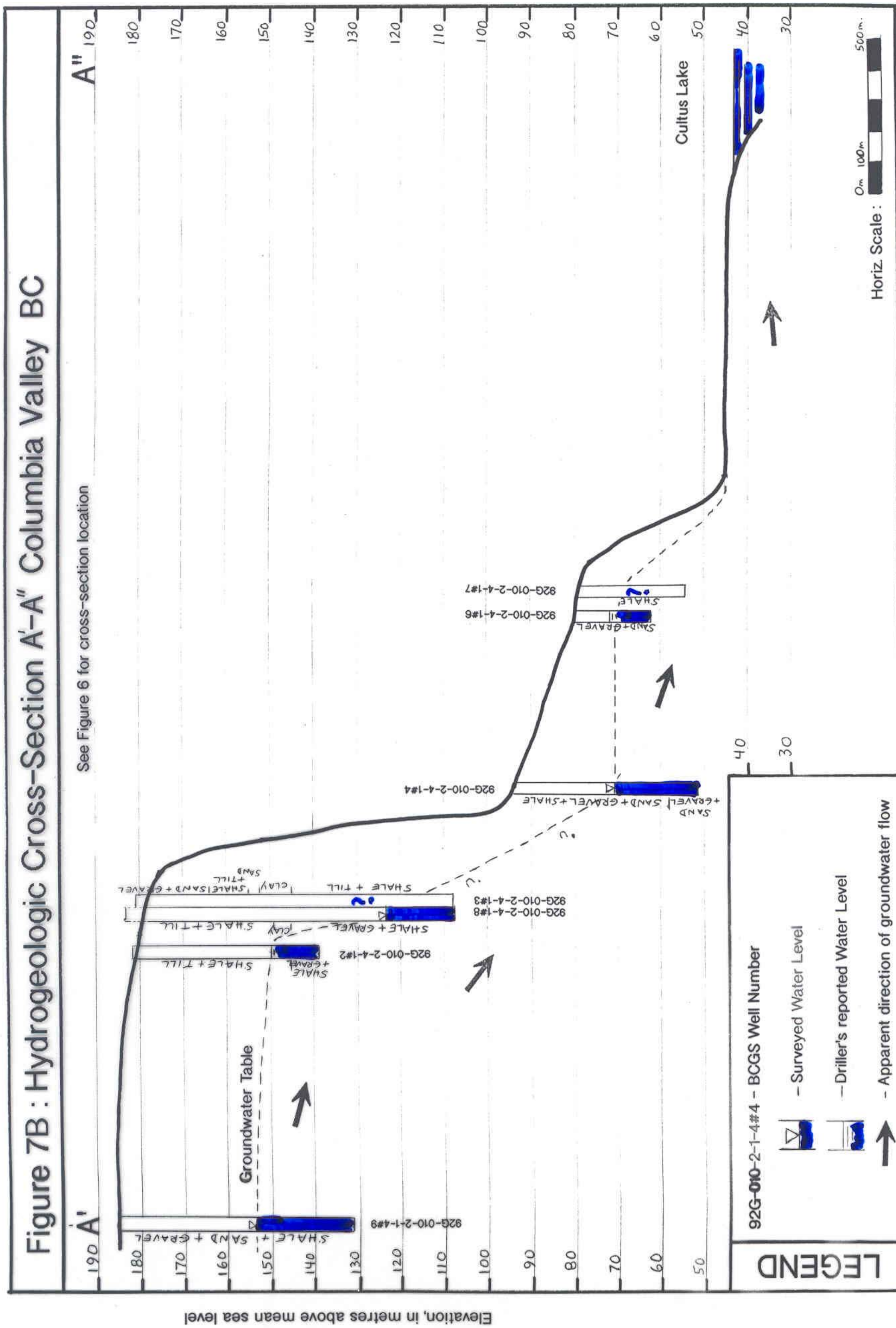


Figure 7B : Hydrogeologic Cross-Section A'-A'' Columbia Valley BC

Figure 8 : Hydrogeologic Cross-Section B-B′ Columbia Valley BC

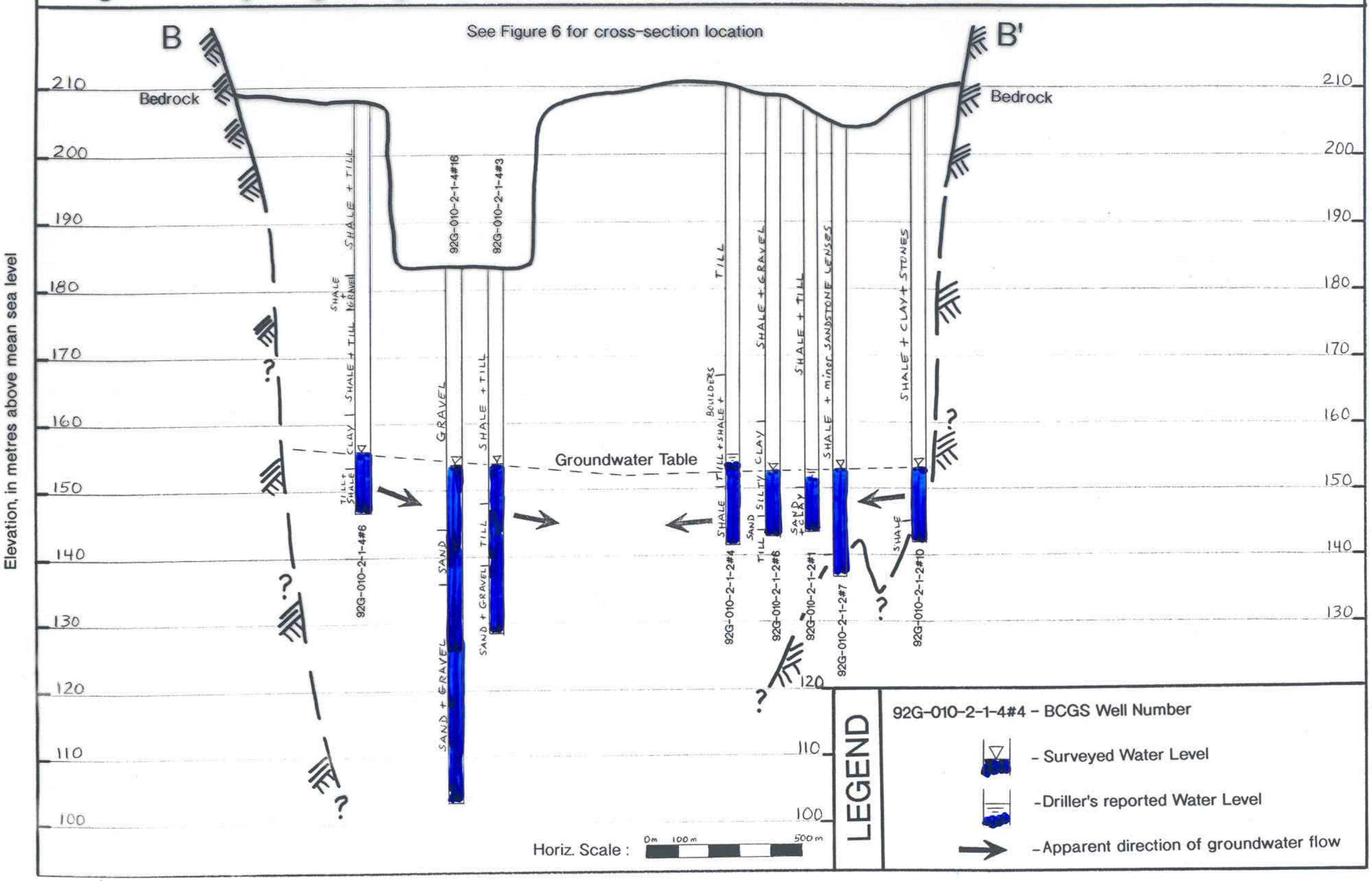
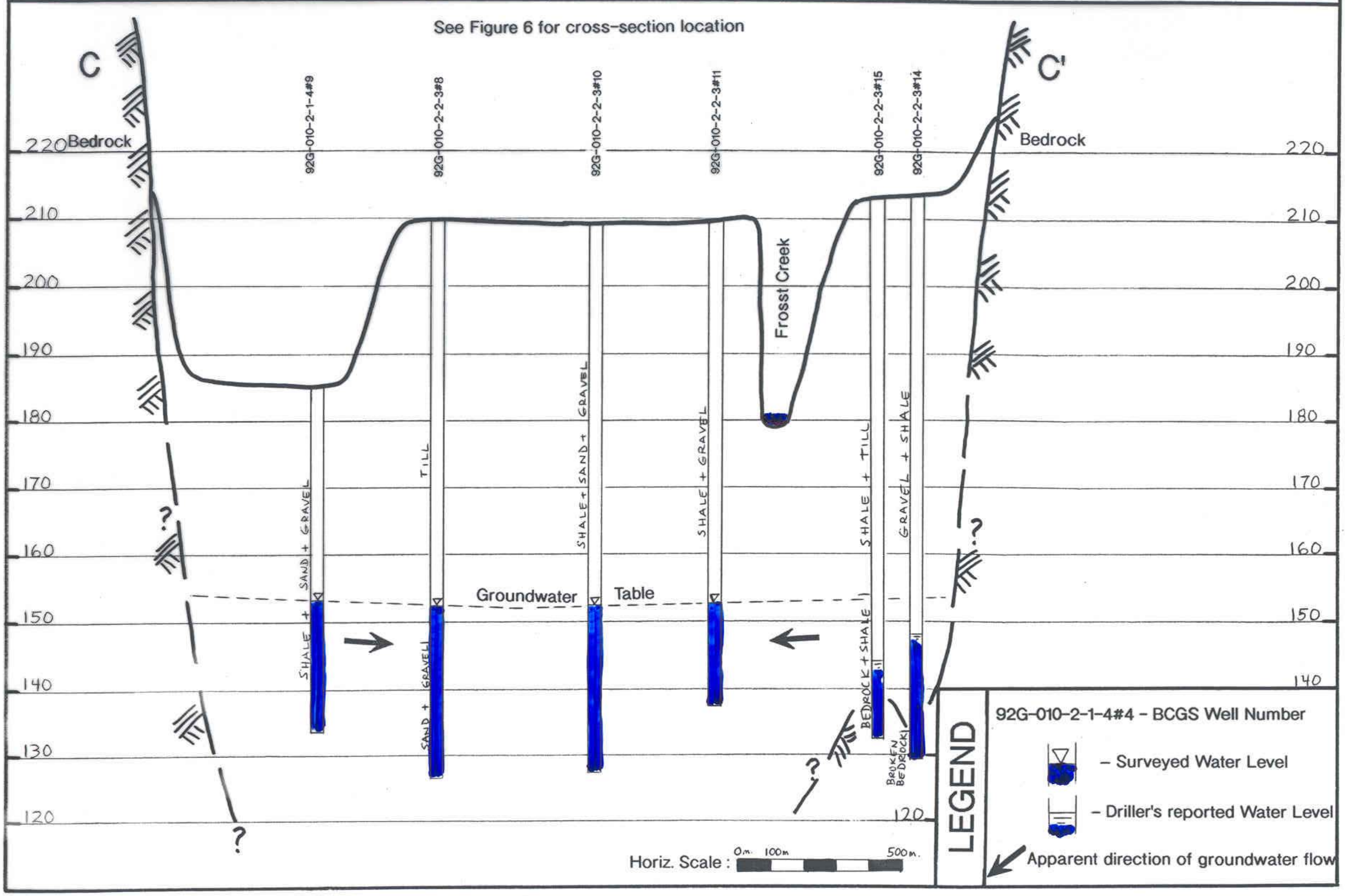


Figure 9 : Hydrogeologic Cross-Section C–C′ Columbia Valley BC



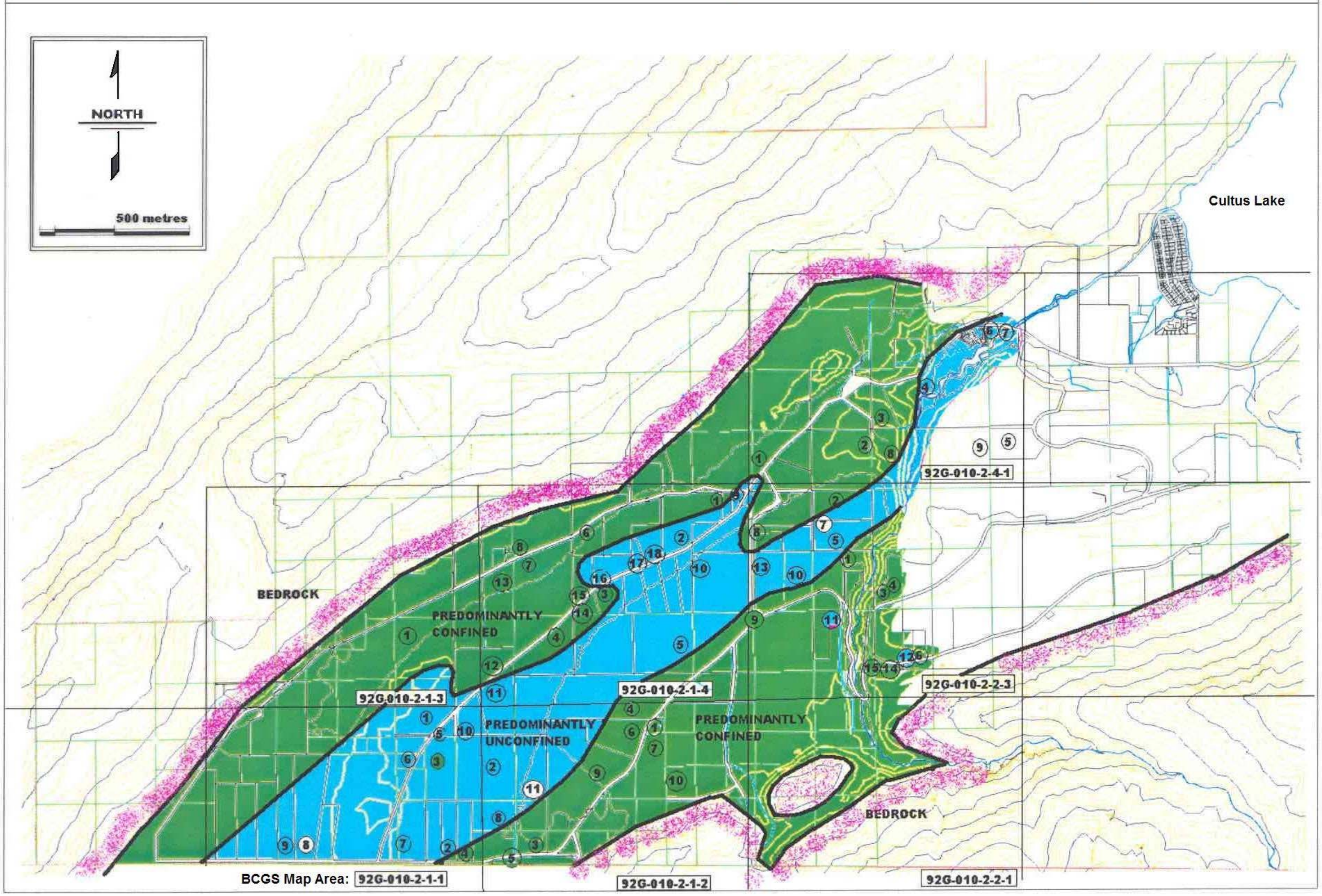
3.3 Aquifers

The subsurface sediments in the Columbia Valley were deposited directly beneath glacial ice and from glacial meltwater streams. They consist of sand, shaly gravel, cobbles, clay and till. The total thickness of these deposits is more than 120 m. During recharge periods, i.e., rainfall or snowmelt, water percolates into the ground until it reaches the groundwater table, below which all the void spaces between sand grains, gravels and cobbles are filled with water. The water-bearing sediments below the water table is called an ***aquifer*** .

Based on water well drillers' reports and the hydrogeologic cross-sections, it is evident that there is an extensive aquifer below the central part of the valley, extending from Cultus Lake to beyond the Canada/U.S. border. It is at least 50 m in thickness and about 1000 m in width. Much of this aquifer, referred to as the Columbia Valley Aquifer, is unconfined. Well record data indicates that parts of the valley are underlain by till/hardpan or clay, which would indicate that parts of the aquifer may be confined or semi-confined, depending on the extent and thickness of the till or clay layer. However, an evaluation of water well records and groundwater level measurements taken during the summer of 1997 (Figures 7A, 7B, 8, 9) indicate that none of these wells are significantly artesian in nature; which implies that these parts of the aquifer are more semi-confined than confined in nature. Based on the well record data, **Figure 10** shows the possible areal distribution of the unconfined and confined/semi-confined nature of the aquifer.

Aquifers can be classified on the basis of their transmissive property. The transmissivity of an aquifer indicates the ability of the aquifer to transmit water through its entire thickness, and is generally obtained from a mathematical evaluation of pumping test data. Transmissivity values for this aquifer are unknown due to the lack of pumping test data. However, based on the drillers' well reports that wells in the study area could produce yields of up to 76 L/s (1000 igpm), the Columbia Valley Aquifer can be tentatively classified as a highly transmissive aquifer.

FIGURE 10: Unconfined and Confined/Semi-Confined Aquifer Extent, Columbia Valley, BC



3.4 Horizontal Groundwater Movement

Groundwater is constantly moving by the force of gravity from areas of recharge, (typically areas of higher elevation) to areas of discharge (such as streams, lakes) at lower elevations. To assess the directions, rates and quantity of groundwater movement, a groundwater elevation study was conducted between July and November 1997, comprising of measurements of depths to water levels in 27 wells using an electronic water level indicator. Depths to water levels in a selected number of wells that were measured at the beginning of the measurement period were then measured a second time at the end of the measurement period to determine the rate of groundwater level change or decline. From this information all water level measurements were adjusted to a common point in time for comparison purposes. **Table 5,** provides a summary of water level measurements taken. In addition to these measurements, during October and November 1997, the 27 well sites were land-surveyed for topographic elevations. The elevations of the measured groundwater levels were then calculated and tabulated and are also reported in the following **Table 5**.

Table 5: Surveyed Groundwater Level Measurements, Columbia Valley, BC

BCGS Well No.	Surveyed Elev. of Well in metres ASL	Depth To Water in Well, in metres	Date Measured	Elevation of Water Level, in metres ASL	Adjusted Elev. in metres to 97/07/31
92G-010-2-1-1 # 4	189.4	36.3	97/07/30	153.1	153.1
92G-010-2-1-1 # 6	180.6	30.4	97/09/17	150.2	151.8
92G-010-2-1-1 # 7	177.0	27.9	97/09/29	149.1	151.1
92G-010-2-1-1 # 8	194.7	45.0	97/09/18	149.7	151.3
92G-010-2-1-1 # 9	193.3	41.4	97/08/13	151.9	152.3
92G-010-2-1-1 #10	185.5	32.6	97/08/18	152.9	153.5
92G-010-2-1-2 # 2	193.4	40.3 44.6	97/08/07 97/11/17	153.1 148.8	153.3
92G-010-2-1-2 # 5	195.2	43.0	97/08/20	152.2	152.9
92G-010-2-1-2 # 6	209.5	56.0	97/07/28	153.5	153.4
92G-010-2-1-2 # 7	204.7	51.4	97/08/12	153.3	153.7
92G-010-2-1-2 # 8	190.1	40.0	97/10/24	150.1	151.9
92G-010-2-1-2 #10	209.5	56.1	97/08/12	153.4	153.8
92G-010-2-1-4 # 3	183.2	29.4	97/07/28	153.8	153.7
92G-010-2-1-4 # 5	211.6	59.9	97/09/08	151.7	153.0
92G-010-2-1-4 # 6	207.5	51.8 54.2	97/08/20 97/11/26	155.7 153.3	156.4

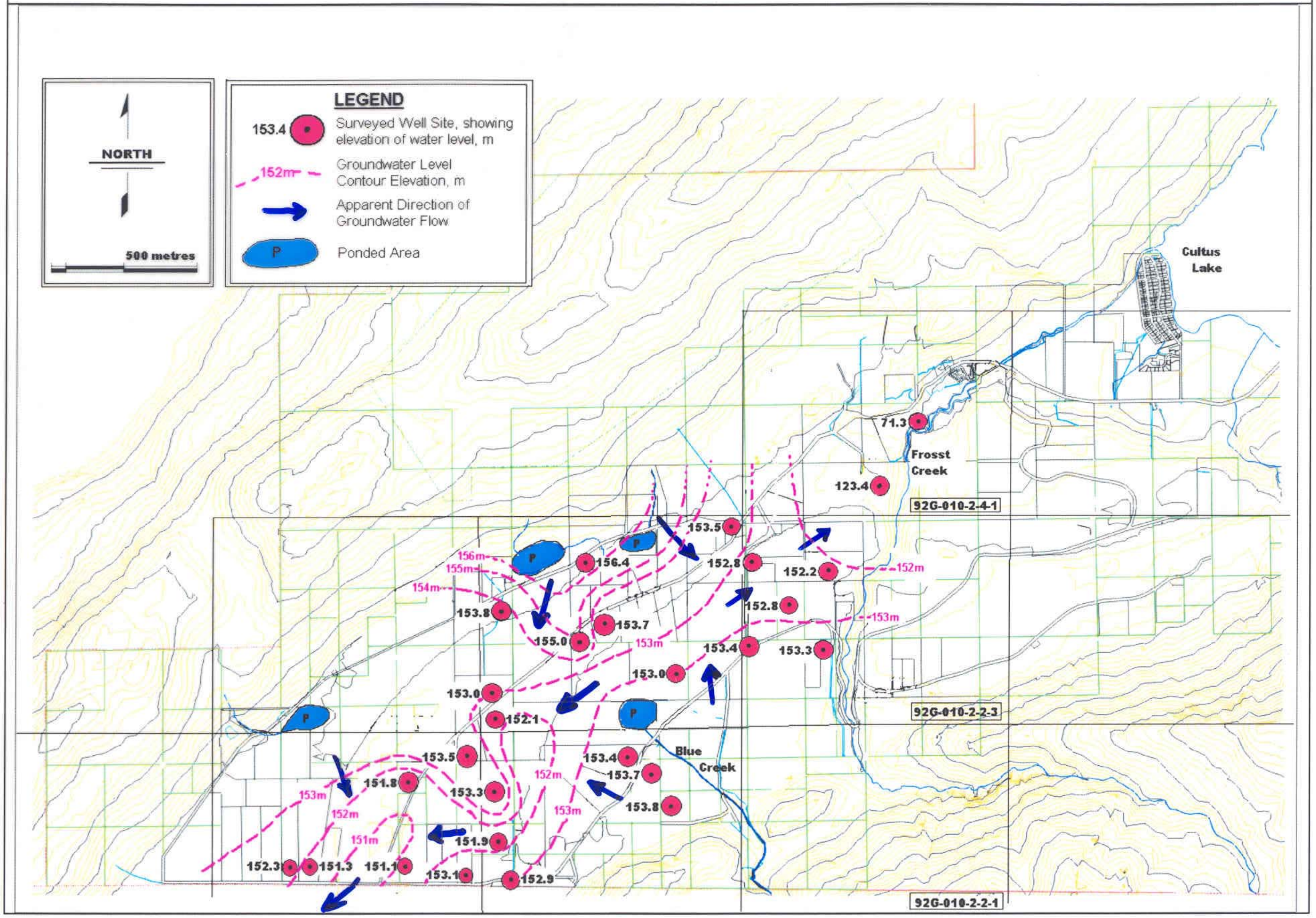
BCGS Well No.	Surveyed Elev. of Well in metres ASL	Depth To Water in Well, in metres	Date Measured	Elevation of Water Level, in metres ASL	Adjusted Elev. in metres to 97/07/31
92G-010-2-1-4 # 9	185.0	32.0	97/08/13	153.0	153.5
92G-010-2-1-4 #11	185.3	34.8	97/09/18	150.5	152.1
92G-010-2-1-4 #12	184.2	31.1 35.8	97/07/28 97/11/17	153.1 148.4	153.0
92G-010-2-1-4 #13	207.1	53.9 57.2	97/08/18 97/11/26	153.2 149.9	153.8
92G-010-2-1-4 #14	182.6	27.5	97/07/28	155.1	155.0
92G-010-2-2-3 # 5	203.3	52.4	97/09/08	150.9	152.2
92G-010-2-2-3 # 8	209.3	56.9	97/08/12	152.4	152.8
92G-010-2-2-3 # 9	206.8	54.0	97/08/18	152.8	153.4
92G-010-2-2-3 #10	209.3	57.8	97/09/10	151.5	152.8
92G-010-2-2-3 #11	210.3	57.7	97/08/20	152.6	153.3
92G-010-2-4-1 # 4	93.8	23.2	97/08/21	70.6	71.3
92G-010-2-4-1 # 8	183.5	60.8	97/08/21	122.7	123.4

Groundwater elevation contours were then constructed using the adjusted water level elevations and are illustrated in **Figure 11**. Directions of groundwater flow are shown perpendicular to the elevation contours. Analysis of the groundwater level contour map indicates:

- that groundwater elevations are highest near the toe of the mountain slopes, and lowest towards the middle part of the valley;
- groundwater flows through the permeable sediments from the north-west edge and south-east edge of the aquifer towards the middle of the valley;
- there is a groundwater mound or divide occurring in the central part of the valley, coincident with areas of surface water discharge/seepage, eg. Blue Creek;
- at the divide, one component of groundwater flow travels towards the Canada – U.S. international border, and the other component of flow travels towards Cultus Lake (see Figure 7A).

The rate of groundwater flow or average velocity is dependent on the hydraulic gradient of the groundwater table, the hydraulic conductivity or permeability of the aquifer material and the porosity of the aquifer material. This can be mathematically expressed in the following

Figure 11 : Groundwater Elevation Contour Map, Columbia Valley, BC



equation as **V = Ki/n**, where **V** is the velocity, **K** is the hydraulic conductivity, **i** is the hydraulic gradient and **n** is the porosity. Assuming the following:

- $K = 5 \times 10^{-4}$ meters per second (m/s) for unconsolidated sand and gravel deposits (according to Freeze and Cherry, 1979, values for clean sand and gravel vary between 10^{-3} to 10^{-2} m/s)
- i = 0.005 (0.5% is the average hydraulic gradient from the central part of the study area towards the Canada – U.S. border and from the central part of the study area toward Frosst Creek)
- n = 0.3 (according to Freeze and Cherry, 1979, values of porosity for unconsolidated sand and gravel can range between 25% to 40%)

then, the average velocity of horizontal groundwater flow in the central part of the valley could realistically be about 260 metres/year. If the cross-sectional area of the aquifer (across the central part of the study area) is at least 50,000 m^2 (50 m thickness X 1000 m width), then the minimum amount of lateral groundwater flow in the valley is estimated at 13 Million m^3/year, or 13 Billion Litres/year.

3.5 Vertical Groundwater Flow

Agricultural chemicals, surface spills and other potential groundwater contaminants can be transported to the water table by natural infiltration and rainfall events. According to Gillham (1982), contaminated water can move vertically down a soil profile as a slug, in response to an infiltration or recharge event, and the soil then becomes saturated to a degree, or is said to have a residual water content. Subsequent infiltration or recharge events can “push” or displace the water that was originally present in the initial saturated soil profile. The vertical movement of water is analogous to wave action, with the water reaching the groundwater table not being the latest water that was added to the soil. Considering this mechanism, the time of arrival of a contaminant to the water table can be calculated on the basis of the residual water content of the soil and the annual rate of infiltration.

In 1996, Agriculture Canada conducted moisture content testing of samples of soil taken from a well at 800 Columbia Valley Road (See **Appendix 2** for details). According to the water well driller's report, the original depth to the water table at the time of well construction was measured at 110 feet, or 33.5 m. Using Agriculture Canada's results, the average moisture content or residual water content of the soils down to 33.5 m is 8%. Mean annual precipitation in the Columbia Valley is approximately 1,533 mm. Based on Kohut's (1987) water balance study in the Abbotsford Upland Aquifer (which has similar characteristics as the Columbia Valley Aquifer) the amount of recharge into the aquifer from precipitation could be as high as 63% of the mean annual precipitation. This assumes that all of the moisture surplus infiltrates to the water table and surface runoff does not occur. Given that the study area is generally underlain by very permeable sand and gravel sediments and that there is practically no surface water runoff, the amount of recharge into the Columbia Valley Aquifer could realistically be 63% of 1533 mm or 0.966 m.

Using a residual water content of 8%, the initial infiltration of 0.966 m of water per year would be distributed in the upper 12 metres of soil (i.e. 0.966 m / 0.08 = 12 m). Each successive annual infiltration of 0.966 m of water would cause a contaminated slug to move down the soil profile another 12 m. As a result, it would take about 2.8 years for the contaminant to reach the water table (i.e. 33.5 m / 12 m per year = 2.8 years). Although this analysis does not consider the effects of dispersion, which would be considered very minimal for permeable sand and gravel deposits, it is a reasonable means of obtaining a first order estimate of the arrival time.

3.6 Aquifer Water Balance

An aquifer water balance can simply be defined as a mathematical accounting or balancing of the annual amount of water that enters or recharges an aquifer system and the annual amount of water that leaves or discharges the same aquifer system. The amount of water entering an aquifer should be balanced by the amount of water leaving an aquifer. This annual relationship depends upon a number of factors, and can be mathematically represented in the following way:

$$\mathbf{RE = DI = (PR + ST + IR + GW) - (RO + EV + GE)}$$

where: RE = Recharge,

DI = Discharge,

PR = Precipitation,

ST = Stream flows, which includes spring flows off the hillsides,

IR = Irrigation return flows,

GW = Groundwater inflow,

RO = Runoff,

EV = Evapotranspiration,

GE = Groundwater extraction.

The Columbia Valley Aquifer is recharged predominantly from precipitation (rainfall and snowmelt). As previously mentioned, the amount of annual recharge into the aquifer was estimated at 0.966 m or approximately 1 metre per year. This assumes that all of the moisture surplus infiltrates to the water table and consequently takes into account evapotranspiration losses. Assuming the areal extent of the aquifer within the study area is about 8.7 km^2, then it is reasonable that there could be about 9 Billion litres of water entering the aquifer each year from precipitation infiltration, i.e., **PR – EV** = $9X10^9$ L/year.

Water from springs, creeks and streams flowing down the mountain sides disappear into the very permeable valley floor, adding to aquifer recharge. The amount of flow from these surface water sources can vary throughout the year. Rough measurements taken of flows on Blue Creek and flows from several minor creeks off Vedder Mountain indicate that average annual streamflows (**ST**) could be in the order of 17 Billion litres per year.

The amount of groundwater withdrawals from water wells is not known due to a lack of metered data. However, based on an estimated daily water requirement of 250 Litres/day per person for domestic use and assuming an average of 3 persons per household, then the estimated amount of groundwater extraction from the 56 known wells in the study area could be in the order of 15 Million Litres per year (15M L/year). Assuming lawn and garden needs for these 56 users is 10,000 litres per day, then for 100 days (summer period), this would total about 56M L/year. Assuming irrigation/agricultural needs for 10 users averages

400,000 litres per day, then for 100 days (summer period), this would total about 40M L/year. For the remaining 265 days, and assuming that agricultural water needs would be less, say about 150,000 litres per day, the additional amount of groundwater extraction could be about 40M L/year. The estimated total amount of groundwater withdrawals or **GE** in the study area could be in the order of 151M L/year, or 0.15B L/year. If 63% of the amount used for irrigation (40M L/year) returns into the ground, then irrigation return flows or **IR** would be about 25M L/year, or 0.03B L/year.

There is no runoff within the study area, consequently **RO** = 0. Evapotranspiration (**EV**) has been accounted for in the amount of precipitation recharging the aquifer. The only source of groundwater inflow (**GW**) that may occur could be from water in the fractures in the bedrock mountains flanking the valley. However, a significant amount of groundwater inflow has already been accounted for as spring flows along Vedder Mountain. It is unknown how much additional groundwater may be discharging from bedrock fractures at depth. Typically, bedrock fractures yield very little water, consequently the value for GW can be assumed negligible or 0.

Entering the above values into the equation:

RE	=	DI
	=	(PR + ST + IR + GW) – (RO + EV + GE)
	=	(9B L/yr + 17B L/yr + 0.03B L/yr + 0) - (0 + 0 + 0.15B L/yr)
	=	26B L/year

Discharge from this aquifer is predominantly northward towards Cultus Lake and southward towards the Canada/U.S. border. Assuming that the quantity of flow across these two areas is relatively the same, then the amount of discharge travelling towards each area is about 13B L/year. This figure agrees reasonably well with the estimated minimum amount of groundwater flow in the valley of 13B L/year (section 3.4).

3.7 Groundwater Storage and Potential for Further Development

Assuming the aquifer extends over an area of about 8.7 km^2, and has a thickness of at least 50 m, its volume would be about 435 Million cubic metres. Using a porosity of 30%, this groundwater reservoir contains at least 130.5 Million cubic metres, or 130.5 Billion Litres of groundwater stored within its pores. In addition to this amount of groundwater storage, precipitation temporarily adds approximately 26 Billion Litres of water into the aquifer each year. The amount of groundwater withdrawal was estimated at 0.15B L/year which represents only about 0.6 % of the amount of recharge into the aquifer. As a general conclusion, there is a tremendous potential for further groundwater development.

4. Hydrochemistry

4.1 Groundwater Quality Sampling and Analysis

In 1994, Project Enviro-Health, a program of the Upper Fraser Valley Health Services Society with assistance from the Abbotsford Health Assessment Unit of the BC Ministry of Health, initiated a groundwater quality study to assess the nitrate and nitrite concentrations in water wells in the Columbia Valley. Water samples were obtained from 26 wells in November 1994 and April 1995 and tested for nitrate-nitrogen. Results of the analyses were tabulated in the August 1995 report: "The Columbia Valley Aquifer, British Columbia: Groundwater Analysis for Nitrate" by Stephen M. Caine and Dr. Ruth Cridland, Ph.D.

In summary, the laboratory results showed that all samples had nitrate-nitrogen concentrations below the 10 mg/L health guideline. Two wells had nitrate-nitrogen concentrations over 3.0 mg/L. There were no indications from this study that general land use practices caused groundwater pollution with respect to nitrate. However, it was concluded that localized sources of contamination may exist, and land use management in these areas was essential to maintaining safe drinking water quality.

During the summer/fall of 1997, a more comprehensive groundwater quality sampling program was initiated in the valley to determine changes in water quality since the Enviro-

Health study and to obtain water quality data on other chemical parameters besides nitrate and nitrite. Samples of water were obtained from 36 water wells and 32 surface water sources (springs, creeks, brooks) and sent to the Environment Canada laboratory in North Vancouver for analysis. Additional samples of groundwater were collected from selected wells during 1998 and 1999 to assess trends in water quality. Results of these groundwater quality analyses, including some historical data obtained from local homeowners, are contained in **Table 6**.

The following section briefly explains the significance of selected physical and chemical parameters and the results of the chemical analyses.

Calcium (Ca) and Magnesium (Mg)

Calcium is common in water and contributes to the “hardness” of water. According to Health and Welfare Canada’s “Guidelines for Canadian Drinking Water Quality” (GCDWQ), fifth edition, currently available data indicates no health risk or aesthetic problems with calcium. The calcium content in the groundwaters of the study area were measured at less than 63 mg/L, which would be considered low in contributing to the hardness of water.

Magnesium is also a mineral which is a universal constituent of natural water and greatly contributes to hardness in water. Currently available data indicates no health risk or aesthetic problems associated with magnesium. The magnesium content in the groundwater within the study area were measured at less than about 8 mg/L, which would be considered very low in contributing to the hardness of water.

Table 6: Groundwater Quality Analyses, Columbia Valley, BC

#	Well Location	Date Sampled	EMS Number	Conductivity (micromhos/cm)	pH	Nitrite-N	Nitrate-N	Silver (Ag)	Aluminum (Al)	Arsenic (As)	Boron (B)	Barium (Ba)
				GCDWQ MAC >>>	6.5 - 8.5	1.0 mg/L	10.0 mg/L	NG	0.2 mg/L	0.025 mg/L	5.0 mg/L	1.0 mg/L
1	1650 Columbia Valley Rd.	97-08-13	E227755	195	7.27	<.002	0.584	<.01	<.06	<.06	.02	.019
2	1185 Columbia Valley Rd.	94-11-00	NorWest	x	x	x	2.17	x	x	x	x	x
2a	1185 Columbia Valley Rd.	95-04-00	NorWest	x	x	x	1.83	x	x	x	x	x
2b	1185 Columbia Valley Rd.	96-08-27	Env-Can	x	7.35	<.002	2.56	x	x	x	x	x
2c	1185 Columbia Valley Rd.	97-06-24	NorWest	200	7.00	x	2.18	x	x	x	0.02	x
2d	1185 Columbia Valley Rd.	97-08-13	E227456	125	7.10	<0.02	1.82	<.01	<.06	<.06	<.01	.01
2e	1185 Columbia Valley Rd.	98-10-27	E227456	x	7.14	<.002	1.71	x	x	x	x	x
3	910 Columbia Valley Rd.	94-11-00	NorWest	x	x	x	7.91	x	x	x	x	x
3a	910 Columbia Valley Rd.	95-04-00	NorWest	x	x	x	7.95	x	x	x	x	x
3b	910 Columbia Valley Rd.	96-03-27	Zenon	x	7.20	<.005	8.61	<.03	<.06	<.04	<.04	.011
3c	910 Columbia Valley Rd.	96-08-27	Env-Can	x	7.63	<.002	9.58	x	x	x	x	x
3d	910 Columbia Valley Rd.	97-03-00	NorWest	x	x	x	12.87	x	x	x	x	x
3e	910 Columbia Valley Rd.	97-07-28	E227421	230	7.26	0.003	8.83	<.01	<.06	<.06	.01	.016
3f	910 Columbia Valley Rd.	98-02-10	E227421	x	x	0.004	9.23	x	x	x	x	x
3g	910 Columbia Valley Rd.	98-08-20	E227421	x	7.34	0.007	8.45	x	x	x	x	x
3h	910 Columbia Valley Rd.	98-10-27	E227421	x	7.33	0.03	6.5	x	x	x	x	x
3i	910 Columbia Valley Rd.	99-03-08	E227421	8.53	7.42	0.01	8.88	x	x	x	x	x
4	800 Columbia Valley Rd.	96-07-03	Zenon	6.23	x	<.005	8.53	<.01	<.02	<.0005	0.03	0.01
4a	800 Columbia Valley Rd.	96-08-27	Env-Can	5.21	8.34	0.028	6.23	<.01	<.06	<.06	<.01	.007
4b	800 Columbia Valley Rd.	97-05-16	NorWest	x	x	x	7.05	x	x	x	x	x

#	Beryllium (Be)	Calcium (Ca)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Potassium (K)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)
MAC>>	**NG**	**NG**	**0.005 mg/L**	**NG**	**0.05 mg/L**	**(<1.0) mg/L**	**(<0.3) mg/L**	**NG**	**500 mg/L**	**(<0.05) mg/L**	**0.25 mg/L**
1	<.001	43.7	<.006	<.006	.015	.008	<.006	<.1	3.9	.001	<.01
2	x	x	x	x	x	x	x	x	x	x	x
2a	x	x	x	x	x	x	x	x	x	x	x
2b	x	x	x	x	x	x	x	x	x	x	x
2c	x	31.7	x	x	x	<.01	0.30	0.7	4.81	0.01	x
2d	<.001	28.6	<.006	<.006	.009	<.006	.17	<.1	4.6	.002	<.01
2e	x	x	x	x	x	x	x	x	x	x	x
3	x	x	x	x	x	x	x	x	x	x	x
3a	x	x	x	x	x	x	x	x	x	x	x
3b	<.001	50.0	<.002	<.004	<.002	0.009	<.05	0.7	6.7	<.002	<.004
3c	x	x	x	x	x	x	x	x	x	x	x
3d	x	x	x	x	x	x	x	x	x	x	x
3e	<.001	43.2	<.006	<.006	<.006	<.006	4.26	0.8	6.5	.08	<.01
3f	x	x	x	x	x	x	x	x	x	x	x
3g	x	x	x	x	x	x	x	x	x	x	x
3h	x	x	x	x	x	x	x	x	x	x	x
3i	x	x	x	x	x	x	x	x	x	x	x
4	x	31.3	<.002	<.003	0.004	0.002	0.111	1.5	7.38	0.012	<.004
4a	<.001	26.4	<.006	<.006	<.006	<.006	0.412	0.7	7.1	0.044	<.01
4b	x	x	x	x	x	x	x	x	x	x	x

#	Sodium (Na)	Nickel (Ni)	Phosphorus (P)	Lead (Pb)	Sulfur (S)	Antimony (Sb)	Selenium (Se)	Silica (Si)	Tin (Sn)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)
MAC>>	**(<200) mg/L**	**NG**	**NG**	**0.01 mg/L**	**NG**	**0.006 mg/L**	**0.01 mg/L**	**NG**	**NG**	**NG**	**NG**	**NG**	**(<5.0) mg/L**
1	2.6	.03	<.1	<.06	5.31	<.06	<.06	4.67	<.06	0.304	<.002	<.01	.037
2	x	x	x	x	x	x	x	x	x	x	x	x	x
2a	x	x	x	x	x	x	x	x	x	x	x	x	x
2b	x	x	x	x	x	x	x	x	x	x	x	x	x
2c	4.4	x	x	x	x	x	x	x	x	x	x	x	0.08
2d	3.2	<.02	<.1	<.06	4.68	<.06	<.06	5.24	<.06	0.335	<.002	<.01	.039
2e	x	x	x	x	x	x	x	x	x	x	x	x	x
3	x	x	x	x	x	x	x	x	x	x	x	x	x
3a	x	x	x	x	x	x	x	x	x	x	x	x	x
3b	4.8	<.01	<.04	<.03	3.60	<.02	<.03	9.00	<.02	0.223	<.003	<.003	0.01
3c	x	x	x	x	x	x	x	x	x	x	x	x	x
3d	x	x	x	x	x	x	x	x	x	x	x	x	x
3e	4.3	<.02	<.1	<.06	2.98	<.06	<.06	9.76	<.06	0.234	.003	<.01	.478
3f	x	x	x	x	x	x	x	x	x	x	x	x	x
3g	x	x	x	x	x	x	x	x	x	x	x	x	x
3h	x	x	x	x	x	x	x	x	x	x	x	x	x
3i	x	x	x	x	x	x	x	x	x	x	x	x	x
4	4.44	<.008	x	<.001	x	x	<.03	x	x	x	x	0.003	0.005
4a	4.0	<.02	<.1	<.06	x	<.06	<.06	6.50	<.06	0.185	<.002	<.01	0.013
4b	x	x	x	x	x	x	x	x	x	x	x	x	x

#	Well Location	DateSampled	EMSNumber	Conductivity (micromhos/cm)	pH	Nitrite-N	Nitrate-N	Silver (Ag)	Aluminum (Al)	Arsenic (As)	Boron (B)	Barium (Ba)
				GCDWQ MAC >>>	6.5 - 8.5	1.0 mg/L	10.0 mg/L	NG	0.2 mg/L	0.025 mg/L	5.0 mg/L	1.0 mg/L
4c	800 Columbia Valley Rd.	97-07-28	E227422	1.93	7.33	.023	5.21	<.01	<.06	<.06	<.01	.008
4d	800 Columbia Valley Rd.	98-02-10	E227422	1.90	x	0.002	1.93	x	x	x	x	x
4e	800 Columbia Valley Rd.	98-08-20	E227422	1.80	7.54	0.026	1.90	x	x	x	x	x
4f	800 Columbia Valley Rd.	98-10-27	E227422	1.90	7.39	<.002	1.80	x	x	x	x	x
4g	800 Columbia Valley Rd.	99-03-08	E227422	x	7.50	<.002	1.90	x	x	x	x	x
5	575 Columbia Valley Rd.	94-11-00	NorWest	x	x	x	ND	x	x	x	x	x
5a	575 Columbia Valley Rd.	95-04-00	NorWest	x	x	x	0.25	x	x	x	x	x
5b	575 Columbia Valley Rd.	96-03-27	Zenon	x	8.10	<.005	<.02	<.03	<.06	<.04	0.15	0.016
5c	575 Columbia Valley Rd.	96-08-27	Env-Can	x	x	<.002	0.004	x	x	x	x	x
5d	575 Columbia Valley Rd.	97-07-28	E227420	228	8.28	<.002	0.002	<.01	<.06	<.06	0.13	.017
6	570 Columbia Valley Rd.	94-11-00	NorWest	x	x	x	1.60	x	x	x	x	x
6a	570 Columbia Valley Rd.	95-04-00	NorWest	x	x	x	2.85	x	x	x	x	x
6b	570 Columbia Valley Rd.	96-08-27	Env-Can	x	8.17	<.002	2.30	x	x	x	x	x
6c	570 Columbia Valley Rd.	97-09-18	E228259	193	7.99	<.002	3.89	<.01	<.06	<.06	<.01	.008
6d	570 Columbia Valley Rd.	98-02-11	E228259	x	x	<.002	4.01	x	x	x	x	x
6e	570 Columbia Valley Rd.	98-10-27	E228259	x	7.88	<.002	2.18	x	x	x	x	x
6f	570 Columbia Valley Rd.	99-03-22	E228259	x	7.96	<.002	2.96	x	x	x	x	x
7	540 Columbia Valley Rd.	97-08-18	E227778	210	7.94	<.002	4.39	.01	.07	<.06	<.01	.007
7a	540 Columbia Valley Rd.	98-02-10	E227778	x	x	<.002	5.06	x	x	x	x	x
7b	540 Columbia Valley Rd.	98-02-19	E227778	x	x	x	x	<.01	<.06	<.06	0.02	0.006

#	Beryllium (Be)	Calcium (Ca)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Potassium (K)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)
MAC>>	NG	NG	0.005 mg/L	NG	0.05 mg/L	(<1.0) mg/L	(<0.3) mg/L	NG	500 mg/L	(<0.05) mg/L	0.25 mg/L
4c	<.001	25.5	<.006	<.006	0.007	<.006	.137	0.7	6.5	.019	<.01
4d	x	x	x	x	x	x	x	x	x	x	x
4e	x	x	x	x	x	x	x	x	x	x	x
4f	x	x	x	x	x	x	x	x	x	x	x
4g	x	x	x	x	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x	x
5a	x	x	x	x	x	x	x	x	x	x	x
5b	<.001	25.3	<.002	<.004	<.002	<.002	0.21	3.2	4.42	0.024	0.016
5c	x	x	x	x	x	x	x	x	x	x	x
5d	<.001	23.2	<.006	<.006	.01	<.006	.151	3.0	4.1	0.026	<.01
6	x	x	x	x	x	x	x	x	x	x	x
6a	x	x	x	x	x	x	x	x	x	x	x
6b	x	x	x	x	x	x	x	x	x	x	x
6c	<.001	46.4	<.006	0.023	<.006	0.008	0.019	1.0	4.9	<.001	<.01
6d	x	x	x	x	x	x	x	x	x	x	x
6e	x	x	x	x	x	x	x	x	x	x	x
6f	x	x	x	x	x	x	x	x	x	x	x
7	.002	51.9	.006	<.006	.023	.016	.022	0.8	3.3	.003	<.01
7a	x	x	x	x	x	x	x	x	x	x	x
7b	<.001	56	<.006	<.006	<.006	<.006	0.027	0.6	3.4	0.001	<.01

#	Sodium (Na)	Nickel (Ni)	Phosphorus (P)	Lead (Pb)	Sulfur (S)	Antimony (Sb)	Selenium (Se)	Silica (Si)	Tin (Sn)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)
MAC>>	(<200) mg/L	NG	NG	0.01 mg/L	NG	0.006 mg/L	0.01 mg/L	NG	NG	NG	NG	NG	(<5.0) mg/L
4c	3.9	<.02	<.1	<.06	2.44	<.06	<.06	7.87	<.06	0.181	<.002	<.01	1.96
4d	x	x	x	x	x	x	x	x	x	x	x	x	x
4e	x	x	x	x	x	x	x	x	x	x	x	x	x
4f	x	x	x	x	x	x	x	x	x	x	x	x	x
4g	x	x	x	x	x	x	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x	x	x	x
5a	x	x	x	x	x	x	x	x	x	x	x	x	x
5b	40.6	<.01	0.10	<.03	21.8	<.02	<.03	5.80	<.02	0.171	<.003	<.003	0.09
5c	x	x	x	x	x	x	x	x	x	x	x	x	x
5d	34.6	<.02	<.01	<.06	19.2	<.06	<.06	5.89	<.06	0.174	0.004	<.01	0.059
6	x	x	x	x	x	x	x	x	x	x	x	x	x
6a	x	x	x	x	x	x	x	x	x	x	x	x	x
6b	x	x	x	x	x	x	x	x	x	x	x	x	x
6c	<.1	0.03	<.1	<.06	5.71	<.06	<.06	6.53	<.06	0.264	<.002	<.01	0.061
6d	x	x	x	x	x	x	x	x	x	x	x	x	x
6e	x	x	x	x	x	x	x	x	x	x	x	x	x
6f	x	x	x	x	x	x	x	x	x	x	x	x	x
7	3.7	0.03	<.1	0.12	5.67	<.06	<.06	4.92	<.06	0.26	0.009	0.02	0.014
7a	x	x	x	x	x	x	x	x	x	x	x	x	x
7b	2.9	<.02	<.1	<.06	6.91	<.06	<.06	5.06	<.06	0.272	<.002	<.01	<.002

#	Well Location	Date Sampled	EMS Number	Conductivity (micromhos/cm)	pH	Nitrite-N	Nitrate-N	Silver (Ag)	Aluminum (Al)	Arsenic (As)	Boron (B)	Barium (Ba)
				GCDWQ MAC >>>	6.5 - 8.5	1.0 mg/L	10.0 mg/L	NG	0.2 mg/L	0.025 mg/L	5.0 mg/L	1.0 mg/L
7c	540 Columbia Valley Rd.	98-08-20	E227778	x	7.98	<.002	3.29	x	x	x	x	x
8	361 Columbia Valley Rd.	97-12-04	E229678	x	8.04	<.002	1.88	<.01	<.06	<.06	0.02	0.043
9	360 Columbia Valley Rd.	94-11-00	NorWest	x	x	x	1.07	x	x	x	x	x
9a	360 Columbia Valley Rd.	95-04-00	NorWest	x	x	x	0.90	x	x	x	x	x
9b	360 Columbia Valley Rd.	96-08-27	Env-Can	x	8.08	<.002	4.24	x	x	x	x	x
9c	360 Columbia Valley Rd.	97-07-31	E227452	190	7.82	<.002	3.64	<.01	<.06	<.06	.02	.005
9d	360 Columbia Valley Rd.	98-02-10	E227452	x	x	<.002	4.37	x	x	x	x	x
9e	360 Columbia Valley Rd.	98-08-20	E227452	x	7.95	<.002	3.23	x	x	x	x	x
9f	360 Columbia Valley Rd.	98-10-27	E227452	x	7.88	<.002	2.79	x	x	x	x	x
9g	360 Columbia Valley Rd.	99-03-22	E227452	x	7.90	<.002	2.45	x	x	x	x	x
10	280 Columbia Valley Rd.	97-09-22	E228258	285	7.86	<.002	3.02	<.01	<.06	<.06	0.02	.007
10a	280 Columbia Valley Rd.	98-02-11	E228258	x	x	<.002	2.89	x	x	x	x	x
11	231 Columbia Valley Rd.	97-09-17	E228140	179	8.03	<.002	2.22	<.01	<.06	<.06	0.02	.008
11a	231 Columbia Valley Rd.	98-08-20	E228140	x	7.93	<.002	2.55	x	x	x	x	x
12	1172 Iverson Road Lot 1	96-02-27	NorWest	241	7.30	x	1.76	x	x	x	0.07	x
12a	1172 Iverson Road Lot 2	96-05-28	NorWest	328	6.63	x	9.67	x	x	x	0.09	x
12b	1172 Iverson Road Lot 3	96-05-07	NorWest	354	8.05	x	0.68	x	x	x	0.03	x
12c	1172 Iverson Road Lot 4	96-03-25	NorWest	276	8.08	x	9.00	x	x	x	0.05	x
13	1070 Iverson Road	97-08-20	E227832	104	7.98	<.002	0.00	.01	.29	<.06	.02	.035
14	1060 Iverson Road	94-11-00	Env-Can	x	x	x	0.49	x	x	x	x	x

#	Beryllium (Be)	Calcium (Ca)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Potassium (K)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)
MAC>>	NG	NG	0.005 mg/L	NG	0.05 mg/L	(<1.0) mg/L	(<0.3) mg/L	NG	500 mg/L	(<0.05) mg/L	0.25 mg/L
7c	x	x	x	x	x	x	x	x	x	x	x
8	0.001	46.8	<.006	0.007	0.03	<.006	0.053	1.0	4.7	0.007	<.01
9	x	x	x	x	x	x	x	x	x	x	x
9a	x	x	x	x	x	x	x	x	x	x	x
9b	x	x	x	x	x	x	x	x	x	x	x
9c	<.001	49.4	<.006	<.006	<.006	.009	.015	0.7	3.5	.002	<.01
9d	x	x	x	x	x	x	x	x	x	x	x
9e	x	x	x	x	x	x	x	x	x	x	x
9f	x	x	x	x	x	x	x	x	x	x	x
9g	x	x	x	x	x	x	x	x	x	x	x
10	<.001	50.9	<.006	<.006	<.006	0.033	0.787	0.4	3.3	0.035	<.01
10a	x	x	x	x	x	x	x	x	x	x	x
11	<.001	44.5	<.006	0.006	<.006	0.025	0.05	0.8	3.2	<.001	<.01
11a	x	x	x	x	x	x	x	x	x	x	x
12	x	34.0	x	x	x	0.02	0.08	1.6	6.4	0.03	x
12a	x	44.6	x	x	x	0.01	0.030	1.9	7.6	0.05	x
12b	x	56.4	x	x	x	0.01	0.110	1.2	6.5	0.05	x
12c	x	40.0	x	x	x	0.01	0.410	1.1	6.3	0.06	x
13	<.001	17.7	<.006	<.006	.018	.013	.878	0.8	5.6	.171	<.01
14	x	x	x	x	x	x	x	x	x	x	x

#	Sodium (Na)	Nickel (Ni)	Phosphorus (P)	Lead (Pb)	Sulfur (S)	Antimony (Sb)	Selenium (Se)	Silica (Si)	Tin (Sn)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)
MAC>>	(<200) mg/L	NG	NG	0.01 mg/L	NG	0.006 mg/L	0.01 mg/L	NG	NG	NG	NG	NG	(<5.0) mg/L
7c	x	x	x	x	x	x	x	x	x	x	x	x	x
8	2.8	<.02	<.1	<.06	9.67	<.06	0.1	6.28	<.06	0.267	0.004	<.01	0.056
9	x	x	x	x	x	x	x	x	x	x	x	x	x
9a	x	x	x	x	x	x	x	x	x	x	x	x	x
9b	x	x	x	x	x	x	x	x	x	x	x	x	x
9c	2.7	<.02	<.1	<.06	6.05	<.06	<.06	5.28	<.06	0.243	.003	<.01	.005
9d	x	x	x	x	x	x	x	x	x	x	x	x	x
9e	x	x	x	x	x	x	x	x	x	x	x	x	x
9f	x	x	x	x	x	x	x	x	x	x	x	x	x
9g	x	x	x	x	x	x	x	x	x	x	x	x	x
10	3	<.02	<.1	<.06	6.80	<.06	<.06	5.31	<.06	0.269	<.002	<.01	0.175
10a	x	x	x	x	x	x	x	x	x	x	x	x	x
11	2.7	<.02	<.1	0.07	6.58	<.06	0.1	5.60	<.06	0.227	<.002	<.01	0.466
11a	x	x	x	x	x	x	x	x	x	x	x	x	x
12	6.5	x	x	x	22.0	x	x	x	x	x	x	x	0.06
12a	5.6	x	x	x	22.7	x	x	x	x	x	x	x	0.01
12b	4.65	x	x	x	53.9	x	x	x	x	x	x	x	0.01
12c	9.6	x	x	x	17.3	x	x	x	x	x	x	x	0.72
13	4.1	<.02	<.1	<.06	3.55	<.06	<.06	7.85	<.06	0.252	.019	.02	.168
14	x	x	x	x	x	x	x	x	x	x	x	x	x

#	Well Location	Date Sampled	EMS Number	Conductivity (micromhos/cm)	pH	Nitrite-N	Nitrate-N	Silver (Ag)	Aluminum (Al)	Arsenic (As)	Boron (B)	Barium (Ba)
				GCDWQ MAC >>>	6.5 - 8.5	1.0 mg/L	10.0 mg/L	NG	0.2 mg/L	0.025 mg/L	5.0 mg/L	1.0 mg/L
14a	1060 Iverson Road	95-04-00	Env-Can	x	x	x	0.55	x	x	x	x	x
14b	1060 Iverson Road	97-07-30	E227459	80	7.58	<.002	0.49	<.01	.1	<.06	<.01	<.001
15	960 Iverson Road	94-11-00	Env-Can	x	x	x	ND	x	x	x	x	x
15a	960 Iverson Road	95-04-00	Env-Can	x	x	x	0.2	x	x	x	x	x
15b	960 Iverson Road	97-07-31	E227457	88	7.74	<.002	0.40	<.01	<.06	<.06	.02	.007
16	40835 Henderson Rd.	97-08-13	E227670	158	7.98	.027	0.62	<.01	<.06	<.06	<.01	.009
17	40895 Henderson Rd.	97-09-15	E228138	165	7.99	<.002	1.93	<.01	<.06	<.06	<.01	.009
18	41421 Henderson Rd.	97-07-30	E227450	x	7.07	<.002	0.87	<.01	<.06	<.06	<.01	.002
19	41525 Henderson Rd.	94-11-00	Env-Can	x	x	x	0.16	x	x	x	x	x
19a	41525 Henderson Rd.	95-04-00	Env-Can	x	x	x	0.7	x	x	x	x	x
19b	41525 Henderson Rd.	97-09-24	E228260	214	7.83	0.003	0.02	<.01	<.06	<.06	<.01	0.004
20	41627 Henderson Rd.	84-04-10	Zenon	330	7.7	0.005	0.17	x	x	x	0.26	0.01
20a	41627 Henderson Rd.	97-09-22	E228257	237	7.98	<.002	0.49	<.01	<.06	<.06	<.01	0.009
21	41632 Henderson Rd.	97-08-20	E227834	110	7.60	<.002	0.71	.02	0.2	<.06	.02	.014
22	290 Colter Road	97-08-07	E227551	218	7.97	<.002	0.63	<.01	<.06	<.06	.02	.002
23	397 Maple Falls Rd.	92-12-15	Zenon	232	7.60	ND	0.2	ND	ND	ND	0.009	.010
23a	397 Maple Falls Rd.	93-08-31	Zenon	235	7.6	ND	0.19	ND	ND	ND	0.011	0.008
23b	397 Maple Falls Rd.	94-11-00	Env-Can	x	x	x	0.16	x	x	x	x	x
23c	397 Maple Falls Rd.	95-04-00	Env-Can	x	x	x	0.15	x	x	x	x	x
23d	397 Maple Falls Rd.	97-07-28	E227423	133	7.74	<.002	0.22	<.01	<.06	<.06	.02	.006

#	Beryllium (Be)	Calcium (Ca)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Potassium (K)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)
MAC>>	**NG**	**NG**	**0.005 mg/L**	**NG**	**0.05 mg/L**	**(<1.0) mg/L**	**(<0.3) mg/L**	**NG**	**500 mg/L**	**(<0.05) mg/L**	**0.25 mg/L**
14a	x	x	x	x	x	x	x	x	x	x	x
14b	<.001	10	<.006	<.006	.016	<.006	<.006	1.0	4	<.001	<.01
15	x	x	x	x	x	x	x	x	x	x	x
15a	x	x	x	x	x	x	x	x	x	x	x
15b	<.001	12.5	<.006	<.006	.021	.02	.134	0.9	5.4	.024	<.01
16	<.001	38.5	<.006	<.006	<.006	<.006	.069	0.3	4.2	.004	<.01
17	<.001	38.9	<.006	0.008	0.018	0.007	0.042	0.6	3	0.005	<.01
18	<.001	31.6	<.006	<.006	.017	<.006	.085	0.5	2.8	.005	<.01
19	x	x	x	x	x	x	x	x	x	x	x
19a	x	x	x	x	x	x	x	x	x	x	x
19b	<.001	48.3	<.006	<.006	0.018	<.006	0.135	0.4	3.7	0.01	<.01
20	x	52.1	x	x	0.01	0.01	0.04	x	3.29	x	x
20a	<.001	54.3	<.006	0.012	0.01	<.006	0.019	0.5	3.5	<.001	<.01
21	.002	25	<.006	<.006	.021	.009	.076	0.5	2.3	.003	<.01
22	.001	58.4	<.006	<.006	<.006	<.006	.071	0.6	3.5	<.001	<.01
23	ND	42.7	ND	ND	ND	0.007	0.33	0.4	2.28	0.095	ND
23a	ND	42.5	ND	ND	ND	0.008	0.06	ND	2.02	0.005	ND
23b	x	x	x	x	x	x	x	x	x	x	x
23c	x	x	x	x	x	x	x	x	x	x	x
23d	<.001	34.1	<.006	<.006	.006	.02	0.04	0.3	1.9	.006	<.01

#	Sodium (Na)	Nickel (Ni)	Phosphorus (P)	Lead (Pb)	Sulfur (S)	Antimony (Sb)	Selenium (Se)	Silica (Si)	Tin (Sn)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)
MAC>>	(<200) mg/L	NG	NG	0.01 mg/L	NG	0.006 mg/L	0.01 mg/L	NG	NG	NG	NG	NG	(<5.0) mg/L
14a	x	x	x	x	x	x	x	x	x	x	x	x	x
14b	3.8	<.02	<.1	<.06	1.89	<.06	<.06	12.7	<.06	0.084	<.002	<.01	.003
15	x	x	x	x	x	x	x	x	x	x	x	x	x
15a	x	x	x	x	x	x	x	x	x	x	x	x	x
15b	4.6	.02	<.1	<.06	2.1	<.06	<.06	8.95	<.06	0.086	.005	<.01	.222
16	2.4	<.02	<.1	<.06	6.63	<.06	<.06	6.30	<.06	0.179	<.002	<.01	.247
17	2.9	<.02	<.1	<.06	4.16	<.06	<.06	7.19	<.06	0.200	0.006	<.01	<.002
18	3.4	<.02	<.1	<.06	6.91	<.06	<.06	5.34	<.06	0.234	.003	<.01	.235
19	x	x	x	x	x	x	x	x	x	x	x	x	x
19a	x	x	x	x	x	x	x	x	x	x	x	x	x
19b	3.3	<.02	<.1	<.06	10.8	<.06	<.06	4.00	<.06	0.268	<.002	<.01	0.01
20	x	x	x	x	x	x	x	x	x	x	x	x	0.02
20a	2.7	<.02	<.1	<.06	9.32	<.06	<.06	4.84	<.06	0.302	<.002	<.01	0.003
21	3.2	<.02	<.1	<.06	5.07	<.06	<.06	5.09	<.06	0.199	.012	.03	.005
22	3.1	<.02	<.1	<.06	12.2	<.06	<.06	5.21	<.06	0.292	<.002	<.01	<.002
23	2.6	ND	ND	0.002	6.20	ND	ND	3.60	ND	0.190	ND	ND	1.01
23a	2.3	ND	ND	0.001	6.0	ND	0.002	3.60	ND	0.188	ND	ND	0.25
23b	x	x	x	x	x	x	x	x	x	x	x	x	x
23c	x	x	x	x	x	x	x	x	x	x	x	x	x
23d	2.0	<.02	<.1	<.06	4.50	<.06	<.06	3.98	<.06	0.174	.005	<.01	0.021

#	Well Location	Date Sampled	EMS Number	Conductivity (micromhos/cm)	pH	Nitrite-N	Nitrate-N	Silver (Ag)	Aluminum (Al)	Arsenic (As)	Boron (B)	Barium (Ba)
				GCDWQ MAC >>>	6.5 - 8.5	1.0 mg/L	10.0 mg/L	NG	0.2 mg/L	0.025 mg/L	5.0 mg/L	1.0 mg/L
24	402 Maple Falls Rd.	97-08-12	E227612	107	7.13	<.002	0.42	<.01	<.06	<.06	<.01	.006
25	525 Maple Falls Rd.	94-11-00	Env-Can	x	x	x	0.37	x	x	x	x	x
25a	525 Maple Falls Rd.	95-04-00	Env-Can	x	x	x	0.35	x	x	x	x	x
26	601 Maple Falls Rd.	96-08-27	Env-Can	x	7.96	0.004	0.57	<.01	<.06	<.06	0.01	.009
26a	601 Maple Falls Rd.	97-08-20	E227779	190	8.19	<.002	0.46	<.01	.16	<.06	<.01	.01
27	280 Kosikar Road	97-08-12	E227756	131	6.91	<.002	0.50	<.01	<.06	<.06	<.01	.005
28	790 Kosikar Road	94-11-00	Env-Can	x	x	x	0.37	x	x	x	x	x
28a	790 Kosikar Road	97-08-18	E227651	147	7.44	<.002	1.22	<.01	<.06	<.06	<.01	.007
29	982 Kosikar Road	94-11-00	Env-Can	x	x	x	0.09	x	x	x	x	x
29a	982 Kosikar Road	95-04-00	Env-Can	x	x	x	0.10	x	x	x	x	x
29b	982 Kosikar Road	97-08-12	E227652	194	7.95	<.002	0.99	<.01	<.06	<.06	<.01	.006
30	995 Kosikar Road	83-11-08	Zenon	230	7.70	0.078	0.98	x	x	x	0.12	0.01
30a	995 Kosikar Road	94-11-00	Env-Can	x	x	x	2.87	x	x	x	x	x
30b	995 Kosikar Road	95-04-00	Env-Can	x	x	x	2.30	x	x	x	x	x
30c	995 Kosikar Road	97-07-30	E227419	x	7.94	<.002	3.21	<.01	<.06	<.06	<.01	.009
30d	995 Kosikar Road	98-02-11	E227419	x	x	<.002	5.11	x	x	x	x	x
30e	995 Kosikar Road	98-08-20	E227419	x	8.02	<.002	3.54	x	x	x	x	x
30f	995 Kosikar Road	98-10-27	E227419	x	7.86	<.002	3.43	x	x	x	x	x
30g	995 Kosikar Road	99-03-22	E227419	x	7.99	<.002	3.51	x	x	x	x	x
31	1072 Kosikar Road	94-11-00	Env-Can	x	x	x	ND	x	x	x	x	x

#	Beryllium (Be)	Calcium (Ca)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Potassium (K)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)
MAC>>	NG	NG	0.005 mg/L	NG	0.05 mg/L	(<1.0) mg/L	(<0.3) mg/L	NG	500 mg/L	(<0.05) mg/L	0.25 mg/L
24	<.001	22.5	<.006	<.006	<.006	.02	2.69	<.1	3.2	0.018	<.01
25	x	x	x	x	x	x	x	x	x	x	x
25a	x	x	x	x	x	x	x	x	x	x	x
26	0.001	53.4	<.006	<.006	0.006	<.006	<.006	0.3	3.1	<.001	<.01
26a	.002	47.8	<.006	.008	.017	.072	.13	0.5	3.1	.002	<.01
27	<.001	28.3	<.006	<.006	<.006	<.006	.524	1.0	3.2	.004	<.01
28	x	x	x	x	x	x	x	x	x	x	x
28a	<.001	41	.009	.01	<.006	.012	.07	0.6	4.1	.003	<.01
29	x	x	x	x	x	x	x	x	x	x	x
29a	x	x	x	x	x	x	x	x	x	x	x
29b	.001	61.9	<.006	<.006	.013	<.006	.016	0.4	3.7	.002	<.01
30	x	39.6	x	x	0.01	0.01	1.12	x	3.19	0.09	x
30a	x	x	x	x	x	x	x	x	x	x	x
30b	x	x	x	x	x	x	x	x	x	x	x
30c	<.001	46.6	<.006	<.006	<.006	<.006	.008	0.7	3.2	<.001	<.01
30d	x	x	x	x	x	x	x	x	x	x	x
30e	x	x	x	x	x	x	x	x	x	x	x
30f	x	x	x	x	x	x	x	x	x	x	x
30g	x	x	x	x	x	x	x	x	x	x	x
31	x	x	x	x	x	x	x	x	x	x	x

#	Sodium (Na)	Nickel (Ni)	Phosphorus (P)	Lead (Pb)	Sulfur (S)	Antimony (Sb)	Selenium (Se)	Silica (Si)	Tin (Sn)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)
MAC>>	(<200) mg/L	NG	NG	0.01 mg/L	NG	0.006 mg/L	0.01 mg/L	NG	NG	NG	NG	NG	(<5.0) mg/L
24	2	.03	<.1	<.06	4.27	<.06	<.06	4.54	<.06	0.143	<.002	<.01	.044
25	x	x	x	x	x	x	x	x	x	x	x	x	x
25a	x	x	x	x	x	x	x	x	x	x	x	x	x
26	2.5	<.02	<.1	<.06	x	<.06	<.06	4.56	<.06	0.274	<.002	<.01	0.195
26a	2.5	<.02	<.1	<.06	7.58	<.06	.07	4.26	<.06	0.251	.011	.02	.118
27	4.7	0.03	<.1	<.06	5.17	<.06	<.06	5.02	<.06	0.181	<.002	<.01	.110
28	x	x	x	x	x	x	x	x	x	x	x	x	x
28a	3.4	<.02	<.1	<.06	7.56	<.06	.08	5.35	<.06	0.230	.014	<.01	.296
29	x	x	x	x	x	x	x	x	x	x	x	x	x
29a	x	x	x	x	x	x	x	x	x	x	x	x	x
29b	3.5	<.02	<.1	<.06	9.68	<.06	<.06	4.72	<.06	0.294	<.002	<.01	.082
30	x	x	x	x	x	x	x	x	x	x	x	x	0.02
30a	x	x	x	x	x	x	x	x	x	x	x	x	x
30b	x	x	x	x	x	x	x	x	x	x	x	x	x
30c	3.2	<.02	<.01	<.06	6.61	<.06	<.06	6.03	<.06	0.210	.004	<.01	.028
30d	x	x	x	x	x	x	x	x	x	x	x	x	x
30e	x	x	x	x	x	x	x	x	x	x	x	x	x
30f	x	x	x	x	x	x	x	x	x	x	x	x	x
30g	x	x	x	x	x	x	x	x	x	x	x	x	x
31	x	x	x	x	x	x	x	x	x	x	x	x	x

#	Well Location	Date Sampled	EMS Number	Conductivity (micromhos/cm)	pH	Nitrite-N	Nitrate-N	Silver (Ag)	Aluminum (Al)	Arsenic (As)	Boron (B)	Barium (Ba)
				GCDWQ MAC >>>	6.5 - 8.5	1.0 mg/L	10.0 mg/L	NG	0.2 mg/L	0.025 mg/L	5.0 mg/L	1.0 mg/L
31a	1072 Kosikar Road	95-04-00	Env-Can	x	x	x	ND	x	x	x	x	x
31b	1072 Kosikar Road	97-08-12	E227553	213	7.85	<.002	0.17	<.01	<.06	<.06	<.01	.024
32	1010 Erho Road	82-01-04	Zenon	338	7.9	0.005	0.02	x	x	x	0.01	.030
32a	1010 Erho Road	97-09-08	E227977	x	7.90	<.002	0.17	<.01	.12	<.06	.02	.039
33	42590 Erho Road	94-11-00	Env-Can	x	x	x	ND	x	x	x	x	x
33a	42590 Erho Road	95-04-00	Env-Can	x	x	x	ND	x	x	x	x	x
33b	42590 Erho Road	97-08-07	E227552	195	8.00	<.002	<.002	<.01	<.06	<.06	.02	.06
34	1320 Janovick Road	95-04-00	Env-Can	x	x	x	ND	x	x	x	x	x
34a	1320 Janovick Road	97-08-21	E227836	200	8.19	<.002	<.002	<.01	<.06	<.06	.02	.061
35	1331 Janovick Road	94-11-00	Env-Can	x	x	x	3.77	x	x	x	x	x
35a	1331 Janovick Road	95-04-00	Env-Can	x	x	x	1.38	x	x	x	x	x
35b	1331 Janovick Road	97-09-09	E227999	x	7.9	<.002	1.71	<.01	<.06	<.06	<.01	<.001
36	781 Blatchford Road	97-08-20	E227833	223	7.85	<.002	0.68	<.01	.1	<.06	.02	.016
37	42621 Canyon Road	95-04-00	Env-Can	x	x	x	ND	x	x	x	x	x
37a	42621 Canyon Road	97-09-10	E228001	250	7.73	<.002	<.002	<.01	<.06	<.06	0.02	.058
38	42651 Canyon Road	88-11-04	Zenon	288	8.0	0.005	0.02	0.01	0.02	0.04	0.02	.051
38a	42651 Canyon Road	97-09-09	E228000	229	8.03	<.002	<.002	<.01	<.06	<.06	0.03	.049

#	Beryllium (Be)	Calcium (Ca)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Potassium (K)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)
MAC>>	**NG**	**NG**	**0.005 mg/L**	**NG**	**0.05 mg/L**	**(<1.0) mg/L**	**(<0.3) mg/L**	**NG**	**500 mg/L**	**(<0.05) mg/L**	**0.25 mg/L**
31a	x	x	x	x	x	x	x	x	x	x	x
31b	<.001	55.7	<.006	<.006	<.006	<.006	11.4	0.9	3.9	.314	<.01
32	x	47.8	x	x	0.01	0.01	0.27	x	3.93	0.01	x
32a	.001	59.1	<.006	<.006	<.006	<.006	1.28	0.7	4.2	.012	<.01
33	x	x	x	x	x	x	x	x	x	x	x
33a	x	x	x	x	x	x	x	x	x	x	x
33b	.001	50	<.006	<.006	.021	<.006	.066	1.0	4.1	.009	<.01
34	x	x	x	x	x	x	x	x	x	x	x
34a	<.001	49	<.006	<.006	<.006	<.006	.266	0.8	4.6	.015	<.01
35	x	x	x	x	x	x	x	x	x	x	x
35a	x	x	x	x	x	x	x	x	x	x	x
35b	<.001	4.3	<.006	<.006	<.006	<.006	<.006	0.3	0.3	0.003	0.01
36	.002	53.2	.008	.015	.033	.028	.879	0.7	5.2	.009	.01
37	x	x	x	x	x	x	x	x	x	x	x
37a	<.001	60.1	<.006	<.006	0.02	<.006	0.15	0.4	4.3	0.014	<.01
38	x	49.5	0.002	0.003	0.002	0.003	0.482	0.9	4.2	0.049	0.005
38a	0.001	52.8	<.006	<.006	<.006	<.006	0.309	0.7	4.0	0.046	<.01

#	Sodium (Na)	Nickel (Ni)	Phosphorus (P)	Lead (Pb)	Sulfur (S)	Antimony (Sb)	Selenium (Se)	Silica (Si)	Tin (Sn)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)
MAC>>	**(<200) mg/L**	**NG**	**NG**	**0.01 mg/L**	**NG**	**0.006 mg/L**	**0.01 mg/L**	**NG**	**NG**	**NG**	**NG**	**NG**	**(<5.0) mg/L**
31a	x	x	x	x	x	x	x	x	x	x	x	x	x
31b	4.1	<.02	<.1	<.06	8.97	<.06	<.06	6.34	<.06	0.261	<.002	<.01	0.54
32	x	x	x	x	x	x	x	x	x	x	x	x	0.49
32a	2.8	<.02	<.1	<.06	13.5	<.06	<.06	5.18	<.06	0.303	.006	<.01	.294
33	x	x	x	x	x	x	x	x	x	x	x	x	x
33a	x	x	x	x	x	x	x	x	x	x	x	x	x
33b	3.2	<.02	<.1	<.06	9.51	<.06	<.06	5.08	<.06	0.294	.006	<.01	<.002
34	x	x	x	x	x	x	x	x	x	x	x	x	x
34a	3.1	<.02	<.1	<.06	9.31	<.06	<.06	4.66	<.06	0.402	<.002	<.01	.131
35	x	x	x	x	x	x	x	x	x	x	x	x	x
35a	x	x	x	x	x	x	x	x	x	x	x	x	x
35b	55.6	<.02	<.1	<.06	5.07	<.06	<.06	5.85	<.06	0.022	<.002	<.01	0.012
36	3.2	.03	<.1	.1	8.26	<.06	.17	5.81	<.06	0.292	.028	.01	.405
37	x	x	x	x	x	x	x	x	x	x	x	x	x
37a	2.7	<.02	<.1	<.06	11.4	<.06	< .06	5.21	<.06	0.319	<.002	<.01	0.458
38	3.66	0.008	x	0.001	x	x	x	x	0.03	x	x	0.003	0.274
38a	2.9	<.02	<.1	0.06	10.6	<.06	<.06	5.74	<.06	0.294	<.002	<.01	0.09

Iron (Fe) and Manganese (Mn)

Iron is generally present in all groundwater and can exist in the dissolved or the insoluble form. The GCDWQ's acceptable limit is less than 0.3 mg/L for **aesthetic** reasons; no health risks are associated with iron. At levels above that iron may stain plumbing fixtures and clothing; give the water a bittersweet astringent taste; contribute to scaling; and in excessive amounts, may encourage bacterial growth. Of 36 wells tested, 75% of the samples analyzed had iron levels below the acceptable aesthetic limit; the highest iron value was 11.4 mg/L. Likely sources of iron could include the soil, water well casing or iron bacteria.

Manganese is commonly found in association with iron. The GCDWQ's acceptable limit is less than 0.05 mg/L for **aesthetic** reasons. At levels exceeding 0.15 mg/L, it may stain plumbing fixtures and laundry, and with iron, it may lead to accumulation of microbial growth in plumbing and leave a black solid residue in the water. Of the samples tested in the summer of 1997, only one had manganese in excess of the acceptable aesthetic limit (i.e. 0.314 mg/L), which incidentally was the same sample that had the highest iron level.

Sodium (Na) and Potassium (K)

Sodium is present in all natural waters. The GCDWQ indicates the maximum acceptable limit for sodium concentration in water is less than 200 mg/L as an aesthetic objective. People on sodium-restricted diets however need to contact the proper medical authority to determine what level is acceptable. Sodium levels in groundwater in the study area measured generally less than 10.0 mg/L. The highest levels were measured at 55.6 mg/L and 34.6 mg/L.

Potassium concentrations are low, less than 3 mg/L, and are considered insignificant.

Specific Conductance

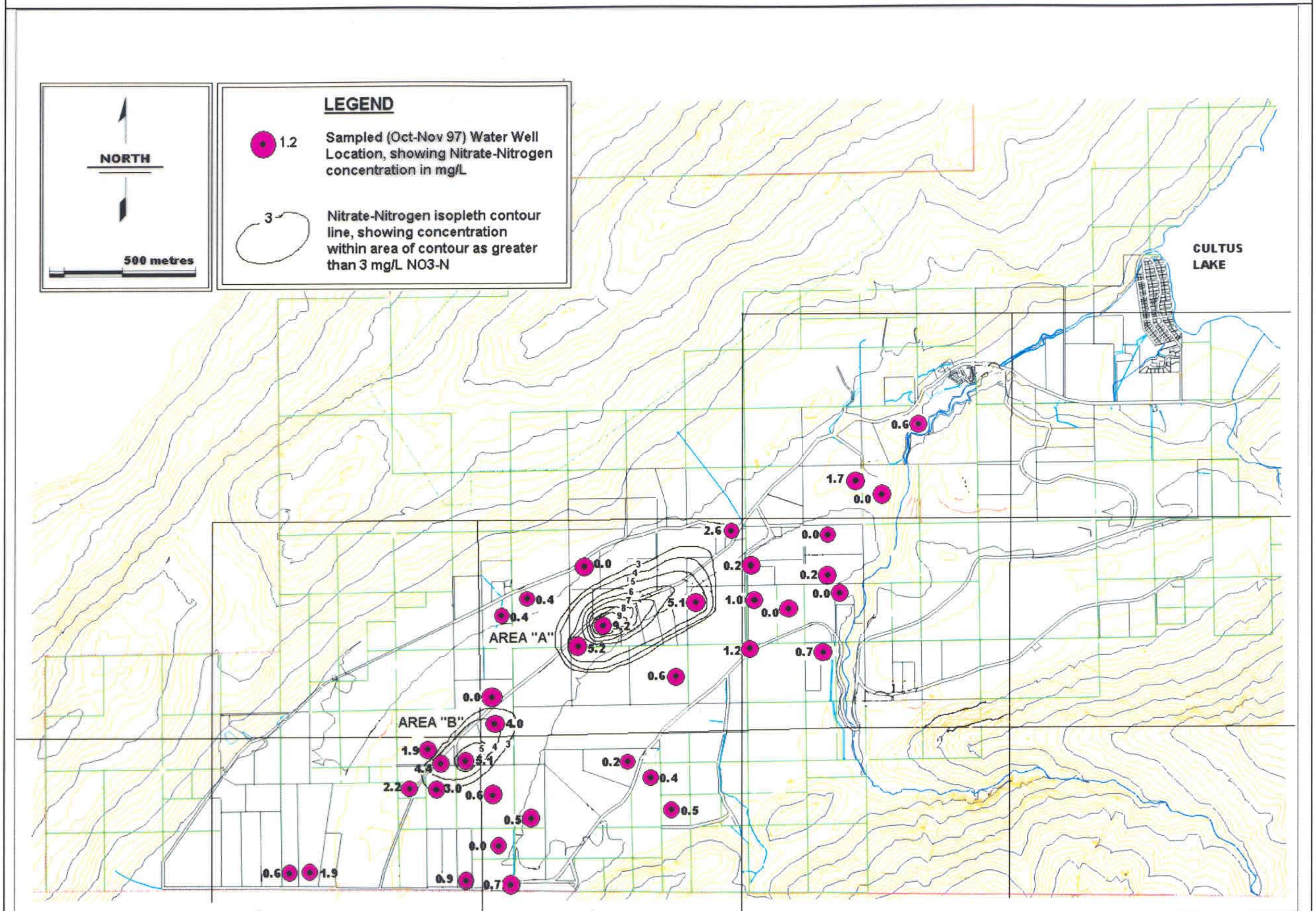
Specific Conductance is a measurement of the ability of water to conduct an electrical current. The greater the ion concentration or amount of mineralization of a water solution, the greater its ability to conduct electricity. In general, specific conductance multiplied by a factor of 0.65 will give an estimate of the total dissolved solids in groundwater. The specific conductance of the groundwater samples tested in the study area were less than 354 microsiemens per centimetre. These values indicate relatively low mineralization in the groundwater.

Nitrate (NO_3) and Nitrite (NO_2)

Nitrate is a common nitrogenous compound in nature as a result of natural microbial processes in the soil. Some groundwater can contain natural or background concentrations of nitrates up to about 3 mg/L (NO3-N). Concentrations above this indicate human activity. The GCDWQ indicates the maximum acceptable concentration (MAC) for nitrate in drinking water is 45 mg/L, <u>which is equivalent to 10 mg/L nitrate as nitrogen</u>. This "equivalent" designation is used throughout this report as the way of reporting nitrate. According to Caine and Cridland (1995) drinking water with nitrate-nitrogen concentrations above this level can cause methemoglobinemia, an adverse effect on health, especially if ingested by infants less than six months old. Potential sources of nitrate in groundwater include: the atmosphere, legume plants, decaying plant debris, land clearing, manure, mass burial of animal carcasses, sewerage (septic systems), nitrogenous fertilizers, ammunitions and industrial wastes.

None of the groundwater samples tested during 1997, 1998 and 1999 were over GCDWQ's maximum acceptable concentration for drinking water. However, more than 20 sample results showed nitrate-nitrogen levels greater than the natural or background concentration of 3 mg/L NO3-N. **Figure 12** shows the location of wells from which groundwater samples were tested for nitrates and the resulting concentrations of nitrate-nitrogen. The concentrations shown are only for samples taken during the 1997 sampling season, and does not include values of nitrates from tests done at other times. The concentrations of

Figure 12: Nitrate-Nitrogen Concentrations, in mg/L, Columbia Valley, BC



nitrates over 3 mg/L NO3-N have been contoured to show the probable distribution and relative extent of elevated nitrate-nitrogen concentrations in the study area. As can be seen there are two main areas of elevated nitrate-nitrogen concentrations, designated as area “A” and area “B”.

It should be noted that Figure 12 shows a “picture” of the nitrate-nitrogen conditions in the study area for one period in time. However, the distribution and concentrations of nitrates can change with time. This is illustrated in **Figure 13** which shows the nitrate-nitrogen concentration trends for individual wells which were sampled by various agencies at various times of the year including historic data from homeowners.

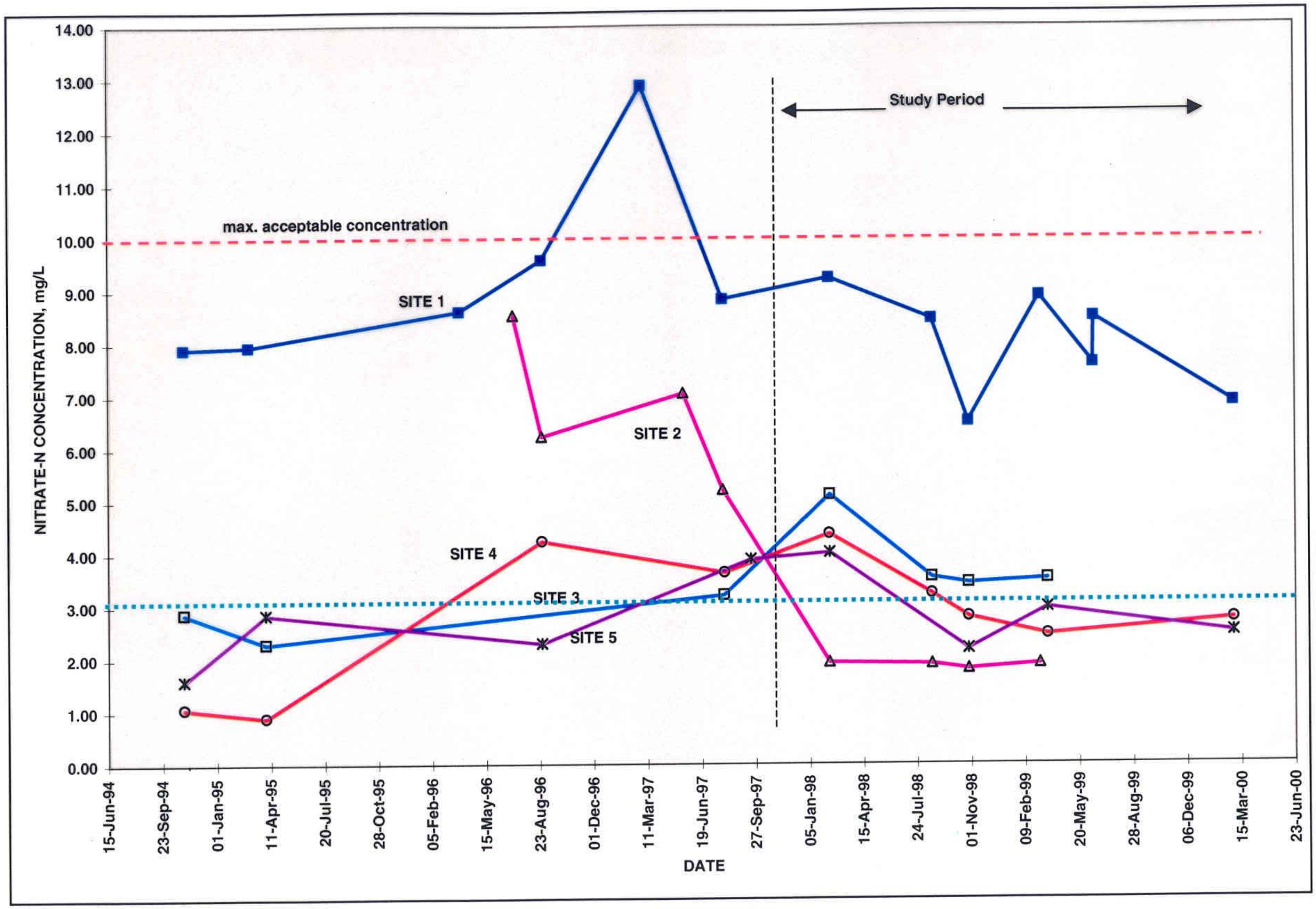
Other Chemical Parameters

Groundwater quality samples were also analyzed for various metal concentrations. The values reported were compared with the CDWQG and generally found to be within acceptable limits, with the exception of some isolated levels of total lead (Pb), total selenium (Se) and total cadmium (Cd) concentrations in excess of the MACs. The MAC for total lead is 0.01 mg/L. Analysis of groundwater samples from four wells showed total lead levels of 0.12, 0.10, 0.07, and 0.06 mg/L. The MAC for total selenium is also 0.01 mg/L, and four samples showed total levels between 0.07 to 0.17 mg/L. The MAC for total cadmium is 0.005 mg/L, and three groundwater samples showed total levels of 0.006, 0.008, and 0.009 mg/L. The source of these elevated metal concentrations is unknown at this time, but is unlikely to be from the aquifer materials. Potential sources include surface water or the water distribution system (piping). The samples were collected at the tap after going through the distribution system which may have contributed to the metals content of the water. Selenium is known to be a feed supplement for livestock; however, how and to what degree this can affect groundwater is unknown.

4.2 Surface Water Quality Sampling and Analysis

There are several small brooks and streams that flow down the mountains to the north-west and south-east and discharge into the porous sediments in the valley. Surface water quality

FIGURE 13 : NITRATE-NITROGEN (mg/L) TREND PLOTS, Columbia Valley, BC



testing of creek waters was conducted in the summer of 1997 and the results are found in **Table 7**. All samples analyzed showed nitrate-nitrogen levels significantly below background of 3 mgN/L, suggesting very little, if any risk of groundwater contamination occurring from surface water sources. It is recognized that the levels of nitrate-nitrogen in these streams can vary depending upon nearby land use activities, especially along Blue Creek where manure piles are known to have been stockpiled adjacent to the creek. Such activities are seasonal and may carry runoff into the creek and eventually result in temporary increased nutrient levels in groundwater. However, no elevated values of nitrate-nitrogen were found during the study period.

4.3 Evaluation of Groundwater Quality -- Potential Sources of Contaminants

The presence of elevated nitrate-nitrogen in groundwater wells and related health concern in drinking water has been one of the primary reasons for conducting a hydrogeologic investigation in the valley. To address this water quality issue it was necessary to define the hydrogeologic framework, including type of sediments underlying the valley; type and extent of aquifer(s); direction(s) of groundwater flow; source(s) of recharge; and, types of land use activities that could generate the amount of nitrates found in the groundwater in the study area.

As part of the land use survey conducted in 1997, residents were requested to provide some information about land use activities that may indicate potential sources of contaminants on their lands. **Table 8** is a summary of these potential sources of contaminants that might affect groundwater. These results are not quantitative, nor are they inclusive of the entire study area but do give a rough indication of the most likely source(s) of groundwater contamination. As can be seen, the most predominant potential source of groundwater contamination is from fertilizers.

Based on an evaluation of the lithologic data from well records, the valley is underlain by an extensive unconfined and in some places semi-confined aquifer of glacial outwash origin. The thickness of the glacial outwash deposit is at least 80m. The aquifer consists of permeable sand and gravel materials and where it is unconfined by a clay or till layer, is highly vulnerable to groundwater contamination from land use activities.

Table 7: Surface Water Quality Analyses, Columbia Valley, B.C.

#	Water Source	Sample Location	Sample Date	EMS Number	Conductivity (micromhos/cm)	pH	Nitrite-N	Nitrate-N	Silver (Ag)
				GCDWQ	MAC >>>	6.5 -8.5	1.0 mg/L	10.0 mg/L	NG
1	Jack Spring	1505 Columbia Valley Road	97-10-21	E228818	x	7.37	<.002	0.112	<.01
2	Mike Spring	1095 Columbia Valley Road	97-07-31	E227455	140	7.81	<.002	0.053	<.01
3	Martin Spring	1610 Robinson Road	97-09-17	E228199	98	7.05	<.002	0.028	<.01
4	Parent Creek	1182 Iverson Road	97-09-09	E227871	141	8.07	<.002	0.055	<.01
5	Arnoldson Spring	1169 Iverson Road	97-08-21	E227838	112	8.14	<.002	0.039	<.01
6	Lumsden Spring	1162 Iverson Road	97-08-13	E227753	75	6.74	<.002	0.313	<.01
7	Spring # 2	1162 Iverson Road	97-09-10	E227754	94	6.96	<.002	0.015	<.01
8	Schoolhouse Ck	1159 Iverson Road	97-08-12	E227757	132	7.81	<.002	0.041	<.01
9	?? Spring	1155 Iverson Road	97-09-16	E228157	110	8.0	<.002	0.219	<.01
10	Rochester Spring	1115 Iverson Road	97-08-21	E227835	128	7.67	<.002	0.010	<.01
11	?? Spring	1060 Iverson Road	97-07-30	E227611	80	8.05	<.002	0.335	<.01
12	Lyon's Spring	1014 Iverson Road	97-08-18	E227781	180	7.53	<.002	0.103	<.01
13	Teschke Creek	965 Iverson Road	97-09-16	E228160	150	8.11	<.002	0.113	<.01
14	Telford Spring	965 Iverson Road	97-09-16	E228159	82	6.99	<.002	0.259	<.01
15	Teskie Creek	960 Iverson Road	97-07-31	E227458	143	8.10	<.002	0.117	<.01
16	Telford Spring	915 Iverson Road	97-08-07	E227550	x	6.45	<.002	0.155	<.01
17	?? Spring	805 Iverson Road	97-09-16	E228158	152	7.95	<.002	0.072	<.01
18	Iverson Creek	586 Iverson Road	97-08-18	E227780	120	8.15	<.002	0.281	<.01
19	Iverson Spring	349 Iverson Road	97-08-07	E227557	146	8.06	<.002	0.219	<.01
20	Iverson Creek	349 Iverson Road	97-08-07	E227610	109	8.08	<.002	0.123	<.01
21	Hellur Spring	41521 Henderson Road	97-09-09	E227998	190	7.89	<.002	0.722	<.01

#	Aluminum (Al)	Arsenic (As)	Boron (B)	Barium (Ba)	Beryllium (Be)	Calcium (Ca)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)
MAC>>	0.2 mg/L	0.025 mg/L	5.0 mg/L	1.0 mg/L	NG	NG	0.005 mg/L	NG	0.05 mg/L	(<1.0) mg/L
1	<.06	<.06	0.01	0.018	<.001	19.4	<.006	<.006	0.009	<.006
2	<.06	<.06	<.01	.016	<.001	23.4	<.006	.006	.018	.006
3	<.06	<.06	0.03	.016	<.001	16.5	<.006	<.006	0.016	0.026
4	<.06	<.06	0.02	.012	<.001	28.6	<.006	<.006	0.021	0.013
5	<.06	<.06	<.01	.017	<.001	20.8	<.006	.007	<.006	<.006
6	<.06	<.06	.01	.013	<.001	13.7	<.006	.009	.008	.007
7	0.24	<.06	<.01	.017	<.001	14.3	<.006	<.006	0.01	<.006
8	.15	<.06	<.01	.023	<.001	23	<.006	.013	.007	.033
9	<.06	<.06	0.03	.036	0.001	42	<.006	<.006	0.008	<.006
10	<.06	<.06	<.01	.036	<.001	24.7	<.006	<.006	<.006	<.006
11	0.96	<.06	.01	.018	<.001	26	<.006	<.006	.019	<.006
12	<.06	<.06	.03	.042	<.001	35.9	.007	.012	<.006	.016
13	0.97	<.06	0.03	.025	<.001	26.9	<.006	<.006	<.006	<.006
14	<.06	<.06	0.02	.009	<.001	12.3	<.006	<.006	<.006	0.077
15	.86	<.06	.02	.025	<.001	25.5	<.006	<.006	.025	<.006
16	<.06	<.06	.02	.007	<.001	6.8	<.006	<.006	.007	<.006
17	<.06	<.06	0.04	.014	<.001	32	<.006	<.006	0.01	<.006
18	.11	<.06	.03	.029	<.001	20.2	.008	.007	.013	.019
19	<.06	<.06	.03	.019	<.001	18.8	<.006	<.006	<.006	<.006
20	0.22	<.06	0.02	.016	<.001	27.4	<.006	<.006	0.01	<.006
21	<.06	<.06	0.01	.025	0.001	43.8	<.006	<.006	<.006	<.006

#	Iron (Fe)	Potassium (K)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)	Sodium (Na)	Nickel (Ni)	Phosphorus (P)	Lead (Pb)
MAC>>	(<0.3) mg/L	NG	500 mg/L	(<0.05) mg/L	0.25 mg/L	(<200) mg/L	NG	NG	0.01 mg/L
1	0.068	0.5	3.5	<.001	<.01	3.7	<.02	<.1	<.06
2	.023	0.3	4	.002	<.01	3.2	<.02	<.1	<.06
3	0.076	0.5	3	0.01	<.01	3.3	<.02	<.1	<.06
4	<.006	0.6	4.1	0.003	0.02	3.2	<.02	<.1	<.06
5	.081	0.7	4	<.001	<.01	2.5	<.02	<.1	<.06
6	.013	<.1	3.8	.004	<.01	3.2	<.02	<.1	<.06
7	0.499	0.6	4	0.012	<.01	4	<.02	<.1	<.06
8	.237	<.1	4.1	.019	<.01	3.8	.02	<.1	<.06
9	0.023	0.8	8.2	<.001	<.01	6.3	<.02	<.1	<.06
10	.038	0.7	5.9	<.001	<.01	4.1	<.02	<.1	<.06
11	.977	0.4	7.7	.043	<.01	3.1	.03	<.1	<.06
12	.032	0.8	6.6	.002	.01	4.8	.03	<.1	<.06
13	0.829	0.5	7.3	0.032	<.01	3.6	<.02	<.1	<.06
14	<.006	0.2	3.6	<.001	<.01	2.5	<.02	<.1	<.06
15	.761	0.4	6.7	.028	<.01	3.6	<.02	<.1	<.06
16	.044	0.3	2.5	.002	<.01	2	<.02	<.1	<.06
17	0.033	0.3	5.6	<.001	<.01	3.8	<.02	<.1	<.06
18	.11	0.4	6	.009	<.01	3.1	<.02	<.1	<.06
19	.013	0.4	5.4	<.001	<.01	2.2	<.02	<.1	<.06
20	0.22	0.5	6.4	0.004	<.01	3.3	<.02	<.1	<.06
21	0.033	0.6	2.3	0.002	<.01	2.2	<.02	<.1	<.06

#	Sulfur (S)	Antimony (Sb)	Selenium (Se)	Silica (Si)	Tin (Sn)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)
MAC>>	NG	0.006 mg/L	0.01 mg/L	NG	NG	NG	NG	NG	(<5.0) mg/L
1	4.14	<.06	<.06	4.87	<.06	0.294	<.002	<.01	0.003
2	5.49	<.06	<.06	4.57	<.06	0.320	<.002	<.01	0.01
3	3.29	<.06	0.1	4.55	<.06	0.214	0.004	<.01	0.017
4	5.96	<.06	<.06	4.54	<.06	0.350	<.002	<.01	0.004
5	4	<.06	.08	4.48	<.06	0.293	.014	<.01	.003
6	2.27	<.06	<.06	5.37	<.06	0.212	<.002	<.01	.024
7	2.25	<.06	<.06	6.06	<.06	0.201	0.01	<.01	0.009
8	3.46	<.06	<.06	4.83	<.06	0.332	.01	<.01	.054
9	13.6	0.06	<.06	4.71	<.06	0.782	0.007	<.01	0.005
10	5.24	<.06	<.06	5.54	<.06	0.381	<.002	<.01	<.002
11	5.14	<.06	<.06	6.95	<.06	0.259	.053	<.01	.013
12	10.1	<.06	.1	5.10	<.06	0.655	.014	<.01	.006
13	5.3	<.06	<.06	7.00	<.06	0.342	0.059	<.01	0.003
14	3.14	<.06	<.06	5.08	<.06	0.140	<.002	<.01	0.015
15	5.04	<.06	<.06	6.89	<.06	0.320	.051	<.01	.005
16	1	<.06	<.06	5.44	<.06	0.073	.006	<.01	<.002
17	7.42	<.06	<.06	4.86	<.06	0.518	0.005	<.01	<.002
18	2.82	<.06	<.06	5.59	<.06	0.219	.022	.01	.004
19	2.48	<.06	<.06	5.53	<.06	0.194	.008	<.01	<.002
20	8.55	<.06	<.06	5.10	<.06	0.318	0.015	<.01	<.002
21	6.36	<.06	<.06	3.80	<.06	0.308	0.004	<.01	<.002

#	Water Source	Sample Location	SampleDate	EMS Number	Conductivity (micromhos/cm)	pH	Nitrite-N	Nitrate-N	Silver(Ag)
				GCDWQ	MAC >>>	6.5 -8.5	1.0 mg/L	10.0 mg/L	NG
22	Hunter Spring	41115 Henderson Road	97-09-15	E228137	150	8.05	<.002	0.072	<.01
23	Blue Creek	651 Maple Falls Road	97-07-30	E227460	58	6.89	<.002	0.871	<.01
24	Dorko Creek	525 Maple Falls Road	97-09-10	E227870	125	8.11	<.002	0.138	<.01
25	Dorko Creek	500 Maple Falls Road	97-07-30	E227451	158	7.96	<.002	1.36	<.01
26	Blue Creek	432 Maple Falls Road	97-07-31	E227453	78	7.16	<.002	0.110	<.01
27	Dune Spring	266 Maple Falls Road	97-08-07	E227554	273	8.02	<.002	0.095	<.01
28	?? Creek	1190 Kosikar Road	97-08-21	E227837	138	8.13	<.002	0.054	<.01
29	Parent Creek	982 Kosikar Road	97-08-12	E227653	119	8.00	<.002	0.057	<.01
30	Dorko Creek	700 Kosikar Rd	97-07-28	E227424	143	7.95	<.002	1.32	<.01
31	Blue Creek	670 Kosikar Rd	97-07-31	E227454	75	6.94	<.002	0.783	<.01
32	Frosst Creek	Upstream Bridge	97-09-15	E228139	90	7.99	<.002	0.029	<.01
33	Frosst Creek	Downstream Bridge	97-09-16	E228161	120	8.1	<.002	0.195	<.01

EMS# - Lab code No.; MAC - Max. Accept. Conc. (GCDWQ); (xx) - Aesthetic Objective; NG - No Guidelines set; x - denotes no data available

#	Aluminum (Al)	Arsenic (As)	Boron (B)	Barium (Ba)	Beryllium (Be)	Calcium (Ca)	Cadmium (Cd)	Cobalt (Co)	Chromium (Cr)	Copper (Cu)
MAC>>	0.2 mg/L	0.025 mg/L	5.0 mg/L	1.0 mg/L	NG	NG	0.005 mg/L	NG	0.05 mg/L	(<1.0) mg/L
22	0.08	<.06	<.01	.013	<.001	28.1	<.006	<.006	<.006	<.006
23	<.06	<.06	<.01	.003	<.001	13	<.006	<.006	.014	.015
24	<.06	<.06	<.01	.002	<.001	29.3	<.006	<.006	0.018	0.01
25	<.06	<.06	<.01	.030	<.001	32.3	<.006	<.006	<.006	<.006
26	<.06	<.06	<.01	.003	<.001	19.3	<.006	<.006	.012	.01
27	<.06	<.06	.02	.015	.001	62.6	<.006	.011	<.006	.01
28	<.06	<.06	.02	.01	<.001	26.6	<.006	.015	<.006	.01
29	<.06	<.06	<.01	.014	<.001	23.5	<.006	.009	<.006	.007
30	.47	<.06	.01	.041	<.001	36.3	<.006	<.006	.022	.01
31	<.06	<.06	.01	.008	<.001	12.5	<.006	.007	<.006	<.006
32	<.06	<.06	0.02	.029	<.001	19	<.006	<.006	<.006	<.006
33	<.06	<.06	0.04	.027	<.001	40.2	<.006	0.014	<.006	<.006

#	Iron (Fe)	Potassium (K)	Magnesium (Mg)	Manganese (Mn)	Molybdenum (Mo)	Sodium (Na)	Nickel (Ni)	Phosphorus (P)	Lead (Pb)
MAC>>	**(<0.3) mg/L**	**NG**	**500 mg/L**	**(<0.05) mg/L**	**0.25 mg/L**	**(<200) mg/L**	**NG**	**NG**	**0.01 mg/L**
22	0.128	0.3	4.2	0.006	<.01	3.3	<.02	<.1	<.06
23	<.006	0.3	1.3	<.001	<.01	2.2	<.02	<.1	<.06
24	0.007	0.4	1.3	<.001	<.01	1.5	<.02	<.1	<.06
25	<.006	0.3	1.3	.002	<.01	1.9	<.02	<.1	<.06
26	.034	0.2	1.3	.002	<.01	1.4	<.02	<.1	<.06
27	.022	0.5	3.7	<.001	<.01	3.1	<.02	<.1	<.06
28	.013	1.0	3.9	<.001	<.01	2.7	<.02	<.1	<.06
29	<.006	1.8	3.3	.004	.02	5.4	.04	<.1	<.06
30	.493	0.3	1.7	.016	<.01	1.9	<.02	<.1	<.06
31	<.006	0.3	1.3	<.001	<.01	1.9	<.02	<.1	<.06
32	0.083	0.3	2.1	0.001	<.01	1.7	<.02	<.1	<.06
33	0.023	0.4	3.1	<.001	<.01	3.5	<.02	<.1	<.06

#	Sulfur(S)	Antimony(Sb)	Selenium(Se)	Silica(Si)	Tin(Sn)	Strontium(Sr)	Titanium(Ti)	Vanadium(V)	Zinc(Zn)
MAC>>	**NG**	**0.006 mg/L**	**0.01 mg/L**	**NG**	**NG**	**NG**	**NG**	**NG**	**(<5.0) mg/L**
22	6.08	<.06	<.06	5.38	<.06	0.412	0.005	<.01	<.002
23	4.51	<.06	<.06	4.89	<.06	0.093	<.002	<.01	.009
24	4.03	<.06	<.06	3.84	<.06	0.144	<.002	<.01	0.043
25	3.63	<.06	<.06	3.80	<.06	0.164	<.002	<.01	<.002
26	3.85	<.06	<.06	3.78	<.06	0.110	<.002	<.01	.006
27	24.7	<.06	<.06	5.38	<.06	0.457	.003	<.01	<.002
28	5.47	<.06	.07	4.38	<.06	0.34	.01	<.01	.005
29	3.35	<.06	<.06	4.32	<.06	0.237	<.002	<.01	.051
30	3.15	<.06	<.06	4.32	<.06	0.186	.034	<.01	.005
31	4.63	<.06	<.06	5.02	<.06	0.089	.007	<.01	.005
32	3.98	<.06	<.06	2.87	<.06	0.151	0.004	<.01	<.002
33	18.1	<.06	<.06	3.77	<.06	0.345	0.002	<.01	<.002

Table 8: Potential Sources of Contaminants, Columbia Valley, BC

Site No.	Land Use	Potential Sources of Contaminants
1	Miscellaneous	Unknown, (unsurveyed areas)
2	Agricultural	manure fertilizer, cultivation
3	Hobby Farm	Septic system
4	Rural Residential	Septic system
5	Rural Residential	Septic system
6	Hobby Farm	manure fertilizer, septic system
7	Hobby Farm	
8	Rural Residential	
9	Agricultural	manure fertilizer and pesticides
10	Agricultural	chemical fertilizer and pesticides
11	Agricultural	manure fertilizer; animal morts
12	Rural Residential	
13	Agricultural	manure fertilizer
14	Rural Residential	
15	Agricultural	manure fertilizer
16	Agricultural	manure fertilizer
17	Hobby Farm	manure fertilizer
18	Agricultural	manure fertilizer
19	Agricultural	manure fertilizer; pesticides
20	Rural Residential	
21	Agricultural	pesticides
22	Agricultural	manure fertilizer
23	Agricultural	
24	Hobby Farm	manure and chemical fertilizers
25	Hobby Farm	
26	Agricultural	manure fertilizer
27	Agricultural	manure fertilizer
28	Rural Residential	
29	Agricultural	manure fertilizer
30	Agricultural	manure fertilizer
31	Rural Residential	
32	Agricultural	manure fertilizer and pesticides
33	Agricultural	manure fertilizer
34	Agricultural	manure fertilizer
35	Hobby Farm	
36	Hobby Farm	manure fertilizer
37	Hobby Farm	
38	Rural Residential	septic effluent (30m from well)
39	Rural Residential	septic effluent (27m upslope from well)
40	Agricultural	chemical fertilizer; herbicides and pesticides
41	Rural Residential	

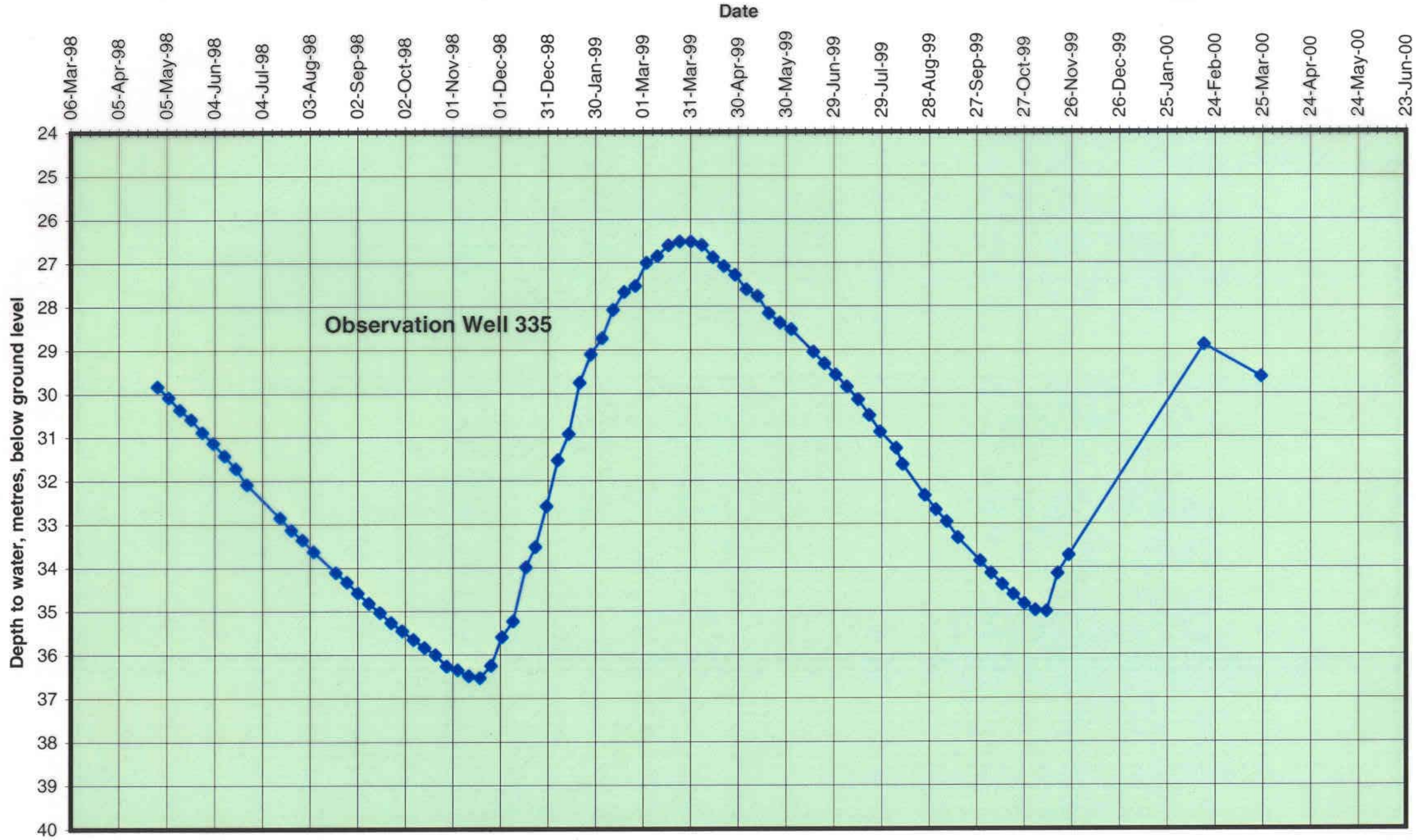
Site No.	Land Use	Potential Sources of Contaminants
42	Agricultural	manure fertilizer
43	Rural Residential	
44	Hobby Farm	
45	Hobby Farm	
46	Hobby Farm	
47	Agricultural	manure fertilizer
48	Agricultural	manure fertilizer
49	Hobby Farm	manure fertilizer
50	Rural Residential	
51	Hobby Farm	manure fertilizer
52	Hobby Farm	
53	Hobby Farm	
54	Agricultural	manure fertilizer
55	Rural Residential	
56	Hobby Farm	
57	Agricultural	manure fertilizer; herbicide
58	Agricultural	deer droppings
59	Rural Residential	
60	Agricultural	manure and chemical fertilizer
61	Agricultural	manure fert.;septic effluent (15m from well)
62	Hobby Farm	
63	Rural Residential	
64	Agricultural	
65	Hobby Farm	
66	Agricultural	manure fert.;septic effluent (20m from well)
67	Rural Residential	
68	Hobby Farm	
69	Hobby Farm	
70	Rural Residential	
71	Agricultural	
72	Agricultural	manure fertilizer
73	Agricultural	manure fertilizer and morts
74	Hobby Farm	
75	Hobby Farm	
76	Rural Residential	
77	Agricultural	manure fertilizer
78	Agricultural	
79	Agricultural	
80	Agricultural	manure fertilizer
81	Hobby Farm	
82	Hobby Farm	
83	Hobby Farm	

Site No. refers to Figure 5

Results of groundwater level measurements in an observation well located within the central part of the study area during the past two years are illustrated in **Figure 14** and indicate that the depth to the groundwater table is relatively deep and fluctuates between about 27m to 37m below ground level. A theory postulated by Kohut et al (1989) in his studies of the Abbotsford Aquifer nitrate contamination, indicates that there is a correlation between nitrate-nitrogen concentrations, groundwater levels and precipitation. It appears that nitrate-nitrogen concentrations are lower during the fall period when groundwater levels are at their seasonal lowest and increase in the spring when groundwater levels are at their seasonal highest as a result of precipitation recharge. Precipitation recharge seems to have two effects: flushing of nitrates below ground surface down to the water table, and raising the groundwater level, resulting in residual nitrates in the ground above the water table being mobilized, thereby increasing the concentration of nitrates in the groundwater. Further monitoring of water levels in the observation well for a period of at least 5 years is recommended to verify the above correlation.

Figure 11 is a groundwater level contour map drawn from surveyed elevations of wells and showing groundwater flow directions. This figure coupled with **Figure 12** showing the areas of high nitrate concentrations, provides information on where potential source(s) of nitrate contamination in wells may be coming from. As shown in **Figure 12**, there are two main areas of nitrate contamination (Area "A" and Area "B"); both of which are limited in areal extent. The groundwater flow direction in the vicinity of Area "A" and area "B" is north-west to south-east. An evaluation of land use in these areas indicates that the land is used mainly for agricultural purposes, and according to local residents, has been for at least the past 10 years. The most likely agricultural sources of nitrate-nitrogen are from leaching of excess manure or chemical fertilizer applications on crop lands, possible minor leakage of manure from storage and/or leaching of uncovered manure piles. When soil contains more nitrogen than crops can use, the excess nitrogen in the form of nitrate moves out of the soil around the plant roots and leaches into the groundwater. According to Zebarth, et al (1997), an excess of 100 kg nitrate-nitrogen per hectare remaining in the soil at the end of the growing season may result in greater than 10 ppm or mg/L nitrate-nitrogen in groundwater. Three related factors determine the amount of excess nitrate in the soil:

FIGURE 14: Observation Well # 335 Hydrograph, Columbia Valley BC



climatic conditions, soil type and the amount of nitrogen fertilizer used. Climate and soil types cannot be controlled, but the amount of fertilizer use can.

The amount of excess nitrate-nitrogen entering the groundwater regime can be estimated by the following calculation. The volume of groundwater below Area "A" that contains nitrate-nitrogen above 3 mg/L is roughly estimated at 6.6 Million cubic metres (1100m X 500m X 40m of aquifer thickness X 0.3 porosity). Assuming an average nitrate-nitrogen concentration of 5 mg/L, then this volume of groundwater contains about 33,000 kg of nitrate-nitrogen. Assuming that agricultural activities in the area have been contributing excess nitrogen to the groundwater for at least the past 10 years at more or less the same rate each year, then the excess nitrogen loading to this area is estimated to be about 3,300 kg per year. Assuming Area "A" is surrounded by approximately 75 hectares of agricultural land upon which manure fertilizer application can occur, then the excess nitrogen loading is equivalent to about 44 kgN/ha/year. This quantity of nitrogen is not an overly excessive amount, and according to the Ministry of Agriculture and Foods, represents about 10% more nitrogen than is needed for a good yielding grass crop.

For Area "B", the estimated volume of groundwater is about 2 million cubic metres (800m X 200m X 40m X 0.3). Assuming an average nitrate-nitrogen concentration of 4 mg/L, then the volume of groundwater in Area B contains about 8,000 kg of nitrate-nitrogen. Again, assuming that agricultural practices in the area have been occurring for the past 10 years, then the excess nitrogen loading to this area is estimated to be about 800 kg per year. Assuming Area B is surrounded by about 15 hectares of agricultural land upon which manure fertilizer application can occur, then the excess nitrogen loading is equivalent to about 53 kgN/ha/year, which is also not an overly excessive amount.

According to Zebarth, et.al.,(1997), improved manure and fertilizer management practices have the potential to substantially reduce nitrogen losses to groundwater. Minor adjustment of manure management would help ensure that no excess nutrients (nitrogen) are applied to the soil that may be leached to the groundwater. Specifically, manure applications to the soils during the winter season, i.e. between November 1 and January 31 in the vicinity of the sensitive areas which are experiencing elevated nitrate-nitrogen concentrations, should be strictly avoided so as to minimize or eliminate the amount of excess nutrients (nitrogen) leaching into the aquifer. For the rest of the year, Haughton, et.al. states that it is necessary to ensure that a balance exists between nutrient supply and crop demand.

Improved manure management practices may already be occurring in the Columbia Valley. Referring to Figure 13, it is of interest to note that during the 1997 – 1999 period, the trend in nitrate-nitrogen concentrations at all five well sites is generally decreasing. A possible reason for this decreasing trend may be related to a decrease in the frequency of manure applications around Area "A" and Area "B" during the past several years, as reported by local residents in the area.

Besides agricultural sources, other potential sources of nitrates may include changes in land use, forest clearcutting activities, uncovered storage of manure on the land, cultivation of grass, possible infiltration of nitrogen-rich surface water, munitions, and atmospheric depositions.

Nitrate loading resulting from atmospheric depositions is not considered significant for the study area. Results of groundwater quality analyses of wells throughout the study area shows that the nitrate-nitrogen concentrations are predominantly less than 1 mg/L.

In the past, Columbia Valley has been the site of various Canadian Forces military activities, which has included the use of munitions. According to the base environmental office at Canadian Forces Base Chilliwack, there has not been any significant use or storage of munitions in the Valley. Consequently, this potential source of nitrate is not considered significant.

Changes in land use, such as from forest to crop land, and cultivation of grass is not known to have occurred in the vicinity of the two areas of elevated nitrate-nitrogen concentrations within the past 10 to 15 years; consequently, these activities are not considered significant potential sources of nitrate loading within the study area.

According to Puckette and Wheeler, 1997, forest clearcutting can release nitrogen to the environment. Some of this nitrogen is released as a gas; some is bound in the root zone and some is transformed by soil bacteria into nitrate. Some can find its way to nearby streams and a portion could infiltrate into the groundwater regime. The increase in nitrogen however is temporary and dissipates to background levels usually within a few years. A review of air photos indicates that the mountain area north of the valley has been clearcut more than 10 years ago. The potential effects of clearcutting would have likely dissipated many years ago and consequently are highly unlikely to have contributed any significant amount of nitrates to the groundwater in the study area.

According to Zebarth (1997), uncovered stockpiles of manure on bare ground can result in dramatic increases in nutrient concentration in the soil below the manure storage area. Precipitation infiltration can carry some of the nitrate-nitrogen down to the groundwater. The main factors that determine how much nitrate-nitrogen leach down to the groundwater depend on the quantity of manure in the pile, the length of time the pile remains on the ground uncovered, the amount of precipitation that infiltrates through the pile and the permeability of the soils below.

In early 1994, several loads of chicken manure were dumped on the soil within 10 m of a water well along Columbia Valley Road, and removed within two months. In the spring of 1998, two samples of soil were collected, one of the sites was in the vicinity of where the solid poultry manure was stored and the other site was away from where the manure was stored. Zebarth (1998) performed soil analyses on these samples and concluded that there was a large input of ammonium and potassium at the first site, consistent with high loading of these nutrients to the soil at some point in the past. He further indicated that there is no conclusive evidence that the elevated values are due exclusively to manure stockpiling; rather, they are consistent with that activity.

Figure 13 shows the nitrate-nitrogen trends for groundwater in a number of well sites in the study area. At site 1, the area of the above noted poultry manure storage site, nitrate-nitrogen concentrations in 1994 were about 8 mgN/L. As mentioned earlier in Section 3.5, it was estimated that it takes about 2.8 years for surface contaminants to reach the groundwater table. Figure 13 shows that in early 1997 (approximately 2.8 years from the time that the poultry manure was stockpiled near the above well site) the nitrate-nitrogen concentration coincidentally increased to almost 13 mgN/L, and within the year declined to the 8 mgN/L concentration. This analysis indicates that although the short term stockpile of chicken manure had a likely temporary impact on the nitrate-nitrogen concentration in groundwater locally, it was not responsible for the background concentration of 8 mgN/L that seems to be persistent at this site since 1994. Furthermore, groundwater quality analyses from some nearby wells drilled in 1996 showed nitrate-nitrogen concentration results of up to 9.67 mgN/L. This additional information supports the conclusion that the elevated nitrate-nitrogen concentration at the site 1 well was more widespread than just at the well site and was due to another, more significant source other than the poultry manure. Based on the above observations, future stockpiles of manure anywhere in the study area should not occur on bare soil for any extended periods of time and should be covered, especially during rainy conditions to prevent leaching of nutrients (nitrates) into the soil and eventually the groundwater.

It is also of interest to note that at Site 2 (Figure 13), nitrate-nitrogen concentrations dramatically declined between April 1997 and April 1998. A possible explanation of this decline may be related to the well use. According to the well owner, this 8-inch diameter well was drilled in October 1995 and was used for domestic and limited irrigation use in 1996. In 1997, the well continued to be used for domestic purposes, but irrigation use increased significantly. The effect of increased groundwater withdrawals would have resulted in groundwater flowing from a radially more extensive area within the aquifer. As a consequence, the increased zone of groundwater withdrawals would have encountered water with little to no nitrate-nitrogen contamination and the resulting “blended” water would have a much lower or diluted concentration of nitrate-nitrogen. To determine if the nitrate-nitrogen concentration may similarly decrease at the Site 1 well, it is suggested that if possible, the well be used for irrigation purpose and pumped at a rate of at least 4 L/s (50+ igpm) during the summer season. Water quality samples should also be obtained and tested before, during and after for possible nitrate-nitrogen concentration changes.

4.4 Evaluation of Water Quality – Health Perspective

As part of this study, the Fraser Valley Health Region conducted an evaluation of the chemical analyses of groundwater and surface water samples. The following is a summary of their evaluation and includes the current status of health concern and risk regarding groundwater in the study area of Columbia Valley.

The primary focus of the study was to determine nitrate contamination levels. In total, 28 groundwater samples and 33 surface water samples were tested during the study. While the focus was the measurement of nitrate levels, the samples were analyzed for a wide range of chemical parameters.

Based on the test results, nitrate (nitrogen) levels are within the Guidelines for Canadian Drinking Water Quality at all sites tested. All surface water sources showed nitrate (nitrogen) levels to be at what can be considered background levels. However, in some groundwater sources, levels are more than double that of normal background concentrations. This indicates area groundwater is being subjected to significant nitrate contamination that if not controlled, could result in levels exceeding health standards. We therefore recommend the following steps be taken:

- Current measures in place to reduce excessive manure application and prevent contamination from storage facilities must be continued and improved upon in order to reduce the amount of nitrate entering the groundwater.
- Periodic monitoring of groundwater nitrate levels should be carried out in order to identify any future changes in the situation.
- Recognizing that Columbia Valley's groundwater is vulnerable to chemical contamination from surface activities, groundwater protection controls should be put in place on future growth and industrial developments.

The study also identified 19 sources where other chemical parameters exceeded Canadian Drinking Water Quality Standards. In most cases, the issue involved exceeding the aesthetic limits for common "nuisance" chemicals, such as iron and manganese. However, in 8 groundwater and 2 surface water sources, concentrations of some chemicals exceeded the guidelines for health related reasons. Selenium was found in excess of the guidelines in 5 groundwater and 2 surface water sources. Excessive levels of lead were found in 4 groundwater sources, although at two of the sites, where multiple samples were taken, lead levels did not exceed the guidelines in all samples. Excessive aluminum was found in 2 wells and one well had cadmium levels above the guidelines.

The elevated levels of aluminum and selenium are not considered a significant health concern at the concentrations found. However, people who are using the sources involved may wish to seek additional information on specific concerns related to the use of the water from the Fraser Valley Health Region in Chilliwack (phone: 604-795-8205). The elevated levels of lead and cadmium indicate a more significant health concern. However, these chemicals are often an indication of contamination from within the supply and distribution system. Further testing should be carried out on the affected wells to determine if contamination is from the source or the building plumbing. Appropriate action should be taken once the source is found.

In conclusion, the test results show there is no public health concerns with groundwater quality in the Columbia Valley (study) area. However, elevated nitrate levels show that water quality has deteriorated and action must be taken to limit further contamination. Several of the sites tested show elevated levels of some chemicals of health significance; however, these appear to be site specific contamination issues that should be addressed on an individual basis.

5. Conclusions

1. The Columbia Valley Aquifer is comprised of very permeable glacio-fluvial sand and gravel deposits to at least 100 m in depth.
2. Columbia Valley is underlain by an extensive unconfined and in places confined/semi-confined aquifer.
3. Groundwater use in the study area is less than 1% of the amount of recharge to the aquifer.
4. Surveyed well water level measurements and groundwater level contour mapping indicate that groundwater flows from the areas flanking the mountains towards the central part of the valley and then flowing out of the valley towards the Canada - U.S. border and towards Cultus Lake,
5. Groundwater levels fluctuate between 27 m and 37 m below ground level.
6. Groundwater from only 8 out of 37 wells tested for nitrate-nitrogen had above background levels, i.e. above 3 mgN/L.
7. Elevated nitrate-nitrogen concentrations in wells are concentrated in only 2 main areas.
8. The most likely significant source of nitrates to the groundwater during the past 10 years is from agricultural land use activities, i.e. manure/fertilizer applications in excess of crop requirements and/or leaking manure storage facilities.
9. None of the groundwater from wells tested during this study had nitrate-nitrogen concentrations above 10 mgN/L.
10. Nitrate-nitrogen concentrations in specific wells show a declining trend during the past 2 years (1998-1999). This declining trend may be attributable to improved manure management practices in the areas of these wells during the past several years.
11. According to the Fraser Valley Health Region, there is no significant risk to health at this time from drinking groundwater from wells in the study area.

6. Recommendations

1. For at least the next five years, continue to sample and test on an annual basis the nitrate-nitrogen concentrations of groundwater from wells that have above background levels of 3 mgN/L.
2. Retest groundwater quality from wells that have elevated cadmium, lead and selenium concentrations, and inform local health authorities for follow-up information and advice about the significance of these concentrations on health. Field filtering of samples and determination of both total and dissolved metals should be undertaken.
3. Minor adjustment of manure management activities particularly in the area of wells with above background nitrate-nitrogen concentrations of 3 mg/L as shown in **Figure 12** should be practised to help ensure that no excess nutrients are applied to the soil that may result in nitrates leaching into the groundwater.
4. All farms should set up and establish a nutrient management plan to ensure no excess nutrients are applied to the soils in the study area.
5. Spreading of manure during the winter season (November 1 to January 31) should be strictly avoided.
6. Manure stockpiles should be covered, especially during rainy conditions, to prevent rainwater from infiltrating the stockpiles and leaching out nitrogen into the soil and eventually the groundwater.
7. Manure stockpiles should be at least 30 m away from water wells or any water courses, and preferably not located on bare soil.
8. If possible, the well at 910 Columbia Valley Road should be pumped at a rate of at least 4 L/s during the summer irrigation season and tested for nitrate-nitrogen concentration before, during and after the season.
9. Incorporate the well at 800 Columbia Valley Road into the provincial Observation Well Network, and continue to monitor water levels in this well for a period of at least 5 years to assess trends in groundwater levels in the study area.
10. The community should consider the implementation of an aquifer protection plan using the provincial Well Protection Toolkit.

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APPENDIX 1

COLUMBIA VALLEY GROUNDWATER ASSESSMENT
1997 WATER WELL SURVEY

BCGS Well Record #: ______________________ Site #: __________ (Office Use)

SITE INFORMATION

Resident's Name: ______________________ Phone #: ______________

Well Site Address: ____

WELL CONSTRUCTION DETAILS - WELL A (sampled well only)

Type of Well:	Water Use:	Well Depth: __________ ft./ m (below grd)
[] Drilled	[] Domestic	Diameter: __________ in / cm
[] Dug	[] Irrigation	Avg. Use: __________ Gpd / Lpd
[] Sandpoint	[] Livestock / poultry	
[]	[]	**DEPTH TO WATER: __________ ft./ m (blw grd)** **Date of measurement: ______________**

Well Site ground elevation surveyed by: ______________ Date: ______________

[] For other well(s) on property (Well B, Well C, etc), record above information on reverse.

[] Well location(s) identified and plotted on Location Map and/or air photo, by Site Number

WATER QUALITY DATA

Resident's observations: ____

Any water filtration / purification / treatment: [Y] / [N]. Any previous water quality analyses: [Y] / [N].

SAMPLE LOCATION: ______________________ **DATE:** ______________

SAMPLE METHOD: ____

POTENTIAL SOURCES OF GROUNDWATER CONTAMINATION

[] Fertilizer / Manure Storage	[] Fertilizer / Manure Use	[] Septic Field:
[] Fuel Storage Tank (abv grd)	[] Fuel Storage Tank (blw grd)	Distance from Well: ______ ft / m
[] Pesticide Storage	[] Pesticide Use	Upslope / Downslope from Well

ADDITIONAL COMMENTS: ____

____

SURVEY CONDUCTED BY: ____

APPENDIX 1

COLUMBIA VALLEY GROUNDWATER ASSESSMENT
1997 LAND USE SURVEY

Resident's Name: ______________________ Site #: ________

GENERAL DATA

Type of operation: ______________________

Total Size: ________ acres

Lease __________ acres to ______________________

Rent __________ acres from ______________________

Number of animals: (by type-annual range or average): ______________________

MANURE DATA (If applicable)

1) Permanent Manure Storage (check all that apply):

Covered ________ Concrete ________ Under-cage storage ________

Uncovered ________ Earthen ________ Under-pen storage ________

Capacity of facility (tons or months): ______________________

Physical Dimensions: ______________________

2) Field Storage:

Covered ________ Uncovered ________

3) Application of manure (specify amount, area, method and crop):

Season: ______________________

On-farm: ______________________

____

Off-farm (specify location): ______________________

Contingency site (specify location): ______________________

MISCELLANEOUS

Handling of mortalities: On-farm ________ Location: ______________________

Off-farm ________ Method: ______________________

Composting facility: Covered ________ Uncovered ________

Type of materials composted: ______________________

Chemical fertiliser application: Type: ______________________

Frequency ________ Amount ________ Crop ________

Pesticide application: Yes ________ No ________ Type: ______________________

Disposal of containers ______________________

Province of
British Columbia

Ministry of Health and
Ministry Responsible for Seniors

Upper Fraser Valley Health Unit
45470 Menholm Road
Chilliwack, BC V2P 1M2
Telephone: (604) 795-8200
Facsimile: (604) 795-8222

File 153-11-1

April 4, 1996

APPENDIX 2

Mr. George Jones
800 Columbia Valley Highway
Lindell Beach, British Columbia
V2R 4X6

RE: Soil Samples from Well Drilling

Dear Mr. Jones,

Thank you again for allowing us to obtain soil samples during the drilling of your well at 800 Columbia Valley Highway. Please find enclosed a copy of your well log, tables of nitrate and moisture results as prepared by Agriculture Canada, and graphs showing the nitrate and moisture content results prepared by our department. Your well was drilled through a clay layer between 125 and 170 feet which would likely not be permeable to water (or contaminants). This indicates that surface water near your well head does not travel straight down to the water table, but rather travels straight down until it is intercepted by the clay layer and diverted horizontally until the clay layer tapers off.

The information we obtained however was very useful. Since the entire valley is believed to be composed of similar deposits, we determined that for those areas that do not have a clay layer under them, the water infiltration rate from the surface to the water table would be 2 to 4 years.

You may have noticed the fluctuating nitrate concentrations as shown on the nitrate graph. According to Agriculture Canada, the complex and difficult procedure of analyzing the gravel created variability within the results, and they consider all these values to be around 3 miligrams / litre.

Should you have any comments regarding this or other environmental health issues, please contact us. Thank you for your assistance.

Sincerely,

Stephen Caine

Stephen Caine
Research Officer

SC/
Enclosures

Abbotsford Environmental Health
#207 - 2776 Bourquin Crescent
Matsqui, BC V2S 6A4
Telephone: (604) 852-5310
Fax: (604) 852-5315

Abbotsford Community Health
2391 Crescent Way
Abbotsford, BC V2S 3M1
Telephone: (604) 864-3400
Fax: (604) 864-3410

Agassiz Health Centre
Box 104, (7170 Cheam Avenue)
Agassiz, BC V0M 1A0
Telephone: (604) 796-2191
Fax: (604) 796-9187

Hope Health Centre
Box 176, (444 Park Street)
Hope, BC V0X 1L0
Telephone: (604) 869-5661
Fax: (604) 869-2332

Mission Health Centre
33313 Third Avenue
Mission, BC V2V 1P1
Telephone: (604) 826-7166
Fax: (604) 826-4719

BC Ministry of Health Columbia Valley well drilling gravel samples

Gravel collected: October 11 & 13, 1995 | (0-102 ft.) | (115-209 ft

Date extracted: January 26, 1996 | FIA: 960130

150g +/- 1g soil : 200ml 2M KCl

Shaken for 15 mins.

Noticed an oily smell to the samples around the 20-30 ft. level.

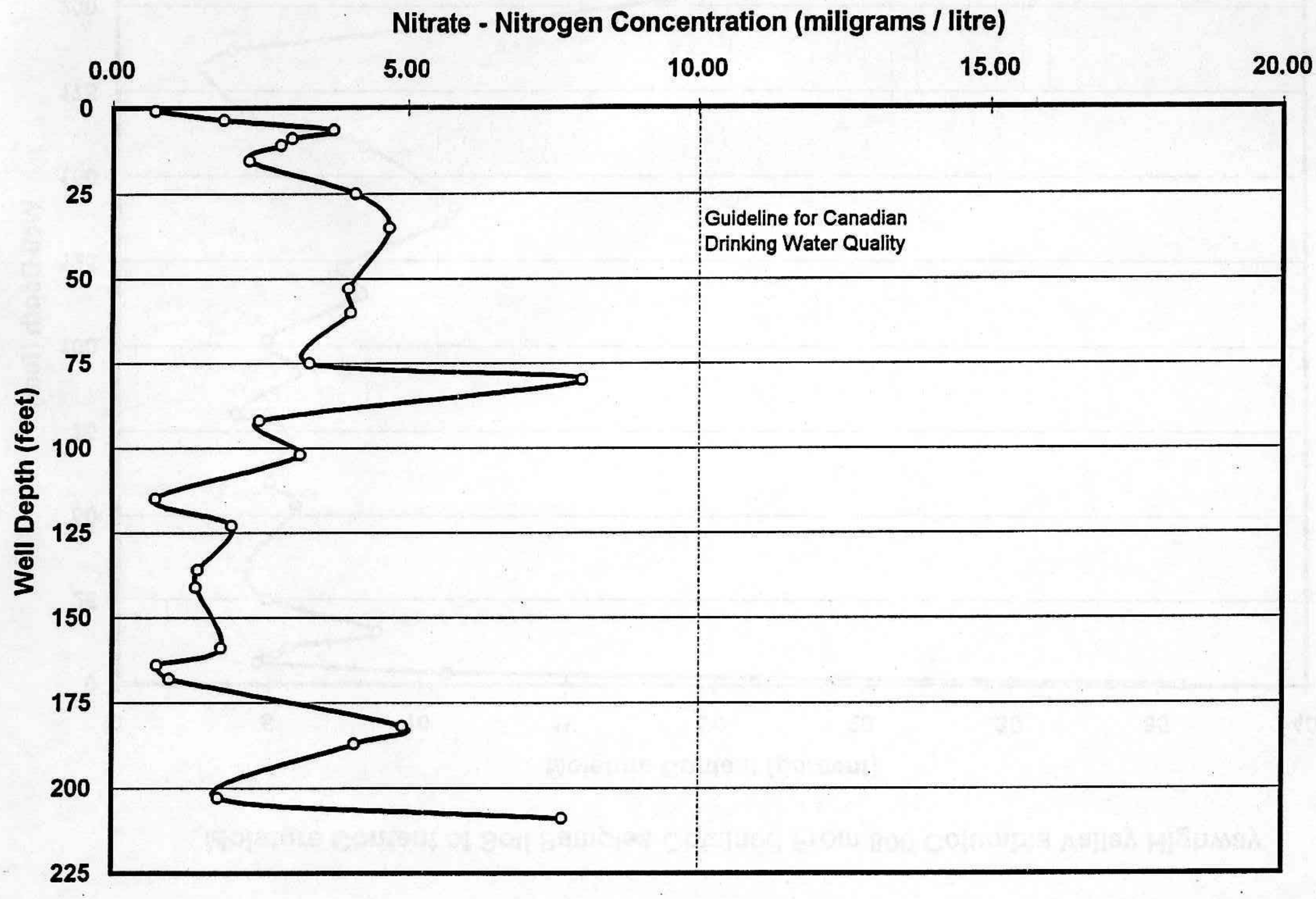
Grew fainter and smelled older with the increasing depth.

Oil present as a surface film on the filter paper; very visible.

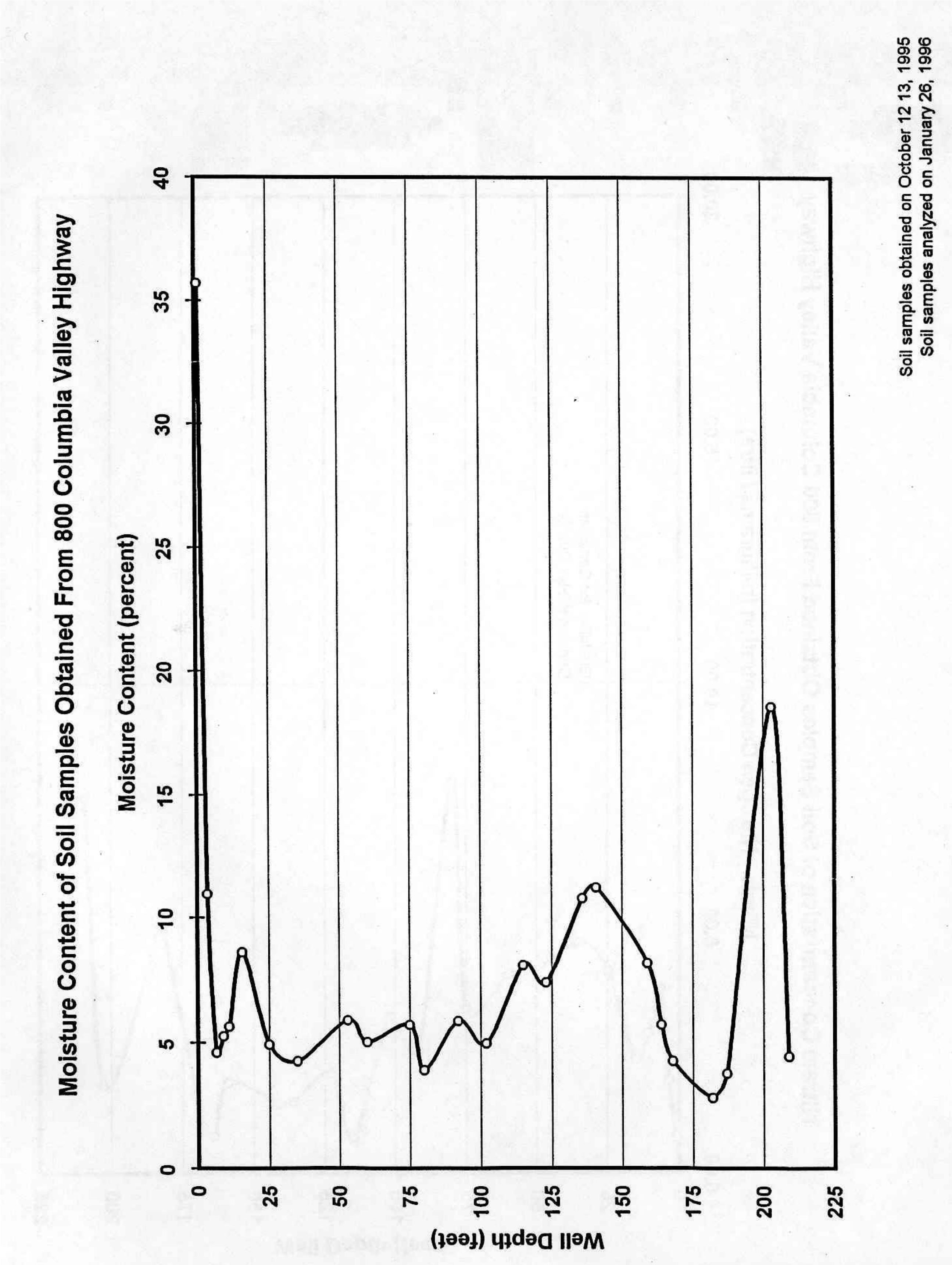
Sample ID	From (ft)	To (ft)	Increment Depth (m)	Water Content (%)	Bulk Density (g/cm3)	Depth of Water (m)	Cumulative Depth of Water (m)
0-2 ft.	0	2	0.61	35.70	1.00	0.36	0.36
2-5 ft.	2	5	0.91	10.95	1.90	0.21	0.57
5-8 ft.	5	8	0.91	4.62	1.90	0.09	0.65
8-10 ft.	8	10	0.61	5.26	1.90	0.10	0.75
10-12 ft.	10	12	0.61	5.66	1.90	0.11	0.86
12-19 ft.	12	20	2.44	8.61	1.90	0.16	1.02
20-30 ft.	20	30	3.05	4.94	1.90	0.09	1.12
35 ft.	30	44	4.27	4.28	1.90	0.08	1.20
52-54 ft.	44	56.5	3.81	5.91	1.90	0.11	1.31
60 ft.	56.5	67.5	3.35	5.03	1.90	0.10	1.41
75 ft.	67.5	77.5	3.05	5.73	1.90	0.11	1.52
80 ft.	77.5	86	2.59	3.93	1.90	0.07	1.59
92 ft.	86	97	3.35	5.88	1.90	0.11	1.70
102 ft.	97	108.5	3.51	4.98	1.90	0.09	1.80
115 ft.	108.5	119	3.20	8.11	1.90	0.15	1.95
123 ft.	119	129.5	3.20	7.42	1.90	0.14	2.09
136 ft.	129.5	138.5	2.74	10.78	1.90	0.20	2.30
141 ft.	138.5	150	3.51	11.21	1.90	0.21	2.51
159 ft.	150	161.5	3.51	8.19	1.90	0.16	2.67
164 ft.	161.5	166	1.37	5.74	1.90	0.11	2.77
168 ft.	166	175	2.74	4.30	1.90	0.08	2.86
182 ft.	175	184.5	2.90	2.85	1.90	0.05	2.91
187 ft.	184.5	195	3.20	3.80	1.90	0.07	2.98
203 ft.	195	206	3.35	18.60	1.90	0.35	3.34
209 ft.	206	212	1.83	4.48	1.90	0.09	3.42

Sample ID	From (ft)	To (ft)	Increment Depth (m)	Nitrate con in soil (mg N/kg s	Nitrate conc. in solution (ppm nitrate-N)
0-2 ft.	0	2	0.61	0.26	0.73
2-5 ft.	2	5	0.91	0.21	1.89
5-8 ft.	5	8	0.91	0.17	3.75
8-10 ft.	8	10	0.61	0.16	3.04
10-12 ft.	10	12	0.61	0.16	2.86
12-19 ft.	12	20	2.44	0.20	2.32
20-30 ft.	20	30	3.05	0.20	4.11
35 ft.	30	44	4.27	0.20	4.68
52-54 ft.	44	56.5	3.81	0.24	4.00
60 ft.	56.5	67.5	3.35	0.20	4.03
75 ft.	67.5	77.5	3.05	0.19	3.34
80 ft.	77.5	86	2.59	0.32	8.02
92 ft.	86	97	3.35	0.15	2.50
102 ft.	97	108.5	3.51	0.16	3.19
115 ft.	108.5	119	3.20	0.06	0.75
123 ft.	119	129.5	3.20	0.15	2.03
136 ft.	129.5	138.5	2.74	0.16	1.46
141 ft.	138.5	150	3.51	0.16	1.42
159 ft.	150	161.5	3.51	0.15	1.85
164 ft.	161.5	166	1.37	0.04	0.77
168 ft.	166	175	2.74	0.04	0.99
182 ft.	175	184.5	2.90	0.14	4.91
187 ft.	184.5	195	3.20	0.16	4.10
203 ft.	195	206	3.35	0.34	1.81
209 ft.	206	212	1.83	0.35	7.71

Nitrate Concentration of Soil Samples Obtained From 800 Columbia Valley Highway



Soil samples obtained on October 12 13, 1995
Soil samples analyzed on January 26, 1996


Moisture Content of Soil Samples Obtained From 800 Columbia Valley Highway
Moisture Content (percent)
0
5
10
15
20
25
30
35
40
Well Depth (feet)
0
25
50
75
100
125
150
175
200
225
Soil samples obtained on October 12 13, 1995
Soil samples analyzed on January 26, 1996