Abbotsford-Sumas Aquifer, British Columbia, Canada
2004 Groundwater Quality Survey - Nitrate and Bacteria

by

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Abbotsford-Sumas aquifer, British Columbia, Canada: 2004 groundwater quality survey - nitrate and bacteria.

DATE	ISSUED TO

Abstract

In 2004, an extensive survey of nitrate and bacteria in groundwater from the Abbotsford-Sumas aquifer in south western British Columbia was conducted jointly by Environment Canada, BC Ministry of Environment, Fraser Health Authority and University College of the Fraser Valley. Over 300 samples were collected from about 150 water well sites located in the study area which encompassed the Canadian side of Abbotsford-Sumas aquifer. About 40 percent of the sampled wells had nitrate concentrations above the Canadian Drinking Water Quality Guideline for nitrate of 10 milligram as Nitrogen per Litre (mg N/L). The nitrate concentrations in over 60 percent of the sampled wells were above 3 mg N/L, indicating input from anthropogenic sources. The nitrate concentration ranged from non-detectable (<0.02 mg/L) to a high of 78.4 mg/L.

Elevated nitrate concentrations (> 10 mg N/L) occurred more frequently in areas where agriculture is the primary land-use activity and where the water table was close to the surface. Groundwater nitrate contamination in the study area appeared to increase in areal extent in October 2004, based on contour mapping of February and October results. However, the mean and median nitrate concentrations for most areas decreased in October. The increase in areal extent and the apparent dilution effect (the decrease in nitrate concentrations) were likely related to increased recharge from higher precipitation in late October.

One hundred and eleven sites were found to have total coliform bacteria as high as 1500 colony forming units (CFU) per 100mL. However, twelve sites showed the presence of fecal coliform bacteria which appeared to be localized to a few specific wells and not reflective of overall aquifer quality. The sources of fecal coliform bacteria were likely the results of localized land-use activities, poor well completion and/or inadequate protection.

Résumé

En 2004, une vaste étude des nitrates et des bactéries dans les eaux souterraines de l'aquifère d'Abbotsford-Sumas dans le sud-ouest de la Colombie-Britannique a été menée par Environnement Canada, le ministère de l'Environnement de la Colombie-Britannique, la Fraser Health Authority et l'University College of the Fraser Valley. Plus de 300 échantillons ont été prélevés d'environ 150 puits dans la zone d'étude, soit le côté canadien de l'aquifère d'Abbotsford-Sumas. Quelque 40 % des puits échantillonnés montraient des concentrations de nitrate supérieures à la valeur des recommandations pour la qualité de l'eau potable au Canada, exprimée en azote, soit 10 milligrammes d'azote par litre (mg N/L). Dans plus de 60 % des puits échantillonnés, les concentration de nitrate dépassaient 3 mg N/L, ce qui indique des apports de source anthropique. Les concentrations allaient de non décelables (< 0,02 mg/L) à 78,4 mg/L.

Les concentrations élevées (> 10 mg N/L) se trouvaient le plus souvent dans des secteurs principalement agricoles et là où la nappe phréatique était près de la surface. La contamination des eaux souterraines par les nitrates dans la zone d'étude semblaient s'étendre en octobre 2004, d'après la carte en courbes établie à partir des résultats de février et d'octobre. Cependant, les concentrations moyenne et médiane ont diminué en octobre dans la plupart des secteurs. L'augmentation de l'étendue de la contamination et l'effet apparent de dilution (diminution des concentrations) étaient sans doute liés à la plus grande alimentation de la nappe en raison des précipitations abondantes à la fin d'octobre.

À 111 sites, le total des bactéries coliformes atteignait jusqu'à 1500 unités formant des colonies (UFC) par 100 mL. Cependant, 12 sites accusaient une présence de coliformes fécaux qui semblait localisée à quelques puits et ne pas témoigner de la qualité générale de l'aquifère. Les sources de coliformes fécaux provenaient vraisemblablement d'activités localisées d'utilisation des terres et du mauvais aménagement ou de la protection inadéquate des puits.

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INTRODUCTION

The objective of this report is to present the results of an extensive 2004 groundwater sampling program on the transboundary Abbotsford-Sumas aquifer in south western British Columbia, Canada. The purpose of the sampling program was to determine the areal extent of nitrate contamination and the presence of pathogenic bacteria in the groundwater.

The Abbotsford-Sumas aquifer (Figure 1) is very susceptible to land-based contamination because it is largely composed of permeable glacio-fluvial sand and gravel deposits. Nitrate contamination of groundwater in several areas of the aquifer has been a concern for several decades. Beginning in 1984, Environment Canada installed and sampled a network of piezometers to monitor nitrate concentrations in groundwater in areas that appeared to be most impacted from nitrate south of the Abbotsford Airport (see Figure 2). Nitrate concentrations in many of these piezometers, some domestic wells and provincial observation wells (BC Ministry of Environment) have exceeded the 10 mg nitrogen per litre, maximum acceptable concentration (MAC) for the Canadian Drinking Water Quality Guideline (CDWQG) for nitrate (CCME, 1996). Guideline levels (MAC) for nitrate have been exceeded in many Environment Canada piezometers since the initial stage of the piezometer installation program in 1984. Liebscher et al. (1992) indicate that nitrate contamination of groundwater in the Abbotsford-Sumas aquifer has been observed since the early 1950's.

High levels of nitrate in drinking water pose a risk to infants and are a health concern because they may cause methemoglobinemia, a serious condition known as "blue baby syndrome". Methemoglobinemia can occur when ingested nitrate is reduced to nitrite in the body. Nitrite binds to haemoglobin in the blood to form methemoglobin, which reduces the oxygen capacity of the blood (Ward *et al.,* 2005). This condition can result in a bluish appearance in the skin and may cause coma or death in susceptible infants. Although there have been no known reports of methemoglobinema in the Abbotsford area, a review of the British Columbia Medical Services Plan records indicates there have been six discharge diagnoses of methemoglobinemia in British Columbia since 1990 in infants less than one year of age (Dr. Ray Copes, personal communication, September 19, 2005). Methemoglobinemia cases resulting from consumption of elevated nitrate levels in drinking water are well documented in the literature (Fan and Steinberg, 1996). As a result, the Fraser Health Authority continues to recommend that infants should not consume water containing nitrates above the CDWQG for nitrate of 10 mg N/L.

The overall extent of nitrate contamination in the Abbotsford-Sumas aquifer is not fully known. Previous studies have reported that approximately 10 to15 percent of wells in the Fraser Valley have nitrate concentrations greater than the MAC for nitrate (Carmichael *et al.,* 1995; Cox and Kahle, 1999). A 1993 study of the

Abbotsford-Sumas aquifer identified 54 percent of wells sampled had nitrate concentrations exceeding the MAC for nitrate (Wassenaar, 1995), with estimates that up to 80 percent of the aquifer was impacted by elevated nitrate concentrations. These reports also identified specific areas of concern for nitrate contamination of groundwater, particularly the area south of the Abbotsford airport, between Fishtrap Creek and the Huntington, BC/Sumas, Washington border crossing, as well as the western region around Bertrand Creek and tributaries. These areas of the aquifer have been the subject of more detailed hydrogeological investigation and delineation of nitrate contamination through focused sampling and studies of a network of piezometers by Environment Canada (Hii *et al.*, 1999).

Nitrate trends in piezometers appear to be site-specific (Liebscher *et al.*, 1992; Hii *et al.*, 1999). This site-specific pattern may be influenced by spatial variability in land use and heterogeneities in both the unsaturated soil matrix and in the aquifer properties. Lower nitrate concentrations have been observed in areas of less intense agricultural use. Nitrate concentrations in some piezometers fluctuate seasonally and concentrations at most locations decrease with depth (Hii *et al.*, 1999).

Nitrate concentrations in most of the municipal production wells in the Abbotsford-Sumas aquifer are historically below the Drinking Water Guideline level of 10 mg N/L. This can be attributed to the fact that many of the wells are greater than 40 meters in depth. A number of these wells are below confining layers (impermeable or semi-permeable lenses above their well screens) which provide some protection from direct infiltration of contaminants from above.

Sources of elevated nitrate concentrations in groundwater sampled from piezometers have historically been attributed to agricultural activities such as improper storage of manure, particularly during the rainy winter season and over-application of manure on berry fields (Liebscher *et al.*, 1992; Wassenaar, 1995; Zebarth *et al.*, 1998; Hii *et al., 1999*).

A large portion of the aquifer has agriculture as the primary land use. The agriculture industry, particularly the raspberry and poultry producers, have been working with government agencies to adopt management practices designed to reduce the potential for nitrate contamination. Some manure handling practices were prescribed through the B.C. Agriculture Waste Control Regulation (1992). But the agriculture industry also voluntarily adopted a number of initiatives and studies since the mid 1990s.

The Ministry of Environment conducted a compliance survey of farms in 2003/04 over the Hopington and Abbotsford-Sumas aquifers. It found that 97% of the berry farms and 92% of the poultry farms were in compliance with the Agriculture Waste Control Regulation (Compliance Report, 2005).

Total and fecal coliform bacteria are commonly used indicators of pathogenic bacterial contamination in water. The total coliform group of bacteria is naturally occurring in the environment. Fecal coliform bacteria are a subset of total coliform bacteria, and are found in the intestinal tracts of warm-blooded animals. Their presence indicates fecal contamination of water.

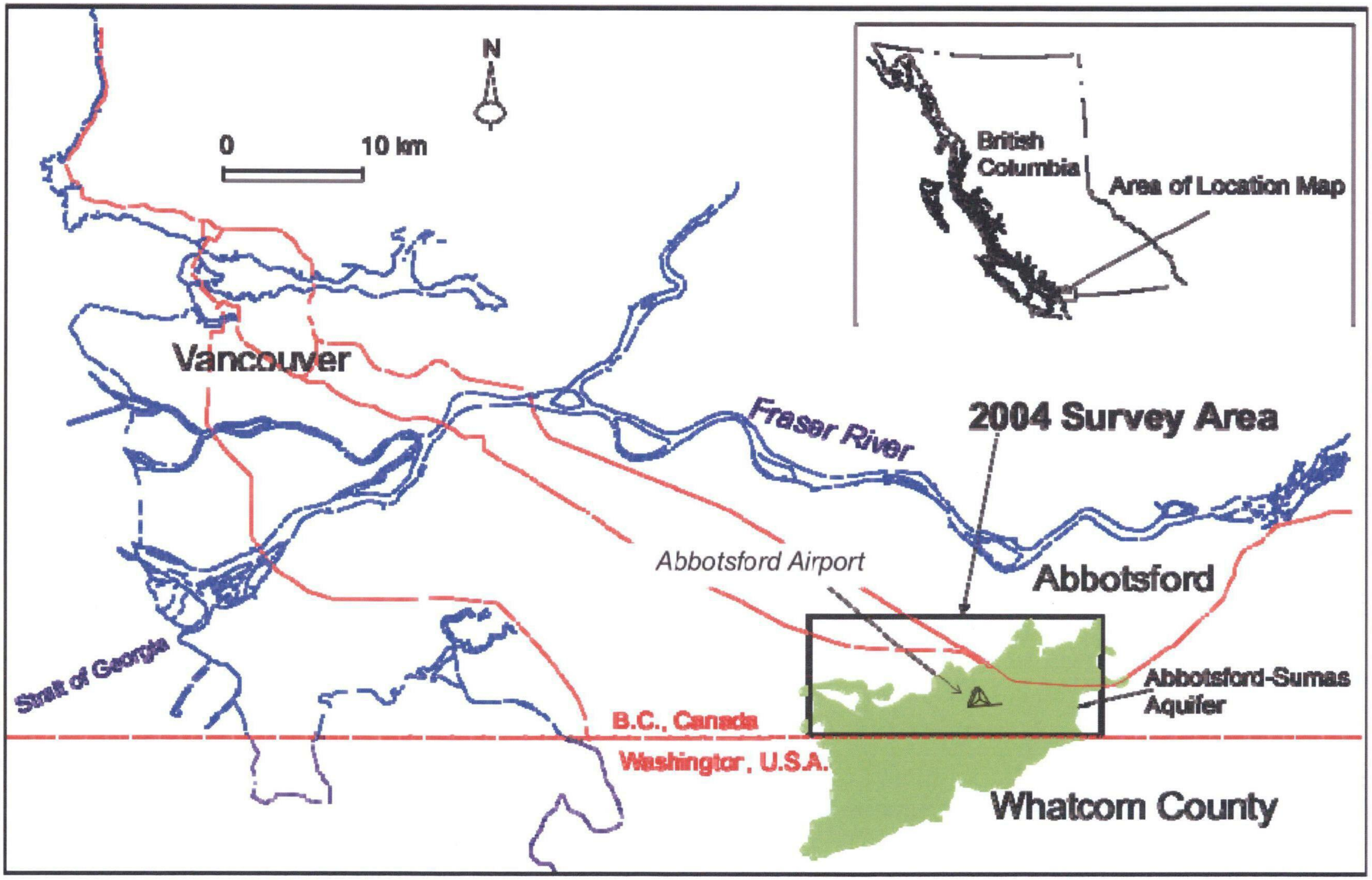


Figure 1: Location of the 2004 survey area over the Abbotsford-Sumas Aquifer.

Several studies have shown that it is possible for pathogens to leach from the surface to the subsurface, particularly if there is a soil structure that allows for fast water transport and if there is sufficient water to carry the pathogens through the unsaturated zone (Gagliardi and Karns, 2000; Matthess & Pekdeger, 1981). Bacteria can be filtered by the soil through several mechanisms including biological factors, mechanical filtration (most effective when soil has a grain size below that of a sandy loam) and chemical sorption (most effective in sandy-gravelly aquifers) (Matthess and Pekdeger, 1981). In consideration of these factors, the presence of fecal coliform bacteria in wells is typically linked to poor well construction, preferential pathway and close proximity to a contaminant source.

Hydrogeology

The Abbotsford-Sumas aquifer is the largest unconfined aquifer (areal extent over 160 sq. km) in south western British Columbia and north western Washington State. The deposits that comprise the aquifer consist primarily of unconsolidated sand and gravel (glacial outwash), with localized discontinuous lenses of clay, peat and till. The glacial outwash overlays an extensive sequence of low permeability clay and silt-rich sediment, with occasional sand and gravel lenses, forming an aquitard at the base of the Abbotsford-Sumas aquifer (Halstead, 1986; Cox and Kahle, 1999). The outwash sand and gravel is over 60 m thick in some areas particularly along the eastern limits of the aquifer where there are also interbedded lenses of low permeability clay-rich till.

Groundwater flow directions and recharge characteristics are complex, given the heterogeneous nature and large areal extent of the aquifer. Precipitation is the main source of groundwater recharge to the aquifer. Groundwater flow occurs from recharge areas (generally associated with upland areas north of the airport) to areas of discharge, typically found at lower elevations along stream channels and lakes. The movement of groundwater is influenced by topography, hydrostratigraphy of the aquifer and the nature of groundwater recharge and discharge in different parts of the aquifer. Recharge rates can be affected by a wide range of variables, including the frequency and duration of rainfall events, conditions at the ground surface, water table depth, background soil moisture conditions and variations in soil type.

The soil cover over the Abbotsford-Sumas aquifer varies from glacial-marine and gravel-rich glacial outwash sediment (with variable silty-eolian or loess capping) in the north-west and south-west areas respectively, to a mixture of gravelly glacial outwash and moderately stratified ice-contact soils over central portions of the aquifer (Luttermerding, 1981; Runka and Kelly, 1964). The eastern portion of the aquifer area features well sorted sand and gravel-rich soils with variable silt loam content to localized areas of silt and clay–rich loams with variable volcanic ash content. Organic soils are also present as localized pockets along portions of Pepin Brook, Fishtrap Creek and Laxton Lake.

The transboundary groundwater flow (at a regional scale) in the study area is primarily towards the Nooksack and Sumas rivers, which represent areas of regional groundwater discharge (Cox and Kahle, 1999). Based on these discharge patterns, groundwater flow is generally southerly with a strong easterly component in the eastern portion of the aquifer (towards the north-east flowing Sumas River). Localized groundwater flows may not be necessarily southerly and groundwater discharge may occur in the areas of Laxton and Judson Lakes as well as mid to lower reaches of creeks such as Fishtrap, Lonzo and Bertrand. Groundwater flow patterns are locally complicated by variations in permeability throughout the aquifer and localized occurrences of semi-confined conditions. Perched water tables occur in some areas due to the presence of low permeability lenses of silt and clay-rich sediment. Depending on local hydrostratigraphy, the average linear groundwater flow velocity perpendicularly across the International Boundary was estimated to range from about 10 to 70 m/y (Hii *et al.*, 1999).

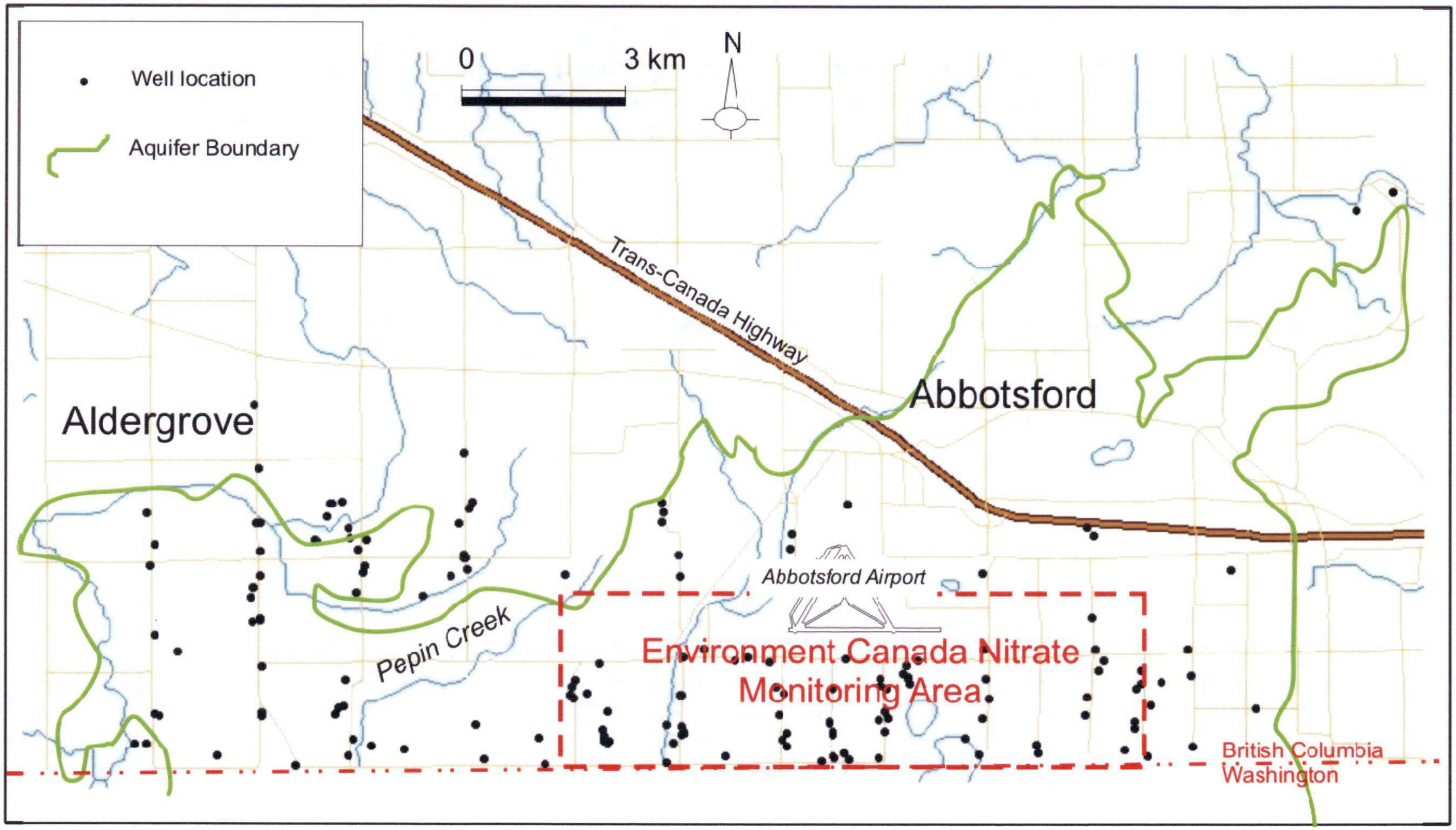


Figure 2: Well locations sampled for nitrate and bacteria during the survey periods - February, August and October of 2004.

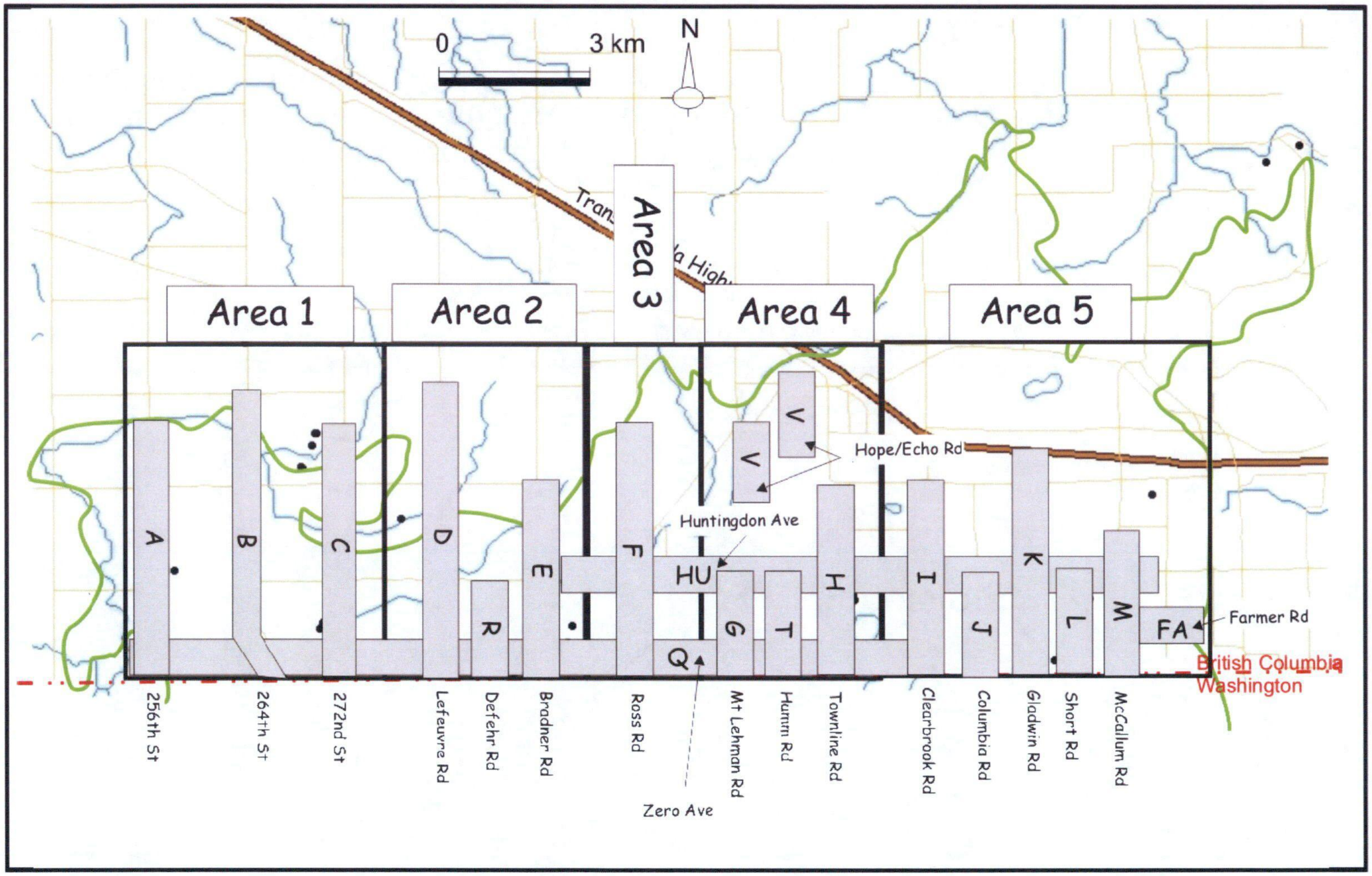


Figure 3: Five areas, showing the major transects, divided according to geography, hydrogeology and land use during the 2004 survey periods.

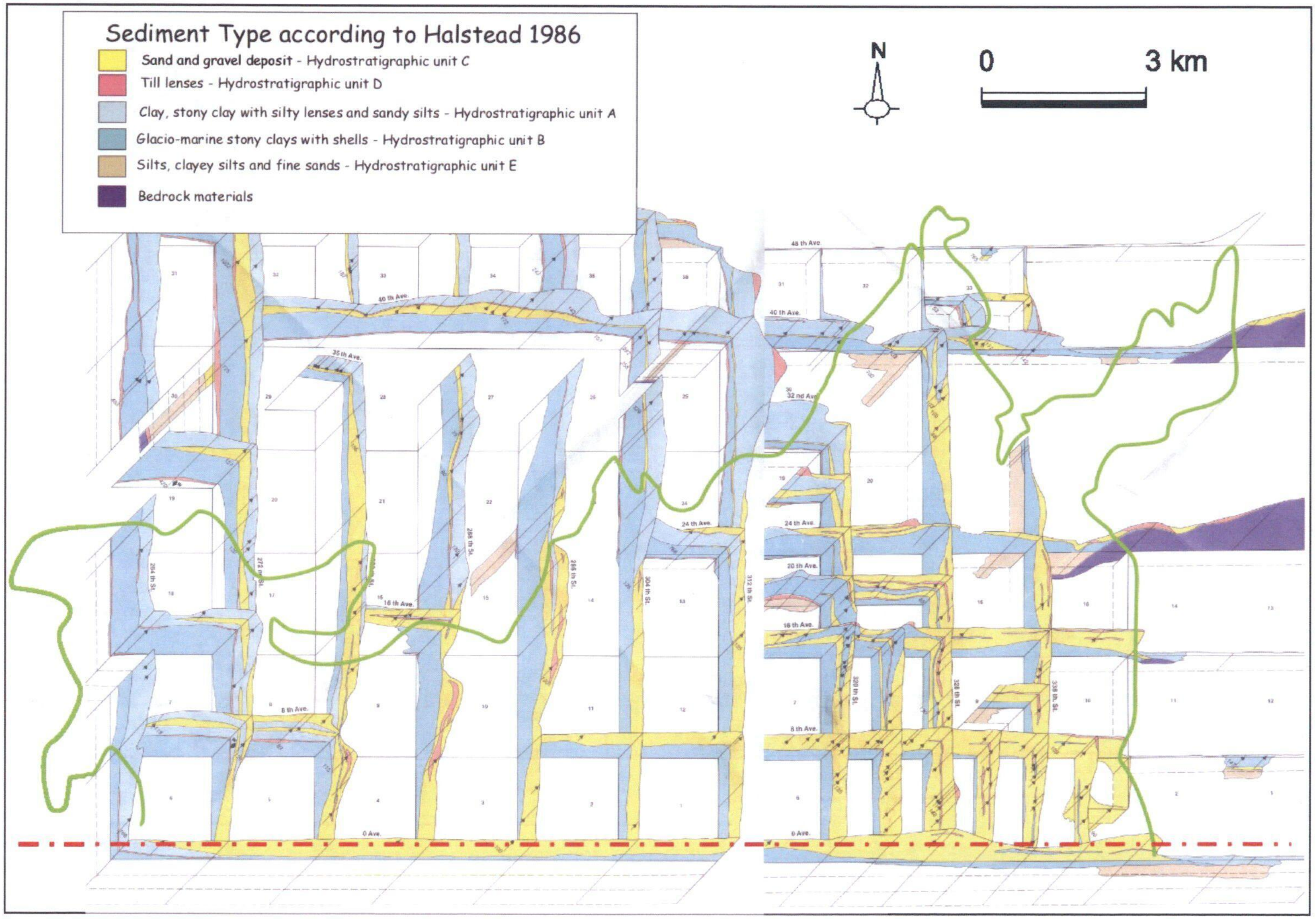


Figure 4: Hydrogeological Fence Diagram
Adapted from "Ground Water Supply - Fraser Lowland, British Columbia" by E.C. Halstead 1986

METHODS

Site Selection and Transects

About 150 well sites were selectively visited by staff from Environment Canada, BC Ministry of Environment and Fraser Health Authority, during an initial site investigation in or before February 2004 and assessed based on availability of well information in the provincial database, field data and homeowners' permission to collect the samples. The locations of wells sampled for nitrate and bacteria during February and October 2004 are shown in Figure 2. Fifteen major transects (Figure 3) were designated to help in the selection of sites (13 are south-north and 2 are west-east transects). Each south-north transect originated from the Canada US International border, ran along the south to north corridors of roads and some stretched up to the northern edge of the aquifer boundary. The Boundary Rd transect ran along the border, whereas the Huntingdon Rd east-west transect (about 1.5 km north of Boundary Rd transect) stretched across the width of the aquifer.

The study area was bounded by 256th St along the west, Sumas Way along the east, Boundary Rd along the south and Highway 1 along the north. The study area was sub-divided into five areas according to geography, hydrogeology and landuse (see Figure 3):

Area 1

Area 1 includes 3 transects (256th, 264th and 272nd Streets) in the western part of the aquifer and includes sections of Bertrand Creek and Pepin Creek. Well records and a hydrogeological fence diagram (Figure 4) according to Halstead, (1986) suggest that the unconfined aquifer is generally thinner in this area than in other parts of the aquifer. Also groundwater flow directions are not known, although based on the flow direction of Bertrand Creek, a southerly groundwater flow direction can be inferred, with localized groundwater discharge to Bertrand and Pepin creeks. According to Halstead, some wells may have tapped into a lower confined aquifer, present in this area. Area 1 is mostly within the Agriculture Land Reserve (ALR) with the primary land-use activity on most parcels being agriculture (Figure 5 - reference). The agriculture operations are diverse -- a large portion of the land being in forage and pasture, and the majority of the remaining parcels in raspberry and blueberry production. Horses are the dominant livestock type, followed by dairy then poultry. Also within the ALR boundary is gravel extraction and a golf course, south of 16th Avenue. The land use in the northern portion of Area 1 is primarily urban residential (Aldergrove). In addition, there is a military reserve outside of the ALR boundary, (on the north side of 16th Avenue, on either side of 272nd), which has no land development. There is a "reclaimed" municipal solid waste landfill site in the east central portion of this area that is currently used as a refuse transfer station.

Area 2

Area 2 includes LeFeuvre Rd and Bradner Rd transects and includes a section of Pepin Creek. Well records and the fence diagram suggest that this area has mainly unconfined sand and gravel deposits with marine clays (Halstead, 1986) exposed in the north. The aquifer thickness is around 20m and groundwater flows predominantly south and southwest, following the general direction of flow in Pepin Creek, with localized groundwater discharge to Pepin Creek. The water table is closer to the surface at the International Boundary than that further north. Area 2 is mainly within the ALR, with the primary land-use activity being agriculture. However there is a large gravel extraction operation south of King Road as well as a regional park (Aldergrove Regional Park) to the southwest of the area. The agriculture activities in Area 2 are diverse, with most of the land use being raspberries, particularly to the north west of LeFeuvre Road, and in the southern portion of this area. There are several parcels in forage production and in pasture. The dominant livestock type in this area is poultry, along with several beef and horse farms.

Note that there is one commercial composting operation and at least two mushroom media producers in the west central portion of the study area , as well as gravel extraction and at least one site that experienced large quantities of organic (industrial/commercial/municipal and agricultural waste deposition).

Area 3

Area 3 includes the Ross Rd transect and a section of Fishtrap Creek. Well records and the fence diagram suggest that much of the area contains stratified silty layers amidst more permeable alluvial deposits (Armstrong, 1980). Fishtrap Creek recharges the groundwater in the vicinity in the winter months (Liebscher *et al.*, 1992). The water table may rise to the surface during the wet months. Groundwater flow direction is inferred to be predominantly southward, following the flow direction in Fishtrap Creek, with localized groundwater discharge in the lower reaches of the creek. This area is within the ALR with the dominant land-use activities being agriculture with many hobby farms and gravel extraction particularly in the northern part of the Ross Road transect. The agriculture land use in the northern portion of Area 3 is mainly pasture (horses). The agriculture activities in the southern portion are berry farms; mainly raspberry, with some blueberry and many poultry farms.

Area 4

Area 4 includes the Mt Lehman Rd and Townline Rd transects, as well as the Hamm Rd transect and includes portions of Enns Brook (tributary of Fishtrap Creek) as well as Laxton Lake. Well records and the fence diagram suggest that this area has mainly unconfined sand and gravel deposits that are thicker in the north and thinner (< 25m) along the international border. The shallow wells are predominantly located in the thinner section of the aquifer. Groundwater flow is inferred to be southward, although the presence of Laxton Lake may be the result of localized groundwater discharge from late fall to early summer months. The northern portion of Area 4 is urban residential land use (City of Abbotsford).

The central portion of Area 4 is the Abbotsford Airport which is mainly paved, however, much of its surrounding lands are also used for growing crops. The rest of Area 4 is within the ALR and the primary land use is agriculture. Raspberries are the prevalent crops, with several parcels of blueberry fields mainly along the international border. There are a few parcels of forage production to the east of the Airport. There are several poultry operations in Area 4.

Area 5

Area 5 includes the Clearbrook , Gladwin, McCallum and McKenzie Road transects, as well as the northern half of Judson Lake. Well records and the fence diagram suggest that the area has unconfined sand and gravel with localized till lenses. The average aquifer thickness is > 30m and wells are generally deeper that at other areas, with higher specific capacities. The greatest groundwater withdrawals are primarily observed in the southeast corner where there are several high capacity production wells. Groundwater flow velocities are also greater in Area 5 because of higher hydraulic gradients, as calculated from equipotential lines (Liebscher *et al.*, 1992). Groundwater flow is inferred to be southeast and eastward, although the presence of Judson Lake indicates local scale groundwater discharge during late fall to early summer months, possibly implying a component of northerly groundwater flow in the vicinity of the lake under a radial discharge pattern. Area 5 is primarily within the ALR, with the land use predominantly agriculture, with some smaller parcels having a primarily residential use. A large parcel on the north side of Huntington Rd, between Gladwin and McKenzie Rd is institutional use and there are several gravel pits within the area. Raspberry is the dominant crop with some blueberry fields throughout. There are also several poultry operations, with only a few horses or beef cattle on smaller lots.

Field Procedures and Data Collection

Groundwater Samples

For the February survey, 173 samples, including 14 replicates and 12 blanks, were collected from 147 well sites and analyzed for nitrate and coliform bacteria. Many of the samples were collected by students from UCFV (as part of their coursework). They followed a standard field procedure, which included a brief questionnaire addressing well information, water and land use at each site (see Appendix II – Questionnaire Form).

Thirty nine sites with elevated nitrate concentrations, based on the February nitrate results, were selected and sampled in August 2004, for nitrate + nitrite total only. These samples were analyzed at the Pacific Environmental Science Center (PESC).

As a follow-up in October 2004, 159 samples, including 25 replicates and 21 blanks, were collected from 113 wells. The main reasons for the October sampling were to repeat the February sites (67 repeated sites) and also to increase sampling in 'hot spot' areas like the Environment Canada Nitrate Monitoring Area, south of the Airport, (Figure 2.) Sixty-five of the sites were the same as those sampled in February. Forty-seven new sites were added. Many of the new sites are located in Areas 3 to 5 and south of the airport that have indicated elevated nitrate concentrations in the past.

All nitrate samples were collected from household taps, except one that was collected using a peristaltic pump. The tap before filtration located at the pump house or closest to it was preferentially sampled. Water was purged from the pressure tank or supply system for several minutes and the 250ml sample bottle was rinsed before filling it. Each tap was carefully wiped with an alcohol swab before collecting samples for bacterial analysis; the bottle was not rinsed. Samples were kept cool and transported to laboratories within 24 hours.

Surface Water Samples

In February 2004, thirty-one surface water samples (Figure 5) from several creeks in the aquifer, were collected by members of the local stakeholders group. Each sample was 'scooped' up from the creek using the sample bottle attached to a long pole.

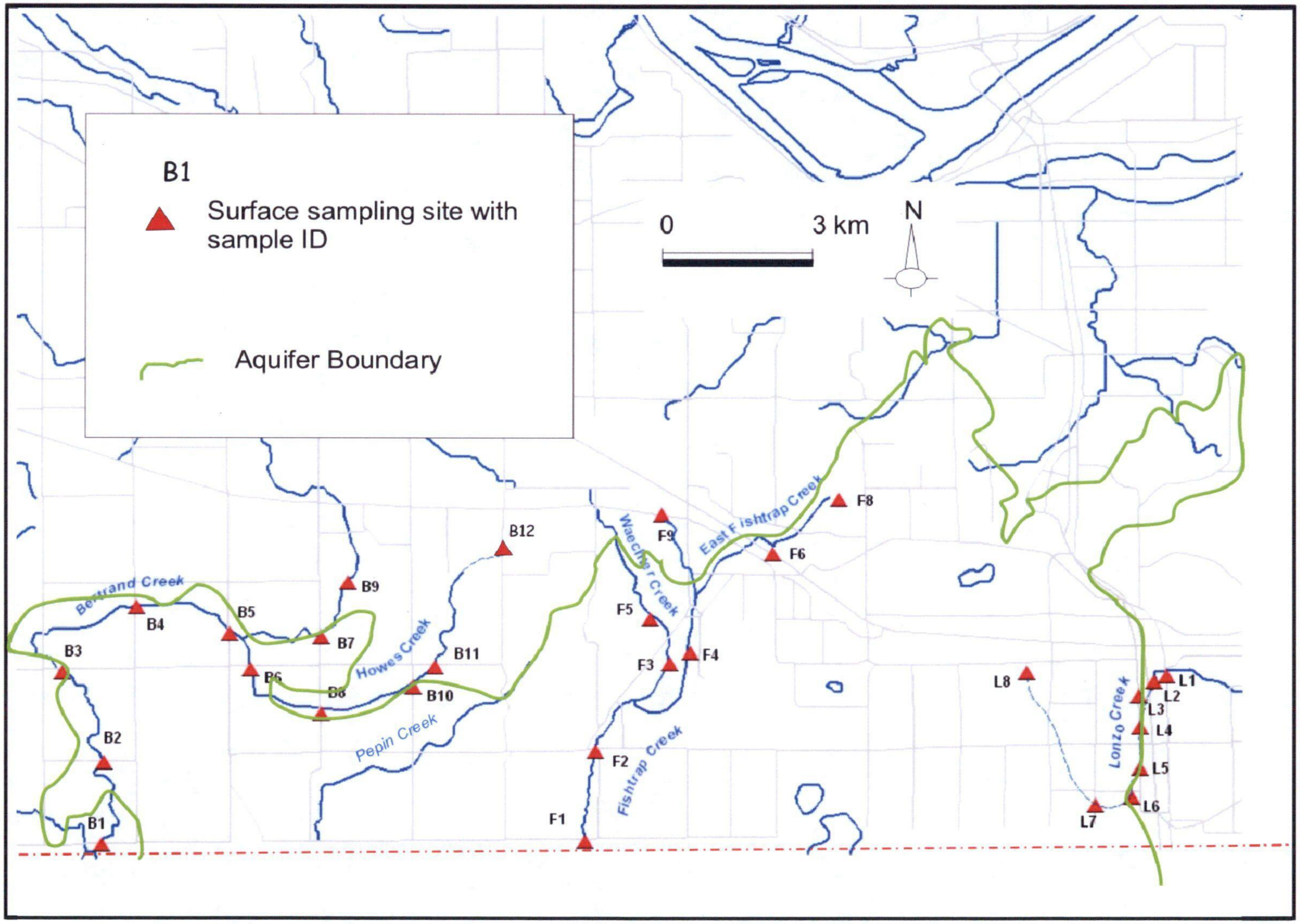


Figure 5: Surface sampling sites in several creeks - February 2004.
(refer to Table 4 for Sampling Site ID)

Sample Analyses

The samples for nitrate + nitrite were analyzed using the Colourimetric Method. Philips Environmental Laboratory (now named Maxxam Lab) in Burnaby, B.C. analyzed samples for nitrate + nitrite for the February and October samplings. Environment Canada's Pacific Environmental Science Centre (PESC) in North Vancouver, B.C., analyzed for total nitrate + nitrite in samples collected in August. BC Health Centre for Disease Control Lab. in Vancouver, B.C. , analyzed the samples for total and fecal coliform bacteria using MPN technique.

Nitrate Iso-concentration Lines

The UTM's Eastings and Northings coordinates for the sample sites, together with the nitrate results were used as x, y and z coordinates respectively, in the grid construction for iso-concentration lines which were generated by SURFER (version 7) program using the Kriging method.

It is important to note that:

1. the iso-concentration lines near the edges of the dataset may not be representative of actual concentrations for the time periods.
2. the depth where each sample was collected has not been factored in the contours or iso-concentration lines. Spatial distribution of nitrate concentrations as shown in the iso-concentration maps are irrespective of depth.
3. there may be 'artifacts' created in the kriging interpolation process, this especially applies to some of the 'peaks and valleys' of the iso-concentration lines.
4. the higher levels of iso-concentration lines (>30) were denoted as point sources.

Land Use Maps

The land use inventory maps were prepared by BC Ministry of Agriculture, Food and Fisheries (BCMAFF) using the cadastral information from the Township of Langley and City of Abbotsford (Land Use Inventory Reports 2002 and 2004). Certain criteria have been used to differentiate land use within the ALR over the aquifer. For example, there are several primary land-use designations, relating to the main activity on each parcel, such as agriculture, hobby farm, residential, gravel extraction, institutional use, etc. The agriculture land-use activities are then described in terms of primary land use (the type of agriculture that is the main income generating activity on the farm) and the ancillary land use (significant agriculture activity but not likely the main agriculture income). Also, a parcel may have several poultry barns in addition to raspberry fields. The primary land use in this case would be confined livestock (poultry) with the secondary or ancillary use being raspberry production. If this same farm also has a horse on a small pasture that would also be noted as the tertiary land-use activity. Therefore, both crops (land cover) and animals are captured.

RESULTS AND DISCUSSIONS

Bacteria

Table 1 summarizes the total and fecal coliform bacteria results. In February, 2 out of 143 (4%) positive detections of fecal coliform bacteria were detected; 7 out of 83 (10%) positive results were found in October. Thirty six percent (51 out of the143) of the wells sampled in February had positive total coliform bacteria, whereas 50 percent (42 out of 84) of the wells sampled in October were positive. Refer to Table A1 in the Appendix I for details on bacterial results. Homeowners, whose wells had positive bacterial results, were contacted immediately by staff from BCWLAP (Ministry of Environment) and their wells were re-tested.

Table 1: Summary of analytical results - bacteria in sampled areas for February and October 2004.

AREA (see Figure 2)	**Total Coliform Bacteria***			**Fecal Coliform Bacteria***		
	Feb	**Aug**	**Oct**	**Feb**	**Aug**	**Oct**
1	18/48	5/7	11/16	0/48	2/7	6/15
2	7/25	2/6	13/21	1/25	0/6	0/21
3	8/20	2/5	4/10	1/20	0/5	0/10
4	7/17	3/6	9/21	0/17	1/6	1/21
5	11/33	6/14	5/16	0/33	0/14	0/16
1-5 total	**51/143**	**18/38**	**42/84**	**2/143**	**3/38**	**7/83**

* *(number of sites with positive results/number of sites sampled)*

One hundred and eleven out of the 150 sites tested showed evidence of total coliform bacteriological contamination and 12 sites were contaminated with fecal coliform bacteria. The MAC for fecal coliform bacteria in drinking water is zero organisms detectable per 100 mL (Federal-Provincial Committee on Environmental and Occupational Health, 1996).

Fecal coliform bacteria may indicate the presence of fecal contamination. The origin of these bacteria are generally from the intestines of warm blooded animals and are found in bodily waste and animal droppings. The survival rate of these bacteria is generally short-lived outside of the host and typically in the range of several days to several months, depending largely on source type, soil and groundwater conditions . The presence of fecal coliform bacteria usually indicates recent contamination of groundwater, which means that there is a preferential flow pathway or a very fast hydraulic connection between the surface source and the groundwater. All of the wells contaminated with fecal coliform bacteria were shallow in nature. They ranged from a general depth of 3 to 6 meters. Several of these wells were in a state of disrepair. In some cases, poor well construction did not provide sufficient barriers for contaminants to enter from the top of the well. Some of these wells were not properly sealed to protect against the entrance of insects and rodents. (see photos in Appendix IV). They were generally located down-slope on the property permitting surface run-off to migrate towards the well. None of the deep wells (> 16 meters) showed evidence of fecal contamination suggesting that fecal coliform bacteria originate from a contaminant source on the property or within the well.

The remaining bacteria are referred to as total coliforms. Total coliform bacteria are considered "indicator organisms" which are used to determine the sanitary condition of the drinking water source. Total coliform bacteria are ubiquitous in the environment but generally absent in deep well sources. Shallow wells on the other hand (< 16 metres) are more prone to surface water intrusion through cracked casings and inadequate well seals.

In February, 51 samples out of 143 (36%) were positive for total coliform bacteria; while 42 out of 84 (50%) samples in October were positive. Well depth information was available for 56% of the well sites. Of these sites, 44 out of 87 (57%) of the shallow wells were positive for total coliform bacteria while 20 out of 81 (24%) of deep wells were positive. The shallow wells showed higher levels of total coliform bacteria, which is likely to be due to poor well construction or improper or missing well head seals and shallow water table conditions.

Variations in total coliform bacteria remained relatively constant in Areas 3, 4 and 5 from February to October. Increases in the percentage of wells with total coliform bacteria occurred in Areas 1 and 2 in October, as compared to February. (Area 1 increased from 38 percent to 69 percent and Area 2 increased from 28 percent to 62 percent). This trend was also noted in mean and median nitrate concentrations. High seasonal variation in the water table level may contribute to larger numbers of bacteria entering the aquifer. Another possible reason could be spatial variability in total coliform bacteria counts during the two phases, as only 46 sites were sampled both in February and October.

Evaluation of Nitrate Concentrations

The nitrate + nitrite concentrations in the groundwater of Abbotsford-Sumas aquifer are mainly nitrate concentrations (typically greater than 99% of the total nitrate + nitrite results was nitrogen from the nitrate form according to Liebscher *et al.* 1992). Table 2 presents the mean and median concentrations total nitrate + nitrite (nitrate) results for each of the five areas sampled, as well as the mean and median concentrations for the entire study area.

Table A1 (Appendix I) presents all the nitrate data for the 2004 surveys.

The median nitrate concentrations for the total area (Areas 1 to 5) in the February and October samplings were similar. The mean nitrate concentrations for the total area in February and October were 10.2 and 9.9 mg N/L, respectively. The higher mean in February is likely skewed by one sample with very high nitrates in Area 4 (78.4 mg N/L). Higher mean and median nitrate concentrations for the total area (13.3 and 13.1 mg N/L respectively), were found in the August sampling period. Results for the August period are skewed due to sampling bias. Over half of the August samples were collected from wells in areas 4 and 5, at sites expected to have higher nitrate concentrations.

The mean and median nitrate concentrations for most areas decreased in October, except for Area 2 which showed increases during October. These increases may be due to unknown point sources and/or heterogeneity of the local sediments. The decreases in the median nitrate concentration over a period of several months may be due to high seasonal variability in recharge from precipitation. Denitrification over time may be a factor for lower seasonal nitrate concentrations, particularly in groundwater adjacent to a stream (Tesoriero *et al.*, 2000).

Part of the explanation for the differences in mean concentrations between the February and October sampling periods is that they don't represent the same sampling sites. Sixty-seven sites were the same in both samplings; but the remaining approximately one-half of the sample sites differed. In October, site selection was biased to areas 3 and 4, to capture greater representation from areas of greater concern because of the type of agricultural activity (berry and poultry production). For sites that remained the same for both samplings, there can be substantial variability (increases and decreases) in nitrate concentrations measured on the two occasions (Table 3), indicating that considerable fluctuations in nitrate concentrations occur locally, and likely reflect the impact of recharge events along with seasonal variation in natural soil processes and agriculture crop production activities.

The frequency of detection at three nitrate concentration ranges (<3 mg N/L, 3-10 mg N/L, >10mg N/L) for February and October sampling periods are presented in Table 4. Nitrate concentrations above 3 mg N/L indicate input from anthropogenic sources. Nitrate concentrations greater than 3 mg N/L occurred at 165 out of 261 (63%) of the sampled wells. The nitrate concentrations in 44 out of 113 (39%) of the wells (October) were over the 10 mg N/L MAC Canadian Drinking Water Guideline. The majority of these wells with elevated nitrate concentrations were mainly located in Areas 3 and 4 where the mean nitrate concentration in each area was consistently over 10 mg N/L for all sampling periods. There were 22 wells with non-detectable nitrate concentrations in their samples and about half of these wells were located in Area 1. These wells are most likely tapped below the confining layers or lenses and are low risk to contamination from the surface.

Areas of Concern

Certain areas in the Abbotsford-Sumas aquifer have been considered high risk from contamination by nitrates (Liebscher *et al.*, 1992, Hii *et al.*, 1999). This is primarily due to the unconfined nature of the aquifer and associated fluctuation of the water table in response to variations in rainfall. These areas of concern include part of Areas 2 and 5, but mainly on Areas 3 and 4, where the dominant land-use activity is berry and poultry production.

Since 1991, nitrate in groundwater has been sampled monthly by Environment Canada from 23 piezometers located in the Environment Canada Nitrate Monitoring Area (see Figure 2). Hii et al. (1999) reported that the nitrate concentrations at these piezometers were site-specific and varied over time. The monthly average nitrate concentrations in piezometers are shown to vary over time, 1991 to 2004; (Appendix I – Figure A1; data available on-line at: *http://www.ecoinfo.ec.gc.ca/env_ind/region/nitrate/nitrate_e.cfm*). All the average nitrate concentrations are above the Canadian Drinking Water Guideline of 10 mg N/L. These nitrate results were also analyzed and compared using the annual mean nitrate concentrations. The annual nitrate means have been declining since 1998 but rose sharply in 2002 and again in 2004 (Figure 6). The annual mean concentration for 2004 in these piezometers is 16 mg N/L. This is similar to the higher mean concentrations measured for Areas 3 and 4 in our 2004 survey, where the mean concentration in these two areas ranged from 9 to 14.6 mg N/L (see Table 2).

In examining the spatial distribution of nitrate concentration in these areas of concern, Hii *et al.* (1999) observed that zones of elevated nitrate concentration appear quite extensive.

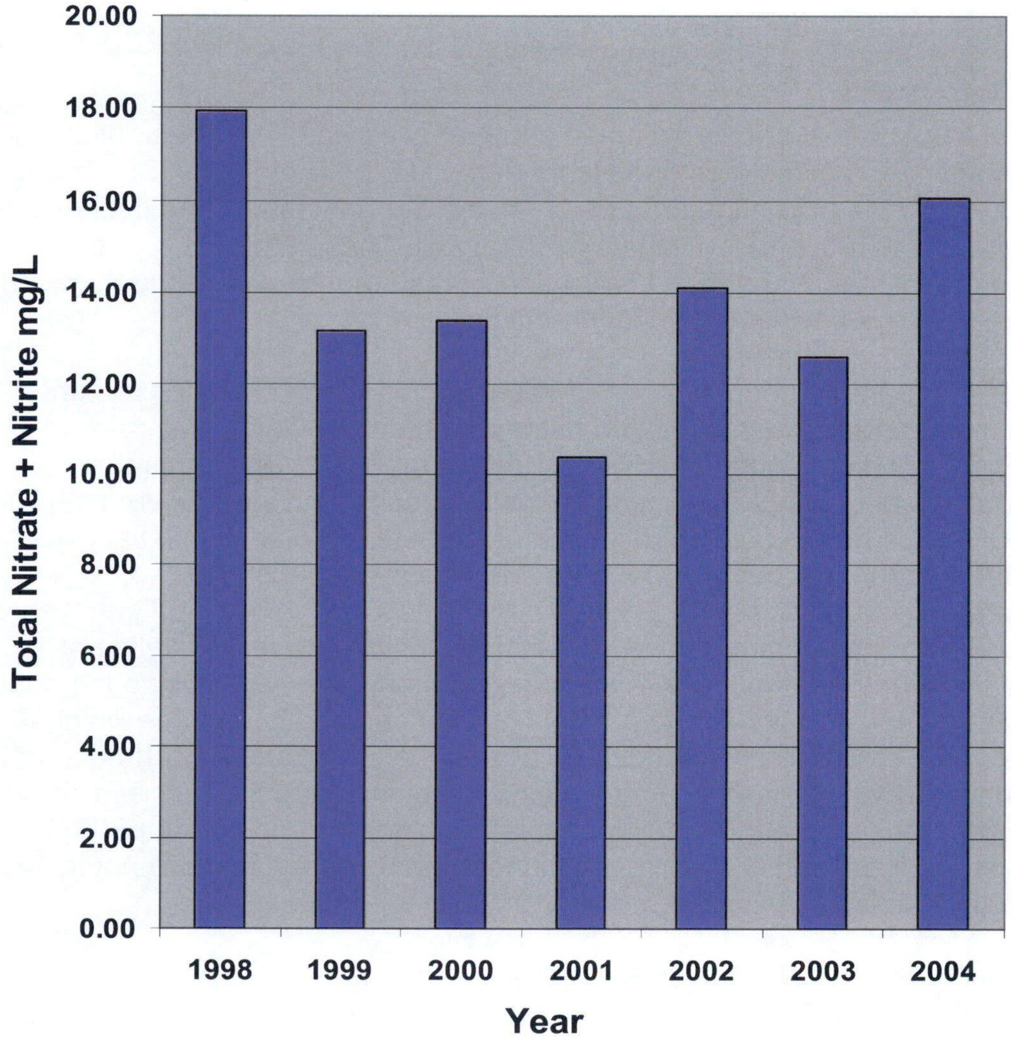


Figure 6: Annual nitrate means for the 23 piezometers, sampled once a month.

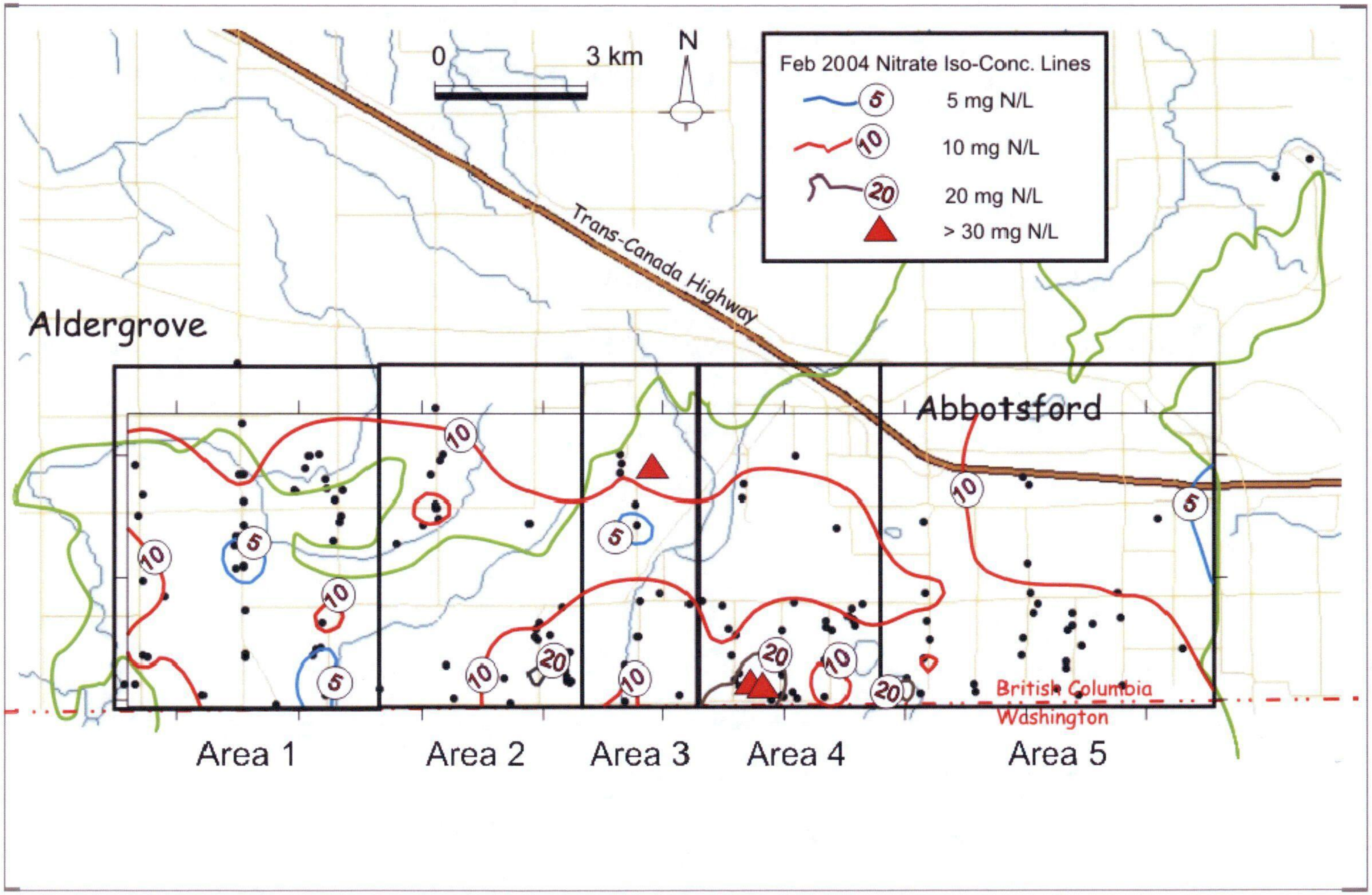


Figure 7: Nitrate iso-concentration lines (February 2004)

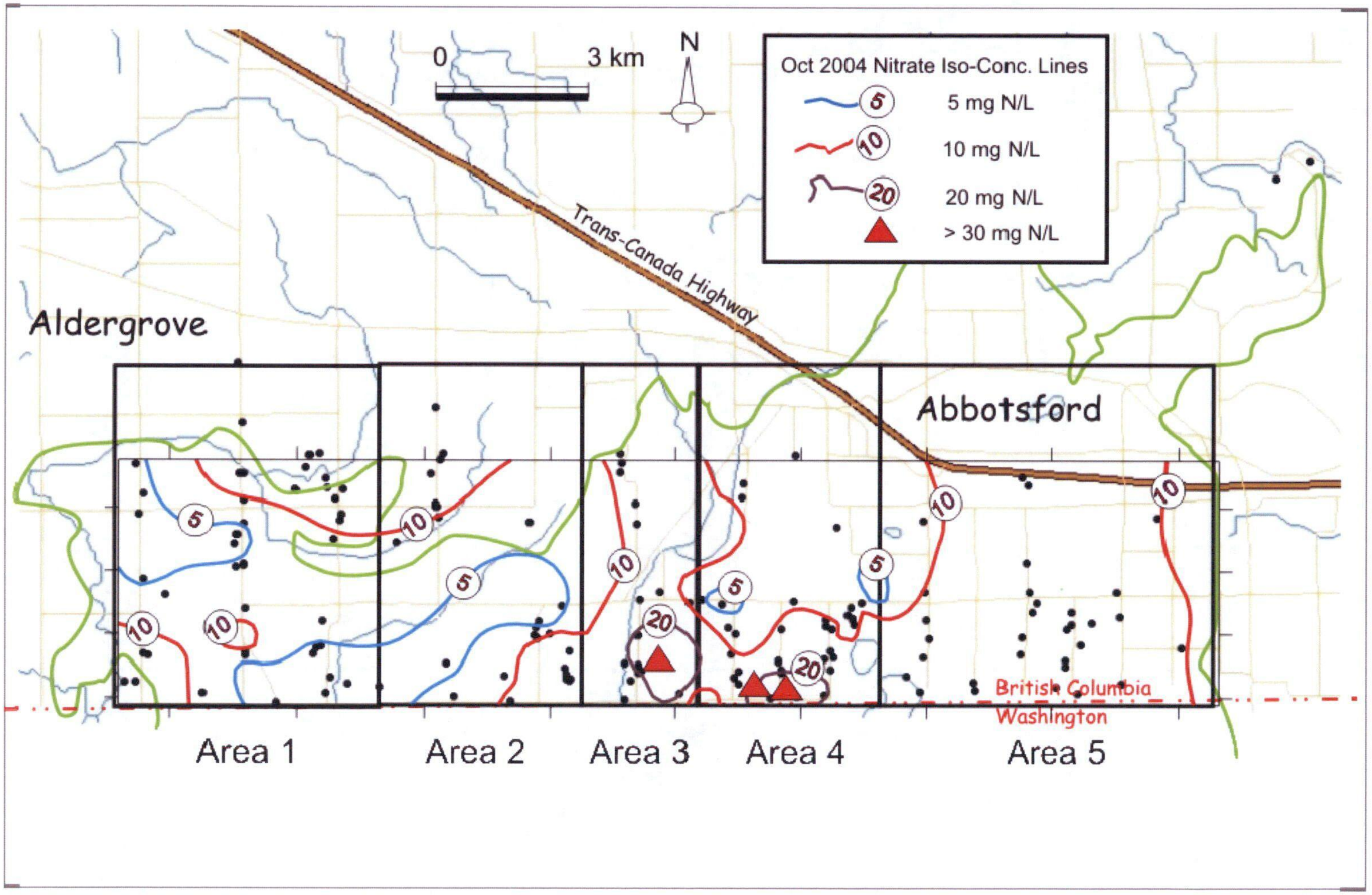


Figure 8: Nitrate iso-concentration lines (October 2004)

Spatial Distribution

Groundwater nitrate iso-concentration maps for two time periods - February and October 2004 (Figures 7 and 8), were produced through kriging interpolation analyses using SURFER® software. Data used for interpolation were from wells

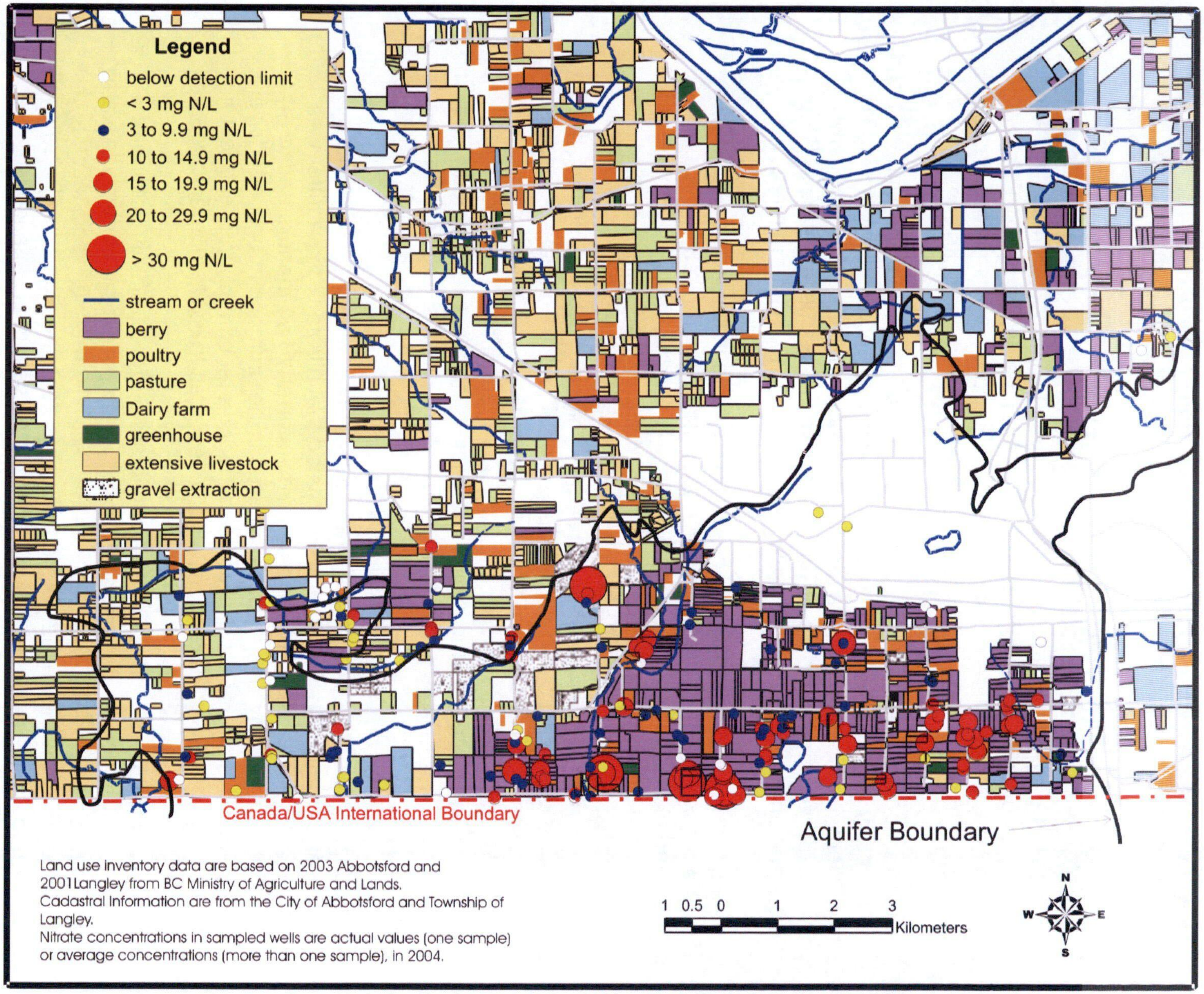


Figure 9: Nitrate concentrations in sampled wells in relation to major land use, 2004.

irrespective of depth. Therefore, these iso-concentration lines may not be a 'true' representation of the spatial extent of nitrate contamination in the aquifer.

The 20 mg N/L iso-concentration line occurred mainly as 'bubbles' in Area 3 and 4. The 10 mg N/L iso-concentration line appeared to be extensive and occurred in all areas (1 – 5). The 5 mg N/L iso-concentration line occurred mainly in Area 1 and 2 and it appeared to be larger in October than that in February. Further investigation will be required to show whether this seasonal difference can be correlated to the type of land use and the seasonal variation in its impact.

The nitrate concentrations, for sites sampled in 2004, were overlaid with the Land Use Inventory (LUI) maps showing major agricultural land uses (Figure 9). The areas where the land use is not agriculture are blank, and most of them are urban residential parcels and also residential use in the smaller parcels. Other parcels primarily relate to gravel extraction are also shown on the map.

The results suggest strong correlations between agricultural land-use activities and nitrate concentration in the groundwater. Nitrate concentration 'circles' of 10 mg N/L and higher, primarily south of Huntington Rd and east of LeFeuvre Rd are correlated to mainly agriculture land use where the ground cover is berry fields (raspberry with some blueberry) and has many poultry barns as well. Nitrate concentration 'circles' of 10 mg N/L and higher, north of Huntington Rd to LeFeuvre Rd. and west of LeFeuvre Rd are correlated to a variety of land uses, including a wide variety of agricultural activities. Most of the land base is in forage or pasture, with some berry and nursery production. The dominant livestock types are horses and beef cattle on small farms, interspersed with some poultry production. These are shown as extensive livestock on the map (see Figure 9).

A previous study of nitrogen origin in the aquifer (Wassenaar, 1995) using nitrogen and oxygen isotope analysis indicated that nitrate in the aquifer was predominantly derived from organic sources, inferred to be manure and to a lesser extent from inorganic sources, inferred to be ammonium based fertilizers. However, data from a recent study (Wassenaar, pers. comm.) may suggest a shift in nitrogen sources, away from organic sources towards inorganic sources.

Wassenaar (1995) also indicated that soil nitrate derived from nitrification of ammonium in manure and ammonium based fertilizers occurs primarily in warm and moist weather; primarily in summer and fall. Increased precipitation and associated groundwater recharge are thought to flush the excess soil nitrate into the aquifer in the fall (Hii *et al.,* 1999). Hence, the seasonal variations in precipitation (Appendix I – Figure A2: Precipitation plot for Abbotsford (2004)) may be a factor in the seasonal variability of nitrate concentrations in the Abbotsford-Sumas aquifer. This seasonal variation pattern for nitrate may also be linked to the timing of fertilizer application on agricultural land (McArthur and Allen, 2005). Li and Schreier (2004) observed a noticeable difference in nitrate concentrations between wells of close proximity, suggesting that low capacity wells with relatively small capture zones may be more prone to contamination from land-use activities within a few hundred meters of the well. In addition to these seasonal effects, crop irrigation may also be a contributing factor for transporting nitrate.

Table 2: Summary of analytical results - nitrate concentrations (mg N/L) in sampled areas for February, August and October 2004.

Area * (see Figure 1)	Mean Concentration			Median Concentration			Minimum Detected Concentration			Maximum Concentration			Number of Sites Sampled		
	Feb	Aug	Oct	Feb	Aug	Oct	Feb	Aug	Oct	Feb	Aug	Oct	Feb	Aug	Oct
1	4.51	9.89	3.97	3.55	10.80	2.59	0.060	1.110	0.002	14.70	17.40	17.10	47	7	22
2	8.31	15.06	9.86	7.93	13.45	10.18	0.030	9.470	0.002	24.40	23.80	19.70	27	6	25
3	14.17	12.45	12.75	13.30	10.15	9.13	2.300	0.009	0.053	44.50	29.50	61.70	20	4	17
4	16.01	15.05	11.79	9.95	12.45	8.62	3.070	0.004	0.300	78.70	41.20	35.10	17	8	30
5	11.06	13.94	10.84	13.30	14.50	13.20	0.050	0.015	0.008	25.60	23.20	22.10	36	14	19
Mean/Median Areas 1 to 5	**10.20**	**13.28**	**9.93**	**8.49**	**13.10**	**9.19**									
Min/ Max Areas 1 to 5							**0.030**	**0.004**	**0.002**	**78.70**	**41.20**	**61.70**			
Total Number of Sites Sampled Areas 1 - 5													**147**	**39**	**113**

Table 3: Change in nitrate concentrations in wells sampled during February and repeated in October 2004.

Area	Site	Nitrate Concentration (mg N/L)		% Change in October for Nitrate Concentration > 3 mg N/L
		Feb	Oct	
1	18th Ave-4	<0.02	0.002	
	A01 Well #1	14.7	17.1	+16%
	A02 Well #2	<0.002	<0.002	
	A05	1.96	1.94	
	A06	11.5	4.25	-63%
	A15	8.77	3.77	-57%
	A16	1.7	0.506	
	A17	<0.02	<0.002	
	B02	2.2	1.44	
	B03	2.28	2.95	
	B15	3.685	0.804	-78%
	B16	2.825	3.12	+10%
	B19	10.6	15.15	+43%
	C01	5.81	1.96	-66%
	C02 (Well #2)	3.55	3.48	-2%
	C03	11.7	8.21	-30%
	C07	1.84	1.27	
	Q09	0.05	0.062	
	Q11	0.05	0.062	
	Q12	0.05	0.062	
	Q13 Well #2	0.05	0.062	
	Q14 Well #1	0.05	0.062	
Average for Area 1		**4.39**	**3.31**	
2	D01	4.79	4.52	-6%
	D03	7.93	7.89	-1%
	D04	14.3	14.7	+3%
	D05	11.5	12.2	+6%
	E03	2.27	3.15	+39%
	E04	10.9	9.54	-12%
	E08	0.03	0.052	
	Montesina-1	2.84	2.87	
	Q05	0.05	0.062	
	Q06	0.05	0.062	
	Smith-1	0.05	0.062	
Average for Area 2		**4.97**	**5.01**	
3	F01	20.9	30.25	+45%
	F02	20.1	61.7	+207%
	F03	<0.02	0.077	
	F06	2.3	2.27	

Table 3: Change in nitrate concentrations in wells sampled during February and repeated in October 2004.				
Area	**Site**	**Nitrate Concentration (mg N/L)**		**% Change in October for Nitrate Concentration > 3 mg N/L**
		Feb	**Oct**	
	F16	8.63	10.5	+22%
	F89 (F21)	8.44	14.2	+68%
Average for Area 3		**12.07**	**19.83**	
4	Laxton-2	14.7	14.9	+1%
	Laxton-3	14.7	14.9	+1%
	Laxton-4	14.7	14.9	+1%
	Laxton-5	14.7	14.9	+1%
	G01A	14.4	14.05	-2%
	G01B	78.7	30	-62%
	H01	3.07	0.831	-73%
	H02	18.3	18.85	+3%
	H04	8.33	6.65	-20%
	Q01	0.05	0.062	
	Q02	0.05	0.062	
	Q03	0.05	0.062	
	Q04	0.05	0.062	
Average for Area 4		**13.98**	**10.02**	
5	I-03	4.39	0.011	-100%
	I-04	13.3	16.2	+22%
	I-05	8.11	8.88	+9%
	K01	<0.02	0.0075	
	K02	14.1	9.65	-32%
	L02	9.6	15.7	+64%
	L03	15.3	15.3	0%
	L05	14.6	14.3	-2%
	L06	15.2	15.2	0%
	L07	14.7	14.9	+1%
	M01	12.4	13.4	+8%
	M02	15	15.8	+5%
	M04	9.81	11.5	+17%
	M05	2.84	2.87	
	P01	0.05	0.062	
Average for Area 5		**10.67**	**10.25**	

Table 4: Nitrate concentration range and frequency in sampled wells along each transect.

transect	street	Number of wells			Number of occurrences for each transect							
		sampled in		repeated in Oct	nitrate concentration < detection limit (DL)		nitrate concentration > DL and < 3 mg N/L		nitrate concentration > 3 mg N/L and < 10 mg N/L		nitrate concentration > 10 mg N/L	
		Feb	Oct		Feb	Oct	Feb	Oct	Feb	Oct	Feb	Oct
A	256 St.	9	7	7	2	2	2	2	2	2	3	1
B	264 St.	15	5	5	3	0	8	4	3	1	1	0
C	272 St.	8	5	4	0	1	4	2	3	2	1	0
D	Lefeuvre Rd.	7	4	4	0	0	1	0	3	2	3	2
E	Bradner Rd.	9	7	3	0	1	3	1	2	3	4	2
F	Ross Rd.	14	10	6	1	2	2	4	4	0	7	4
FA	Farmer Rd.	0	1	0	0	0	0	0	0	1	0	0
G	Mt. Lehman Rd.	6	5	2	0	1	0	1	3	1	3	2
H	Townline Rd.	4	10	3	0	1	0	2	3	4	1	3
HU	Huntingdon Ave.	0	9	0	0	0	0	1	0	5	0	3
I	Clearbrook Rd.	6	5	3	0	0	1	1	2	2	3	2
J	Columbia St.	2	0	0	0	0	0	0	0	0	2	0
K	Gladwin Rd.	6	2	2	3	0	0	1	1	1	2	0
L	Short Rd.	8	5	5	1	0	1	0	1	0	5	5
M	McCallum Rd.	6	4	4	0	0	2	1	1	0	3	3
O	4th Ave.	1	0	0	0	0	0	0	1	0	0	0
P	Old Clayburn Rd.	1	1	1	0	0	1	1	0	0	0	0
Q	0 Ave.	15	10	11	7	2	1	2	3	3	4	3
R	Defehr St.	3	4	0	0	0	0	0	1	0	2	4
T	Hamm St.	0	6	0	0	1	0	0	0	0	0	5
269	269 St.	1	0	0	1	0	0	0	0	0	0	0
Laxton	Laxton Rd.	5	4	4	0	0	0	0	1	2	4	2
V	Hope/Echo Rd.	0	5	0	0	1	0	1	0	0	0	3
Montesina	Montesina Ave.	1	1	1	0	0	1	1	0	0	0	0
Queen	Queen St.	1	0	0	0	0	0	0	1	0	0	0
Smith	Smith Rd.	2	2	1	1	1	1	1	0	0	0	0
Wright	Wright St.	3	0	0	1	0	1	0	1	0	0	0
18 Ave.	18 Ave.	4	1	1	1	0	1	1	1	0	0	0
20 Ave.	20 Ave.	3	0	0	3	0	0	0	0	0	0	0
	Provincial monitored wells	8	0	0	1	0	0	0	3	0	4	0
Total		**148**	**113**	**67**	**25**	**13**	**30**	**27**	**40**	**29**	**52**	**44**
% Total					**16.9%**	**11.5%**	**20.3%**	**23.9%**	**27.0%**	**25.7%**	**35.1%**	**38.9%**

Nitrate Concentration and Well Depth

The relationship between nitrate concentration and well depth is shown in Figure 10. The graph is a scatter plot of total nitrate + nitrite concentration versus well depth. Many of the well depths have been estimated, but the well depth should provide a reasonable approximation of depth to water table.

The regression line shows a very low correlation between nitrate concentration and well depth. Overall distribution of the data indicates that highest nitrate concentrations occur at shallow depths. However, nitrate concentrations at depths may also be affected by other factors such as:

- point and non-point sources.
- contaminant flow path through unsaturated zone .
- confining layers in the saturated zone.
- potential denitrification.

Nitrate Concentration and Municipal Wells

There are 15 municipal wells at 10 locations or well-fields (Figure 11) in the Canadian side of Abbotsford-Sumas aquifer. All the municipal wells are of high capacity and are tapped deeper into the aquifer (Appendix I – Table A4: Municipal Well Data). These wells are back-up sources to the primary source of water supply from Norrish Creek to the City of Abbotsford. The back-up sources are typically used to augment peak water demands during the summer and at other times when Norrish Creek is too turbid to use.

Nitrate concentrations in the production wells (Appendix I – Table A2) have been historically low mainly because they are deeper (greater than 40m below ground) and some of them are below confining lenses of silt, till or clay. However, water quality in a few of the production wells has become a concern, due to the increasing nitrate concentrations in these wells over the years. The nitrate concentrations in a few of the municipal wells fluctuated significantly in 2004 (Figure 12). There are not enough data to show whether this fluctuation is seasonal or can be correlated to factors such as seasonal variation in precipitation and changes in the water table.

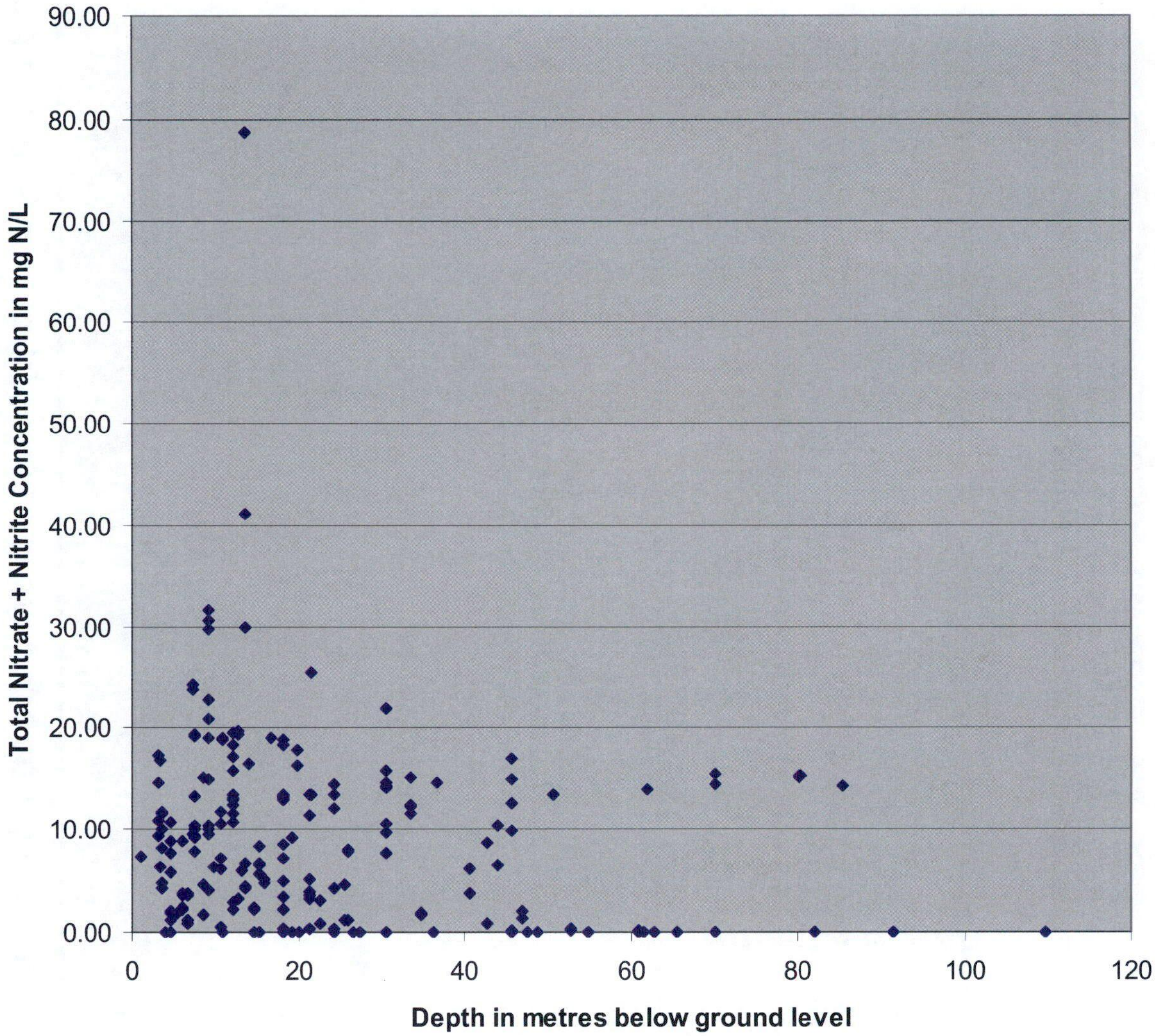


Figure 10: Nitrate concentrations in wells sampled in February, August and October, versus well depths.

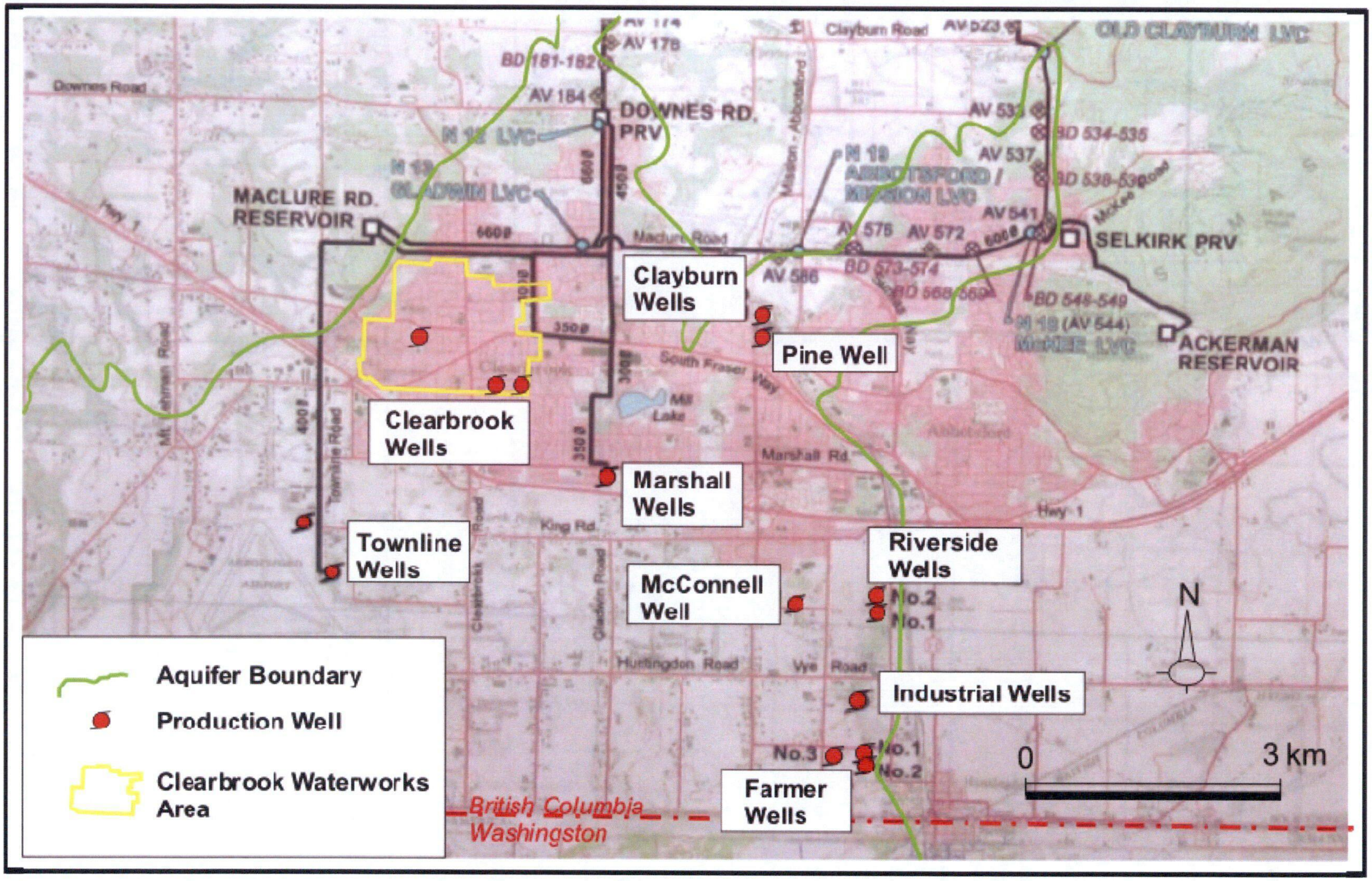


Figure 11: Location map of municipal production wells in the Abbotsford-Sumas Aquifer.
(The base map showing water supply lines and reservoirs, is from the City of Abbotsford)

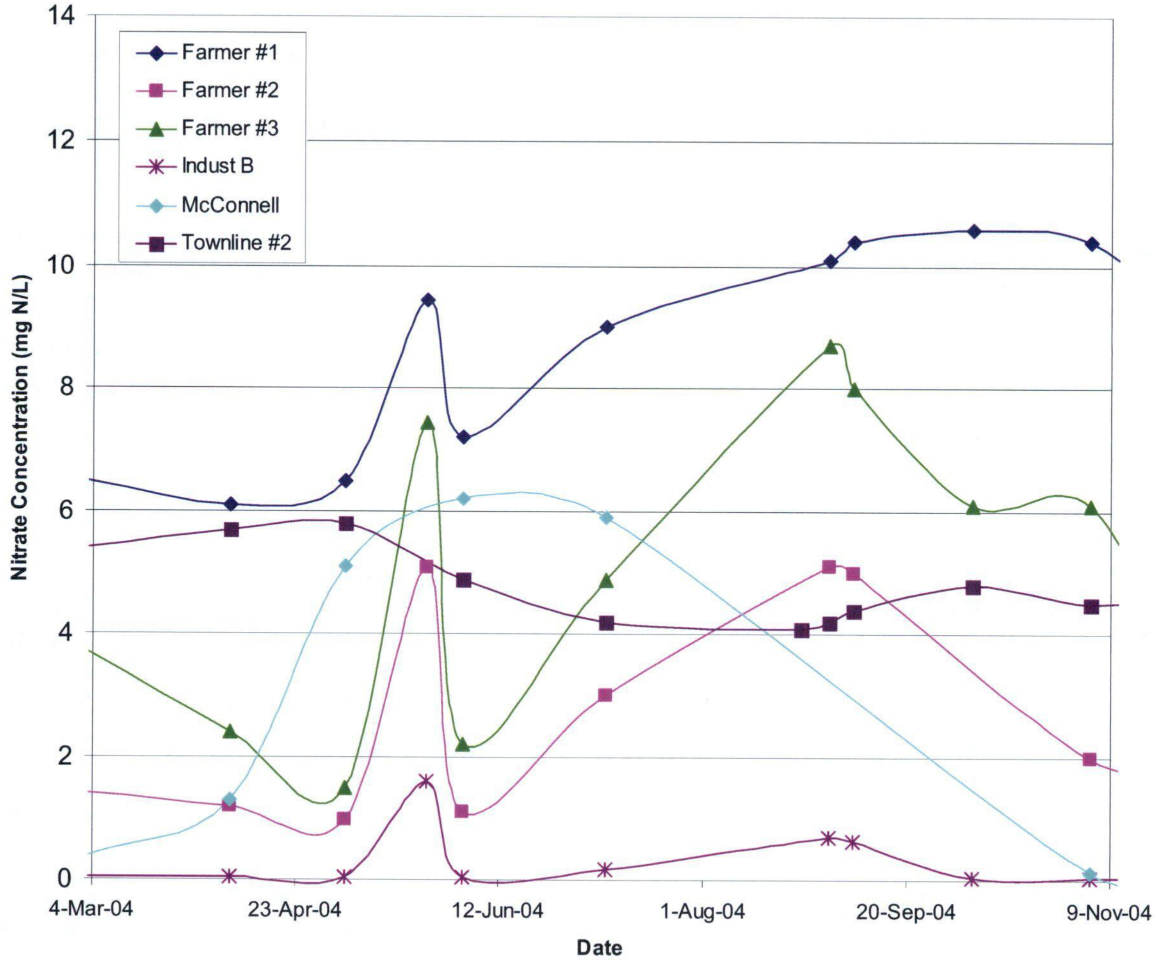


Figure 12: Nitrates in municipal wells (2004).

Nitrate Concentration and Provincial Observation Wells

Seven provincial observation wells in the Abbotsford-Sumas aquifer (Figure 13) are sampled regularly for a range of groundwater quality parameters. Nitrate concentrations in these wells have been monitored for the past 20 years. The graphs of nitrate concentrations in observation wells (see Figure 13) indicate variable nitrate concentrations, depending on the location and on the depth of the wells. The observation wells vary in depth from 15m to over 90m below ground level. The observation wells (Obs. Wells #002 and #008) that showed the highest nitrate concentrations are completed at shallower depths of 19m and 26m respectively. The observation well data generally support the trend of decreasing nitrate concentration with depth, with lowest nitrate concentrations observed in the deepest well (Obs. Well #015 at 98m in depth).

Nitrate concentrations were also observed to vary somewhat over time. All the observation wells showed no significant nitrate concentrations before 1992. However, four wells (Obs. Wells #008, #002, #272 and #299) have shown some nitrate impact with two of the wells (Obs. Wells #008 and #002) at or above the MAC of 10 mg N/L for all sampling events after 1992. Sampling practices in these wells have not been uniform over the period of record. Prior to 1992, samples were taken using a bailer, without significant purging of the observation wells prior to sampling. After 1992, pumps were used for sampling that allowed an estimated 3 well volumes to be purged prior to sampling. This shift in sampling methodology may have contributed to the change in nitrate concentrations around 1992. There is no Agriculture Land Use Inventory data available prior to 1996. However, there was a marked growth in the poultry industry in the early 1990's, possibly resulting in increased application of poultry manure to farm fields during this period and consequential nitrate impacts to groundwater.

Seasonal Nitrate Variations 2004

Sixty-seven sites throughout the five areas were sampled in February and repeated in October 2004 (see Table 3). The average and median nitrate concentrations in all areas are shown in Figure 14. The average and median nitrate concentrations in Area 1 and 2 were below the MAC of 10 mg N/L in February and relatively unchanged in October 2004, whereas the average and median nitrate concentrations in Areas 3, 4 and 5 were at or above the MAC during both sampling periods. The average nitrate concentration in Area 3 also increased significantly in October.

Twenty sites throughout the five areas were sampled in each of the three sampling periods (February, August and October) in 2004. Although each site demonstrated some variability between the three measurements (Figure 15), many do not vary by more than about 4 mg/L (see Appendix I – Table A1). The greatest variability between sites as well as within a site appears to be in Areas 3 and 4. One site near Fishtrap Creek with negligible nitrate concentrations in all 3 sampling periods may indicate faster denitrification rates in groundwater adjacent to the creek. Other sites showing greater seasonal variability may be responding to seasonal impacts of land-use inputs and natural soil processes or may be located in a more permeable location of the aquifer.

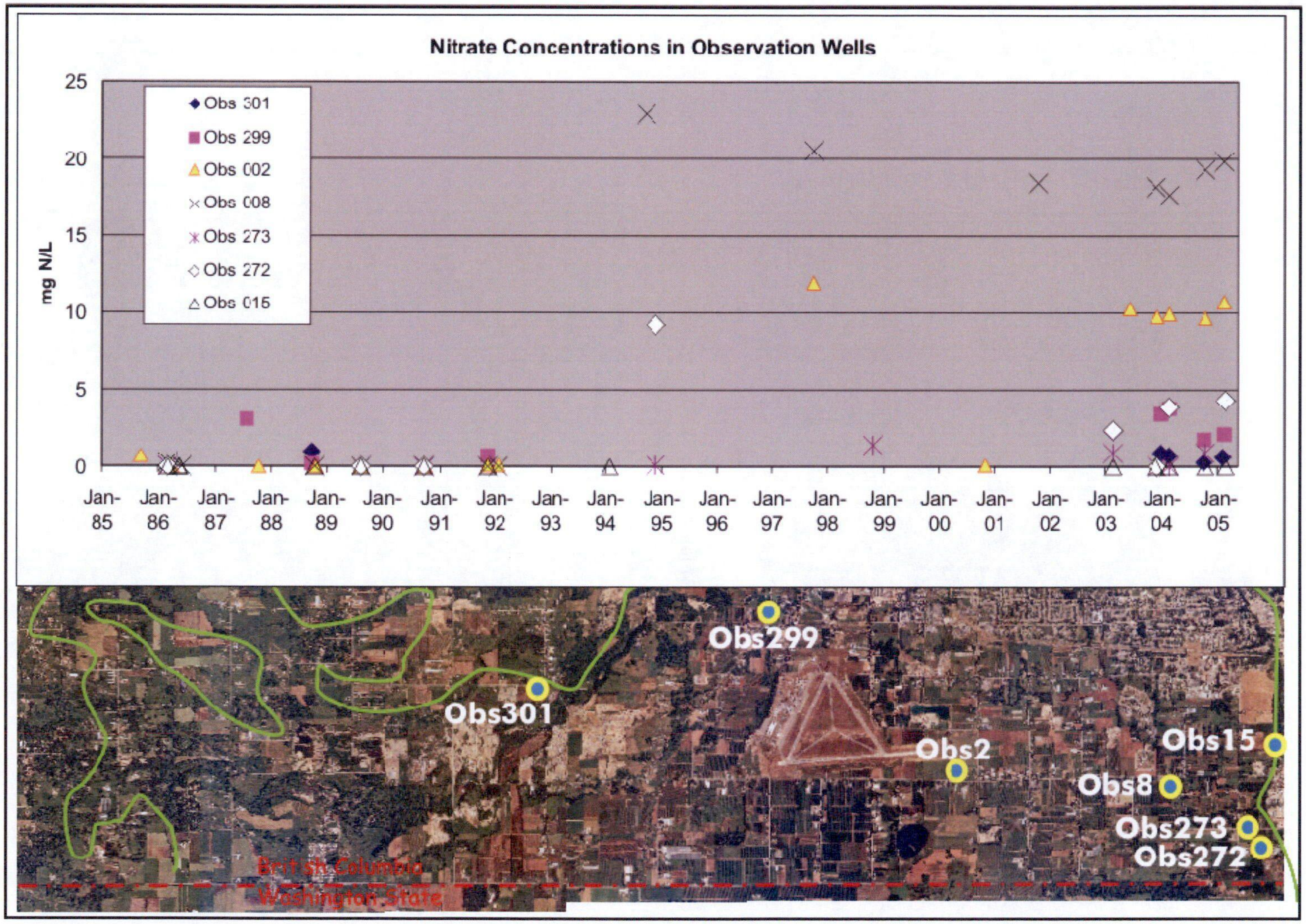
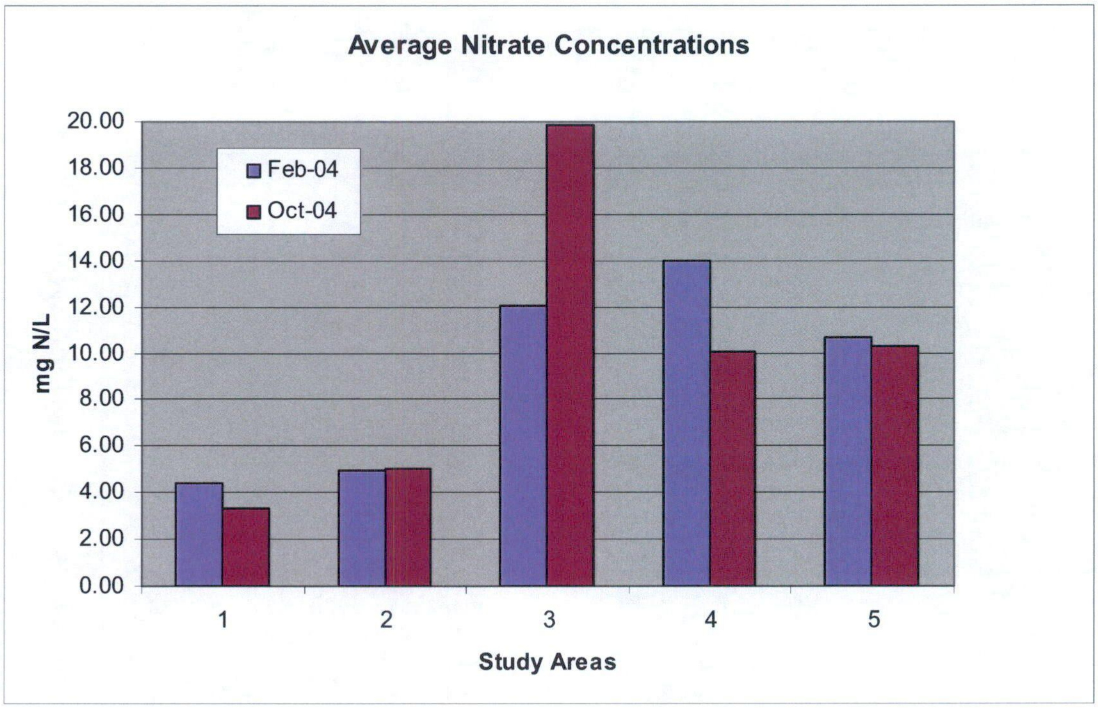


Figure 13: Plot of nitrate concentrations in provincial observation wells located in the Abbotsford aquifer.



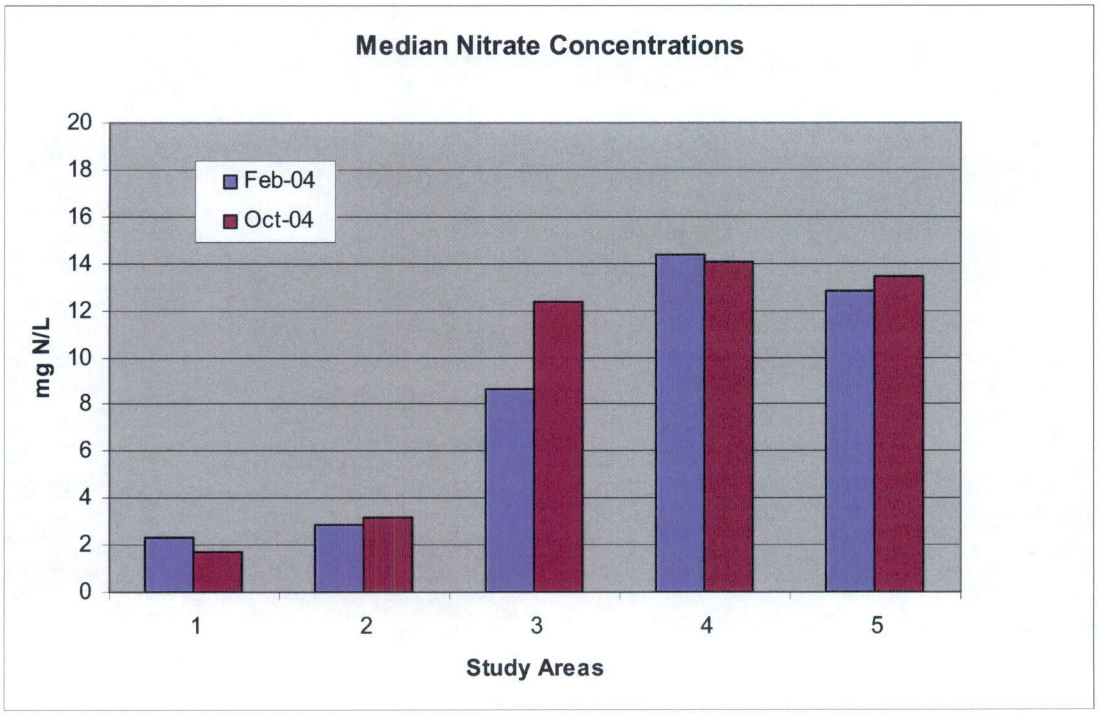


Figure 14: Average and median nitrate concentrations in the five areas, for February and October 2004 sampling periods.

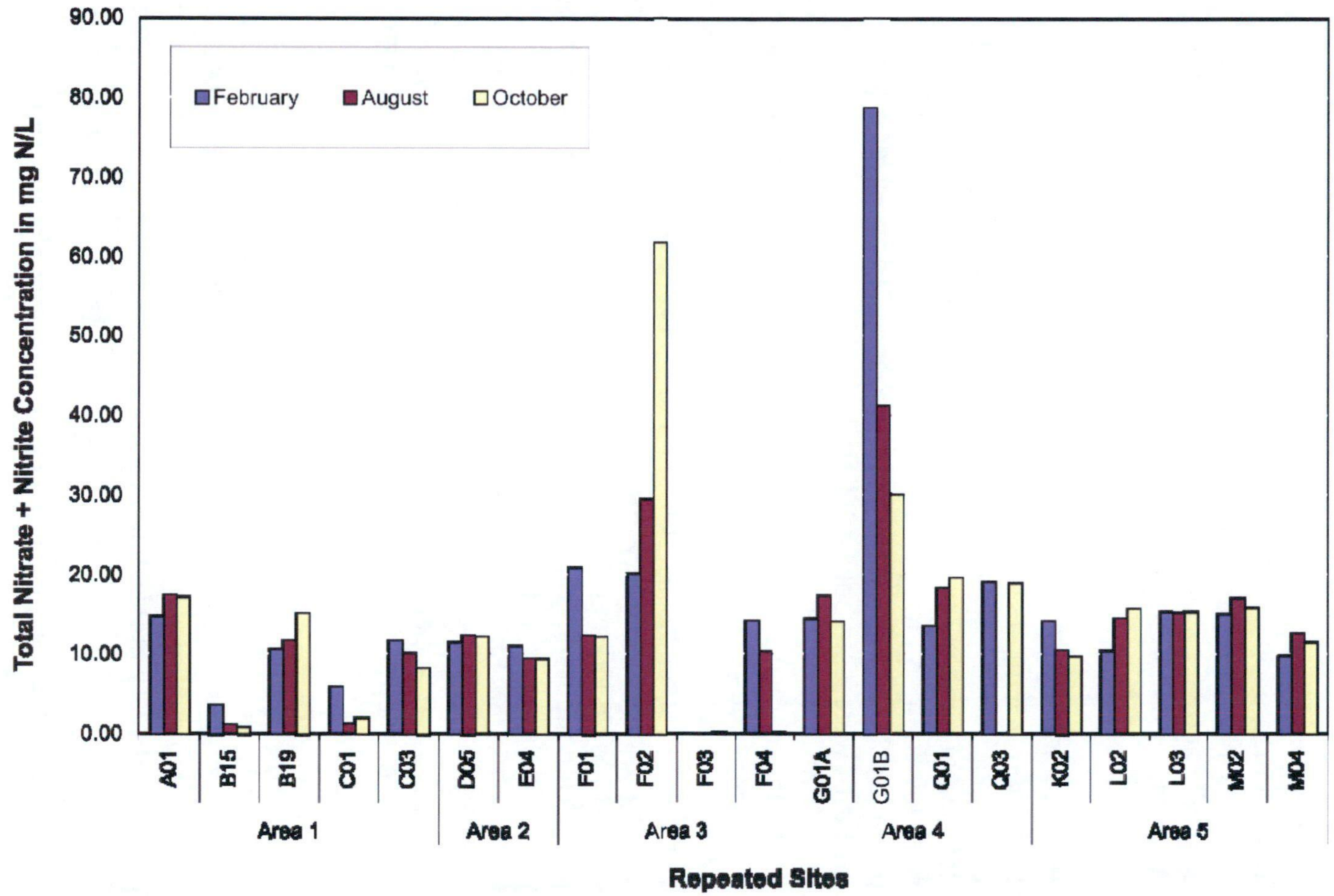


Figure 15: Nitrate seasonal variations for sites sampled in February, repeated in August and October, 2004.

Nitrate in Surface Water

The nitrate (total nitrate and nitrite) concentration results of water samples from Bertrand, Fishtrap and Lonzo creeks and their tributaries are summarized in Figure 16; details are presented in Appendix I - Table A3. These creeks were selected and sampled because of their suspected interactions with groundwater in the aquifer. Fishtrap Creek appears to act alternatively as a recharge/discharge zone for the aquifer for several months of the year (Liebscher *et al.*, 1992). Bertrand and Lonzo creeks, especially at their lower reaches, may be mainly discharging the aquifer as they form the aquifer boundary (Bertrand Creek along the west and Lonzo Creek along the eastern edge).

The nitrate concentrations at other surface water sampling locations were greater than 3 mg N/L, suggesting anthropogenic sources. In contrast, typical nitrate concentrations in relatively pristine surface-water locations are < 1 mg N/L. For example, total nitrate and nitrite for Elk Creek in Chilliwack, at a location upstream of any intensive development, ranged from 0.1 to about 0.5 mg N/L (Fluegel *et al.*, 2004); the total dissolved nitrogen concentrations in Fraser River at Hope and in Cheakamus River were both below 0.3 mg/L (*http://www.waterquality.ca/EN/home.htm*). Therefore, it appears that the likely sources of nitrate include run-off from agricultural fields directly into surface water bodies or their tributaries such as drainage ditches and smaller creeks. Examples of input from tributary creeks are Howes and Waechter creeks, tributaries of Bertrand and Fishtrap creeks, respectively. Both of these creeks have higher nitrate concentrations than the creek they are flowing into. Also, both Bertrand and Fishtrap creeks demonstrate an increase in nitrate concentration downstream of the confluence with the tributary. Nitrate concentrations generally increased from upstream to downstream in the creeks sampled with some exceptions. Lonzo Creek had a lower nitrate concentration further downstream; indicating discharges of lower nitrate water upstream of the L3 and L1 locations. Nitrate concentration at the L3 location in Lonzo Creek appears to be caused by dilution from groundwater (which has a low nitrate concentration) discharged from Fraser Valley Trout Hatchery nearby. Downstream dilution of nitrate was also observed for Howes and Waechter creeks.

Nitrate concentrations in nearly all locations of Lonzo Creek were higher than those in Bertrand and Fishtrap creeks. The nitrate values in some sampling locations of Bertrand and Lonzo creeks were nearly equal to the groundwater mean nitrate concentrations (February 2004) in the respective areas (see Table 2). This may suggest a hydraulic connection; that the surface waters in Bertrand and Lonzo creeks are fed by groundwaters discharged from areas 1 and 5 respectively and that there are no significant denitrification processes at the surface/groundwater interface.

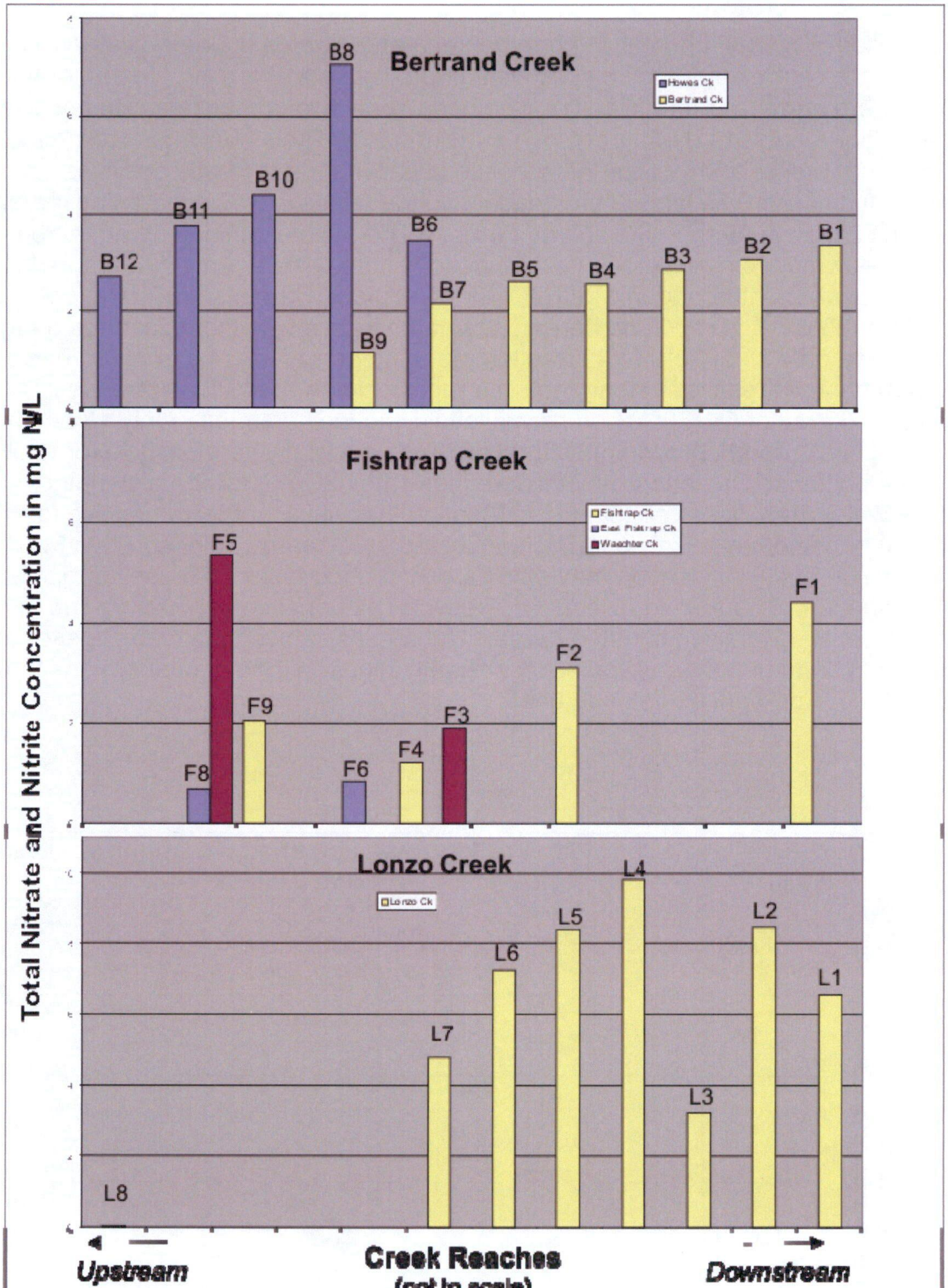


Figure 16: Nitrate concentrations in Bertrand, Fishtrap and Lonzo Creeks.

Comparison of Nitrate and Coliform Levels

The presence of total or fecal coliform bacteria and nitrates in groundwater do not appear to be correlated. Of the sites with nitrate levels >10 mg N/L, 66 out of 98 (67%) were negative for total coliform bacteria. Only two of the sites with positive fecal coliform bacteria had nitrate levels >10 mg N/L. Tables 5A & 5B outline the nitrate and total coliform bacteria associated with various land-use activities occurring on the study area. The land-use categories in the tables were based on observations at each site, as entered in the survey forms. The table examines nitrate nitrogen levels below and above 3 mg/L. Concentrations in excess of 3 mg N/L are usually associated with anthropogenic activities (Madison and Brunett, 1985). Seventy seven out of 96 (80%) sites reporting berry farms had nitrate levels that exceeded 3 mg N/L. In contrast, only 33 out of 79 (42%) sites reporting berry farms have positive total coliform bacteria results. Among the sites reporting non agricultural land-use activities, 33 out of 56 (59%) had nitrate levels exceeding 3 mg/L. Only 18 out of 49 (37%) of sites reporting non agricultural land-use activities were positive for total coliform bacteria. Bacteria are considered less mobile and less persistent in groundwater than dissolved nitrate, suggesting that wells that were positive for coliform bacteria have likely been contaminated by a nearby point-source. Poor well construction and well location may also be contributing factors in cases of bacterial contamination. There is no evident link between bacterial contamination and nitrate contamination of wells in the study area. The results showed that sample sites in agricultural land use areas showed significantly higher nitrate concentrations than areas under non-agricultural land use.

Table 5A: Nitrate levels in relation to land-use activities – number of sites for each crop type

Nitrate Level	Berries	Animals	Greenhouses	Non Agricultural land use	Unknown Land Use	Total
0-2.99 mg/L	19	30	6	23	21	**99**
> 3.0 mg/L	77	52	13	33	27	**202**
Total	**96**	**82**	**19**	**56**	**48**	**301**

Table 5B: Total coliform bacteria in relation to land-use activities – number of

occurrences for each crop type						
Total Coliforms	Berries	Animals	Greenhouses	Non Agricultural land use	Unknown Land Use	Total
< 1 cfu/100 mL	44	39	8	30	32	**153**
> 1 cfu/100 mL	33	31	8	18	9	**99**
OG	2	2	0	1	4	**9**
Total	**79**	**72**	**16**	**49**	**45**	**261**

Nitrate and Agricultural Activities

The major land uses overlying the Abbotsford area include agriculture, urban development and gravel extraction. In the past, manure was used as a fertilizer and soil conditioner for raspberry production. Use of manure in excess of crop nutrient needs was identified as a contributor to nitrates in the aquifer as well as improper storage of poultry manure in the winter on fields (Liebscher *et al.,* 1992; Zebarth *et al.,* 1998: Wassenaar, 1995).

The agriculture sector has responded through changes in farming management practices and water management. These include the following:

- The Sustainable Poultry Farming Group shipped manure from poultry farms on the aquifer to other locations off the aquifer for application. Over 100,000 cubic meters of manure have been moved.
- The Raspberry Industry Development Council spearheaded a move to better nutrient management planning by farmers. This has lead to a reduction in the use of manure and inorganic fertilizers and an increase in the use of cover crops.
- The raspberry industry undertook a 4 year post-harvest nitrate analysis since 2000, to check whether soils had excess nitrate in the fall. Results indicate that the available post-harvest nitrate that could be leached into the aquifer is lower than expected (Mouritzen, 2003).

BC Ministry of Environment's annual audits of agriculture practices; the results of the Raspberry Industry Development Council's post harvesting nitrate testing; City of Abbotsford's Environmental Pledge program; and records of poultry manure removal activities over the aquifer show that the industry as a whole has responded, and this is acknowledged. However, the extent of nitrate contamination throughout the aquifer has not changed significantly since the 1990s. Nitrate trends (based on Environment Canada piezometers' data) have been generally stable over the past several years. The potential impacts of changes in agricultural practices remain uncertain. Therefore, the identification of highly impacted areas with respect to nitrate contamination will require more detailed assessment of land-use activities.

CONCLUSIONS

The distribution of bacteria contamination appears to be localized to a few specific wells and not reflective of overall aquifer quality. The sources of fecal coliform bacteria were likely the results of localized land-use activities, poor well completion and/or inadequate protection.

The results of the well survey indicate average groundwater nitrate concentrations in the study area to be in excess of the maximum acceptable concentrations (MAC) for drinking water in all but the western-most portion of the study area (Area 1). Results indicate that (with the exception of the western-most sub-area) about 40 percent of wells in the study area exceed the 10 mg N/L MAC for nitrate in drinking water.

The spatial distribution of elevated nitrate concentrations (> 10 mg N/L) in groundwater suggests a link with agricultural activities, particularly in the south-central portion of the study area.

The vertical distribution of nitrate in the aquifer indicates that nitrate concentrations decrease with depth.

Nitrate contamination of groundwater in the study area appeared to increase in aerial extent, based on contour mapping, in the October 2004 sampling event, in comparison with the February 2004 sampling. In contrast, both mean and median nitrate concentrations decreased from February to October in all but the western portions of the study area (Areas 1 and 2. The increase in nitrate contamination in February may be due to the impact of the recharge of fall rains. The decrease in nitrate concentrations in October may be due to processes such as denitrification over the period of little recharge or dilution from up gradient groundwater.

Nitrate contaminations in most of the City of Abbotsford municipal wells are historically lower than 10 mg N/L.

Elevated nitrate concentrations in groundwater samples are more indicative of a regional problem, likely related to non-point source pollution from land-use activities over portions of the Abbotsford-Sumas aquifer.

RECOMMENDATIONS

Based on the results of this survey and supporting studies and in consideration of the importance of the Abbotsford-Sumas aquifer as a source of drinking water, irrigation and industrial (trout hatchery) uses for communities on both sides of the international border, the following steps are recommended:

1. Develop a multi-agency Science Group to jointly identify potential sources of nitrate and associated land use activities that may be responsible for nitrate "hot spots" or aquifer zones with nitrate concentrations that are well above the 10 mg N/L MAC for drinking water.

2. Environment Ministries (provincial and federal), the Regional Health Authority (Fraser Health), the City of Abbotsford and Agriculture Ministries (federal and provincial) should develop a joint strategy to address mitigation of nitrate loading to the aquifer. While efforts are being made by various government agencies and industry associations in this regard, there is a perceived need for greater coordination of activities and the establishment of common goals. An evaluation of the net effects of current agricultural BMP (Best Management Practices) on groundwater quality should be conducted.

3. Environment Ministries (provincial and federal) should continue to monitor nitrate concentrations in groundwater on a regular basis in order to further evaluate nitrate trends in the Abbotsford-Sumas aquifer. An update report should be generated.

4. The B.C. Ministry of Agriculture and Lands should update the land-use inventory maps to include current distributions of poultry, livestock and berry farms on the aquifer.

5. B.C. Ministry of Environment and Fraser Health should continue with public education and outreach programs, including reminders to residents in areas with elevated nitrate concentration in groundwater to treat their ground water; avoid using such well water for drinking, particularly in the preparation of infant formula; or seek an alternate source of drinking water

6. B.C. Ministry of Environment and Fraser Health should continue educational outreach efforts to promote proper well construction, maintenance practices and water quality testing, in order to help protect wells from sources of contamination at the land surface and safeguard human health. Migration of contaminated surface water into the well is typically preventable through proper well construction, maintenance and other wellhead protection measures. Well owners and operators should be aware of these issues and potential remedies,

including regulatory requirements under the new B.C. Ground Water Protection Regulation.

7. All relevant government agencies should continue participation in the City of Abbotsford's Abbotsford-Sumas Aquifer Stakeholders' Group Committee meetings and the efforts of this committee to assist in the development of a municipal groundwater protection strategy.

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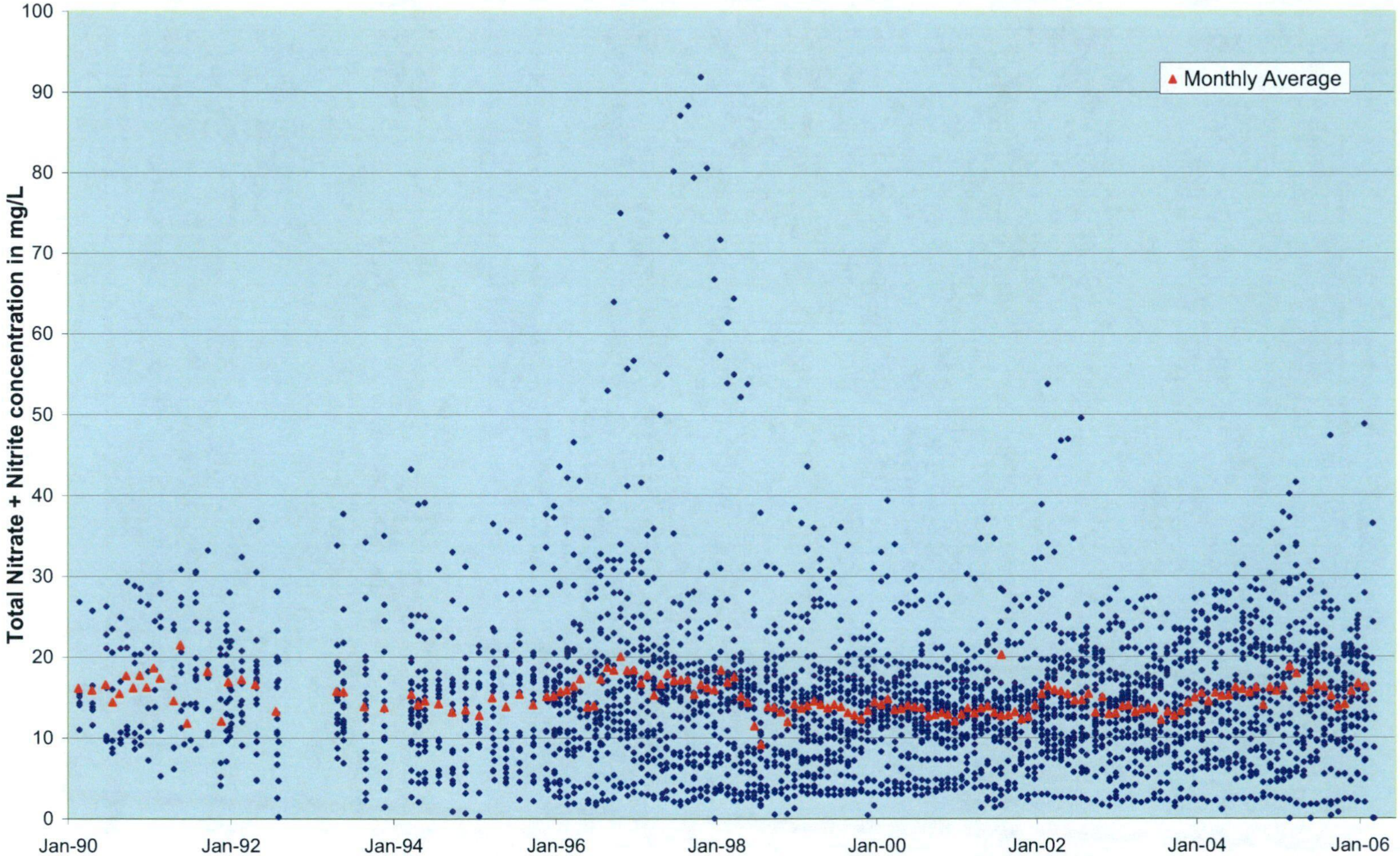
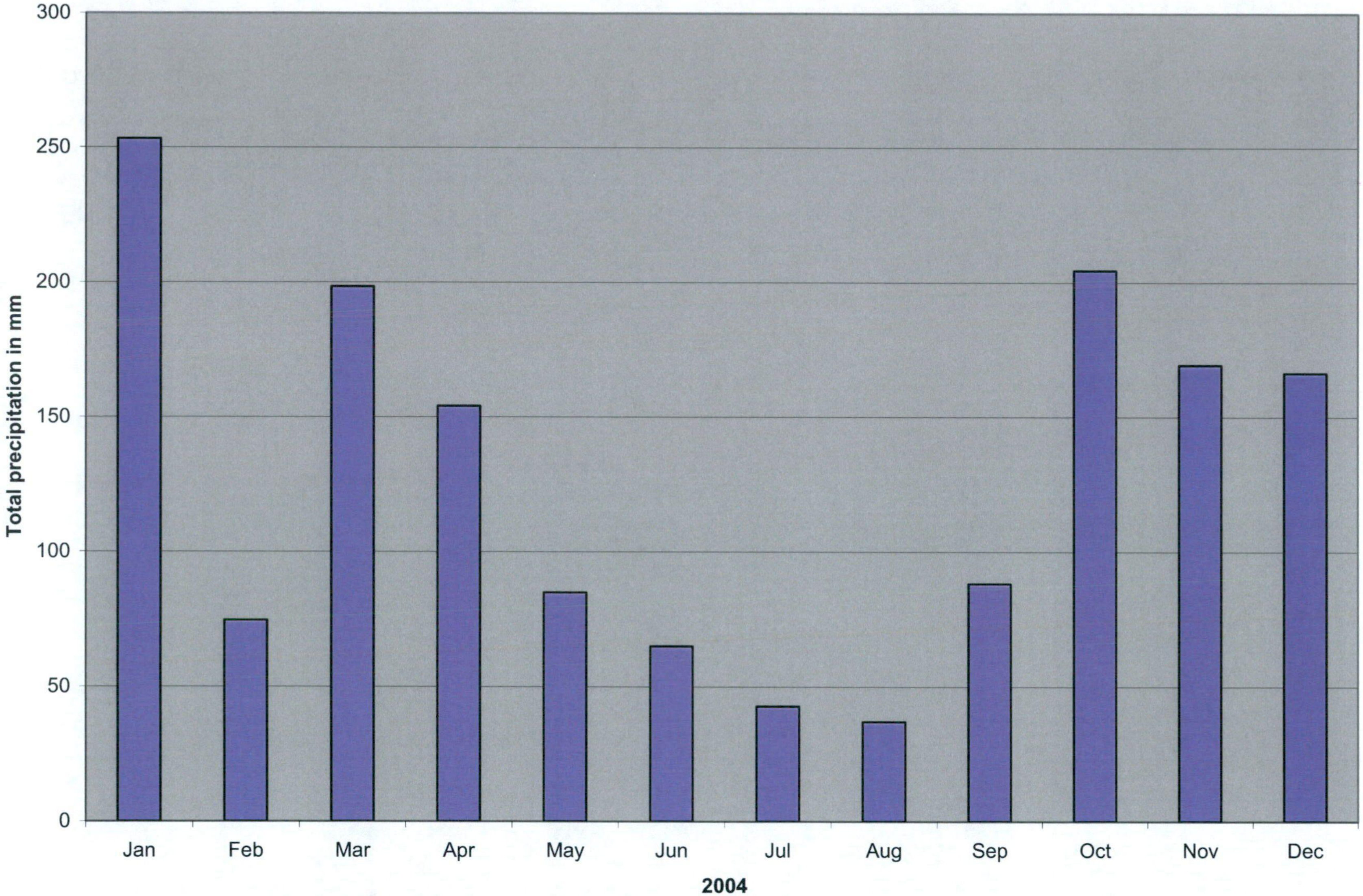


Appendix I – Figure A1: Monthly average nitrate concentrations in piezometers.



Appendix I – Figure A2: Monthly total precipitation plot for Abbotsford in 2004.

APPENDIX I - Table A1: 2004 Survey Nitrate and Bacteria Results

Project	Sample	Nitrate	NO3+NO2	Total Coliform	Fecal Coliform	Depth of
Site ID	Date	mg/L	mg/L	MPN/100 mL	MPN/100 mL	Well
18th Ave-1	2004-02-26	<0.02	<0.002	<1	<1	15.2 m
18th Ave-2	2004-02-26	1.93	1.93	5	<1	5.5 m
18th Ave-3	2004-02-26	6.60	6.61	<1	<1	15.2 m
18th Ave-4	2004-02-26	<0.02	0.003	5	<1	24.4 m
18th Ave-4	2004-11-04	0.002	0.002			24.4 m
18th Ave-4 REP	2004-11-04	<0.002	<0.002			24.4 m
20th Ave-1	2004-02-26	<0.02	<0.002	OG	<1	65.5 m
20th Ave-2	2004-02-26	<0.02	<0.002	<1	<1	20.1 m
20th Ave-3	2004-02-26	<0.02	0.002	<1	<1	91.4 m
269-1	2004-03-01	<0.02	0.002	<1	<1	4 m
269-1 REP	2004-03-01	<0.02	<0.002			
A01 Well #1	2004-02-23	14.7	14.7	90 est.	<1	
A01 Well #1	2004-08-09	17.4		19 est.	<1	
A01 Well #1	2004-10-25	17.1	17.1	1	n/a	6-12 m
A02 Well #2	2004-02-23	<0.002	0.002	<1	<1	15.0 m
A02 Well #2	2004-10-25	<0.002	<0.002	<1	<1	61.0 m
A02 Well #2 REP	2004-10-25	<0.002	<0.002			0.0
A03	2004-02-23	10.7	10.7	<1	<1	4.6 m
A03	2004-08-09	10.8		68 est.	<1	
A04	2004-02-23	7.39	7.39	<1	<1	
A05	2004-02-23	1.96	1.96	<1	<1	
A05	2004-10-25	1.94	1.94	<1	<1	
A06	2004-02-23	11.5	11.5	190 est.	<1	3.7 m
A06	2004-11-04	4.24	4.24			3.7 m
A06 REP	2004-11-04	4.26	4.26			
A15	2004-02-23	8.77	8.77	<1	<1	6.1 m
A15	2004-10-25	3.77	3.77	74	3	6.1 m
A16	2004-02-23	1.70	1.70	150 est.	<1	
A16	2004-10-25	0.506	0.508	400 est.	4	Shallow
A17	2004-02-23	<0.02	0.008	<1	<1	
A17	2004-11-04	<0.002	<0.002			
B01	2004-02-23	<0.02	0.003	4 est.	<1	
B02	2004-02-23	2.20	2.20	20 est.	<1	
B02	2004-10-26	1.44	1.44	270 est.	5	
B03	2004-02-23	2.28	2.28	1 est.	<1	
B03	2004-10-26	2.95	2.95	170 est.	9	12.2 m
B04	2004-02-23	0.10	0.101	340 est.	<1	45.7 m
B05	2004-02-23	4.28	4.28	<1	<1	24.4 m
B05 REP	2004-02-23	4.24	4.24	<1	<1	

Project	Sample	Nitrate	NO3+NO2	Total Coliform	Fecal Coliform	Depth of
Site ID	Date	mg/L	mg/L	MPN/100 mL	MPN/100 mL	Well
B06	2004-02-23	7.76	7.76	<1	<1	7.6 m
B07	2004-02-23	2.10	2.10	450 est.	<1	
B15	2004-02-25	3.60	3.60	14 est.	<1	6.7 m
B15	2004-08-09	1.11		<1	<1	
B15	2004-10-26	0.804	0.814	<1	<1	6.7 m
B15 REP	2004-02-25	3.77	3.77			
B16	2004-02-25	2.80	2.80	1	<1	
B16	2004-10-26	3.12	3.12	<1	<1	Shallow
B16 REP	2004-02-25	2.85	2.85			
B17	2004-02-25	<0.02	<0.002	<1	<1	
B18	2004-02-25	<0.02	<0.002	<1	<1	82.0 m
B19	2004-02-25	10.6	10.6	<1	<1	10.7 m
B19	2004-08-09	11.7		<1 BGG	<1	
B19	2004-10-26	15.1	15.1	OG	<1	8.5 m
B19 REP	2004-10-26	15.2	15.2			
B20	2004-02-25	0.56	0.569	<1	<1	
B21	2004-02-25	0.59	0.591	<1	<1	10.7 m
B22	2004-02-25	0.76	0.758	<1	<1	
C01	2004-02-24	5.81	5.81	41	<1	4.6 m
C01	2004-08-09	1.19		340 est.	1	
C01	2004-10-27	1.89	1.89	350 est.	2	4.6 m
C01 REP	2004-10-27	2.03	2.03			
C02	2004-02-24	3.55	3.59	<1	<1	21.3 m
C02 (Well #2)	2004-10-27	3.48	3.52	OG	<1	18.3 m
C02A (Well #1)	2004-10-27	<0.002	<0.002	1	<1	30.5 m
C03	2004-02-24	11.7	11.7	15	<1	3.7 m
C03	2004-08-09	10.1		17 est.	OG	
C03	2004-10-27	8.21	8.21	18	2	3.7 m
C04	2004-02-24	0.07	0.07	<1	<1	
C05	2004-02-24	0.82	1.68	<1	<1	42.7 m
C05 REP	2004-02-24	0.82	1.68			
C06	2004-02-24	2.08	2.08	<1	<1	
C07	2004-02-24	1.84	1.84	150 est.	<1	
C07	2004-11-04	1.27	1.53			
C07 REP	2004-11-04	1.21	1.47			
C08	2004-02-24	6.28	6.28	OG	<1	3.4 m
C08	2004-08-09	16.9		est. 26	<1	
Q09	2004-02-23	0.06	0.063	<1	<1	45.7 m
Q10	2004-02-23	<0.02	0.005	<1	<1	47.5 m
Q11	2004-02-23	<0.02	0.006	1 est.	<1	36.3 m
Q11	2004-11-03	<0.002	<0.002			30.5 m

Project	Sample	Nitrate	NO3+NO2	Total Coliform	Fecal Coliform	Depth of
Site ID	Date	mg/L	mg/L	MPN/100 mL	MPN/100 mL	Well
Q11 REP	2004-02-23	<0.02	0.002			
Q12	2004-02-23	<0.02	0.002	<1	<1	70.1 m
Q12	2004-11-03	0.212	0.212	1	<1	61.0 m
Q12 REP	2004-11-03	0.003	0.003			
Q13 Well #2	2004-02-23	4.50	4.50	<1	<1	
Q13 Well #2	2004-10-27	2.18	2.18	<1	<1	18.3 m
Q13 Well #2 REP	2004-10-27	2.26	2.26			
Q14 Well #1	2004-02-24	3.98	3.98	<1	<1	18-21 m
Q14 Well #1	2004-10-27	3.26	3.26			
Q15	2004-02-24	5.09	5.09	<1	<1	18-21 m

Project	Sample	Nitrate	NO3+NO2	Total Coliform	Fecal Coliform	Depth of
Site ID	Date	mg/L	mg/L	MPN/100 mL	MPN/100 mL	Well
D01	2004-02-24	4.79	4.79	<1	<1	3.7 m
D01	2004-10-25	4.52	4.52	85	<1	8.5 m
D02	2004-02-24	0.31	0.314	<1	2	
D03	2004-02-24	7.93	7.93	1	<1	25.9 m
D03	2004-10-25	7.85	7.85	1 est.	<1	25.9 m
D03 REP	2004-10-25	7.93	7.93			
D04	2004-10-25	14.7	14.7	4	<1	36.6 m
D04	2004-02-23	14.3	14.3	<1	<1	73-85 m
D05	2004-02-24	11.5	11.5	<1	<1	33.5 m
D05	2004-08-09	12.4		<1	<1	
D05	2004-11-03	12.2	12.2			33.5 m
D05 REP	2004-02-24	11.5	11.5			
D06	2004-02-23	8.72	8.72			42.7 m
D07	2004-08-09	13.5		<1	<1	
D07	2004-02-23	12.1	12.1	<1	<1	24.4 m
E01	2004-02-24	6.40	6.40	4	<1	
E02	2004-02-24	1.67	1.67	3	<1	6-9 m
E03	2004-02-24	2.27	2.27	<1	<1	14.6 m
E03	2004-10-25	3.15	3.15	est. 150	<1	12.8 m
E03 REP	2004-02-24	2.36	2.36			
E04	2004-02-24	10.9	11.0	1500 est.	<1	3.0 m
E04	2004-08-09	9.40		67 est.	<1	
E04	2004-10-24	9.30	9.30	360 est.	<1	7.6 m
E04	2004-10-25	9.54	9.54	780 est.	<1	7.3 m
E04 REP	2004-10-25	9.54	9.54			
E05	2004-02-24	19.0	19.0	<1	<1	9.1 m
E06	2004-02-24	16.4	16.4	830 est.	<1	19.8 m
E06	2004-08-09	17.8		<1	<1	
E07	2004-02-24	24.4	24.4	<1	<1	7.3 m
E07	2004-08-09	23.8		est. 2	<1	
E08	2004-02-24	0.03	0.038	<1	<1	
E08	2004-10-25	0.052	0.086	<1	<1	
E100	2004-03-01	9.09	9.09			
E12	2004-10-26	<0.002	<0.002	<1	<1	26.5 m
E15	2004-10-26	19.3	19.3	2	<1	7.6 m
E15 REP	2004-10-26	19.4	19.4			
E19	2004-11-03	9.84	9.84			
E19 REP	2004-11-03	9.94	9.94			
E28	2004-10-27	12.7	12.7	<1	<1	
Montesina-1	2004-02-26	1.74	1.74	<1	<1	
Montesina-	2004-10-25	1.83	1.83	4	<1	34.7 m

Project Site ID	Sample Date	Nitrate mg/L	NO3+NO2 mg/L	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL	Depth of Well
1						
Q05	2004-11-03	13.2	13.2			
Q05	2004-02-23	12.9	12.9	<1	<1	18.3 m
Q05 REP	2004-02-23	13.1	13.1			
Q06	2004-02-23	<0.02	0.012	<1	<1	19.2 m
Q06	2004-10-27	9.19	9.19	<1	<1	
Q07 North Well	2004-02-25	<0.02	<0.002	270 est.	<1	48.8 m
Q08 South Well	2004-02-25	<0.02	<0.002	<1	<1	109.7 m
R01	2004-02-25	13.0	13.0	<1	<1	
R02	2004-02-23	11.4	11.4	<1	<1	21.3 m
R02	2004-08-10	13.4		<1	<1	
R03	2004-02-25	6.23	6.24	<1	<1	
R03 REP	2004-02-25	6.03	6.05			
R05	2004-10-26	15.3	15.3	14 est.	<1	
R06	2004-10-26	13.9	14.8	<1	<1	
R09	2004-10-26	19.7	19.7	530 est.	<1	Shallow
R13	2004-10-26	10.1	10.1	12	<1	
R13 REP	2004-10-26	10.2	10.2			
Smith-1	2004-02-26	<0.02	0.003	<1	<1	
Smith-1A (south)	2004-11-03	<0.002	0.004			
Smith-1B (north)	2004-11-03	0.002	0.002			
Smith-2	2004-02-26	0.04	0.040	<1	<1	
Smith-3	2004-02-26	4.18	4.18	90 est.	<1	
V01	2004-10-26	10.1	10.1	<1	<1	7.6 m
V01 REP	2004-10-26	10.3	10.3			
V03	2004-10-26	10.7	10.7	270 est.	<1	12.2 m
V08	2004-10-26	0.368	0.368	1 est.	<1	Drilled
V10	2004-10-26	18.5	18.5	<1	<1	Drilled
V14	2004-10-26	<0.002	<0.002	<1	<1	14.6 m

Project Site ID	Sample Date	Nitrate mg/L	NO3+NO2 mg/L	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL	Depth of Well
E207089 (see T08)	2004-02-26	<0.02	0.026	<1	<1	
F01	2004-02-24	20.9	20.9	4 est.	<1	
F01	2004-08-10	10.0		1	<1	
F01	2004-10-25	29.8	29.8			9.1 m
F01 REP	2004-10-25	30.7	30.7			
F02	2004-02-24	20.1	20.1	2 est.	<1	
F02	2004-08-10	29.5		<1	<1	
F02	2004-10-25	61.7	61.7			
F03	2004-02-24	<0.02	0.006	3 est.	<1	
F03	2004-08-10	0.009		<1 BGG	<1	
F03	2004-10-25	0.077	0.077			
F04	2004-02-24	14.1	14.1	6	<1	
F04	2004-08-10	10.2		1	<1	
F04	2004-11-04	0.053	0.053	<1	<1	
F04 Redo (F99)	2004-02-26	7.79	7.79	<1	<1	
F04 REP	2004-11-04	0.053	0.053			
F04 REP	2004-08-10	10.4		<1	<1	
F05	2004-02-24	20.8	20.8	<1	<1	
F05 REP	2004-02-24	20.6	20.6			
F06	2004-02-24	2.30	2.30	4 est.	<1	
F06	2004-10-25	2.27	2.27	20 est.	<1	6.1 m
F07	2004-02-24	3.55	3.55	<1	<1	
F07 REP	2004-02-25	3.55	3.55			
F08	2004-02-25	2.62	2.62	<1	<1	
F15	2004-02-24	14.3	14.3	<1	<1	
F16	2004-02-24	8.63	8.63	<1	<1	
F16	2004-10-25	10.5	10.5	14	<1	
F17	2004-02-24	40.9	40.9	90 est.	2	
F17 Redo (F17A)	2004-03-01	44.5	44.5	<1	<1	
F25	2004-10-26	0.648	0.648			
F25 REP	2004-10-26	0.104	0.104			
F30 (East Well)	2004-10-26	<0.002	<0.002			18.3 m
F32 (West Well)	2004-10-26	<0.002	<0.002	<1	<1	18.3 m
F89	2004-02-26	8.44	8.44	OG	<1	
F89 (F21)	2004-10-26	14.2	14.2	<1	<1	Shallow
FA1	2004-10-27	4.87	4.87	<1	<1	18.3 m
HU22	2004-10-28	12.9	12.9	1 est.	<1	12.2 m
HU23	2004-10-28	5.88	5.88	<1	<1	
Laxton-1	2004-02-25	15.9	15.9	<1	<1	12.2 m
Laxton-2	2004-02-25	11.6	11.6	1	<1	
Laxton-2	2004-10-25	15.8	15.8	9 est.	<1	10-12 m
Laxton-2 REP	2004-02-25	11.6	11.6			
Laxton-3	2004-02-25	15.0	15.0	<1	<1	9.1 m

Project Site ID	Sample Date	Nitrate mg/L	NO3+NO2 mg/L	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL	Depth of Well
Laxton-3	2004-11-03	19.0	19.0			16.8 m
Laxton-4	2004-02-25	13.3	13.3	<1	<1	7.6 m
Laxton-4	2004-10-25	9.13	9.13	<1	<1	
Laxton-5	2004-02-25	4.45	4.45	<1	<1	13.7 m
Laxton-5	2004-11-03	4.43	4.43			
Laxton-5 REP	2004-11-03	4.20	4.20			
Laxton-5 REP	2005-02-25	4.31	4.31			

Project Site ID	Sample Date	Nitrate mg/L	NO3+NO2 mg/L	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL	Depth of Well
E213035 N	2004-02-26	10.4	11.1	<1	<1	
E213035 S	2004-02-26	8.34	8.65	<1	<1	
G01A	2004-03-01	14.4	14.4	<1	<1	24.4 m
G01A	2004-08-09	17.3		<1	<1	
G01A	2004-11-03	13.7	13.7			
G01A REP	2004-08-09	17.3				
G01A REP	2004-11-03	14.4	14.4			
G01B	2004-03-01	78.7	78.7	<1	<1	13.7 m
G01B	2004-08-09	41.2		<1	<1	
G01B	2004-11-03	30.0	30.0			
G02	2004-08-09	22.8		8	<1	
G02	2005-02-23	31.7	31.7	<1	<1	9.1 m
G03	2004-08-09	7.60		430 est.	16	
G03	2005-02-23	8.90	8.90	55	<1	4.6 m
G04	2004-02-25	9.49	9.49	<1	<1	9.1 m
G05	2004-02-25	7.12	7.12	65 est.	<1	10.7 m
G05	2004-08-09	6.13		36 est.	<1	
G25	2004-10-26	6.24	6.24	21 est.	<1	9.8 m
G31	2004-10-26	<0.002	<0.002	<1	<1	
G31 REP	2004-10-26	<0.002	<0.002			
G32	2004-10-26	1.20	1.62	8	<1	25.6 m
H01	2004-02-25	3.06	3.52	<1	<1	22.6 m
H01	2004-10-25	0.831	1.02	<1	<1	22.6 m
H01 REP	2004-02-25	3.08	3.55			
H02	2004-02-25	18.3	18.3	OG	<1	18.3 m
H02	2004-10-25	18.9	18.9	<1	<1	18.3 m
H02 REP	2004-10-25	18.8	18.8			
H03	2004-02-25	8.49	8.49	<1	<1	18.3 m
H03	2004-08-09	7.10				
H04	2004-02-25	8.33	8.33	1 est.	<1	15.2 m
H04	2004-11-03	6.65	6.65			13.7 m
H05	2004-11-03	9.61	9.61			
H08	2004-10-26	4.65	4.65	170 est.	<1	25.6 m
H09	2004-10-26	11.9	11.9	4 est.	<1	Drilled
H10	2004-10-26	5.50	5.50	<1	<1	
H10 REP	2004-10-26	5.45	5.45			
H13	2004-10-26	13.5	13.6	120 est.	<1	18.3 m
H19	2004-10-26	0.311	0.311	<1	<1	21.3 m
H23	2004-10-26	<0.002	0.002	<1	<1	
HU01	2004-10-28	0.300	0.423			24.4 m
HU01 REP	2004-10-28	0.299	0.421			
HU02	2004-10-28	7.63	7.63	<1	<1	30.5 m
HU03	2004-10-28	5.30	5.30	<1	<1	

Project Site ID	Sample Date	Nitrate mg/L	NO3+NO2 mg/L	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL	Depth of Well
HU20	2004-10-28	3.56	3.56	24 est.	<1	6.1 m
HU21	2004-10-28	4.06	4.06	<1	<1	
HU21 REP	2004-10-28	4.13	4.13			
Q01	2004-08-09	18.3				
Q01	2004-11-04	19.6	19.6			9-12 m
Q01 Well #1	2004-02-23	13.5	13.5	7 est.	<1	
Q02	2004-02-23	<0.02	0.003	<1	<1	
Q02	2004-11-04	<0.002	<0.002			27.4 m
Q03	2004-02-23	19.1	19.1	80 est.	<1	
Q03	2004-08-09	0.004		<1	<1	
Q03	2004-11-04	18.9	18.9			11.0 m
Q04	2004-02-23	10.4	10.4	1	<1	9.1 m
Q04	2004-11-04	4.16	4.17			9.1 m
Queen-1	2004-03-01	5.89	5.89	<1	<1	13.1 m
T01	2004-10-26	29.3	29.3	50 est.	1	
T02	2004-10-26	35.1	35.1	60 est.	<1	Shallow
T06	2004-10-26	19.3	19.3	<1	<1	
T08	2004-10-26	<0.002	<0.002	<1	<1	
T12	2004-10-26	19.4	19.4	1110 est.	<1	12.8 m
T12 REP	2004-10-26	19.7	19.7			
T14	2004-10-26	16.5	16.5	<1	<1	14.0 m

Project Site ID	Sample Date	Nitrate mg/L	NO3+NO2 mg/L	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL	Depth of Well
E207111	2004-02-26	19.9	19.9	<1	<1	
E207113	2004-02-26	19.2	19.2	22 est.	<1	
E207115	2004-02-26	5.19	5.19	<1	<1	
E207115 REP	2004-02-26	5.23	5.23			
E216978	2004-02-26	4.76	4.78	<1	<1	
E252849	2004-02-26	18.1	18.1	<1	<1	
HU04	2004-10-28	13.2	13.2	<1	<1	
HU05	2004-10-28	11.2	11.2	<1	<1	
I-01	2004-02-25	0.38	0.386	27 est.	<1	
I-01	2004-08-10	0.015		<1	<1	
I-02	2004-02-25	22.5	22.5	22 est.	<1	
I-02	2004-08-10	7.78		120 est.	<1	
I-03	2004-02-25	4.39	4.40	1	<1	
I-03	2004-10-25	0.011	0.014	<1	<1	
I-04	2004-02-25	13.3	13.3	1	<1	
I-04	2004-10-25	16.2	16.2	120 est.	<1	
I-05	2004-02-25	8.13	8.13	<1	<1	
I-05	2004-10-25	8.88	8.88	<1	<1	Drilled
I-05 REP	2004-02-25	8.09	8.09			
I-06	2004-02-25	13.9	13.9	<1	<1	62.0 m
I-10	2004-10-26	22.0	22.1	170 est.	<1	27-31 m
I-13	2004-10-26	5.76	5.78	101	<1	
J01	2004-02-25	16.0	16.0	<1	<1	
J01	2004-08-10	20.9		2 est.	<1	
J02	2004-08-10	23.2		2 est.	<1	
J02	2005-02-23	16.7	16.7	<1	<1	
K01	2004-02-25	<0.02	<0.002	<1	<1	62.8 m
K01	2004-11-03	0.006	0.006			61.6 m
K01 REP	2004-11-03	0.009	0.009			
K02	2004-02-25	14.1	14.1	<1	<1	30.5 m
K02	2004-08-10	10.5		<1 BGG	<1	
K02	2004-10-26	9.65	9.65	<1	<1	30.5 m
K03	2004-02-25	<0.02	0.006	11	<1	
K03 REP	2004-02-25	<0.02	0.003			
K10	2004-03-01	<0.02	<0.002	<1	<1	
K102	2004-03-01	25.6	25.6			71.0 m
K102	2004-08-10	13.5		<1	<1	
K103	2004-03-01	5.36	5.36			
K103	2004-08-10	4.93		<1 BGG	<1	
L01	2004-02-25	1.20	1.20	2	<1	25.9 m
L02	2004-08-10	14.5		90 est.	<1	
L02	2004-10-26	15.7	15.7	160 est.	<1	Drilled
L02	2005-02-23	9.60	10.4	OG	<1	

Project Site ID	Sample Date	Nitrate mg/L	NO3+NO2 mg/L	Total Coliform MPN/100 mL	Fecal Coliform MPN/100 mL	Depth of Well
L03	2004-02-25	15.3	15.3	<1	<1	80.2 m
L03	2004-08-10	15.2		140 est.	<1	
L03	2004-10-26	15.3	15.3	<1	<1	80.5 m
L04	2004-02-25	19.0	19.0	OG	<1	
L04	2004-08-10	19.6		<1 BGG	<1	
L04 REP	2004-02-25	19.0	19.0			
L04 REP	2005-08-10	20.7				
L05	2004-02-25	14.6	14.6	<1	<1	30.5 m
L05	2004-10-25	14.3	14.3	<1	<1	
L06	2004-02-25	15.2	15.2	<1	<1	33.5 m
L06	2004-11-03	15.2	15.2			33.5 m
L07	2004-02-25	14.7	14.7	<1	<1	
L07	2004-10-25	14.9	14.9	<1	<1	
L08	2004-02-25	<0.02	<0.002	<1	<1	
M01	2004-02-25	12.4	12.4	2	<1	
M01	2004-08-10	13.1		<1	<1	
M01	2004-10-25	13.4	13.4	2	<1	12.2 m
M02	2004-02-25	15.0	15.0	<1	<1	45.7 m
M02	2004-08-10	17.0		<1	<1	
M02	2004-10-25	15.8	15.8	<1	<1	30.5 m
M02 REP	2004-10-25	15.8	15.8			
M03	2004-02-25	14.5	14.5	<1	<1	70.1 m
M03	2004-08-10	15.5		<1 BGG	<1	
M04	2004-02-24	9.81	9.81	<1	<1	45.7 m
M04	2004-08-10	12.6		1	<1	
M04	2004-10-25	11.5	11.5	<1	<1	33.5 m
M05	2004-02-25	2.84	2.86	OG	<1	
M05	2004-10-25	2.87	2.91	<1	<1	
M06	2004-02-25	0.15	0.148	<1	<1	
M06 REP	2005-02-25	0.14	0.144			
O-10	2004-03-01	7.89	7.89			
O-10 REP	2004-03-01	7.88	7.88			
Wright-1	2004-02-26	<0.02	0.003	<1	<1	
P01	2004-02-25	0.050	0.055	<1	<1	54.9 m
P01	2004-11-03	0.062	0.069			61.0 m

Appendix I – Table A2: Nitrate in Abbotsford Municipal Wells (2004 results)

Production Well	Date	Nitrate in mg N/L
Farmer #1	3-Mar-04	6.5
Farmer #1	7-Apr-04	6.1
Farmer #1	5-May-04	6.5
Farmer #1	25-May-04	9.43
Farmer #1	3-Jun-04	7.2
Farmer #1	8-Jul-04	9
Farmer #1	1-Sep-04	10.1
Farmer #1	7-Sep-04	10.4
Farmer #1	6-Oct-04	10.6
Farmer #1	4-Nov-04	10.4
Farmer #1	2-Dec-04	8.9
Farmer #2	3-Mar-04	1.4
Farmer #2	7-Apr-04	1.2
Farmer #2	5-May-04	0.97
Farmer #2	25-May-04	5.08
Farmer #2	3-Jun-04	1.1
Farmer #2	8-Jul-04	3
Farmer #2	1-Sep-04	5.1
Farmer #2	7-Sep-04	5
Farmer #2	4-Nov-04	2
Farmer #2	2-Dec-04	1.8
Farmer #3	3-Mar-04	3.7
Farmer #3	7-Apr-04	2.4
Farmer #3	5-May-04	1.5
Farmer #3	25-May-04	7.45
Farmer #3	3-Jun-04	2.2
Farmer #3	8-Jul-04	4.9
Farmer #3	1-Sep-04	8.7
Farmer #3	7-Sep-04	8
Farmer #3	6-Oct-04	6.1
Farmer #3	4-Nov-04	6.1
Farmer #3	2-Dec-04	2.7
Industrial A	3-Mar-04	13.5
Industrial A	7-Apr-04	13.4
Industrial B	3-Mar-04	0.05
Industrial B	7-Apr-04	0.05
Industrial B	5-May-04	0.05
Industrial B	25-May-04	1.61
Industrial B	3-Jun-04	0.05
Industrial B	8-Jul-04	0.17
Industrial B	1-Sep-04	0.69
Industrial B	7-Sep-04	0.63
Industrial B	6-Oct-04	0.05
Industrial B	4-Nov-04	0.05
Industrial B	2-Dec-04	0.05

Production Well	Date	Nitrate in mg N/L
Industrial C	3-Mar-04	0.05
Industrial C	7-Apr-04	0.05
Industrial C	25-May-04	0.05
Industrial C	4-Nov-04	0.05
Industrial C	2-Dec-04	0.05
Marshall #1	3-Mar-04	0.87
Marshall #1	5-May-04	1.3
Marshall #1	3-Jun-04	0.56
Marshall #1	8-Jul-04	0.08
Marshall #1	25-Aug-04	0.06
Marshall #1	1-Sep-04	0.05
Marshall #1	7-Sep-04	0.06
Marshall #1	4-Nov-04	1.1
Marshall #1	2-Dec-04	1
Marshall #2	3-Mar-04	2.4
Marshall #2	7-Apr-04	2.6
Marshall #2	5-May-04	2.5
Marshall #2	3-Jun-04	2.4
Marshall #2	8-Jul-04	2.6
Marshall #2	1-Sep-04	2.4
Marshall #2	7-Sep-04	2.4
Marshall #2	6-Oct-04	2.5
Marshall #2	4-Nov-04	2.6
Marshall #2	2-Dec-04	2.3
Marshall #3	3-Mar-04	1.3
Marshall #3	7-Apr-04	1.9
Marshall #3	5-May-04	1.6
Marshall #3	3-Jun-04	1.6
Marshall #3	8-Jul-04	1.7
Marshall #3	25-Aug-04	1.53
Marshall #3	1-Sep-04	1.5
Marshall #3	7-Sep-04	1.6
Marshall #3	6-Oct-04	2
Marshall #3	4-Nov-04	2.1
Marshall #3	2-Dec-04	1.9
McConnell	3-Mar-04	0.4
McConnell	7-Apr-04	1.3
McConnell	5-May-04	5.1
McConnell	3-Jun-04	6.2
McConnell	8-Jul-04	5.9
McConnell	4-Nov-04	0.13
McConnell	2-Dec-04	0.13
Riverside #1	3-Mar-04	6.5
Riverside #1	7-Apr-04	5.5
Riverside #1	5-May-04	5.4
Riverside #1	25-May-04	5.44

Production Well	Date	Nitrate in mg N/L
Riverside #1	3-Jun-04	5.4
Riverside #1	8-Jul-04	4.9
Riverside #1	1-Sep-04	5.4
Riverside #1	7-Sep-04	5.5
Riverside #1	6-Oct-04	5.5
Riverside #1	4-Nov-04	5.6
Riverside #1	2-Dec-04	5.2
Riverside #2	3-Mar-04	4.8
Riverside #2	7-Apr-04	4.8
Riverside #2	5-May-04	5
Riverside #2	3-Jun-04	5.1
Riverside #2	7-Sep-04	4.8
Riverside #2	6-Oct-04	4.8
Riverside #2	4-Nov-04	5.1
Riverside #2	2-Dec-04	4.6
Townline #1	3-Mar-04	9.8
Townline #1	7-Apr-04	10.6
Townline #1	5-May-04	10.5
Townline #1	3-Jun-04	10.4
Townline #1	8-Jul-04	11.2
Townline #1	25-Aug-04	10.6
Townline #1	1-Sep-04	10.7
Townline #1	7-Sep-04	10.6
Townline #1	6-Oct-04	10.3
Townline #1	4-Nov-04	10
Townline #1	2-Dec-04	9.1
Townline #2	3-Mar-04	5.4
Townline #2	7-Apr-04	5.7
Townline #2	5-May-04	5.8
Townline #2	3-Jun-04	4.9
Townline #2	8-Jul-04	4.2
Townline #2	25-Aug-04	4.1
Townline #2	1-Sep-04	4.2
Townline #2	7-Sep-04	4.4
Townline #2	6-Oct-04	4.8
Townline #2	4-Nov-04	4.5
Townline #2	2-Dec-04	4.7
Clearbrook Lynden #7	Oct-04	1.84
Clearbrook Jantzen #4	Oct-04	1.24

Appendix I – Table A3: Nitrate Concentrations in Bertrand, Fishtrap and Lonzo Creeks.

Sample ID *(see Figure 4)*	Descriptive Location	Sample Date	Nitrate+Nitrite mg N/L
B1	Bertrand Creek at 0 Ave. crossing	2004-02-24	3.36
B2	Bertrand Creek at 8th Ave. crossing	2004-02-24	3.06
B3	Bertrand Creek at 16th Ave. crossing, 25100 block	2004-02-24	2.86
B4	Bertrand Creek at 256th St. crossing	2004-02-24	2.56
B5	Bertrand Creek at 264th St. crossing	2004-02-24	2.60
B6	Howes Creek at 16th Ave. crossing, 26900 block	2004-02-24	3.36
B6 REP		2004-02-24	3.53
B7	Bertrand Creek at 272nd St. crossing	2004-02-24	2.14
B8	Howes Creek at 272nd St. crossing, 1200 block	2004-02-24	7.06
B9	Bertrand Creek at 24th Ave. r/o/w (dam)	2004-02-24	1.13
B10	Howes Creek at Lefeuvre Road crossing	2004-02-24	4.41
B11	Howes Creek at King Road crossing, 28200 block	2004-02-24	3.75
B12	Howes Creek at Bradner Road crossing	2004-02-24	2.69
F1	Fishtrap Creek at 0 Ave. crossing	2004-02-24	4.42
F2	Fishtrap Creek at Huntingdon Road crossing	2004-02-24	3.08
F3	Waechter Creek at King Road crossing	2004-02-24	1.87
F4	Fishtrap Creek at Marshall Road crossing	2004-02-24	1.20
F5	Waechter Creek at Marshall Road crossing	2004-02-24	5.33
F6	East Fishtrap Creek at Townline Road crossing	2004-02-24	0.82
F6 REP		2004-02-24	0.82
F8	East Fishtrap Creek at Fishtrap Creek Park	2004-02-24	0.68
F9	Fishtrap Creek at Fraser Hwy crossing	2004-02-24	2.05
L1	Lonzo Creek at Sumas Way crossing, 1400 block	2004-02-24	6.57
L2	Lonzo Creek at Hwy 13 (west side of Sumas Way 1400 block)	2004-02-24	8.48
L3	Lonzo Creek at Riverside Road, 1300 block	2004-02-24	3.24
L4	Lonzo Creek at Riverside Road, 1000 block	2004-02-24	9.83
L5	Lonzo Creek at Riverside Road, 600 block	2004-02-24	8.39
L6	Lonzo Creek at Farmer Road crossing	2004-02-24	7.26
L7	Lonzo Creek at McKenzie Road crossing	2004-02-24	4.72
L7 REP		2004-02-24	4.82
L8	Lonzo Creek at Kildare Terrace crossing	2004-02-24	0.03

Appendix I – Table A4: Municipal Well Data

Identification	Completion Date	Location	Casing Diameter (centimeters)	Depth (meters)	GPM (US)	Static Level (meters)	Status
Farmer well #1*	1973	34080 Farmer Rd	45.7	43.9	1320	4.0	operational
Farmer well #2*	1977	34080 Farmer Rd	45.7	46.9	753	6.4	operational
Farmer well #3*	1982	34080 Farmer Rd	30.5	40.5	800	6.1	operational
Industrial Well A*	1992	34000 Manufactures Way	20.3	50.6	380	3.0	operational
Industrial Well B*	1993	34000 Manufactures Way	30.5	61.0	600	3.0	operational
Industrial Well C*	1994	34000 Manufactures Way	30.5	45.7	970	2.6	operational
Riverside Well #1*	1968	1201 Riverside Rd	30.5	15.2	420	7.3	operational
Riverside Well #2*	1972	1201 Riverside Rd	30.5	16.0	280	4.6	operational
McConnell Well*	1992	33899 McConnell Rd	40.6	52.7	460	9.3	operational
Pine Well*	1960	Pine St & Montrose Ave	30.5	21.3	198	11.6	Off-line in May 2003 due to diesel spill in vicinity
Townline Well #1	1975	1595 Townline Rd.	45.7	26.8	842	8.2	operational
Townline Well #2	1974	1595 Townline Rd.	25.4	18.6	477	3.7	operational
Marshall Well #1	1967	32769 Marshall Rd.	35.6	37.8	996	19.2	operational
Marshall Well #2	1958	32769 Marshall Rd.	30.5	36.0	498	18.0	operational
Marshall Well #3	1991	32769 Marshall Rd.	61.0	41.8	1244	19.8	operational
Clayburn Well		Near Pine well					Not part of municipal well network

**Information provided by CPI Equipment Ltd c/o Derrick Casey, Superintendent, FVRD, October 2005*

Appendix II – (Form B1) Questionnaire Form

Environment Canada | Environnement Canada | BC Ministry of Water, Land & Air Protection

GROUNDWATER NITRATE SURVEY (2004)

ABBOTSFORD-SUMAS AQUIFER

PROPERTY INFORMATION DATE/TIME:____________________

- SITE NUMBER / SAMPLE #: ____________________
- WELL SITE ADDRESS: ____________________
  ____
- WELL OWNER'S NAME: ____________________
- HOME PHONE: ____________ FAX / EMAIL: ____________________
- GPS SITE READING FOR WELL (NAD83 datum preferred)
  N ____________ W ____________ Datum____________

WELL / DISTRIBUTION SYSTEM CHARACTERISTICS

- WELL TYPE: Drilled __________ Shallow __________
- WELL DEPTH __________ WATER DEPTH __________
- ELEVATION OF WELL ____________________(surveyed/estimate circle one)
- AGE OF WELL: __________
- WHO DRILLED THE ORIGINAL WELL? ____________________
- HAS THE WELL BEEN DEEPENED? __________
  If Yes: When? __________
  How much deeper? __________
  Who deepened the well? __________
- WHAT TYPE OF PIPING IS USED: a) from the well to the house? ____________
  b) in the house? ____________________
- IS THERE A PRESSURE TANK ON THE DISTRIBUTION SYSTEM? __________
  If yes, what is its storage capacity? ____________________
- ARE THERE OTHER WELLS IN USE ON THE PROPERTY? ____________
- ARE THERE ANY ABANDONED WELLS ON THE PROPERTY? ____________

- WELL OWNER'S WATER QUALITY OBSERVATIONS:
  - Taste: ____
  - Odour: ____
  - Colour: ____
  - Other: ____

WATER TREATMENT

- IS THE WELL WATER TREATED OR UNTREATED? ____________________

  If treated, specify which type(s):
  - ☐ µv filter
  - ☐ sand filter
  - ☐ chlorine
  - ☐ other (specify, ________________________________)

- WHEN WAS THE WELL LAST DISINFECTED? ______________________
- WHEN WAS THE LAST COLIFORM ANALYSIS? _________ TC Result? _________
  FC Result? _________
- WHEN WAS THE LAST CHEMICAL ANALYSIS? _________ Nitrate level? ________

LAND USE ACTIVITIES (All land use activities must be identified on the site map drawing)

- ARE THERE ANY LAND USE ACTIVITES OCCURRING ON THE PROPERTY? Y/N

  If yes, check (✓) all that apply:
  - ☐ Manure piles
  - ☐ Farming
  - ☐ Raising livestock
  - ☐ Hobby farms (specify type and number of animals _______________)
  - ☐ Septic system
  - ☐ Fertilizer use (describe type of fertilizer ____________________)
  - ☐ Other (specify ________________________________)

- WHAT IS THE WATER USED FOR AND WHAT IS THE AVERAGE DAILY VOLUME OF WATER USED? **(fill in chart)**

WATER USE (Circle Yes or No)	AVERAGE DAILY USE
Domestic (Yes/No)	# of people _________
Irrigation (Yes/No)	Gallons per day used _________
Stock watering (Yes/No)	Gallons per day used _________
Other (Yes/No) (specify_______________)	Gallons per day used _________

Note: If the water usage is domestic only, record the number of people using the well.
If the use is non-domestic, record the usage in gallons per day (gpd).
If the water is used for a mixture of purposes, record the best estimate in gpd.

WELL PROTECTION

- IS THE WELL COVERED? __________ IS THE WELL HEAD SEALED? _______
- IS THE WELL HEAD PROTECTED SO NO VERMIN CAN ENTER? ________________
- IS THERE STANDING WATER AROUND THE WELL? __________________________
- IS THE ELECTRICAL /PLUMBING LINE ENTRANCE TO THE WELL SEALED? ______
- ADDITIONAL COMMENTS / OBSERVATIONS:

____

____

____

SAMPLING DETAILS

- DESCRIBE LOCATION OF WELL

  ____

- DESCRIBE LOCATION WHERE SAMPLE WAS COLLECTED (i.e. outside tap, kitchen tap etc.)

  ____

- WAS THE SAMPLE TAP IN GOOD CONDITION? (If no, provide details) Yes/No

  ____

- DESCRIBE SAMPLING TECNIQUHE (Check (✓) all that apply)

  - ☐ Tap was disinfected with an alcohol swab
  - ☐ Water was flushed for 2 minutes
  - ☐ Samples were stored in a cooler during transport
  - ☐ Other (specify ____________________________)

Additional Comments and/or Observations:

____

____

____

____

____

SITE VISIT BY: ______________________________________

and ______________________________________

MAP OF AREA

The following information must be provided on the site map:

1. Location of:
   - ☑ House
   - ☑ Well
   - ☑ Barn(s)
   - ☑ Manure piles
   - ☑ Fertilizer use
   - ☑ Septic system
   - ☑ Livestock / Farm animals
   - ☑ Any other potential source of well contamination

2. All distances MUST be paced out and estimated in feet from the well.
3. Arrow pointing NORTH

Appendix III - The Drinking Water Protection Act, Part 5 – Drinking Water Protection Plans

which states:

"Order designating area for planning process

31 (1) The minister may, by order made on the recommendation of the Provincial health officer, designate an area for the purpose of developing a drinking water protection plan for the area.

(2) The Provincial health officer may only recommend that an order be made under this section if

(a) based on monitoring or assessment results, the Provincial health officer is satisfied that a drinking water protection plan will assist in addressing or preventing a threat to drinking water that the Provincial health officer considers may result in a drinking water health hazard, and

(b) no other practicable measures available under this Act are sufficient to address or prevent the drinking water health hazard.

(3) The Provincial health officer must consider whether to make a recommendation under this section if requested by a drinking water officer.

(4) A local authority or water supplier may request a drinking water officer to make a request under subsection (3)."

- Review the Farm Practices Protection (Right to Farm) Act with MAFF to ensure "normal farm practice"is not compromising the Abbotsford/Summas Aquifer. Under the act normal farm practice is defined:

"normal farm practice" means a practice that is conducted by a farm business in a manner consistent with

(a) proper and accepted customs and standards as established and followed by similar farm businesses under similar circumstances, and

(b) any standards prescribed by the Lieutenant Governor in Council,

and includes a practice that makes use of innovative technology in a manner consistent with proper advanced farm management practices and with any standards prescribed under paragraph (b)."

Power to make regulations

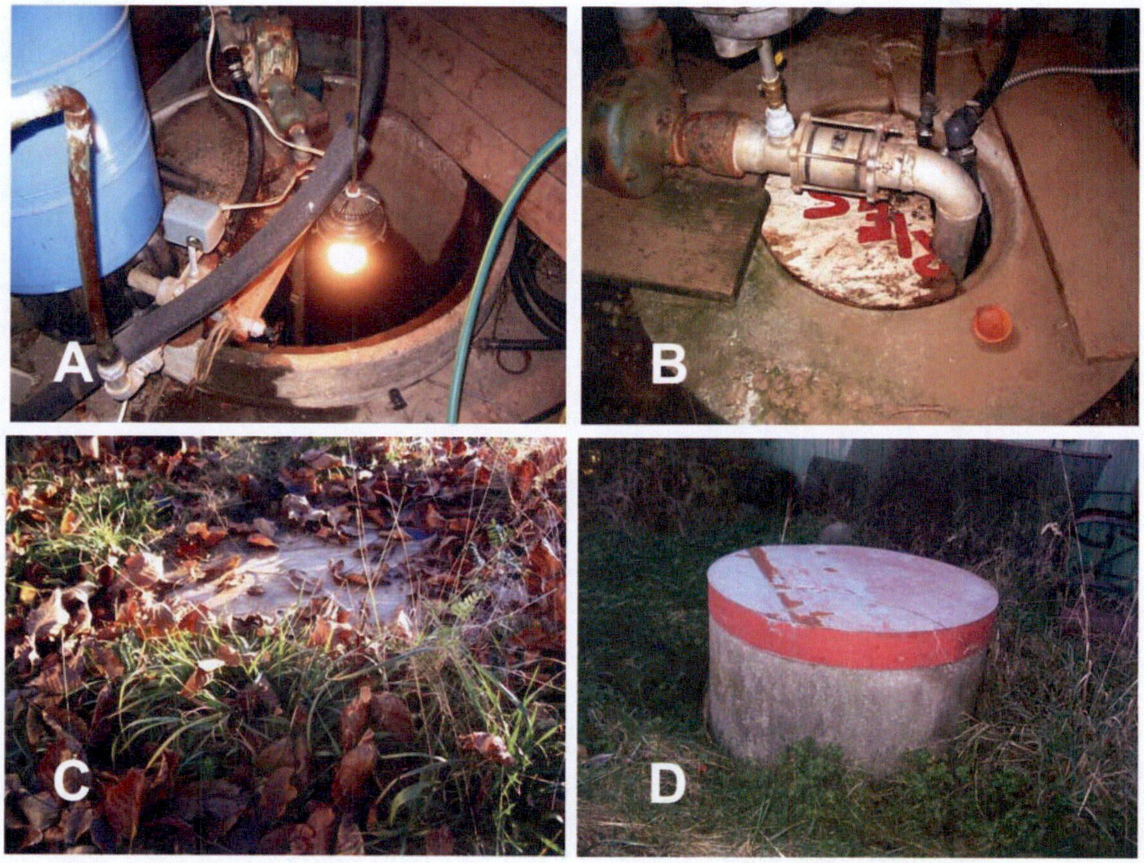
12 (1) The Lieutenant Governor in Council may make regulations referred to in section 41 of the *Interpretation Act.*

(2) Without limiting the generality of subsection (1), the Lieutenant Governor in Council may make regulations as follows:

(a) prescribing fees payable in respect of an application made under section 3;

(b) respecting standards for the purpose of the definition of "normal farm practice";

Appendix IV – Photos of dug wells in the Abbotsford Aquifer showing improper and proper well head seals.



A - Improper well head seal permitting entrance of insects and rodents

B - Well cap located within 4 inches of ground surface subject to flooding

C - Wooden cover on top of shallow well not suitable in protecting drinking water

D - Proper riser and cover for shallow well