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Sumas-Blaine Aquifer
Nitrate Contamination Summary

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Sumas-Blaine Aquifer Nitrate Contamination Summary

by

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Abstract

The Sumas-Blaine Aquifer in northwestern Whatcom County, Washington is the major drinking water source for 18,000 to 27,000 local residents. The aquifer is the southern (U.S.) portion of the transboundary Abbotsford-Sumas Aquifer.

Based on water quality studies conducted by the Washington State Department of Ecology (Ecology) and the U.S. Geological Survey over the past 30 years, 29% of sampled wells in the aquifer exceeded the nitrate maximum contaminant level (MCL) of 10 mg/L-nitrogen (N). A total of 14% of wells had concentrations more than double the MCL. Groundwater from 36% of shallow wells (less than 40 feet deep) exceeded the MCL. About 20% of the deeper wells exceeded the MCL. The highest documented nitrate concentration in a domestic drinking water well is 73 mg/L-N.

The purpose of this report was to summarize the available data on nitrate in the Sumas-Blaine Aquifer, physical characteristics that make the aquifer vulnerable to nitrate contamination, and major sources of nitrate to the aquifer.

The Sumas-Blaine Aquifer is highly vulnerable to nitrate contamination due to several factors including:

1. Shallow depth to water (less than 10 feet in most areas).
2. The aquifer's limited thickness (mostly less than 50 feet).
3. Intensive agricultural production (97% of the estimated annual nitrogen load to the ground overlying the aquifer).
4. Heavy rainfall during the non-growing season that carries unused nitrate to the water table.

In addition to aquifer-wide studies, intensive field investigations by Ecology in the Sumas-Blaine Aquifer are summarized. Two studies indicate that the amount and timing of manure applied to a grass crop greatly affected underlying groundwater nitrate concentrations. In years when the amount of nitrogen applied exceeded the amount removed, groundwater nitrate concentrations exceeded the MCL by a factor of 2 to 3. Groundwater nitrate concentrations were closer to the MCL (better) in winters when the amount of nitrogen applied to the grass crop the previous growing season was close to the amount removed in the grass crop.

Although groundwater data are not available for all areas where dairies and berries are prevalent, high nitrate concentrations occurred beneath and downgradient of both major land use areas.

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Introduction

The Sumas-Blaine Aquifer (SBA) covers about 150 square miles of mostly rural, low-lying farmland in northwest Whatcom County, Washington (Figure 1). The aquifer is the exclusive source of drinking water for 18,000 to 27,000 area residents (*1*). The SBA is part of the larger Abbotsford-Sumas Aquifer that straddles the U.S.-Canada border (Figure 1).

Widespread nitrate contamination has been documented in groundwater over large areas of the SBA for over 40 years (*3*-*13*). Past sampling by the Washington State Department of Ecology (Ecology) and others suggests that the aquifer has some of the most widespread and elevated groundwater nitrate concentrations in Washington State. The SBA nitrate problem is severe enough that several public water supply wells near the City of Lynden were taken off line in recent years, leaving 1,200 people without a potable water supply (*14*).

The USGS and Ecology have conducted regional studies of nitrate in the SBA for 30 years. These studies indicate that nitrate concentrations continue to be affected by overlying land use and jeopardize use of the aquifer for drinking water. Ecology currently conducts annual nitrate sampling at 25 private wells in the SBA.

Highlights of past studies include an aquifer-wide survey of 248 private domestic wells in 1997 which found that 21% of wells had nitrate concentrations exceeding the maximum contaminant level (MCL) of 10 mg/L-nitrogen (N) (Chapter 246-290 WAC, *8*). Follow-up monitoring in areas where nitrate concentrations were elevated in 1997 indicated that 50 to 70% of wells in those areas exceeded the MCL in 1999 and 2003 to 2005 (*7*, *12*).

Ecology has also conducted small-scale groundwater investigations over the past 15 years to observe the effects of typical management practices such as application of manure to crops and lagoon storage of manure.

Agriculture is the predominant land use over the SBA. Dairy farming has been the predominant agricultural activity over the SBA for the past 50 years with raspberry and other berry production becoming more widespread in the past 20 years. A small percentage of the land is residential, with the cities of Lynden, Nooksack, and Everson overlying the aquifer (*6*).

This report is a primer for readers wanting a brief summary of groundwater nitrate contamination affecting the SBA. The objectives of this report are to:

- Summarize historic groundwater quality information and results of intensive investigations.
- Describe the characteristics of the aquifer that make it vulnerable to contamination.
- Describe the major contamination sources with regard to land use.
- Provide general recommendations for future actions to monitor and improve water quality.

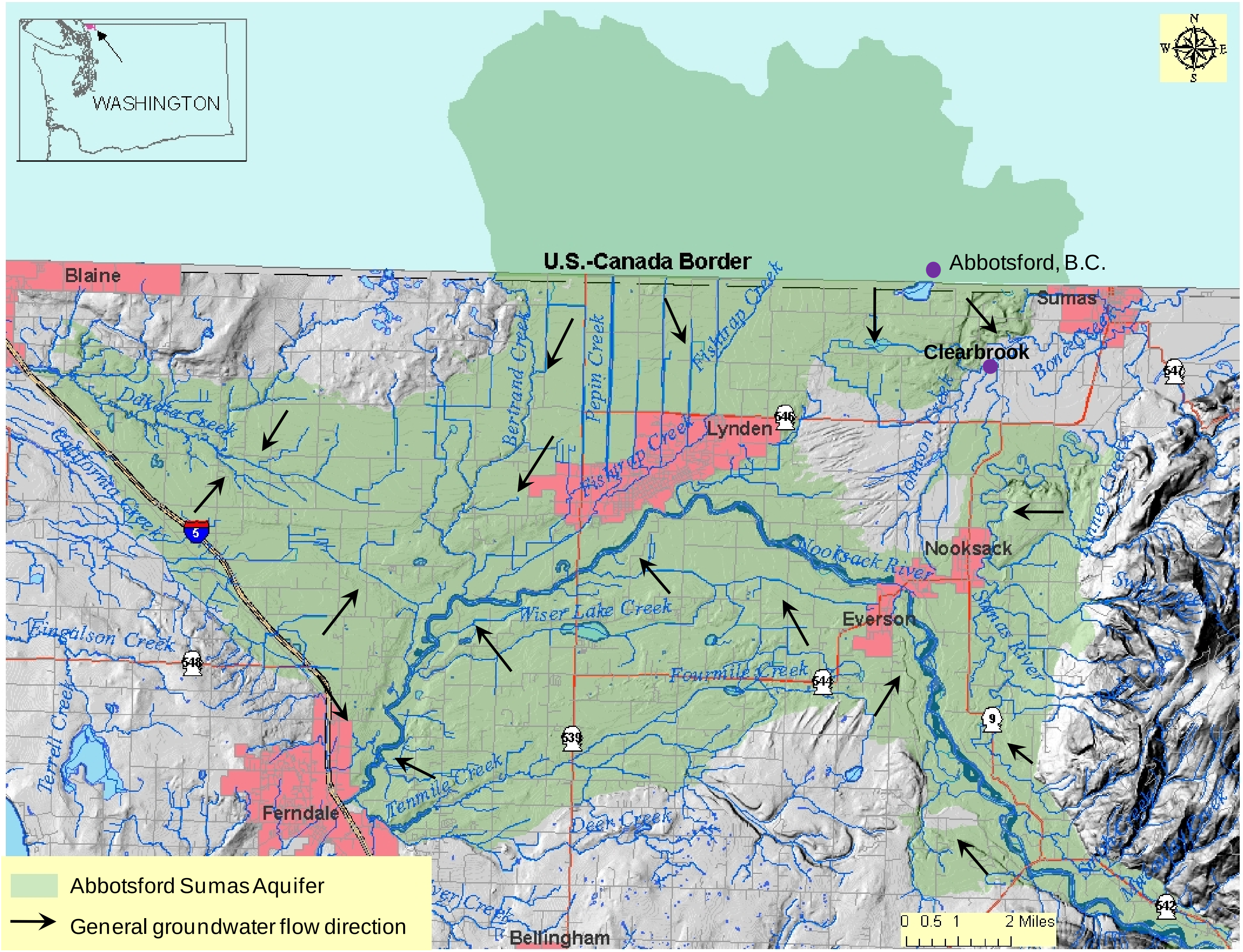

Figure 1. Location of the Sumas-Blaine Aquifer, the portion of the Abbotsford-Sumas Aquifer in northwest Washington (*2*).

Groundwater Nitrate Data Analysis

Historical data for nitrate concentrations were used to evaluate spatial and temporal relationships in the SBA. Data from Ecology and USGS studies available from agency databases between 1981 and 2010 were used (EIM for Ecology data and NWIS for USGS data). Appendix B lists the procedures used to ensure that data used were of adequate quality for the analysis.

Aquifer-wide spatial patterns

The maximum nitrate concentrations observed in 515 wells sampled over the past 30 years are mapped in Figure 2. For the majority of wells, only one measurement was available.

Nitrate concentrations in 29% of the wells shown in Figure 2 were 10 mg/L-N or greater. In 14% of the wells, nitrate exceeded 20 mg/L-N. The highest nitrate value in a private domestic well was 73 mg/L-N.

Depth

Well depths ranged from 9 to 92 feet deep, but depths were not known for 18 wells. Of the wells with reported depths, 80% are less than 40 feet deep and referred to here as shallow. Maximum nitrate concentrations exceeded 10 mg/L-N in 36% of shallow wells shown in Figure 3. Nitrate exceeded 20 mg/L-N in 17% of shallow wells.

A total of 20% of the 60 deep wells (40 feet deep and greater) had maximum nitrate concentrations above 10 mg/L-N; in 5% of the deep wells, nitrate exceeded 20 mg/L-N (Figure 4). Although spatial coverage for the deeper depths was relatively sparse, the high percentage of wells with elevated nitrate indicates that contamination may be affecting much of the aquifer volume.

Because groundwater typically moves more quickly in the horizontal direction than in the vertical direction, impacts on groundwater from activities at the surface usually show up first at the shallowest depths. In addition, elevated concentrations of contaminants at deeper depths may be due to land use practices that occurred at some distance upgradient and probably at some time in the near or distant past.

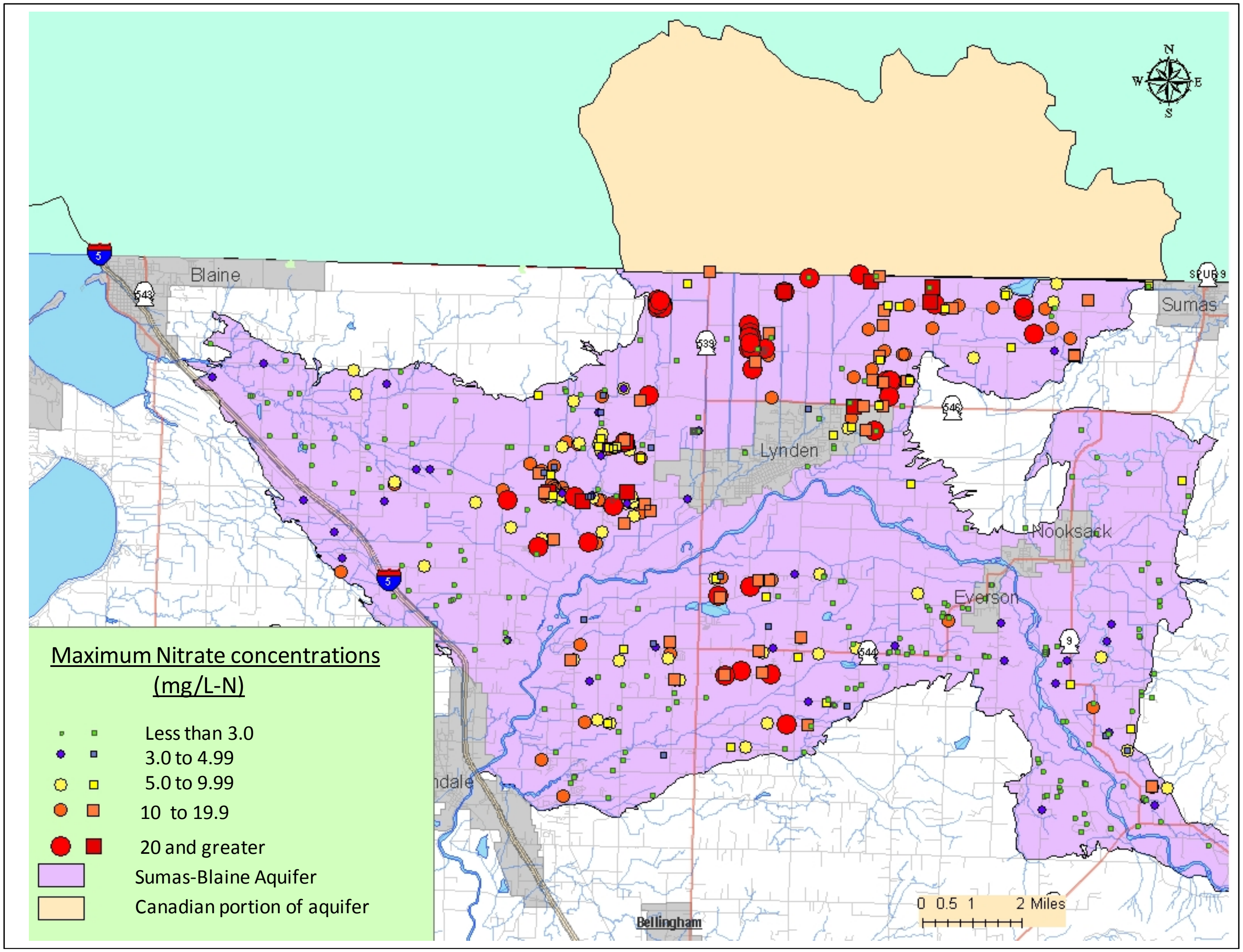

Figure 2. Maximum nitrate-N concentrations in wells sampled by Ecology and USGS between 1981 and 2008.

Circles represent Ecology data (335 wells); squares represent USGS data (216 wells). Data are listed in Appendix C. Ecology data are also available at www.ecy.wa.gov/eim/. USGS data are available at http://waterdata.usgs.gov/wa/nwis/nwis/.

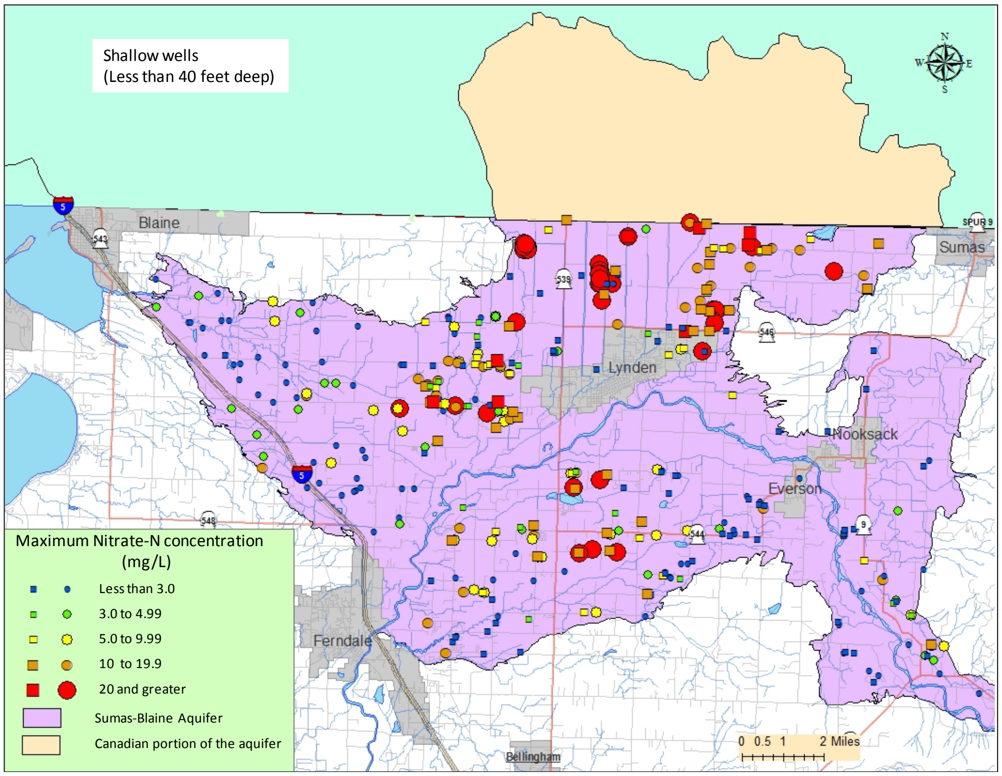

Figure 3. Nitrate-N concentrations in wells less than 40 feet deep.
Squares represent wells sampled by the USGS; circles by Ecology.

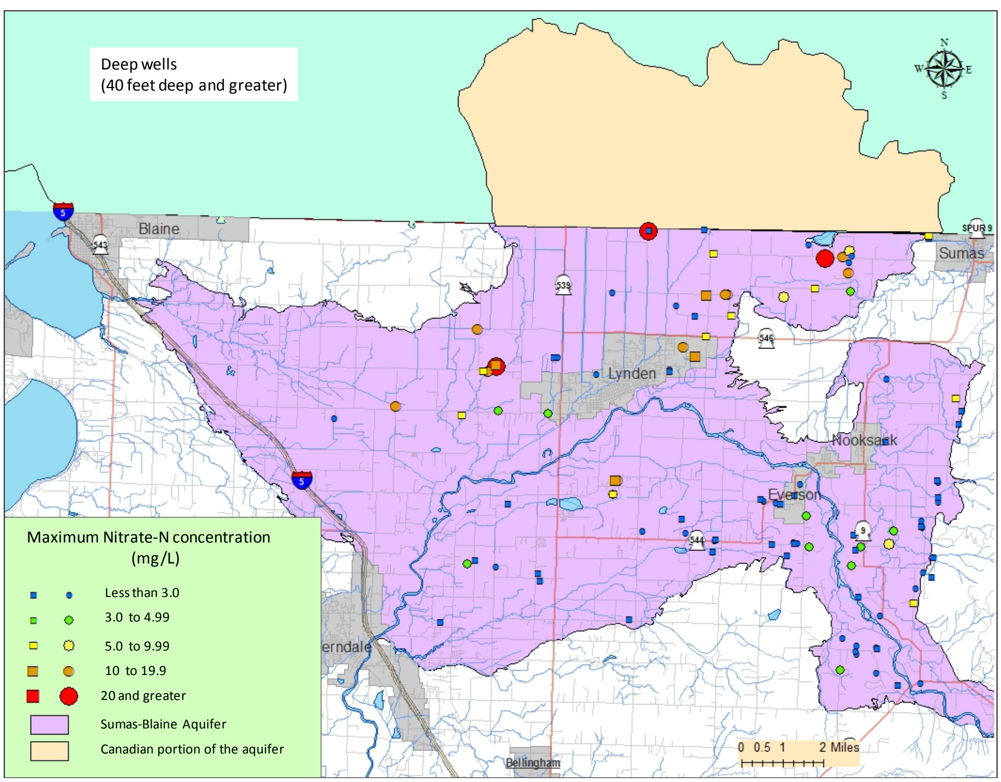

Figure 4. Nitrate-N concentrations in wells 40 feet deep and greater.
Squares represent wells sampled by the USGS; circles by Ecology.

Aquifer-wide patterns over time

Figure 5 shows nitrate concentrations for a subset of 11 wells with long-term records. The highest nitrate concentration in wells with long-term records was 53 mg/L-N in a 29-foot deep well (Well G, Figure 5). Shallow wells tended to have the highest nitrate concentrations (G and I); however, two wells greater than 40 feet deep (Wells E and K) also consistently exceeded 10 mg/L-N. The tendency for higher nitrate concentrations in shallow wells has been found around the U.S. (*22, 23*).

Several wells with long-term nitrate records have concentrations that vary seasonally or over time (Wells A, B, C, F, H, and I), while other wells have fairly stable concentrations (Wells D, E, and K). Changes in upgradient land use (including change in crop, nutrient application rate, and nutrient application method) as well as weather-related crop uptake of nitrogen and recharge can all influence year-to-year and seasonal nitrate variation (*21-32*).

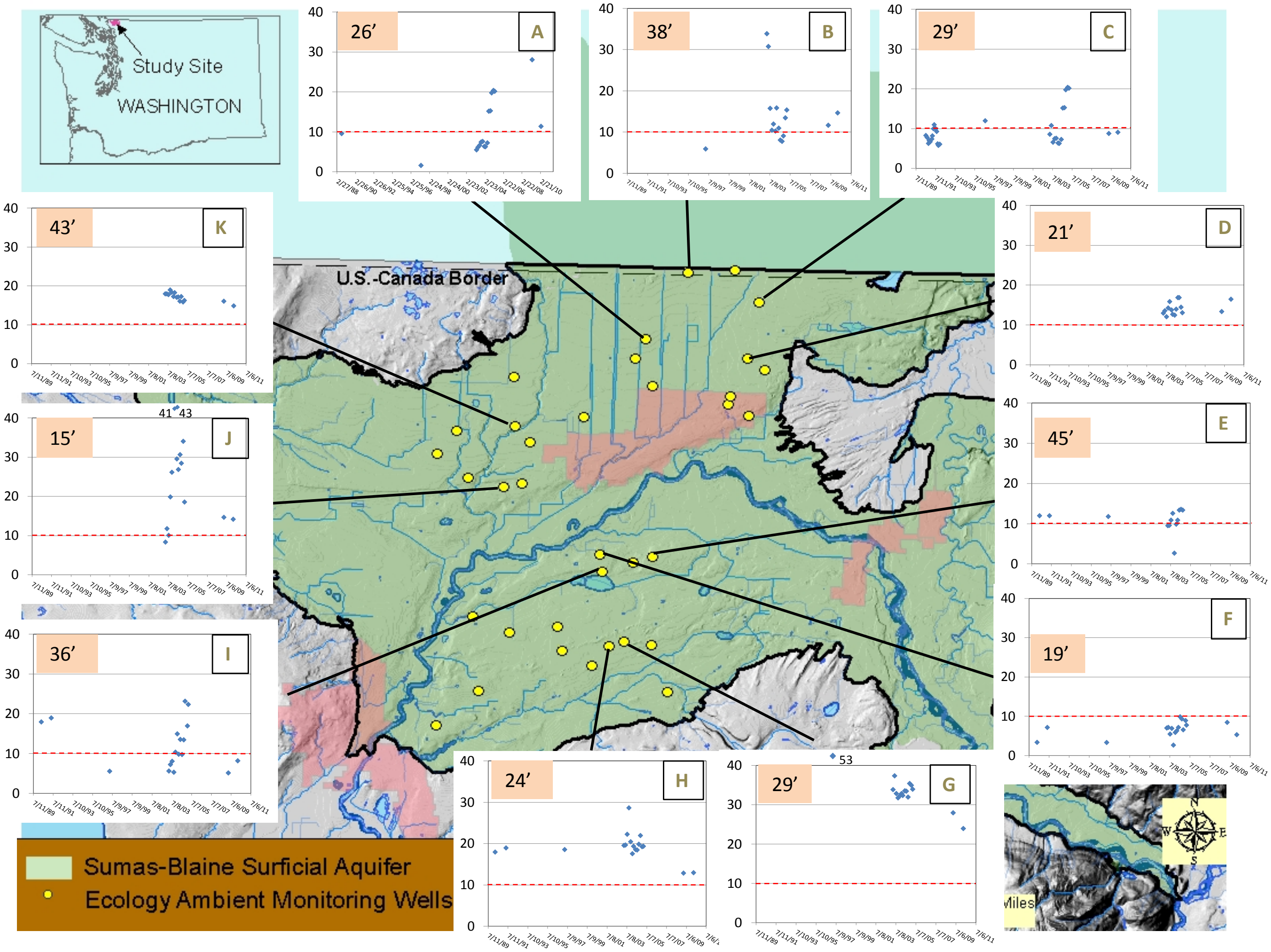

Figure 5. Representative graphs of nitrate concentrations in drinking water wells (mg/L-N) with long-term records.

Yellow dots represent wells monitored since 2003 as part of Ecology's SBA ambient monitoring program (12, 13). Results from previous studies by the USGS (6) and Ecology (4, 8) at several wells are also included. Well depths are shown in the upper left corner of each graph.
Ecology data are available at www.ecy.wa.gov/eim/; USGS data at http://waterdata.usgs.gov/wa/nwis/nwis/.

Intensive Study Findings

Ecology has conducted a number of targeted field studies to better understand the potential sources and mechanisms that contribute excess nitrate loads to the SBA. These studies relate land application of manure and leaking manure lagoons to groundwater quality.

Nitrogen balance study

A study of nitrogen inputs to and outputs from a manured grass field over the SBA was conducted from 2004 through 2008 (*19, 33*). The draft preliminary findings include:

- Average winter nitrate concentrations in groundwater near the top of the water table beneath the field were 11 to 13 mg/L-N when nitrogen inputs were similar to nitrogen outputs. However, average shallow winter groundwater nitrate-N concentrations were 17 to 24 mg/L when nitrogen inputs exceeded outputs.
- Timing of manure application affected nitrate concentrations in:
    - Fall: Application in October, just prior to the heavy rainfall season, was followed by an increase in shallow groundwater nitrate of up to 18 mg/L-N.
    - January through March: Continued high potential for nitrate leaching due to high water table and recharge that can carry nitrate below the root zone.

2002 land application of manure study

Beneath a manured grass field with higher than recommended manure application, the median winter groundwater nitrate concentrations near the top of the water table were 27 to 31 mg/L-N. Nitrate reached 74 mg/L-N in shallow groundwater beneath this field. At the field with close to the recommended application rate, the median nitrate concentration in shallow groundwater was 10 mg/L-N (*9*).

Lagoon studies

Leakage to groundwater was found at two manure storage lagoon systems from 1990 to 1993 (*34-36*). Leakage impacted nearby long-term groundwater quality, including ammonia, but not nitrate. Decreases in ammonium in groundwater over time and lack of nitrate increases were attributed to adsorption, biological and chemical degradation, and dispersion.

Studies of lagoon and wastewater ammonium plume movement indicate that large amounts of ammonium can be stored in shallow aquifers by adsorption (*37, 38*). Redox conditions often determine whether ammonium converts to nitrogen gas (denitrification) or mineralizes to nitrate (nitrification). Nitrification is generally restricted to the margins of an ammonium plume where oxygen is present (*37*). Recharge and pumping play a key role in redox conditions and thereby the fate of ammonium leached from lagoons (*38*).

Vulnerability Analysis

Reasons for widespread nitrate contamination in the SBA are related to the aquifer's vulnerability. Aquifer vulnerability consists of two aspects (*39*):

- Susceptibility due to natural characteristics such as hydrogeology, climate, and soils.
- Activities that together with susceptibility present a high likelihood of contamination.

Erwin and Tesoriero (*40*) found that the Lower Nooksack Valley (including the SBA) had a very high vulnerability for nitrate contamination compared to most of the Puget Sound area due to the shallow depth to water and high density of agricultural land use. They found a 50% probability that nitrate in public drinking water wells was 3 mg/L-N or greater.

The main local factors that contribute to the SBA's susceptibility to contamination include:

- Hydrogeology
- Climate and recharge

Hydrogeology

The SBA lies in the Fraser-Whatcom Lowlands, a glacial outwash plain. Outwash from the last glacial episode left gravel and cobble deposits near the Canadian border. These deposits grade finer southward to sand and some clay layers in the Lynden area as well as peat bogs and layers in many areas (*41*).

In more recent times, the Nooksack and Sumas rivers have eroded the glacial deposits, resulting in the current flat terrace flood plain. The principal hydrogeologic units in the area are shown in Figure 6 and include:

- Sumas-Blaine Aquifer (SBA)
- Everson-Vashon Semiconfining Unit
- Bedrock

The SBA consists of stratified sand and gravel outwash with minor clay and peat lenses (*6*, *41*). Groundwater flows predominantly toward the Nooksack River, from north to south (Canada to the U.S.) in the northern part of the aquifer and south to north in the southern part (Figures 1 and 6).

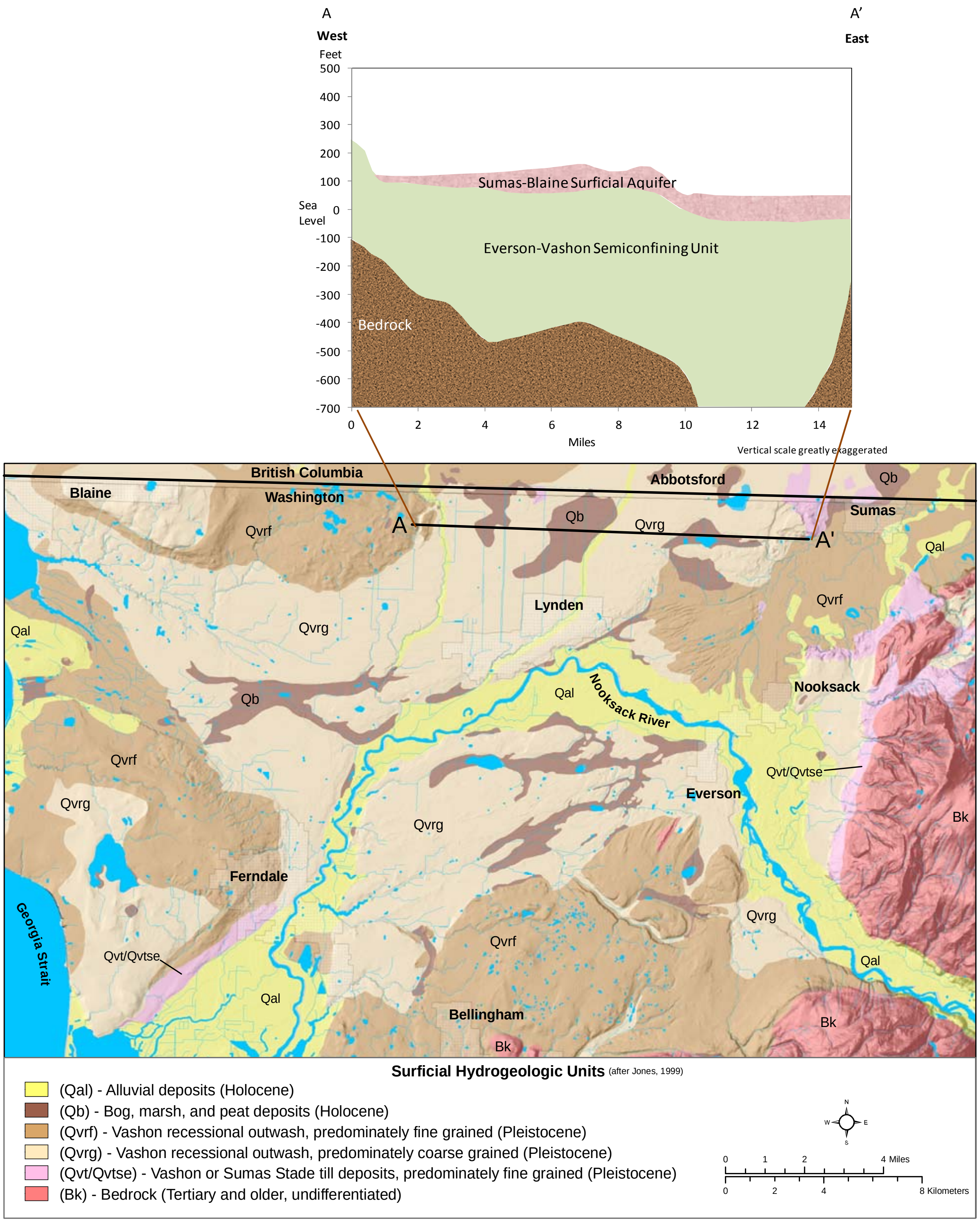

Figure 6. Surficial hydrogeology of the Sumas-Blaine Aquifer (from *41*, *42*) and cross-section A-A’ showing the principal aquifer units (from *6*).

The depth to groundwater is less than 10 feet across most of the SBA, making it highly susceptible to contamination from activities on the land surface (Figure 7). During the winter months (October through March), heavy precipitation carries nitrate left over in the soil to the water table which in many areas rises close to the land surface (*6*). Once nitrate reaches the water table, it moves slowly and mainly in a horizontal direction. A system of ditches and tile drains helps to control high water table conditions in many areas of the SBA and prevents some nitrate-laden water from reaching groundwater in the winter (*6*).

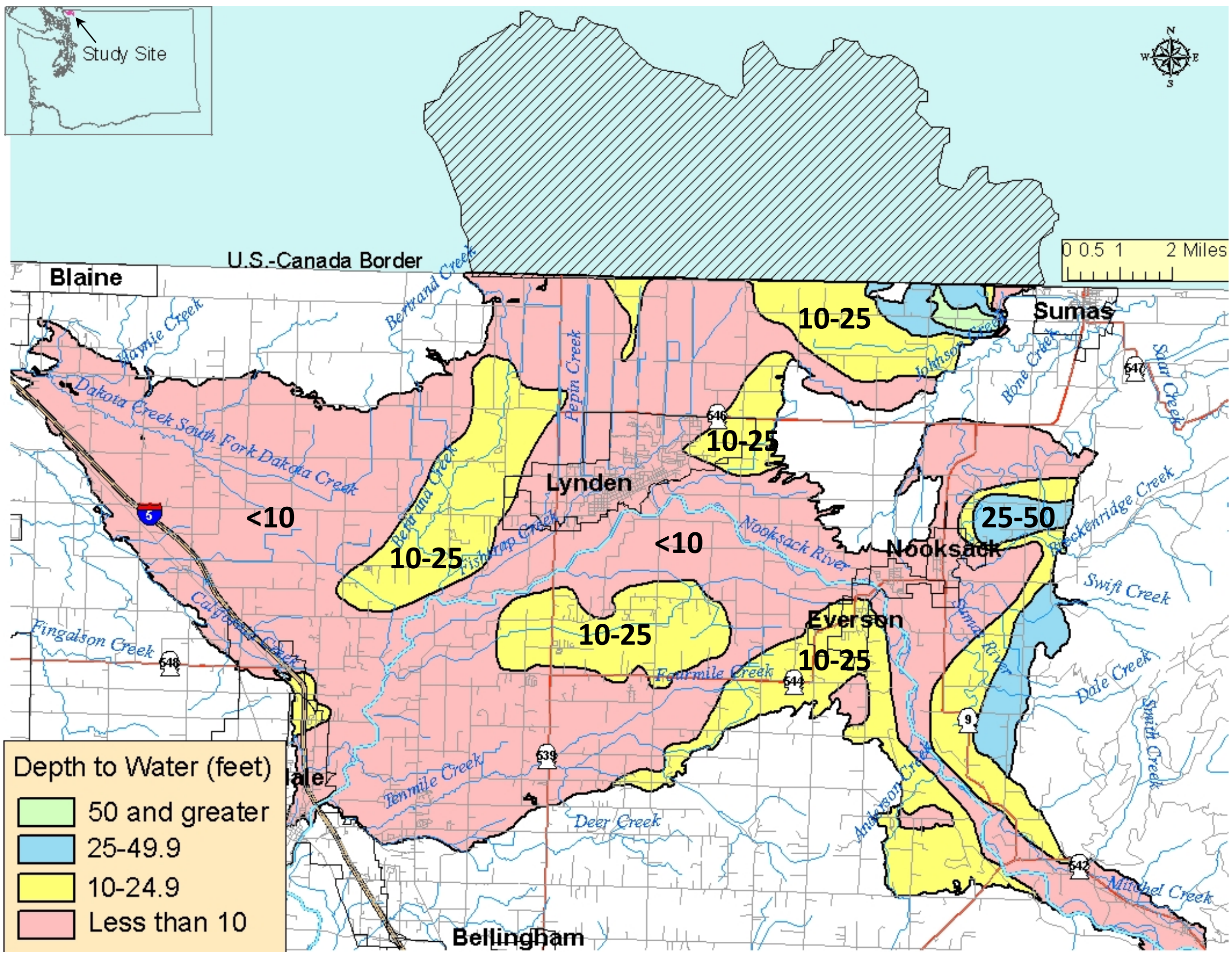

Figure 7. Depth to water in the Sumas-Blaine Aquifer in feet below ground surface based on drilling logs (*2*).

In addition to shallow depth, the SBA is susceptible due to its limited thickness. The aquifer ranges from 75 feet thick near Sumas to 25 feet thick near Blaine. Most of the aquifer is less than 50 feet thick (Figure 8). Low quality and quantity of occasional water-bearing zones in the underlying Everson-Vashon Semiconfining Layer prevent this deeper unit from providing significant usable water (Figure 6).

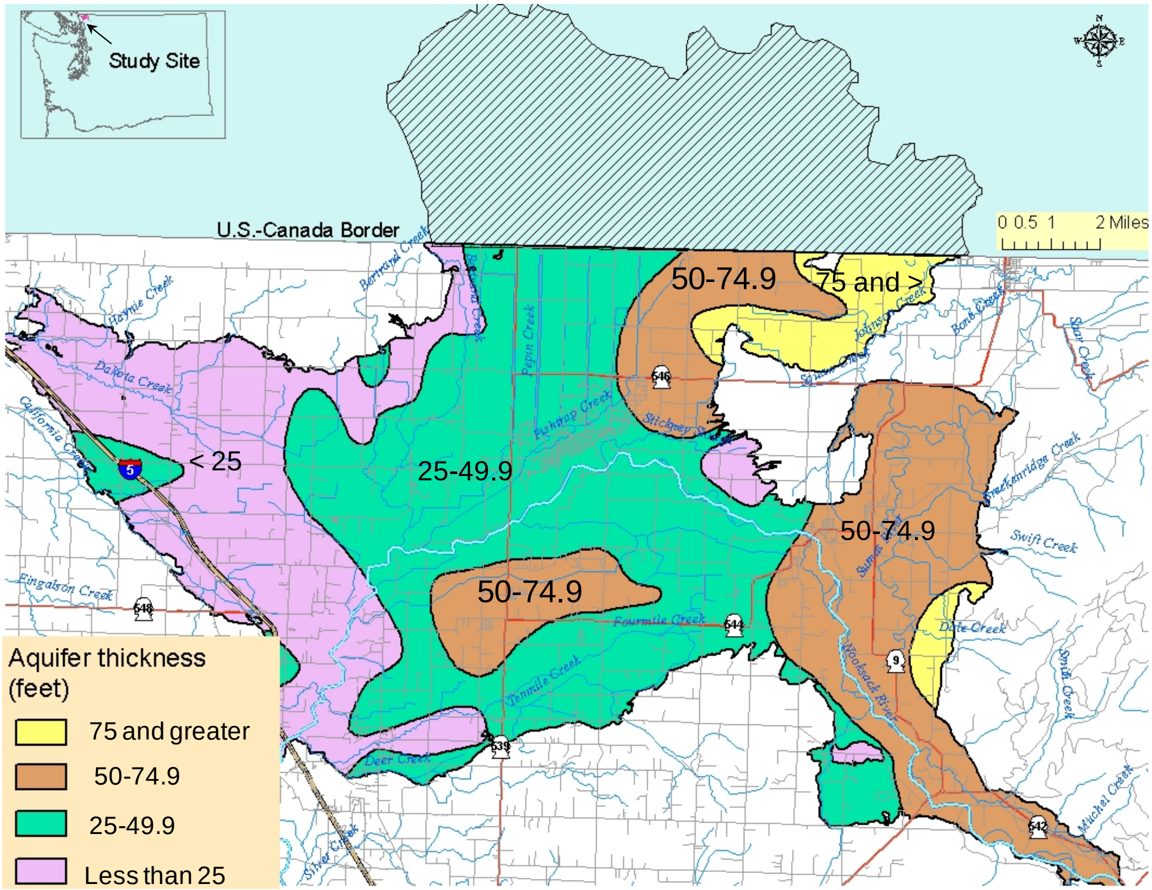

Figure 8. Thickness of the Sumas-Blaine Aquifer in feet based on drilling logs (*2*).

Climate and recharge

Annual precipitation over the SBA ranges from 32 inches near the southwest corner of the aquifer to 50 inches on the eastern edge. The average annual precipitation at Clearbrook, Washington (Figure 1) is 46 inches for the period of 1970 to 2010 (*43*). Over the past 40 years, 67% of rainfall in Clearbrook, Washington fell between October and March, when crop uptake is lowest (*43*).

The generally low rainfall intensity and flat topography allow much of the precipitation that occurs during the non-growing season to move through the soil and into the groundwater or tile drain system (*6*).

The average annual estimated groundwater recharge over the aquifer is 16 to 30 inches (6). During warm, dry summers, evapotranspiration is about twice the amount of precipitation, and little water moves below the soil zone.

Land use and nitrogen loading

Until recently, Whatcom County had more dairy cows than any other county in Washington. The number of milking cows decreased from 67,000 in 1997 to 41,000 in 2010, although the density of dairy cows increased due to land use shifts (*15*, *16*, *44*). Whatcom County is also the leading producer of raspberries in the U.S (*17*).

Nitrogen is added to the SBA each year from several sources including agriculture, atmospheric deposition, and on-site sewage systems. A rough estimate of the relative contributions of nitrogen from these sources is shown in Figure 9 (details in Appendix D). These estimates do not account for nitrogen lost due to volatilization, crop uptake, denitrification, or flow to tile drains.

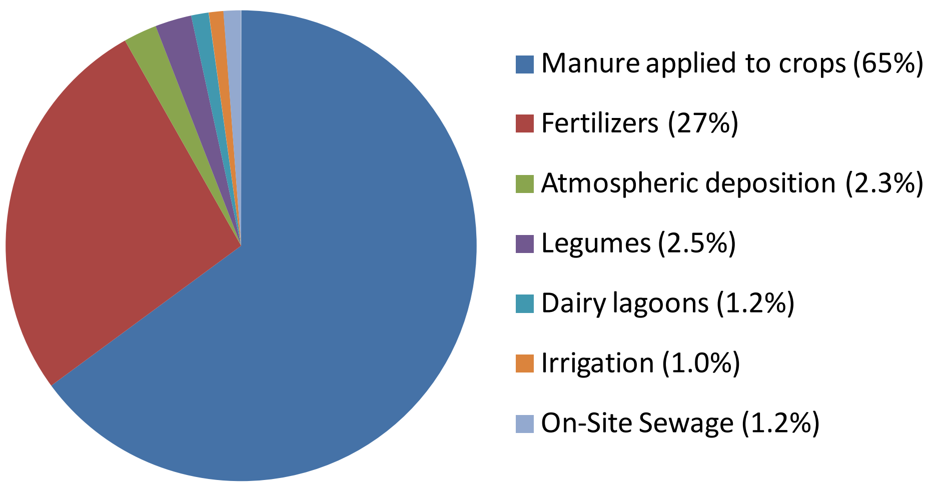

Figure 9. Distribution of estimated annual nitrogen inputs to the land and subsurface of the SBA (*16*, *45*, *46*).

Most of the nitrogen added to the ground overlying the SBA is from agriculture (97%). Within the agriculture category, roughly two-thirds of the nitrogen applied over the SBA is from manure applied to crops, while one-third is from inorganic fertilizer. On-site sewage systems account for 1% of the nitrogen added to land overlying the SBA. Atmospheric deposition makes up about 2% of the loading. The individual sources of nitrogen and assumptions made for the estimates are described below.

Manure applied to crops

The estimate of nitrogen applied to crops from manure is based on (1) the number of cows in Whatcom County in 2010, including milking and dry cows, heifers, and calves (*16*) and (2) the map locations of licensed dairies. The total number of cows at dairies with addresses over the SBA in 2010 was 40,834. This may be a conservative estimate, because dairies with addresses near the border of the SBA were not included but may apply manure to fields over the aquifer.

Between 10 and 12 million pounds of manure-derived nitrogen are applied to crops over the SBA annually, assuming 20 to 35% processing loss (*16, 47*). This equates to 64 to 68% of the total annual load of nitrogen applied the ground overlying the aquifer.
Manure applied to crops, mainly grass and corn, is in the forms of ammonium and organic nitrogen. Although not considered in the source inventory, some of the manure ammonium volatilizes after it is applied to the crop. The amount of nitrogen volatilized depends on the method of application and weather conditions.

Ammonium is rapidly converted to nitrate by bacteria when the temperature is above 5°C, and the nitrate is then available for crop uptake. A portion of the organic nitrogen also mineralizes each year to ammonium and then to nitrate.

Nitrate is very soluble in water and does not adhere to soil particles. This makes it very susceptible to leaching loss during the rainy months, October through March. Crop uptake is the main mechanism for nitrate removal in the SBA (*30*). A lesser amount of nitrate can be lost due to microbial conversion of nitrate to nitrogen gas (denitrification) depending on local redox conditions (*48*).

Fertilizers

The estimate of nitrogen applied as inorganic fertilizer to the SBA is based on acreage estimates for various crops and application rates for each crop including lawns and manured fields (*46*). The total estimate of nitrogen applied as inorganic fertilizer is 4.6 million pounds per year, or 25 to 29% of the annual total.

Raspberries, the largest crop over the SBA that receives mainly inorganic fertilizer, cover roughly 7,000 acres (*17*). Chesnaux et al. (*49*) and Hirsch (*50*) found that spring rainfall can move inorganic nitrate fertilizer from the root zone of berries to the water table.

Legumes

Clover is a common component of pasture lands in the SBA. Clover can fix nitrogen from the air and is assumed to contribute 5 pounds per acre of nitrogen (*46*). The estimated annual nitrogen contribution from legumes over the SBA is 428,000 pounds, 2.5% of the total.

Dairy lagoons

The estimate of nitrogen from dairy lagoons assumes that 110 dairies with addresses over the SBA have a lagoon with the same assumptions used in Cox and Kahle (*6*): an average surface area of 30,000 square feet that leaks 1 mm/day and has an ammonia concentration of 840 mg/L. These assumptions result in the following estimate for lagoon leakage:

$$(110\ \text{dairies})\ \text{x}\ (1{,}880\ \text{lb N leached/dairy-year}) = 206{,}800\ \text{lb N/year}$$

Although the total estimate for lagoon leakage, 206,800 lb N/year, is a small percentage of the total input of nitrogen to the land overlying the entire aquifer (1.2%), lagoons may have significant localized impacts on groundwater nitrate depending on how they are constructed and managed.

Atmospheric deposition

The estimated total of wet and dry atmospheric nitrate deposition was 380,000 pounds, or 2.2% of the total amount reaching the land surface annually (*46*).

On-site sewage systems

The up to 23,000 people living on the SBA outside sewered areas were assumed to contribute to the nitrogen estimate from on-site sewage systems (*1*). Each person was assumed to contribute 9 pounds of nitrogen per year (*51*). The total amount of nitrogen contributed annually by on-site sewage systems was 270,000 pounds, or 1.2% of the total.

Discussion

Information from regional and site-specific nitrate studies in the SBA between 1980 and 2010 were compiled and analyzed. Regional monitoring studies revealed that 29% of 515 private wells have exceeded the nitrate MCL, and 14% of the total have had nitrate concentrations at least double the MCL.

Shallow depth to water and limited thickness of the SBA make the aquifer especially vulnerable to contamination from overlying land use. Agriculture contributes 97% of the nitrogen inputs to the ground overlying the aquifer. Figure 10 shows the below-ground nitrogen scenario during the two main seasons: (A) fall/winter/spring, when the water table is relatively close to the surface and excess nitrate is likely to leach to groundwater and (B) summer, when evapotranspiration exceeds precipitation and little leaching occurs.

Climate and timing of nitrogen application to crops

Of the major crops grown over the SBA, grass removes the most nitrogen (*30*). Figure 10-C shows the timing of precipitation and grass growth as well as application of manure and fertilizer to grass and berries. Times of high vulnerability occur when precipitation is high and nitrogen uptake by grass is low. Application of manure or fertilizer to crops during this time presents a high risk of nitrate leaching to groundwater. Conventional timing of manure application to grass includes the high vulnerability time in the early spring and late fall.

Ecology's nitrogen balance study indicated an almost immediate increase in soil nitrate followed by shallow groundwater nitrate beneath a grass field following an early October application of manure (*19*).

Inorganic fertilizer application outside of the recommended timeframe (Figure 10-C) or recommended amount, especially on coarse-grained soils, also poses a high risk for nitrate leaching to groundwater. In addition, berry crops remove very little of the nitrogen applied indicating a substantial leaching potential (*30*).

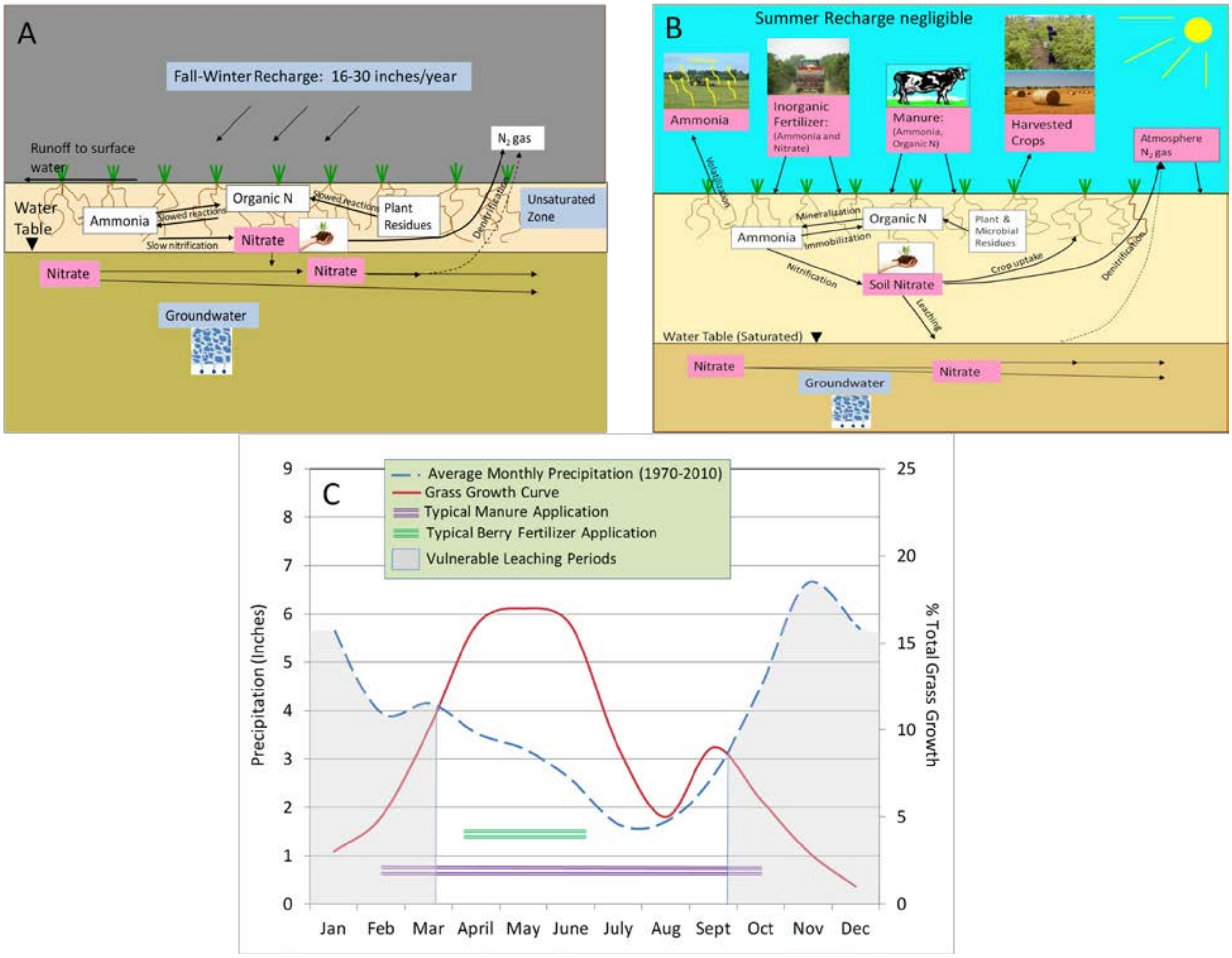

Figure 10. Schematics of recharge and nitrogen cycling patterns during the fall-winter-early spring (A) and summer (B) periods in the SBA area and average precipitation, grass growth, and typical manure and raspberry fertilizer application dates (C).

Sources: Winter recharge estimate in (A):6; Grass growth curve and manure application dates in (C):53; Berry fertilizer timing (C):54.

Major land uses and groundwater nitrate

Figure 11 is designed to provide a generalized perspective on the location of the major agricultural land uses over the SBA and nitrate concentrations in nearby wells.

- Figure 11-A shows a general approximation of the number of milking cows within each section. We assumed that manure is applied to cropland close to the dairy where it is generated. However, because dairy locations were based on the address of the dairy, and the location of the manure application for the dairy may not be in the same section, these ratings are inexact.
- Figure 11-B shows the sections where berries are the primary crop.

Figure 12 shows the primary crop for each section overlying the SBA. Dairy farms apply manure primarily to grass and corn crops. Although groundwater data are not uniformly distributed in areas where dairies and berries are prevalent, high nitrate concentrations have been found beneath both land use areas.

Once nitrate reaches the water table, it continues to move slowly downgradient and gradually deeper into the aquifer. Therefore, depending on depth in the aquifer, current groundwater nitrate concentrations in private wells are probably the result of activities upgradient in years past. To further complicate nitrate source-tracking, much of the land now in berry production was formerly manured cropland. Organic nitrogen remaining in the soil from past practices gradually mineralizes to nitrate, contributing nitrate to groundwater for years after manure application has ended.

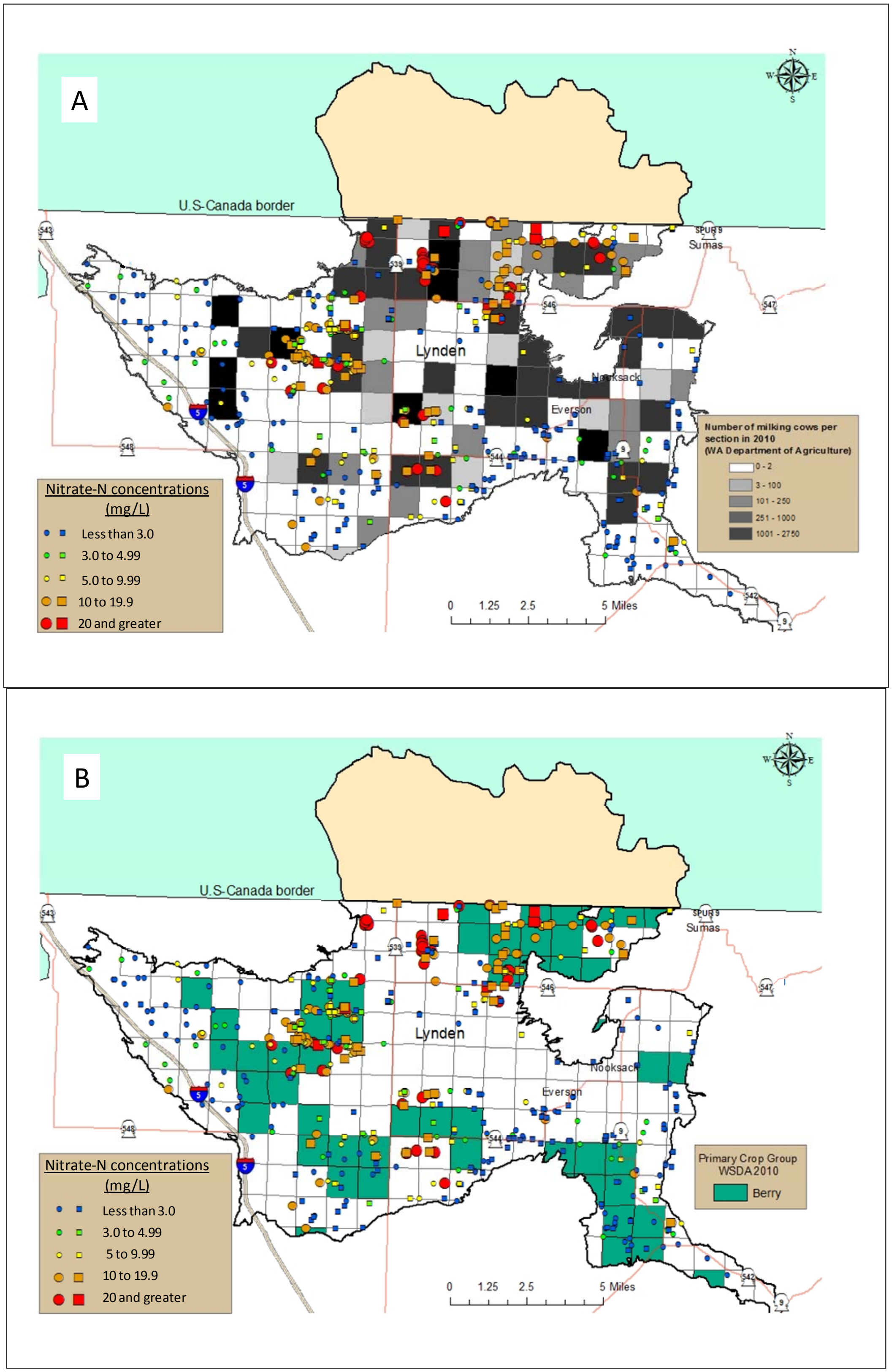

Figure 11. Maximum nitrate-N concentrations and number of milking cows per section in 2010 (A), sections where berries were the primary crop in 2010 (B) (*16*, *52*).

Circles represent Ecology data; squares represent USGS data. Nitrate data are listed in Appendix C.

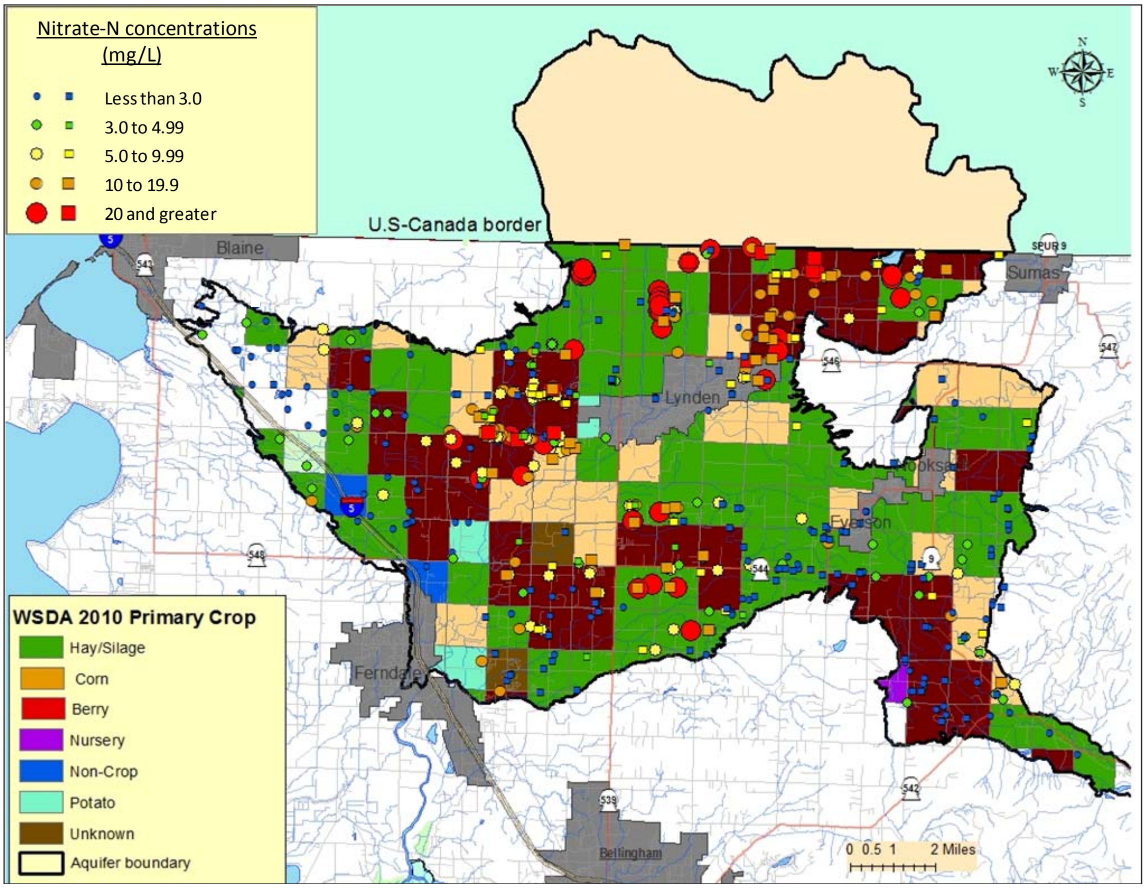

Figure 12. Maximum nitrate-N concentrations and the primary crops for sections overlying the Sumas-Blaine Aquifer in 2010 (*16*, *52*).

Circles represent Ecology data; squares represent USGS data. Nitrate data are listed in Appendix C.

Depth, soil texture, and denitrification

More than one-third of wells less than 40 feet deep exceeded the MCL for nitrate. Nitrate concentrations are typically higher near the top of the water table than at deeper depths. This is because land use impacts are more recent, and significant dilution with aquifer water has not yet occurred (*22*, *23*). Also denitrification, which converts nitrate to nitrogen gas, is less common in shallow, oxygenated zones, especially in coarse-grained material (*21*, *25*, *27*).

Groundwater with little or no oxygen commonly occurred in groundwater less than 10 feet deep at two study sites with fine-grained material (*9*, *19*). Areas with fine-grained soil and aquifer material in the SBA, including peat lenses, probably lose a significant amount of nitrogen to denitrification. Groundwater nitrate concentrations in fine-grained materials around the SBA would probably be higher were it not for loss of nitrogen to denitrification.

Sandy, coarse-grained materials without peat or clay lenses pose the highest risk of nitrate contamination from manure and fertilizer application. Deeper depth to water likewise adds to the risk of nitrate leaching: organic matter, available closer to the surface in manured fields, is needed for denitrification but can decompose before reaching the water table (*23, 55)*.

Conclusions

Groundwater quality data from aquifer-wide studies by Ecology (1981 to 2010) and the U.S. Geological Survey (1981 to 2008) indicate that:

- A total of 29% of 515 wells had results exceeding the 10 mg/L-nitrogen (N) maximum contaminant level (MCL) for nitrate in drinking water. 14% of wells exceeded 20 mg/L-N of nitrate.
- The highest nitrate concentration in a domestic drinking water well was 73 mg/L-N in a 25-foot deep well.
- A total of 36% of 214 wells less than 40 feet deep had results exceeding the MCL for nitrate.
- A total of 20% of 60 wells 40 feet deep and greater had results exceeding the MCL for nitrate.
- Out of 11 wells with long-term records, shallow wells tended to have higher nitrate concentrations than deeper wells, although two wells over 40 feet deep consistently exceeded the MCL.
- The highest nitrate concentration observed in wells with long-term records was 53 mg/L-N in a 29-foot deep well.
- Nitrate concentrations close to the water table in the Sumas Blaine Aquifer (SBA) are probably most influenced by nearby upgradient land use.

Results of intensive groundwater studies by Ecology and cooperators between 1990 and 2011 indicate that:

- In a nitrogen balance study
  - A balance of nitrogen applied in manure and removed in a grass crop corresponded with lower shallow groundwater nitrate below the field, but concentrations still exceeded the MCL.
  - When the amount of nitrogen applied substantially exceeded the amount removed in the crop, shallow groundwater nitrate was roughly two times the MCL.
  - A substantial increase in shallow groundwater nitrate resulted from application of manure in early October (up to 18 mg/L-N increase).

- In 2002 land application of manure study
  - Winter median nitrate concentrations in shallow groundwater beneath a field receiving excess nitrogen were 2 to 3 times the MCL.
  - Where manure nitrogen was applied at the recommended rate, median shallow winter groundwater nitrate was at the MCL.
  - Nitrate reached 74 mg/L-N in shallow groundwater at the field with excess manure.

- In lagoon studies
  - Ammonium leakage observed at two manure storage lagoons was related to recent construction and the proximity of the bottom of the ponds to the water table.
  - Downgradient nitrate concentrations were not elevated compared to upgradient, but ammonium was elevated.

The SBA is vulnerable to contamination due to several factors:

- Shallow depth to water (less than 10 feet in most areas). Permeable soils, many coarse-grained.
- Limited aquifer thickness (mostly less than 50 feet thick) underlain by a thick semi-confining layer. Drilling deeper to avoid shallow contamination is not a long-term solution.
- Heavy rainfall during the non-growing season which carries left-over nitrate to the water table.
- Long-term, intensive agricultural production that makes up 97% of the estimated nitrogen applied to the ground overlying the SBA.
  - 10 to 12 million pounds of nitrogen per year produced by dairy cows.
  - 4.6 million pounds of inorganic nitrogen per year applied to crops.
- Because groundwater moves slowly, it may take years, if not decades, of significantly reduced nitrate input to groundwater to improve water quality in the SBA.

Recommendations

Results of this study support the following recommendations.

- Conduct aquifer-wide follow-up nitrate monitoring in shallow wells to compare with 1997.
- Monitor nitrate concentrations in wells 40 feet deep and greater in the Sumas-Blaine Aquifer (SBA) to evaluate the extent of nitrate contamination throughout the aquifer.
- Work cooperatively among government agencies, with agriculture, environment, and human health responsibilities, to ensure that residents of the SBA are not harmed by drinking water above the nitrate maximum contaminant level (MCL).
- Encourage all residents on private wells to have their drinking water tested for nitrate.
- Provide public education and outreach to residents whose well water exceeds 10 mg/L-nitrogen (N).
- Intensify efforts to minimize nitrate leaching. Examples of strategies include:
    - Improving synchronization of nitrogen application and crop need
    - Track nitrogen mass balance for all crops grown on the SBA
    - Include groundwater and drinking water standards into technical standards for crop management.
    - Curtail fall nitrogen application.
- Coordinate with Canadian federal, provincial, and academic groups conducting monitoring and research to improve groundwater nitrate conditions on both sides of the transboundary Abbotsford-Sumas Aquifer. Investigate the degree of influence of Canadian nitrate sources on groundwater in Washington.

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References

1. U.S. Census, 2010. http://2010.census.gov/2010census/

2. Tooley, J. and D. Erickson, 1996. Nooksack Watershed Surficial Aquifer Characterization. Washington State Dept. of Ecology, Olympia, WA. Publication No. 96-311. 12 pages + appendices and plates. www.ecy.wa.gov/biblio/96311.html

3. Obert, W. C., 1973. Nitrate in groundwater, Western Whatcom County, Washington. Western Washington University, Bellingham, Washington, MS thesis. Department of Geography. 167 pages.

4. Erickson, D. and D. Norton, 1990. Washington State Agricultural Chemicals Pilot Study, Final Report. Washington State Department of Ecology, Olympia, WA. Publication No. 90-46. 76 pages + appendices. www.ecy.wa.gov/biblio/9046.html

5. Garland, D. and D. Erickson, 1994. Ground water quality survey near Edaleen Dairy, Whatcom County, Washington. Washington State Department of Ecology, Olympia, WA. Publication No. 94-37. 20 pages. www.ecy.wa.gov/biblio/9437.html

6. Cox, S. E. and S. C. Kahle, 1999. Hydrogeology, ground water quality, and sources of nitrate in lowland glacial aquifers of Whatcom County, Washington, and British Columbia, Canada. U.S. Geological Survey Water-Resources Investigations Report 98-4195. 251 pages, 5 plates.

7. Erickson, D., 2000. Northcentral Sumas-Blaine Surficial Aquifer Nitrate Characterization Project – June 1999. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-010. 13 pages. www.ecy.wa.gov/biblio/0003010.html

8. Erickson, D., 1998. Sumas-Blaine Surficial Aquifer Nitrate Characterization. Washington State Department of Ecology, Olympia, WA. Publication No. 98-310. 27 pages. www.ecy.wa.gov/biblio/98310.html

9. Carey, B., 2002. Effects of land application of manure on groundwater at two dairies over the Sumas-Blaine Surficial Aquifer: Implications for agronomic rate estimates. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-007. 75 pages. www.ecy.wa.gov/biblio/0203007.html

10. Almasri, M. N. and J. J. Kaluarachchi, 2004. Implications of on-ground nitrogen loading and soil transformations on groundwater quality management. Journal of the American Water Resources Association. Volume 40, Issue 1, pages 165-186.

11. Mitchell, R., S. Babcock, H. Hirsch, L. McKee, R. Matthews, and J. Vandersypen, 2005. Water Quality: Abbotsford-Sumas Final Report. Western Washington University, Bellingham, WA. 144 pages. http://kula.geol.wwu.edu/rjmitch/Report_2005.pdf

12. Redding, M., 2011. Sumas-Blaine Surficial Aquifer Long-Term Groundwater Quality Monitoring Network, 2009 Annual Report. Washington State Department of Ecology, Olympia, WA. Publication No. 11-03-015. www.ecy.wa.gov/biblio/1103015.html

13. Redding, M., 2008. Nitrate trends in the Central Sumas-Blaine Aquifer. Washington State Department of Ecology, Olympia, WA. Publication No. 08-03-018. 117 pages. www.ecy.wa.gov/biblio/0803018.html

14. Pell, Derek, 2010. Personal communications. Assistant Regional Manager Northwest Drinking Water Operations, Washington State Department of Health.

15. Gillies, J., 2000. Personal communication. Natural Resources Conservation Service, Whatcom County. October 11, 2000.

16. Prest, V., 2011. Personal communication. Washington Department of Agriculture, Olympia, WA. March 3, 2011.

17. Washington Red Raspberry Commission, 2011. www.red-raspberry.org/

18. Redding, M., 2011. EDB and 1,2-DCP in Domestic Groundwater Supplies, Follow-Up Investigation: Bertrand Creek Area (Whatcom County). Washington State Department of Ecology, Olympia, WA. Publication No. 11-03-050. 43 pages + appendices. www.ecy.wa.gov/biblio/1103050.html.

19. Carey, B., J. Harrison, L. VanWieringen, in preparation. Nitrate in groundwater, soil, and grass in a manured field overlying the Sumas-Blaine Aquifer. Washington State Department of Ecology, Olympia, WA.

20. NRCS, 2011. Agricultural waste management field handbook. Part 651. **(**H_210_NEH_651 - Amend. 45 - November 2011) www.info.usda.gov/viewerFS.aspx?hid=21430

21. Boumans, L. J. M., D. Fraters, and G. Van Drecht, 2005. Nitrate leaching in agriculture to upper groundwater in the sandy regions of the Netherlands during the 1992-1995 period. Environmental Monitoring and Assessment, Volume 102, pages 225-241.

22. Burrow, K. R., B. T. Nolan, M. G. Rupert, and N. M. Dubrovsky, 2010. Nitrate in groundwater of the United States, 1991-2003. Environmental Science and Technology. Vol. 44, pages 4988-4997.

23. Burrow, K. R, J. L. Shelton, and N. M. Dubrovsky, 2008. Regional nitrate and pesticide trends in ground water in the eastern San Joaquin Valley, California. Journal of Environmental Quality, Vol. 37, (5 Supplement):S249-263.

24. Oenema, J., S. Burgers, and K. Verloop, 2010. Multiscale effects of management, environmental conditions, and land use on nitrate leaching in dairy farms. Journal of Environmental Quality, Volume 39, pages 2016-2028.

25. de Ruijter, F. J., L. J. M. Boumans, A. L. Smit, and M. van den Berg, 2007. Nitrate in upper groundwater on farms under tillage as affected by fertilizer use, soil type, and groundwater table. Nutrient Cycling in Agroecosystems. Vol. 77, pages 155-167.

26. Bittman, S., C.G. Kowalenko, T. Forge, D.E. Hunt, F. Bounaix, and N. Patni, 2007. Agronomic effects of multi-year surface-banding of dairy slurry on grass. Bioresource Technology, Volume 98, pages 3249–3258.

27. van Es, H. M., J. M. Sogbedji, and R. R. Schindelbeck, 2006. Effect of Manure Application Timing, Crop, and Soil Type on Nitrate Leaching. Journal of Environmental Quality, Volume 35, pages 670-679.

28. Wassenaar, L. I., M. J. Hendry, and N. Harrington, 2006. Decadal geochemical and isotopic trends for nitrate in a transboundary aquifer and implications for agricultural beneficial management practices. Environmental Science and Technology, Volume 40, pages 4626-4632.

29. Goulding, K.W.T, P.R. Poulton, C.P. Webster, and M. T. Howe, 2000. Nitrate leaching from the Broadbalk wheat experiment, Rothamsted, UK, as influenced by fertilizer and manure inputs and the weather. Soil Use and Management, Volume 16, pages 244-250.

30. Zebarth, B. J., B. Hii, H. Liebscher, K. Chipperfield, J. W. Paul, G. Grove, and S. Szeto, 1998. Agricultural land use practices and nitrate contamination in the Abbotsford Aquifer, British Columbia, Canada. Agriculture Ecosystem Environment. Volume 69, pages 99-112.

31. Rozemeijer, J. C., H. P. Broers, F. C. vanGeer, and M. F. P. Bierkens, 2009. Weather-induced temporal variations in nitrate concentrations in shallow groundwater. Journal of Hydrology, Volume 378, pages 119-127. doi:10.1016/j.hydrol.2009.09.011.

32. Gehart, J. M., 1986. Ground-water recharge and its effects on nitrate concentration beneath a manured field site in Pennsylvania. Ground Water, Volume 24(4), pages 483-489.

33. Carey, B., 2004. Quality Assurance Project Plan: Groundwater, Soil, and Crop Nitrogen at a Field Where Dairy Waste is Used as Fertilizer in Whatcom County. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-112. 32 pages. www.ecy.wa.gov/biblio/0403112.html

34. Erickson, D., 1994. Effects of leakage from four dairy waste storage ponds on ground water quality, final report. Washington State Department of Ecology, Olympia, WA. Publication No. 94-109. 50 pages + appendices. www.ecy.wa.gov/biblio/94109.html

35. Erickson, D., 1992. Ground water quality assessment Whatcom County Dairy Lagoon #2-Lynden, Washington. Washington State Department of Ecology, Olympia, WA. Publication No. 92-e25. 26 pages + appendix. www.ecy.wa.gov/biblio/92e25.html

36. Erickson, D., 1991. Edaleen dairy lagoon groundwater quality assessment, February 1990 to February 1991. Washington State Department of Ecology, Olympia, WA. Publication No. 91-e11. 32 pages + appendices. www.ecy.wa.gov/biblio/91e11.html

37. Böhlke, J.K., Smith, R.L., and Miller, D.N., 2006, Ammonium transport and reaction in contaminated groundwater–Application of isotope tracers and isotope fractionation studies: Water Resources Research, v. 42, W05411, doi: 10.1029/.

38. McNab, W. W., M. J. Singleton, J. E. Moran, B. K. Esser, 2006. Assessing the Impact of Animal Waste Lagoon Seepage on the Geochemistry of an Underlying Shallow Aquifer. Environmental Science and Technology, Vol. 41, No. 3, pages 753-758.

39. Focazio, M. J., T. E. Reilly, M. G. Rupert, and D. R. Helsel, 2002. Assessing Ground-Water Vulnerability to Contamination: Providing Scientifically Defensible Information for Decision Makers. U.S. Geological Survey Circular 1224, 33 pages. http://pubs.usgs.gov/circ/2002/circ1224/index.html#pdf

40. Erwin, M. L. and A. J. Tesoriero, 1997. Predicting ground-water vulnerability to nitrate in the Puget Sound Basin. USGS Fact Sheet 061-97. http://wa.water.usgs.gov/pubs/fs/fs.061-97/

41. Jones, M., 1999. Geologic framework for the Puget Sound Aquifer System, Washington and British Columbia. U.S. Geological Survey, Professional Paper 1424-C. 31 pages + 18 plates.

42. Easterbrook, D. J., 1971. Geology and geomorphology of western Whatcom County. Western Washington University, Department of Geology, 68 pages.

43. NOAA, 2011. National Climatic Data Center, National Oceanic and Atmospheric Administration. Surface data for Clearbrook, WA.

44. Embertson, N. M., 2010. Protecting Puget Sound Watersheds from agricultural runoff using a progressive manure application risk management (ARM) system. EPA grant application: Protecting watershed, water quality and aquatic resources from impacts of growth, FFY 2010. 12 pages.

45. Redding, M., B. Carey, and K. Sinclair, 2011. Poster: Nitrate Contamination in the Sumas-Blaine Aquifer, Whatcom County, Washington. Presented at the Eighth Washington Hydrogeology Symposium on April 26, 2011, in Tacoma WA. Washington State Department of Ecology, Olympia, WA. Publication No. 11-03-027. www.ecy.wa.gov/biblio/1103027.html

46. Almasri, M. N. and J. J. Kaluarachchi, 2003. Regional variability of on-ground nitrogen loading due to multiple land uses in agriculture-dominated watersheds. Proceedings for Diffuse Pollution Conference, Dublin, Ireland, pages 10-53 to 10-58.

47. University of California, Agriculture and Natural Resources, 2006. Groundwater Quality Protection: Managing dairy manure in the Central Valley of California. Committee of Experts on Dairy Manure Management. Publication 9004. 65 pages + appendices.

48. Tesoriero, A. J., H. Liebscher, and S. E. Cox, 2000. Mechanism and rate of denitrification in an agricultural watershed: Electron and mass balance along groundwater flow paths. Water Resources Research, Volume 36, Number 6, pages 1545-1559.

49. Chesnaux, R., D. M. Allen, and G. Graham, 2007. Assessment of the impact of nutrient management practices on nitrate contamination in the Abbotsford-Sumas Aquifer. Environmental Science and Technology, Volume 41, pages 7229-7234.

50. Hirsch, H. R., 2007. Applicability of the NLOS model for predictions of soil water movement and nitrogen transport in an agricultural soil, Agassiz, B.C. M.S. Thesis, Western Washington University, Bellingham, WA.

51. U.S. EPA, 2002. Onsite wastewater treatment systems manual. EPA/625/R-00/008. U.S. Environmental Protection Agency, Office of Water, Office of Research and Development. http://nepis.epa.gov/EPA/html/DLwait.htm?url=/Exe/ZyPDF.cgi?Dockey=30004GXI.PDF

52. U.S. Department of Agriculture, 2011. Washington cropland layer, National Agricultural Statistics Service, Washington, D.C.

53. Embertson, N., 2010. Whatcom Conservation District, Lynden, Washington. Power-point presentation –April 30, 2010.

54. Walters, Thomas, 2011. Personal communication. Washington State University-Northwest Washington Research and Extension Center, Mount Vernon, Washington. November 28, 2011.

55. Starr, C. R. and R. W. Gillham, 1993. Denitrification and organic carbon availability in two aquifers. Ground Water, Volume 31, pages 934-947.

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Appendices

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Appendix A. Glossary, acronyms, and abbreviations

Glossary

Aquifer: An underground bed of saturated material.

Recharge: The downward flow of water through the soil and unsaturated zone to the water table. Also the amount of water added over a period of time (i.e., inches/year).

Redox conditions: The system of oxidation and reduction reactions. Oxidizing systems typically contain relatively high oxygen concentrations, while reducing systems have very low or virtually no oxygen. Microbial reactions involving electron transfer in groundwater and soil (i.e., mineralization, denitrification) are greatly affected by redox conditions.

Water table: The top of the saturated surface of an unconfined aquifer.

Acronyms and Abbreviations

B.C.	British Columbia, Canada
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database www.ecy.wa.gov/eim/
MCL	Maximum contaminant level
N	Nitrogen
SBA	Sumas-Blaine Aquifer
USGS	United State Geological Survey
WAC	Washington Administrative Code

Units of Measurement

mg/L:	milligrams per liter

Appendix B. Quality assurance procedures for data and sources of data

The following procedures were used to ensure that data used were of adequate quality for the analysis:

- Removed duplicate entries and outliers.
- Combined information for wells with different names but the same location and well depth.
- Included non-detects in the mapping category "less than 3.0 mg/L nitrate-N".
- Combined filtered and unfiltered results.
- Assumed USGS wells 10 to 60 feet deep are in the Sumas-Blaine Aquifer (SBA).
- Included all Ecology wells, because studies included only wells in the SBA.
- Included 446 private domestic wells and 69 monitoring wells.

Table B-1. Sources of groundwater nitrate data used in Figures 2 through 4.

Agency	Sampling dates	Number of wells	Type of wells	Frequency of sampling	Wells sampled in other studies	Quality assurance level*	Study citation
Ecology	1988	28	Domestic	Once		5	*4*
Ecology	1997	298	Domestic	Once	Some USGS 1990-91	5	*8*
Ecology	1997-2000	15	Monitoring	Monthly	None	5	*9*
Ecology	2003-2005	32	Domestic	Quarterly	Several from Ecology 1997	2	*13*
Ecology	2004-2008	7	Monitoring	Monthly	None	2	*19*
Ecology	2007	32	Domestic	Once	2 in Ecology 1988; 2 in Ecology 1997; 1 in Ecology 1997-2010	2	*18*
Ecology	2009-2010	27	Domestic	Annually	Most also in 2003-2005	2	*12*
USGS	1990-1991	201	Domestic	Most once, 11 wells monthly for 15 months	Some in Ecology 1997, 2003-2010	5	*6*
USGS	1995		Domestic			5	
USGS	1997-2008		Domestic	Every 2 years		5	

* Quality Assurance levels: 1. Data neither verified nor assessed for usability.
2. Data verified.
3. Data verified and assessed for usability.
4. Data verified and assessed for usability in a formal study report.
5. Data verified and assessed for usability and published in a report.

Appendix C. Groundwater nitrate data

Table C-1. Groundwater data used in maps and statistics.

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
Ecology		817_BBL	48.93480873	-122.5247589		1/31/2007	0.010	U	
Ecology		N39205D2	48.90428	-122.59461	21	4/28/1997	0.010	U	
Ecology		N39211K1	48.88055	-122.51805	47	3/12/1997	0.010	U	
Ecology		N39214C1	48.87381	-122.51924	35	3/13/1997	0.010	U	
Ecology		N39316A2	48.87598	-122.42414	34	3/26/1997	0.010	U	
Ecology		N39321D2	48.86211	-122.43704	30	3/12/1997	0.010	U	
Ecology		N39409J2	48.88124	-122.28856	25	4/14/1997	0.010	U	
Ecology		N39419A1	48.86092	-122.33313	31	4/15/1997	0.010	U	
Ecology		N39420M1	48.85098	-122.33003	33	4/17/1997	0.010	U	
Ecology		N40108A1	48.97729	-122.70528	20	3/27/1997	0.010	U	
Ecology		N40210N2	48.96686	-122.54728	38	3/10/1997	0.010	U	
Ecology		N40309G1	48.97469	-122.42456	65	4/28/1997	0.010	U	
Ecology		N40333J1	48.91255	-122.42111	33	3/21/1997	0.010	U	
Ecology		N40335R2	48.90635	-122.37535	51	3/24/1997	0.010	U	
Ecology		WHWS16	48.93753	-122.53142	23	8/25/1988	0.010	U	
Ecology		N39206B1	48.90258	-122.60198	29	3/11/1997	0.012		
Ecology		N39222K1	48.85351	-122.53846	17	3/13/1997	0.014		
Ecology		TI_MW1D	48.95523	-122.48773	60	7/15/2003	0.020		
Ecology		N39426L1	48.83777	-122.25728	37	4/16/1997	0.022		
Ecology		N39206A1	48.90396	-122.59542	28	3/10/1997	0.026		
Ecology		N40116A2	48.96225	-122.68557	16	3/27/1997	0.026		
Ecology		N40217D1	48.96256	-122.59562	25	3/14/1997	0.027		
Ecology		N40417R1	48.95059	-122.31067	40	4/15/1997	0.031		
Ecology		N40429H2	48.92824	-122.31033	59	4/14/1997	0.032		
Ecology		N40123Q1	48.93718	-122.6482	16	3/26/1997	0.037		
Ecology		N40319A1	48.94986	-122.46685	40	4/28/1997	0.037		
Ecology		N40308D2	48.9788	-122.45902	46	3/12/1997	0.039		
Ecology		N40232C1	48.91854	-122.59135	21	3/13/1997	0.041		
Ecology		N39205D1	48.90539	-122.59212	20	3/11/1997	0.043		
Ecology		N41336J2	48.99763	-122.35439	92	2/18/1997	0.043		
Ecology		N40406A1	48.99162	-122.33201	75	2/18/1997	0.045		
Ecology		N40231N1	48.90651	-122.61395	23	3/11/1997	0.046		
USGS	A484331122383803	37N/01E-02H03D1	48.726773	-122.643788	37.9	6/19/1995	0.050	U	Dissolved
USGS	A484320122384701	37N/01E-02K01	48.722051	-122.6474	42	5/30/1995	0.050	U	Dissolved

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
USGS	A484310122385008	37N/01E-02Q08	48.71844	-122.648233	24.5	6/1/1995	0.050	U	Dissolved
USGS	A484648122382410	37N/01E-02Q11	48.719829	-122.648511	46	5/31/1995	0.050	U	Dissolved
USGS	A484303122385201	37N/01E-11B01	48.717329	-122.649622	59	5/26/1995	0.050	U	Dissolved
USGS	A485412122304001	39N/02E-02A01 SU16	48.902888	-122.512377	40	8/7/1996	0.050	U	Dissolved
USGS	A485251122165801	39N/04E-10M01	48.880672	-122.284046	44	4/27/1991	0.050	U	Dissolved
USGS	A485826122295101	40N/02E-12C01	48.975948	-122.497941	26	8/22/1991	0.050	U	Dissolved
USGS	A485721122292001	40N/02E-13J04	48.95567	-122.490164	16.2	7/19/1991	0.050	U	Dissolved
USGS	A485719122292001	40N/02E-13J05	48.955114	-122.490164	16	8/13/1991	0.050	U	Total
USGS	A485719122291701	40N/02E-13J07	48.955114	-122.489331	15.8	7/19/1991	0.050	U	Dissolved
USGS	A485900122271901	40N/03E-05L01	48.983172	-122.456551	17.6	8/14/1991	0.050	U	Dissolved
USGS	A485607122161101	40N/04E-22R01	48.935119	-122.270988	60	5/3/1991	0.050	U	Dissolved
USGS	A485546122202601	40N/04E-30G01	48.929284	-122.341825	37	10/3/1991	0.050	U	Dissolved
Ecology		N39429A3	48.84325	-122.3112	18	4/17/1997	0.052		
Ecology		N39429A1	48.8449	-122.31637	28	4/17/1997	0.055		
USGS	A485342122193003	39N/04E-05N01P3	48.894838	-122.32627	42.5	10/25/2004	0.060	U	Dissolved
USGS	A485341122191202	39N/04E-05P03P2	48.894561	-122.321269	27	4/1/2004	0.060	U	Dissolved
USGS	A485341122195301	39N/04E-06R03 AFK-177	48.894525	-122.331436	18	9/28/2004	0.060	U	Dissolved
USGS	A485858122282901	40N/03E-06L02	48.982616	-122.475996	34	7/22/1981	0.060		Dissolved
Ecology		N40116A1	48.96234	-122.68697	19	3/25/1997	0.060		
USGS	A485727122190001	40N/04E-17G01	48.958452	-122.317934	26	10/3/1991	0.062		Dissolved
Ecology		N39223B1	48.86081	-122.51628	10	3/12/1997	0.073		
USGS	A484327122384201	37N/01E-02K08	48.72344	-122.647677	60	5/31/1995	0.080		Dissolved
USGS	A485659122321501	40N/02E-20E01 MW-WC-20	48.949558	-122.538777	19.6	10/1/1998	0.080		Dissolved
Ecology		N40115N1	48.95079	-122.67752	22	3/24/1997	0.081		
Ecology		N40215F1	48.96066	-122.54343	26	3/12/1997	0.087		
USGS	A490007122243301	40N/03E-33J03 MW-WC-03	49.001784	-122.410437	57	9/28/1998	0.090		Dissolved
Ecology		N39427C1	48.84437	-122.27827	37	4/16/1997	0.097		
USGS	A484329122391801	37N/01E-02M02	48.724829	-122.656845	35.7	5/31/1995	0.100		Dissolved
USGS	A485244122293901	39N/02E-12Q01	48.878723	-122.495444	44	4/13/1990	0.100	U	Total
USGS	A485138122324601	39N/02E-22D02	48.860388	-122.547391	48	4/10/1990	0.100	U	Total
USGS	A485112122321501	39N/02E-22K02	48.853166	-122.53878	17	4/10/1990	0.100	U	Total
USGS	A485121122311301	39N/02E-23F01	48.855666	-122.521557	20	4/12/1990	0.100	U	Total
USGS	A485131122305801	39N/02E-23G02	48.858444	-122.51739	10	4/10/1990	0.100	U	Total
USGS	A485055122300901	39N/02E-24N02	48.848444	-122.503778	29	4/12/1990	0.100	U	Total
USGS	A485332122235701	39N/03E-03R02	48.892059	-122.400439	40	3/20/1990	0.100	U	Total
USGS	A485424122253001	39N/03E-04B01	48.905948	-122.426274	31	3/21/1990	0.100	U	Total
USGS	A485317122240201	39N/03E-10H02	48.887892	-122.401829	47	3/29/1990	0.100	U	Total
USGS	A485314122212401	39N/03E-12G01	48.887059	-122.361827	48	3/27/1990	0.100	U	Total

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual- ifier	Fraction
USGS	A485316122165401	39N/04E-10D01	48.887617	-122.282935	51	5/22/1990	0.100	U	Total
USGS	A485144122195601	39N/04E-18R01	48.862059	-122.333493	28	4/25/1990	0.100	U	Total
USGS	A485104122192501	39N/04E-20L01	48.850948	-122.324882	37	4/24/1990	0.100	U	Total
USGS	A485105122194001	39N/04E-20M02	48.851226	-122.329049	33	4/24/1990	0.100	U	Total
USGS	A485028122184401	39N/04E-29H01	48.840948	-122.313493	20	4/25/1990	0.100	U	Total
USGS	A485727122291001	40N/02E-13H01	48.959281	-122.487941	26	8/15/1990	0.100	U	Total
USGS	A485720122291901	40N/02E-13J02	48.955392	-122.489886	40	8/17/1990	0.100	U	Total
USGS	A485848122274001	40N/03E-05N01	48.979838	-122.462384	18	7/11/1990	0.100		Total
USGS	A485817122244702	40N/03E-10L02 FP-08	48.971228	-122.414327	40	2/10/1998	0.100		Dissolved
USGS	A485425122223201	40N/03E-35R02	48.906782	-122.376827	51	4/25/1990	0.100		Total
Ecology		N40115E1	48.96047	-122.67895	30	3/24/1997	0.114		
Ecology		N39409J1	48.88233	-122.28862	70	4/14/1997	0.120		
USGS	A485234122293401	39N/02E-13B01	48.875945	-122.494055	52	4/26/1991	0.130		Dissolved
Ecology		N40122A1	48.9477	-122.66206	27	3/24/1997	0.132		
Ecology		N40113A1	48.9605	-122.61816	25	3/14/1997	0.189		
USGS	A485224122191801	39N/04E-17C01	48.873171	-122.322937	52.3	5/23/1990	0.200		Total
USGS	A485703122394301	40N/01E-15R01 MW-SU-007A	48.950822	-122.666477	22.5	8/20/1996	0.200		Dissolved
USGS	A485659122275601	40N/03E-19A01	48.949559	-122.46683	39.5	7/19/1990	0.200		Total
USGS	A485726122314701	40N/02E-15J01	48.957058	-122.530999	24	4/29/1991	0.210		Dissolved
Ecology		N39436D1	48.83035	-122.24242	40	4/16/1997	0.229		
USGS	A485336122195301	39N/04E-06R07 AFK-173	48.893383	-122.331494	17	12/4/2003	0.230		Dissolved
Ecology		N40211N1	48.96676	-122.52968	30	4/28/1997	0.237		
USGS	A484556122362001	38N/02E-19L03	48.765385	-122.606842	12	5/17/1995	0.250		Dissolved
Ecology		N39204N1	48.89497	-122.57097	26	3/10/1997	0.266		
Ecology		N39212M1	48.88334	-122.50743	23	3/12/1997	0.280		
Ecology		N40136H1	48.91392	-122.61767	17	3/27/1997	0.280		
Ecology		WHWS03	48.94941	-122.57177	20	8/22/1988	0.280		
USGS	A485106122322101	39N/02E-22K03	48.851499	-122.540447	25	4/11/1990	0.300		Total
USGS	A485418122225401	39N/03E-02B02	48.904837	-122.382938	39.5	3/19/1990	0.300		Total
USGS	A485358122250401	39N/03E-03E01	48.899281	-122.419051	43	3/20/1990	0.300		Total
USGS	A485806122122901	40N/05E-07K01	48.968177	-122.209318	31	5/30/1990	0.300		Total
Ecology		AKG-726	48.99319	-122.50517	38	10/19/2004	0.330		Dissolved
Ecology		N40110D1	48.97812	-122.67678	22	3/26/1997	0.332		
USGS	A485736122255901	40N/03E-16F01	48.959838	-122.434328	21	5/1/1991	0.350		Dissolved
Ecology		N39417C1	48.87294	-122.32122	36	4/14/1997	0.381		
USGS	A485326122223601	39N/03E-11A02	48.890393	-122.377939	36.5	4/12/1990	0.400		Total
USGS	A485328122220701	39N/03E-12D02	48.890948	-122.369883	43	4/9/1990	0.400		Total
Ecology		N39422M1	48.85386	-122.28379	22	4/16/1997	0.406		

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
Ecology		N40232N1	48.90851	-122.59403	21	3/13/1997	0.449		
Ecology		N39309Q2	48.87798	-122.42693	25	3/26/1997	0.455		
Ecology		N39301C1	48.90557	-122.36831	49	3/25/1997	0.475		
Ecology		N39316F1	48.87016	-122.43587	38	3/21/1997	0.482		
Ecology		N40210Q1	48.96514	-122.54036		3/28/1997	0.483		
USGS	A485342122193002	39N/04E-05N01P2	48.894838	-122.32627	27	4/1/2004	0.490		Dissolved
USGS	A485410122222301	39N/03E-01D01	48.902615	-122.374327	39	3/20/1990	0.500		Total
Ecology		1003_BBL	48.93392068	-122.539157		1/30/2007	0.504		
Ecology		N40126A1	48.93462	-122.63992	24	3/26/1997	0.538		
USGS	A485658122340901	40N/02E-21D01	48.94928	-122.570446	18	8/20/1991	0.590		Total
USGS	A485258122314101	39N/02E-11M01	48.882611	-122.529334	40	4/10/1990	0.600		Total
USGS	A485658122331401	40N/02E-21A01	48.94928	-122.554611	21	8/14/1990	0.600		Total
USGS	A485202122310601	39N/02E-14L01	48.867056	-122.519612	21	4/25/1991	0.630		Dissolved
Ecology		N39204D1	48.90527	-122.56986	21	3/11/1997	0.642		
USGS	A485610122311901	40N/02E-23Q04 MW-WC-13	48.935947	-122.523221	30	9/30/1998	0.680		Dissolved
USGS	A485241122253401	39N/03E-09Q02	48.877891	-122.427385	20	3/29/1990	0.700		Total
Ecology		N39310M2	48.88113	-122.41526	32	3/27/1997	0.716		
Ecology		N39409R1	48.87646	-122.29214	67	4/14/1997	0.789		
USGS	A485846122304401	40N/02E-02Q01	48.981504	-122.514609	23	8/15/1990	0.800		Total
USGS	A485808122122401	40N/05E-07K02	48.968732	-122.207929	33.5	5/30/1990	0.800		Total
USGS	A485223122330501	39N/02E-16H03	48.872889	-122.552669	19	4/25/1991	0.830		Dissolved
USGS	A485342122193001	39N/04E-05N01P1	48.894838	-122.32627	12	4/1/2004	0.860		Dissolved
Ecology		N39302P2	48.89372	-122.39092	24	3/25/1997	0.883		
Ecology		N39422M2	48.85113	-122.28624	32	4/16/1997	0.905		
Ecology		N40333G1	48.91393	-122.43004	28	3/24/1997	0.916		
Ecology		N39215B1	48.87429	-122.53954	21	3/10/1997	0.920		
Ecology		N39420L2	48.8537	-122.32368	54	4/15/1997	0.920		
Ecology		N39420H1	48.85509	-122.31256	41	4/15/1997	0.959		
Ecology		N40123M1	48.94242	-122.65887	20	3/25/1997	0.968		
Ecology		N39420L1	48.85264	-122.32346	46	4/15/1997	0.982		
Ecology		WHWS04	48.93104	-122.56283		8/23/1988	1.04		
Ecology		N40114P1	48.95067	-122.64902	21	3/24/1997	1.10		
Ecology		N39101A1	48.90465	-122.62053	20	3/12/1997	1.12		
Ecology		N39302A1	48.90372	-122.37699	39	3/20/1997	1.19		
Ecology		N40219D1	48.94939	-122.61463	30	3/14/1997	1.19		
USGS	A485330122212401	39N/03E-01R01	48.891504	-122.357938	46	3/20/1990	1.20		Total
USGS	A485213122255901	39N/03E-16F02	48.870113	-122.43433	37	4/30/1991	1.20		Dissolved
USGS	A485032122175801	39N/04E-28F01	48.842059	-122.300715	52	4/26/1991	1.20		Dissolved

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
USGS	A485545122215901	40N/03E-25F01	48.929005	-122.367659	29	8/21/1991	1.20		Dissolved
Ecology		N40434P1	48.90744	-122.28142	57	4/14/1997	1.21		
USGS	A485450122254601	40N/03E-33G01	48.913726	-122.430718	28	4/27/1990	1.30		Total
Ecology		N39204M1	48.89261	-122.57017	25	3/10/1997	1.31		
Ecology		N39302P1	48.89223	-122.39019	11	3/25/1997	1.31		
Ecology		N40219J1	48.94143	-122.59736	28	3/14/1997	1.34		
Ecology		N40110F1	48.97279	-122.67157	21	3/24/1997	1.35		
Ecology		N40231B1	48.92018	-122.60567	20	3/27/1997	1.39		
USGS	A485148122264001	39N/03E-17R03	48.863168	-122.44572	60	4/23/1991	1.40		Total
USGS	A485758122324401	40N/02E-10N02	48.965947	-122.546833	38	8/21/1991	1.40		Dissolved
USGS	A485752122234601	40N/03E-10R02	48.964284	-122.397382	38	5/1/1991	1.40		Dissolved
Ecology		N40115B2	48.96328	-122.66911	11	3/25/1997	1.45		
Ecology		WHWS08	48.93738	-122.55077	18	8/24/1988	1.49		
USGS	A484503122382901	38N/01E-26J01	48.750662	-122.641844	16.3	6/21/1995	1.50		Dissolved
USGS	A485330122233001	39N/03E-02N02	48.891503	-122.392939	29.5	3/19/1990	1.50		Total
USGS	A485706122253301	40N/03E-16Q01	48.951505	-122.427106	50	7/19/1990	1.50		Total
USGS	A485957122230801	40N/03E-35L02 MW-WC-07	48.999007	-122.386825	25	9/29/1998	1.50		Dissolved
USGS	A485604122191601	40N/04E-20F01	48.94484	-122.321268	18	2/19/1991	1.50		Total
Ecology		N39417J1	48.86653	-122.3109	60	4/17/1997	1.52		
Ecology		N40230G1	48.93178	-122.60702	40	3/13/1997	1.52		
Ecology		N40113Q1	48.9505	-122.62655		3/28/1997	1.53		
USGS	A485333122195203	39N/04E-06R11 AFK-169	48.89245	-122.331883	12	2/24/2003	1.62		Dissolved
Ecology		N39409N1	48.87855	-122.30933	20	4/15/1997	1.66		
Ecology		N40232E1	48.91598	-122.58982	28	3/13/1997	1.67		
Ecology		N40124P1	48.93678	-122.62777	30	3/25/1997	1.68		
Ecology		N40321E1	48.94593	-122.439		4/28/1997	1.69		
USGS	A485052122311901	39N/02E-26C01	48.84761	-122.523224	30	4/18/1990	1.70		Total
USGS	A485755122253901	40N/03E-09Q03 AG-05	48.965111	-122.4285	28	8/16/2006	1.71		Dissolved
Ecology		N39429A2	48.84629	-122.31258	42	4/17/1997	1.74		
Ecology		N39404H1	48.89837	-122.28964	41	4/14/1997	1.78		
Ecology		N39213F1	48.87378	-122.49755	33	3/13/1997	1.79		
USGS	A485333122234401	39N/03E-02N03	48.892337	-122.396828	36	3/20/1990	1.80		Total
USGS	A485506122332401	40N/02E-33B02	48.918168	-122.557946	36	10/2/1991	1.80		Dissolved
USGS	A485341122195302	39N/04E-06R04 AFK-176	48.894525	-122.331444	26	9/28/2004	1.85		Dissolved
Ecology		N39420F1	48.85564	-122.32332	60	4/15/1997	1.91		
Ecology		N40434F1	48.91421	-122.2815	51	4/15/1997	1.97		
Ecology		N40336J2	48.91242	-122.35609	37	3/20/1997	1.98		
Ecology		N40115A1	48.96334	-122.6651	22	3/25/1997	1.99		

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
USGS	A485754122251001	40N/03E-09R03	48.964839	-122.420716	36	7/22/1981	2.00		Dissolved
Ecology		N39310M1	48.88134	-122.41861	20	3/27/1997	2.02		
Ecology		N39208C1	48.88987	-122.5844	24	3/11/1997	2.03		
Ecology		N39302B1	48.90581	-122.38414	20	3/27/1997	2.05		
Ecology		N39204C1	48.90545	-122.56291	25	3/11/1997	2.19		
Ecology		N39421K1	48.85458	-122.29556	35	4/29/1997	2.19		
Ecology		N39301R2	48.89155	-122.35629	40	4/29/1997	2.20		
Ecology		N39304N1	48.8945	-122.43997	40	3/25/1997	2.20		
Ecology		N39211B1	48.89071	-122.51817	26	3/12/1997	2.23		
Ecology		N40434D1	48.91986	-122.28666	30	4/14/1997	2.24		
Ecology		N41431R2	48.99378	-122.33056	71	2/18/1997	2.28		
USGS	A485431122212701	40N/03E-36Q01	48.908449	-122.358771	45	4/30/1991	2.30		Dissolved
USGS	A490005122262001	41N/03E-33E01	49.001228	-122.44016	43	6/29/1990	2.30		Total
USGS	A485624122160701	40N/04E-22J01	48.939841	-122.269877	56	5/2/1991	2.40		Dissolved
Ecology		N40123D1	48.94811	-122.65849	28	3/24/1997	2.40		
Ecology		N40421B1	48.94602	-122.29604		4/15/1997	2.43		
Ecology		N40112J1	48.97033	-122.62035	18	3/24/1997	2.44		
Ecology		N39303N2	48.89431	-122.41654	40	3/28/1997	2.45		
Ecology		N39302M1	48.89636	-122.39587	36	3/25/1997	2.46		
USGS	A485725122242701	40N/03E-15F01 FP-01	48.956652	-122.408913	29	6/17/1998	2.50		Dissolved
Ecology		WHWS09	48.9333	-122.54834	17	8/23/1988	2.50		
Ecology		N39404H2	48.9005	-122.29005	44	4/14/1997	2.57		
USGS	A485704122303901	40N/02E-14R01	48.950947	-122.512109	30	8/15/1990	2.60		Total
Ecology		N40124D1	48.94832	-122.63425	20	3/25/1997	2.60		
USGS	A485340122195301	39N/04E-06R01 AFK-179	48.894519	-122.331319	16	2/24/2003	2.61		Dissolved
Ecology		N39316A1	48.87641	-122.42441	21	3/26/1997	2.64		
USGS	A485505122171801	40N/04E-33A03	48.917895	-122.289601	34	6/15/1990	2.70		Total
USGS	A485336122195201	39N/04E-06R05 AFK-175	48.893377	-122.331316	15	12/4/2003	2.73		Dissolved
Ecology		N39420E1	48.85814	-122.33109	43	4/15/1997	2.74		
Ecology		N40336J1	48.91249	-122.35565	51	3/20/1997	2.75		
USGS	A485340122195302	39N/04E-06R02 AFK-178	48.894525	-122.331327	23	9/28/2004	2.76		Dissolved
Ecology		39307N1	48.8776	-122.48119	30	3/28/1997	2.77		
USGS	A485257122244101	39N/03E-10L01	48.882336	-122.412662	34.9	2/21/1991	2.80		Total
USGS	A485324122192001	39N/04E-08C02	48.889838	-122.324881	46	5/22/1990	2.80		Total
USGS	A485428122262901	40N/03E-32Q01	48.907614	-122.450719	25	4/25/1991	2.80		Dissolved
Ecology		N40124M1	48.94196	-122.63358	20	3/25/1997	2.81		
USGS	A485336122195302	39N/04E-06R08 AFK-172	48.893383	-122.331502	25	12/4/2003	2.85		Dissolved
Ecology		N40305N2	48.97969	-122.45868	24	2/18/1997	2.93		
USGS	A485341122191201	39N/04E-05P03P1	48.894561	-122.321269	43	4/1/2004	2.96		Dissolved

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
USGS	A485234122250301	39N/03E-15D02	48.875947	-122.418774	35	3/29/1990	3.00		Total
Ecology		786_BBL	48.93614783	-122.5189868		2/6/2007	3.00		
Ecology		N40226C1	48.93366	-122.51895	32	3/11/1997	3.03		
Ecology		N40405N2	48.98116	-122.33054	85	4/29/1997	3.07		
Ecology		1155_CK	48.92025	-122.55626		2/7/2007	3.08		
Ecology		N39303R1	48.89379	-122.39843	12	3/25/1997	3.08		
Ecology		N40225B1	48.93537	-122.49203	40	3/11/1997	3.11		
USGS	A485336122195202	39N/04E-06R06 AFK-174	48.893375	-122.33133	23	12/4/2003	3.14		Dissolved
Ecology		N39404M1	48.89662	-122.30469	41	4/15/1997	3.14		
USGS	A485333122195204	39N/04E-06R12 AFK-168	48.89245	-122.331897	24	12/4/2003	3.15		Dissolved
USGS	A485333122195502	39N/04E-06R10 AFK-170	48.892447	-122.331758	22	12/4/2003	3.17		Dissolved
USGS	A485754122314601	40N/02E-15A02	48.964836	-122.530721	12	8/21/1991	3.20		Total
USGS	A485736122314801	40N/02E-15H02	48.959836	-122.531277	15	8/21/1991	3.20		Total
Ecology		N39422P1	48.84898	-122.28176	30	4/16/1997	3.20		
Ecology		729_LT	48.94931132	-122.5227633		2/7/2007	3.25		
Ecology		N39404F1	48.90167	-122.30254	32	4/15/1997	3.25		
Ecology		N40219L1	48.94204	-122.60647	25	3/12/1997	3.29		
Ecology		N41332J1	48.99942	-122.4418	24	3/19/1997	3.39		
Ecology		N39407D1	48.89013	-122.34985	50	4/14/1997	3.41		
Ecology		N40233A1	48.9202	-122.55749	33	3/13/1997	3.47		
Ecology		N39408E1	48.88404	-122.32692	57	4/14/1997	3.48		
Ecology		N40332H1	48.914	-122.44379		3/27/1997	3.48		
USGS	A485358122320701	39N/02E-03G01	48.899279	-122.536556	32	4/10/1990	3.50		Total
USGS	A485209122180701	39N/04E-16L02	48.869005	-122.304325	28.5	5/24/1990	3.60		Total
Ecology		N39408C1	48.89057	-122.32189	46	4/14/1997	3.61		
Ecology		N39210J1	48.88143	-122.53321	40	3/12/1997	3.63		
Ecology		N39416F1	48.8699	-122.30249	22	4/14/1997	3.64		
Ecology		WHWS15	48.95985	-122.53259		8/23/1988	3.76		
USGS	A485335122301501	39N/02E-01N01	48.89289	-122.505444	25	4/10/1990	3.80		Total
USGS	A485137122295401	39N/02E-24C02	48.860111	-122.499611	22	4/10/1990	3.80		Total
USGS	A485608122320101	40N/02E-22R02	48.935391	-122.534889	30	8/15/1990	3.80		Total
Ecology		N40127A1	48.93205	-122.66212	18	3/24/1997	3.87		
Ecology		N39422N1	48.85047	-122.28614	39	4/16/1997	3.88		
Ecology		N39305Q1	48.89223	-122.45256	9	3/25/1997	3.92		
Ecology		N40126Q1	48.92301	-122.64809	12	3/25/1997	3.92		
Ecology		WHWS10	48.93592	-122.54739	24	8/25/1988	3.92		
Ecology		N39420N1	48.84702	-122.33165	46	4/17/1997	3.97		
USGS	A485608122320501	40N/02E-22Q02 WC-15	48.935391	-122.536	30	8/30/2006	4.02		Dissolved
Ecology		N40112Q1	48.96668	-122.6266	20	3/27/1997	4.04		

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
Ecology		909_LT	48.94970589	-122.5299087		1/31/2007	4.06		
Ecology		N40108R1	48.96709	-122.70424	23	3/26/1997	4.06		
Ecology		N39204N2	48.8926	-122.57015	24	3/10/1997	4.07		
Ecology		994_BBL	48.93566858	-122.5347152		1/31/2007	4.15		
Ecology		N39201N1	48.89193	-122.50434	25	3/10/1997	4.16		
Ecology		WHWS23	48.93579	-122.51867	40	8/22/1988	4.20		
Ecology		N40219M1	48.94175	-122.61253	26	3/12/1997	4.33		
USGS	A485701122302701	40N/02E-14R02 MW-WC-14	48.950114	-122.508776	39	9/30/1998	4.34		Dissolved
Ecology		N40125B1	48.93249	-122.62661	30	3/26/1997	4.40		
Ecology		N40135G1	48.91539	-122.64461	25	3/27/1997	4.40		
Ecology		N39406E1	48.90122	-122.35184	67	4/14/1997	4.48		
Ecology		TI_MW1S	48.95523	-122.48775	14	7/15/2003	4.50		
USGS	A485739122261901	40N/03E-16D01	48.962338	-122.439328	27	8/8/1990	4.60		Total
Ecology		N40110E1	48.9718	-122.68153	19	3/27/1997	4.60		
Ecology		WHWS05	48.94236	-122.55677	18	8/24/1988	4.60		
Ecology		WHWS21	48.95153	-122.52044	32	8/22/1988	4.60		
Ecology		N39316C1	48.8769	-122.43621	24	3/20/1997	4.74		
USGS	A485632122331701	40N/02E-21J05	48.942057	-122.556001	17	8/21/1991	4.80		Total
USGS	A485638122330101	40N/02E-22E02	48.943724	-122.551556	21	8/21/1991	4.80		Total
Ecology		8525_WD	48.94729615	-122.530767		1/31/2007	4.86		
USGS	A485351122271301	39N/03E-05L02	48.898724	-122.454886	38	3/21/1990	4.90		Total
Ecology		WHWS27	48.93183	-122.50855	11	8/25/1988	4.97		
Ecology		N39309C1	48.89097	-122.43218	25	3/26/1997	5.00		
Ecology		973_BBL	48.9349074	-122.5337496		1/31/2007	5.02		
Ecology		N41336J1	48.99749	-122.3528		3/13/1997	5.03		
USGS	A484618122360401	38N/02E-19B02	48.77233	-122.602953	11.8	6/20/1995	5.10		Dissolved
USGS	A485727122250801	40N/03E-16H06	48.957338	-122.420161	28	8/8/1990	5.20		Total
USGS	A485639122161801	40N/04E-22G01	48.944008	-122.272932	42	6/21/1990	5.20		Total
Ecology		WHWS14	48.95069	-122.54081	18	8/22/1988	5.43		
Ecology		N39212C2	48.88853	-122.49882	24	3/14/1997	5.47		
Ecology		N40124Q2	48.93824	-122.62211	23	3/26/1997	5.49		
Ecology		N40231F1	48.91381	-122.60769	20	3/13/1997	5.51		
USGS	A485855122205501	40N/04E-06M01 MW-WC-11	48.981785	-122.349879	40	9/29/1998	5.52		Dissolved
Ecology		N41431R1	48.99559	-122.33162	77	2/18/1997	5.58		
USGS	A485701122312101	40N/02E-23C01	48.950114	-122.523777	38	8/14/1990	5.60		Total
USGS	A485659122312601	40N/02E-23D01	48.949558	-122.525166	30.4	7/10/1990	5.60		Total
USGS	A485427122271701	40N/03E-32P01	48.907336	-122.455997	40	4/24/1990	5.60		Total
Ecology		N39404N1	48.89184	-122.30695	52	4/15/1997	5.72		

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
USGS	A485237122253601	39N/03E-16B02	48.87678	-122.427941	23	3/29/1990	5.90		Total
Ecology		N40228D5	48.93353	-122.5728	22	3/12/1997	5.90		
Ecology		N40335P1	48.90949	-122.38909		3/20/1997	5.90		
Ecology		N40111J1	48.97038	-122.64141	14	3/24/1997	5.96		
Ecology		N40305N1	48.97958	-122.45784		3/12/1997	6.00		
Ecology		WHWS12	48.96312	-122.54373	21	8/23/1988	6.00		
USGS	A485147122172901	39N/04E-16H02	48.871227	-122.293213	48	5/25/1990	6.20		Total
USGS	A485839122242501	40N/03E-10C02	48.977339	-122.408215	18	5/3/1991	6.20		Total
Ecology		39211F1	48.88747	-122.52039	30	3/11/1997	6.26		
USGS	A485303122190901	39N/04E-08G01 AG03	48.883808	-122.320441	29	11/12/1997	6.26		Dissolved
USGS	A480006122171701	41N/04E-33H02	49.000676	-122.289598	58	6/4/1990	6.30		Total
Ecology		N39214E1	48.87004	-122.52922	28	3/14/1997	6.32		
Ecology		39212K2	48.88229	-122.49559	20	3/17/2003	6.33		
Ecology		8591_WD	48.948649	-122.5308958		1/31/2007	6.40		
Ecology		N39317N1	48.863	-122.46363	20	3/12/1997	6.40		
Ecology		N39308C1	48.8908	-122.45685	32	3/26/1997	6.42		
Ecology		40211P1	48.96709	-122.52149	31	3/19/2003	6.47		
USGS	A485149122280601	39N/03E-18Q01	48.86289	-122.470165	21	4/11/1990	6.50		Total
USGS	A485608122330201	40N/02E-22N08 MW-WC-02	48.935391	-122.551834	23	9/28/1998	6.50		Dissolved
Ecology		756_BBL	48.93565448	-122.516562		2/7/2007	6.55		
USGS	A485954122293601	41N/02E-36K01	48.998171	-122.494607	29	8/14/1990	6.60		Total
USGS	A485753122332901	40N/02E-16B02	48.964558	-122.559333	20	8/15/1990	6.70		Total
Ecology		N39416Q2	48.86498	-122.29423	33	4/17/1997	6.80		
Ecology		1201_WIL	48.92241	-122.55622		1/31/2007	6.82		
Ecology		N39317F1	48.87029	-122.45418		3/28/1997	6.82		
Ecology		7766_RTH	48.92516	-122.52971		2/6/2007	6.84		
Ecology		N39212K1	48.88225	-122.49354	27	3/12/1997	6.88		
USGS	A485328122310201	39N/02E-11B01	48.890945	-122.5185	26	4/10/1990	6.90		Total
Ecology		N40114A1	48.96332	-122.64036	26	3/26/1997	7.06		
Ecology		N40228M1	48.92578	-122.57	20	3/12/1997	7.08		
USGS	A485719122253601	40N/03E-16K01	48.955116	-122.427939	33	7/23/1990	7.20		Total
Ecology		N40222N7	48.93577	-122.54787	18	3/11/1997	7.62		
Ecology		1313_BBL	48.93487921	-122.5527129		1/30/2007	7.65		
Ecology		1223_BBL	48.93502017	-122.5488076		2/6/2007	7.78		
USGS	A485209122312501	39N/02E-14M01	48.869	-122.52489	34	4/11/1990	8.00		Total
USGS	A485629122330501	40N/02E-21J01	48.941224	-122.552667	21	8/17/1990	8.00		Total
USGS	A485700122313401	40N/02E-23D02 AG-01	48.949722	-122.527594	48	8/14/1990	8.00		Total
Ecology		N39422K1	48.85394	-122.27622	38	4/16/1997	8.09		

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
USGS	A485818122233601	40N/03E-11E04	48.971506	-122.394604	44	8/8/1990	8.10		Total
USGS	A485709122314701	40N/02E-15R03	48.952336	-122.530999	26	8/21/1991	8.20		Total
Ecology		WHWS24	48.94936	-122.5185	32	8/25/1988	8.24		
Ecology		N39303N1	48.89304	-122.41544	20	3/27/1997	8.55		
Ecology		950_LT	48.95057957	-122.5322047		2/6/2007	8.58		
USGS	A485937122241502	41N/03E-34Q03 MW-FP-03	48.993291	-122.405305	48	11/10/1997	8.69		Dissolved
Ecology		N40316H2	48.95714	-122.42129	28	4/28/1997	8.77		
Ecology		N40333F1	48.91422	-122.43237	29	3/24/1997	8.89		
USGS	A485751122242401	40N/03E-10Q02 MW-WC-04	48.964005	-122.407938	55	9/28/1998	8.97		Dissolved
USGS	A485924122224301	40N/03E-02B01	48.992896	-122.379602	25	5/2/1991	9.00		Dissolved
Ecology		AAF282	48.98673	-122.4659	10	6/26/1997	9.00		
Ecology		N41431H1	49.00093	-122.33062		3/12/1997	9.06		
Ecology		40222D1	48.94973	-122.54795		3/28/1997	9.08		
Ecology		WHWS22	48.93359	-122.51943	25	8/22/1988	9.10		
Ecology		N40301P1	48.9785	-122.3666	49	3/20/1997	9.18		
Ecology		N40221R6	48.93857	-122.55254	30	3/10/1997	9.23		
USGS	A485629122233101	40N/03E-23M01	48.941227	-122.393216	20	7/23/1981	9.30		Dissolved
Ecology		1119_BBL	48.94936329	-122.5185145		2/7/2007	9.38		
Ecology		N40229C1	48.93268	-122.58611	20	3/13/1997	9.42		
USGS	A485324122262401	39N/03E-09D02	48.889836	-122.441275	38	3/23/1990	9.50		Total
USGS	A485700122315001	40N/02E-15R04 MW-WC-12	48.949836	-122.531833	26	9/30/1998	9.50		Dissolved
Ecology		WHWS06	48.93611	-122.55323	26	8/24/1988	9.60		
Ecology		WHWS25	48.93008	-122.51537	32	8/22/1988	9.67		
Ecology		N39214L2	48.8691	-122.52354	24	3/13/1997	9.76		
USGS	A485936122235501	40N/03E-03A02	48.993173	-122.399881	26	5/1/1991	9.90		Dissolved
USGS	A485951122210601	41N/03E-36J01	48.997341	-122.352934	37	7/6/1990	9.90		Total
Ecology		40331L1	48.91229	-122.47877	30	3/25/1997	9.92		
USGS	A485937122241503	41N/03E-34Q04 MW-FP-04	48.993291	-122.405344	23	11/10/1997	9.98		Dissolved
USGS	A485337122294801	39N/02E-01P02	48.893446	-122.497944	33.5	4/12/1990	10.0		Total
USGS	A485346122261901	39N/03E-04M02	48.895947	-122.439885	37	3/21/1990	10.0		Total
USGS	A485214122255901	39N/03E-16F01	48.870391	-122.435719	28	4/11/1990	10.0		Total
Ecology		1264_BBL	48.9359082	-122.5511894		1/30/2007	10.1		
USGS	A485541122310501	40N/02E-22Q01 MW-WC-16	48.927891	-122.519333	25	9/30/1998	10.1		Dissolved
Ecology		WHWS19	48.94937	-122.52724	29	8/23/1988	10.3		
Ecology		WHWS20	48.93281	-122.52606	33	8/23/1988	10.4		
Ecology		N40331L2	48.91268	-122.47587	19	3/24/1997	10.5		
Ecology		39212C1	48.88975	-122.49768	32	3/12/1997	10.6		

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
Ecology		950_WL	48.92161	-122.53192		2/6/2007	10.7		
Ecology		39221H1	48.8579	-122.55389	27	3/17/2003	10.8		
Ecology		N41431Q1	48.99358	-122.33535	50	2/18/1997	10.8		
Ecology		N39301E1	48.90151	-122.37478	39	3/25/1997	10.9		
Ecology		N40124Q1	48.9374	-122.62207	23	3/25/1997	10.9		
Ecology		N40215Q1	48.95045	-122.54118	26	3/10/1997	10.9		
USGS	A485555122302401	40N/02E-26A04	48.93178	-122.507943	24.5	8/16/1990	11.0		Total
USGS	A485835122274301	40N/03E-07A02	48.976227	-122.463218	21	5/1/1991	11.0		Dissolved
USGS	A485848122191301	40N/04E-05P01	48.979841	-122.321545	23	5/2/1991	11.0		Dissolved
Ecology		N40135K1	48.91133	-122.64483	21	3/26/1997	11.1		
USGS	A485725122244401	40N/03E-15F02 MW-WC-05	48.956783	-122.413494	40	9/28/1998	11.2		Dissolved
Ecology		N40311E1	48.9716	-122.39544	36	3/14/1997	11.2		
Ecology		8138_BH	48.93785336	-122.5511035		2/7/2007	11.3		
Ecology		N40308D1	48.97801	-122.45766		3/12/1997	11.4		
Ecology		N40223D4	48.9497	-122.52494	43	3/10/1997	11.6		
Ecology		N40406H1	48.9877	-122.33199	40	2/18/1997	11.6		
Ecology		943_BBL	48.93439995	-122.5312391		1/31/2007	11.8		
Ecology		1124_BBL	48.9377	-122.54787		1/30/2007	11.9		
USGS	A485258122293901	39N/02E-12K03	48.882612	-122.495444	27	4/13/1990	12.0		Total
USGS	A485932122241601	40N/03E-03B01 MW-SU-017	48.991983	-122.406369	29	8/7/1996	12.0		Dissolved
USGS	A485818122234001	40N/03E-11E03	48.971506	-122.395715	36	8/8/1990	12.0		Total
USGS	A485445122271201	40N/03E-32L01	48.912336	-122.454608	50	4/25/1991	12.0		Dissolved
USGS	A485850122191401	40N/04E-05P02	48.980397	-122.321822	28	8/29/1990	12.0		Dissolved
USGS	A490008122290001	41N/03E-31E01	49.00206	-122.484607	30	6/29/1990	12.0		Total
Ecology		N40332M1	48.91169	-122.4601	26	3/24/1997	12.5		
Ecology		40223A3	48.94682	-122.51331	23	8/23/1988	12.7		
USGS	A485751122241601	40N/03E-10Q01 AG-04	48.964133	-122.405941	30	8/17/2006	12.9		Dissolved
Ecology		WHWS13	48.93491	-122.54174	21	8/24/1988	12.9		
USGS	A485444122272801	40N/03E-32M01	48.912058	-122.459053	25.5	4/24/1991	13.0		Total
Ecology		N40223B2	48.94974	-122.51819	35	3/10/1997	13.0		
Ecology		1064_BBL	48.93614783	-122.5460181		2/7/2007	13.1		
USGS	A485936122223001	40N/03E-02A02 WC-09	48.993174	-122.376269	38	9/29/1998	13.1		Dissolved
Ecology		8132_BH	48.93738	-122.55077		1/31/2007	13.1		
Ecology		N40302B1	48.99268	-122.38015	27	3/14/1997	13.4		
Ecology		N40302F1	48.98699	-122.38509	35	3/14/1997	13.5		
Ecology		40332L1	48.91216	-122.45375	45	3/24/1997	13.6		
Ecology		N41335N1	48.99358	-122.39608	28	3/13/1997	13.6		
USGS	A485843122242301	40N/03E-03P04 FP-05	48.978663	-122.407955	59	11/11/1997	13.9		Dissolved

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual- ifier	Fraction
USGS	A485316122322601	39N/02E-10F01	48.887612	-122.541835	20	4/12/1990	14.0		Total
USGS	A485558122303101	40N/02E-26A03	48.933724	-122.510721	33	8/17/1990	14.0		Total
USGS	A485522122325701	40N/02E-27N02	48.922612	-122.550445	26	4/30/1991	14.0		Dissolved
USGS	A485843122242302	40N/03E-03P05 FP-06	48.978663	-122.40798	29	11/11/1997	14.1		Dissolved
USGS	A485750122244901	40N/03E-15D02 MW-WC-01	48.963728	-122.414883	27	9/28/1998	14.1		Dissolved
Ecology		N40303E1	48.98623	-122.41324	20	3/21/1997	14.1		
Ecology		1349_BBL	48.93499198	-122.5552663		1/30/2007	14.2		
Ecology		N40310K1	48.97108	-122.4065	30	3/14/1997	14.2		
Ecology		N39408R1	48.87722	-122.31001	35	4/15/1997	14.3		
Ecology		N41334E1	49.00199	-122.4183	20	3/13/1997	14.3		
Ecology		AAF274	48.96912	-122.40347	23	5/28/1998	14.5		
Ecology		N40223P4	48.93611	-122.51896	30	3/11/1997	14.8		
Ecology		N41336Q1	48.99354	-122.35846	34	2/18/1997	14.8		
USGS	A485330122272601	39N/03E-08C02	48.891502	-122.458498	27	3/22/1990	15.0		Total
Ecology		40226B1	48.93391	-122.51625	30	3/18/2003	15.0		
Ecology		40316H1	48.96015	-122.42001	58	4/28/1997	15.0		
USGS	A490008122242701	41N/03E-34F01	49.002062	-122.40877	21.7	7/5/1990	15.0		Total
Ecology		WHWS07	48.94409	-122.55141	26	8/25/1988	15.0		
Ecology		N39227C1	48.84755	-122.5439	23	3/13/1997	15.1		
Ecology		N40303Q1	48.98016	-122.40625	30	3/20/1997	15.4		
Ecology		1157_BBL	48.93502017	-122.547048		2/7/2007	15.6		
USGS	A485751122304601	40N/02E-14B01 AGREF	48.964003	-122.514054	25	8/21/2008	15.7		Dissolved
Ecology		39215J1	48.86916	-122.53468	21	3/13/1997	15.8		
USGS	A485631122332401	40N/02E-21J06 MW-WC-18	48.94178	-122.557945	27	10/1/1998	15.9		Dissolved
Ecology		WHWS11	48.95102	-122.54603	24	8/24/1988	16.0		
Ecology		WHWS18	48.96454	-122.53108	40	8/22/1988	16.2		
Ecology		40221J5	48.94264	-122.55677	17	3/10/1997	16.6		
Ecology		N40405L1	48.985	-122.32359	38	4/29/1997	16.7		
Ecology		40310F1	48.97469	-122.41128	21	3/13/1997	16.9		
Ecology		N40226A4	48.9311	-122.51229	33	3/11/1997	17.1		
Ecology		WHWS17	48.95206	-122.53129		8/24/1988	17.1		
Ecology		40303B1	48.99216	-122.40645	29	3/13/1997	17.2		
Ecology		N40303R3	48.97928	-122.39815	73	4/28/1997	17.2		
Ecology		N41336N1	48.99389	-122.37391	26	3/13/1997	17.2		
Ecology		40308P1	48.96547	-122.45574	15	5/14/2003	17.5		
Ecology		7969_RTH	48.93428718	-122.5303164		1/31/2007	17.5		
Ecology		N39422L1	48.85429	-122.2827	30	4/16/1997	17.5		
Ecology		N40221G1	48.94437	-122.56219	25	3/12/1997	17.8		

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
USGS	A485708122311301	40N/02E-14P03 AG-16	48.95215	-122.520305	42	8/25/2006	18.0		Dissolved
USGS	A485905122272201	40N/03E-05M05	48.984561	-122.457384	11.7	8/14/1991	18.0		Total
Ecology		AAF276	48.9668	-122.40477	25	5/28/1998	18.2		
USGS	A485817122244701	40N/03E-10L01 AG-13	48.971563	-122.411111	18	8/30/2006	18.7		Dissolved
Ecology		39203Q1	48.89201	-122.53794	31	3/10/1997	19.0		
USGS	A485304122282001	39N/03E-07K02	48.884279	-122.473498	24	4/26/1991	19.0		Dissolved
USGS	A485917122241901	40N/03E-03G02 AG-06	48.987841	-122.40675	28	8/28/2002	19.4		Dissolved
Ecology		AAF273	48.96894	-122.40474	24	5/28/1998	19.4		
Ecology		N40309H1	48.97225	-122.4193	21	3/13/1997	19.5		
Ecology		40332M2	48.91028	-122.46308	20	3/18/2003	19.6		
Ecology		WHWS01	48.93663	-122.57383	43	8/24/1988	19.6		
USGS	A485611122330801	40N/02E-21R01	48.936224	-122.553501	23.5	4/30/1991	20.0		Dissolved
USGS	A485613122310401	40N/02E-23P01	48.93678	-122.519055	28.6	8/22/1991	20.0		Total
USGS	A485951122244501	41N/03E-34M01	49.000395	-122.413215	20	5/1/1991	20.0		Dissolved
USGS	A485749122250301	40N/03E-16A01 AG-15	48.963355	-122.418958	32	8/29/2006	20.1		Dissolved
Ecology		40307H1	48.97378	-122.4645	21	3/19/1997	20.2		
Ecology		40305N3	48.97976	-122.45945	26	3/19/1997	20.4		
Ecology		413340	49.00199	-122.4183	12	3/20/2003	20.5		
USGS	A485607122321401	40N/02E-27B01 AG-02	48.933955	-122.538425	41	8/15/1997	20.7		Dissolved
Ecology		AAF277	48.96674	-122.40365	25	5/28/1998	20.7		
USGS	A485957122230401	41N/03E-35L01	48.999007	-122.385714	25	5/1/1991	21.0		Dissolved
Ecology		N41431P1	48.99362	-122.3451		3/13/1997	21.3		
Ecology		AAF281	48.98666	-122.46686	9	6/26/1997	21.4	J	
Ecology		1055_WL	48.92179651	-122.5352356		2/6/2007	21.5		
Ecology		39308F2	48.88473	-122.45327	20	3/18/2003	21.8		
Ecology		39317H1	48.87012	-122.44533		3/18/2003	22.1		
USGS	A485941122230601	40N/03E-35Q01 MW-WC-08	48.994563	-122.386269	28	9/29/1998	22.8		Dissolved
Ecology		AKG-727	48.99319	-122.50632	12.8	9/20/2004	22.8		Dissolved
USGS	A485706122310801	40N/02E-14P02	48.951503	-122.520165	39	8/14/1990	23.0		Total
Ecology		AAF275	48.97127	-122.40347	20	5/28/1998	23.0		
Ecology		N41335Q1	48.99397	-122.38459	25	3/12/1997	23.0		
Ecology		40331P3	48.90709	-122.47724	36	3/26/1997	23.2		
Ecology		N40211R1	48.96549	-122.51013	29	4/28/1997	23.5		
Ecology		40315L1	48.95659	-122.41007	20	4/28/1997	24.4		
Ecology		1152_WL	48.9202	-122.55749		2/7/2007	24.5		
Ecology		WHWS02	48.9335	-122.57185	12	8/25/1988	24.5		
Ecology		AAF284	48.98297	-122.46673	10	6/26/1997	26.2		
Ecology		AKG-724	48.99108	-122.50506	12	9/21/2004	27.8		Dissolved

Agency	USGS site number	Station name	Latitude (HARN83)	Longitude (HARN83)	Well depth (feet)	Sample date	Maximum Nitrate+ Nitrite-N (mg/L)	Qual-ifier	Fraction
Ecology		AKG-724	48.99108	-122.50506	12.4	9/21/2004	27.8		Dissolved
Ecology		AKG-721	48.99328	-122.50732	13	9/21/2004	28.3		Dissolved
Ecology		40214P1	48.95155	-122.52049	43	3/10/1997	28.6		
Ecology		39307K2	48.884	-122.47326	24	3/17/1997	28.7		
Ecology		BR_BW2	48.97113	-122.40284	10	7/18/2003	29.0		
Ecology		AAF278	48.9796	-122.46653	11	6/26/1997	31.0		
Ecology		N40332M2	48.91028	-122.46308	25	3/21/1997	32.3		
Ecology		N40406G1	48.98616	-122.34024	20	3/13/1997	33.4		
Ecology		41333M1	49.00092	-122.44033	43	3/13/1997	33.9		
Ecology		AKG-725	48.99207	-122.50724	13.2	9/20/2004	35.5		Dissolved
Ecology		40227C1	48.93517	-122.54201	32	3/11/1997	36.5		
Ecology		AAF283	48.98293	-122.46561	11	6/26/1997	39.3		
Ecology		AKG-723	48.99101	-122.50722	12.7	9/21/2004	39.5		Dissolved
Ecology		N40406C1	48.99262	-122.34474	71	2/18/1997	42.0		
Ecology		AAF272	48.97128	-122.40493	19	5/28/1998	42.3		
USGS	A485949122270001	41N/03E-32Q01	48.996783	-122.451272	73	8/13/1991	43.0		Dissolved
Ecology		40226D2	48.93268	-122.52493	15	3/11/1997	43.1		
Ecology		AKG-722	48.99211	-122.50506	12	9/20/2004	45.3		Dissolved
Ecology		AAF279	48.98136	-122.46599	11	6/26/1997	45.9		
Ecology		AAF285	48.98435	-122.46617	11	6/26/1997	50.7		
Ecology		AAF280	48.97962	-122.46542	10	6/26/1997	52.0		
Ecology		39307H1	48.88541	-122.46641	29	3/17/1997	53.0		
Ecology		N41332Q1	48.99657	-122.45137	25	3/12/1997	73.0		
Ecology		AAF286	48.986	-122.46541	10	6/26/1997	74.1		

Appendix D. Estimated nitrogen loading to the Sumas-Blaine Aquifer by source

Table D-1. Estimated annual nitrogen loading to the ground overlying the Sumas-Blaine Aquifer (SBA) in lb/acre.

Source	Nitrogen Loading (lb/year)	Mean % of total
Manure applied to crops[1]	10-12,000,000	65
Fertilizers[2]	4,600,000	27
Atmospheric deposition[3]	380,000	2.3
Legumes[2]	428,000	2.5
Dairy lagoons[4]	206,800	1.2
Irrigation[2]	170,000	1.0
On-Site Sewage Systems[5]	207,000	1.2

[1] Washington State Department of Agriculture 2010 dairy summary (*16*). Includes only farm addresses over the SBA. Assumes 20-35% loss before applied to crops. Lagoon leaching subtracted from total.

[2] Almasri and Kaluarachchi, 2003 (*46*).

[3] Assumes 0.26 mg/L nitrogen in precipitation (*6*) over the 150 square miles of the SBA with 45.8 inches annual precipitation, plus 46% more for dry deposition (*46*).

[4] Assumes all dairies have a lagoon with leakage as estimated in Cox and Kahle (1999):
(110 dairies with addresses over the SBA in 2010) x (1,880 lb N leached/dairy-year).

[5] US EPA (*51*) per capita nitrogen output from on-site systems (9 lb/person/year) assuming 23,000 residents outside sewered areas.