Island County

Groundwater Nitrate Study

Prepared by:

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December 1997

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Introduction

Groundwater is the sole source of potable water for 75% of the residents of Island County, Washington. Island County, located in northwestern Washington, includes approximately 134,000 acres, and consists of Whidbey and Camano Islands. The primary land uses within the county include forests (51% of land area), agriculture (16%), residential (14%), and open lands (4%). Excluding the city of Oak Harbor and Whidbey Naval Air Station, all drinking water sources in the county utilize groundwater. These sources include over 750 small public water systems, thousands of individual wells, and a few springs. Because of the importance of the groundwater resource in Island County, in 1982 the U.S. Environmental Protection Agency designated both Whidbey and Camano Islands as Sole Source Aquifers.

Groundwater has long been recognized as a valuable natural resource, but only relatively recently has the susceptibility of groundwater aquifers to contamination been understood and appreciated. A contaminant can be defined as anything which can affect the aesthetics or usability of the water resource. While groundwater quality in Island County is generally good, the county's dependence upon the resource dictates that actions be directed at preventing groundwater pollution, but before specific actions or policies can be implemented, specific problems must be adequately identified, investigated, and described.

The contamination of groundwater and rural drinking water supplies by nitrates has been recognized as a potential public health hazard worldwide. Nitrate (NO_3) is a form of nitrogen that is soluble in water, relatively stable, and very mobile in soils. Because the nitrate molecule is negatively charged, it tends to leach through the soil profile with water movement. The degree of leaching and potential for groundwater contamination are dependent upon several factors, including soil texture and pH, amount of rainfall, depth of aquifers, presence of restrictive geologic formations, and the amount of nitrogen present as nitrate. The amount of nitrate present in a given environment is influenced by biological and chemical processes such as nitrification, denitrification, and mineralization. These processes are in turn subject to many environmental factors, including temperature, moisture, aeration, pH, and the presence of organic carbon.

Common sources of nitrates include sewage disposal systems, agricultural fertilizers, animal feedlots, manure lagoons, and decaying vegetation. Although the exact contribution of individual sources is difficult to establish, most cases of groundwater contamination by nitrates can be traced to a particular source through analysis of nearby nitrate sources, topography, and direction of groundwater flow. The majority of cases are attributable to human activities, and can be associated with specific land uses.

Nitrate contamination of drinking water sources is a concern because of its potential adverse effects on human health. Once ingested nitrate is converted to nitrite in the stomach. The nitrite then reacts with the hemoglobin in the blood to form methemoglobin. As a result, the capacity of the blood to carry oxygen is reduced, and symptoms of oxygen starvation begin to occur. This condition is known as methemoglobinemia, or Blue Baby Syndrome. While it is extremely rare in adults, children under one year of age are very susceptible due to their blood chemistry and low stomach acidity. Long term exposure to nitrates has also been associated with increased risk of stomach and intestinal cancers in adults, but the evidence is inconclusive. Because of public health concerns, a nationally recognized maximum contaminant level (MCL) for nitrate nitrogen in drinking water has been set by the Environmental Protection Agency at 10 mg/L. While public water systems are required to monitor nitrate levels periodically, most private domestic wells in Island County have never been tested for nitrate. Prior to 1990, there were no sampling requirements for individual wells. Since 1990, in response to Growth Management Act requirements, all individual wells must be tested for nitrates prior to building permit approval.

The following report is a summary of the findings of a study undertaken by the Island County Health Department in 1995 to determine the degree and extent of nitrate contamination of the groundwater aquifers in the county, to attempt to identify nitrate sources, and to recommend strategies for preventing further contamination in the future. This study was funded by the Washington State Department of Ecology through the Centennial Clean Water Fund.

The data used in this study does not represent a random sampling of wells in the county, and should not be used to make general conclusions about average nitrate levels throughout the county.

Objectives and Methods

The primary objectives of this study were to identify areas within Island County where groundwater quality has been affected by nitrates and to attempt to determine sources of nitrate contamination. Other goals included tracing contaminant flow pathways, assessing the susceptibility of wells to contamination, and raising public awareness about the health effects of nitrates. The findings of this study will hopefully be valuable in understanding how drinking water wells become contaminated and how to prevent further impacts to the county's aquifers.

The study began with a thorough search of all water quality data in county and state Department of Health records. Any drinking water well having shown a nitrate level greater than 2.0 mg/L was included in the background study. The well locations and nitrate concentrations were transferred to maps so that the spatial distribution of the affected wells could be studied.

A site survey was conducted at each well site included in the background study. These surveys noted such factors as well location and depth, topography, drainage patterns, surrounding land uses, and any potential sources of nitrates in the vicinity. Based upon historical water quality data and upon the findings of the surveys, Nitrate Focus Areas were identified for further study throughout the county. Criteria for Focus Area designations also included historical land uses and the number of drinking water wells in the area.

Water sampling was conducted in the Focus Areas, as well as further investigation of potential sources of nitrates in the vicinity. Wells were selected for sampling based upon landscape position, well depth, cooperation of well owners, and proximity to potential nitrate sources and/or wells with historically elevated nitrate levels. Water samples were collected from approximately 80 private wells and analyzed for nitrate nitrogen by a Washington State Department of Ecology certified laboratory. Samples were collected and transported in accordance with laboratory protocol and the Department of Ecology approved Quality Assurance Plan for this project. Additional information about each well's design and construction was recorded during site inspections, including well depth, static water level, type of construction, condition of the well head, susceptibility to surface water intrusion, and any potential nitrate sources nearby. Temperature and conductivity measurements were taken at the time of sample collection using field instruments. Well owners were notified in writing of sample results and provided with information about potential health effects of nitrates and wellhead protection measures.

It should be noted that due to the well selection process, most notably homeowner cooperation and spatial distribution of wells, the sample results are not intended to provide a complete survey of nitrate levels in each aquifer throughout the Focus Area. Rather, it is hoped that each Focus Area and potentially each individual well can serve as a type of case study, and that lessons can be gleaned from the data regarding wellhead protection, contaminant flow pathways, susceptibility factors for wells, and the pollution potential of various nitrate sources.

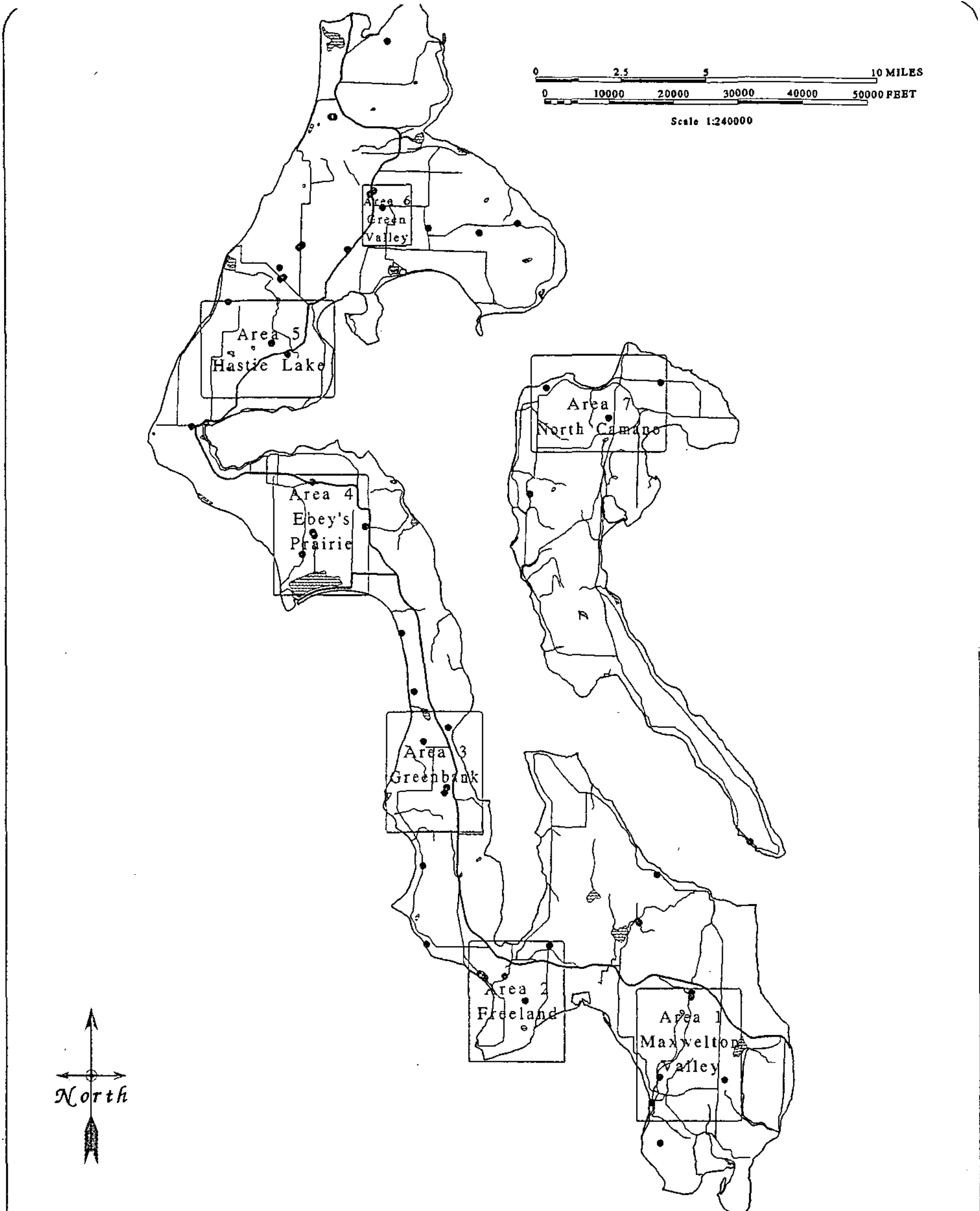
For the purpose of this report, it will be assumed that contaminant plumes will generally follow the direction of groundwater flow, and that higher nitrate concentrations within a given aquifer will indicate a closer proximity to the source than will a lower concentration within the same aquifer. The depths of various aquifers at a given location, as well as the direction of groundwater flow within a given aquifer, will be assumed to be consistent with the findings of the Island County Groundwater Management Plan Technical Memorandum (Economic and Engineering Services, 1989). Aquifers are defined as A through E, with A being the deepest and E being the most shallow.

Results

Of the 449 individual wells reviewed by the Island County Health Department from 1992 through the start of this study in 1995, 50 showed nitrate levels above 2.0 mg/L (11.1%). Of these, 22 were above 5.0 mg/L (4.9%) and 5 were above the drinking water standard of 10.0mg/L (1.1%). Background nitrate level in Island County groundwater is typically less than .05 mg/L.

There are roughly 750 water systems in Island County. A search of state and county records found that 93 of these have at some time recorded nitrate concentrations above 2.0 mg/L (12.5%). Of these, 25 had recorded levels above 5.0 (3.3%) and 5 had levels above the drinking water limit of 10.0 mg/L (0.7%). The highest nitrate concentration recorded in Island County in the course of this study was 68.0 mg/L, which was found in a private well on a commercial farm. It should be noted that these figures represent the highest levels on record, and that several of these systems have either connected to other systems or have developed new sources.

Based upon the nitrate concentrations and distribution of the wells identified in the background study, seven Focus Areas were designated for further sampling (See Fig. 1.2). The findings from each Focus Area will be discussed separately.



Legend

- Background Nitrate Sample > 5 <= 10 mg/L
- Background Nitrate Sample > 10 mg/L
- Focus Area Location

Figure 1.1
Nitrate Study
Focus Area Locations

I. Maxwelton Focus Area

This Focus Area consists of the basin surrounding Maxwelton Creek from Highway 525 south to where the creek discharges into a large wetland near Maxwelton Beach (Fig. 2.1). To the west of the creek lie gently sloping pastures, while eastern side of the basin consists of steeper slopes rising to wooded uplands. The basin has historically been the site of numerous small to mid-sized animal farms, particularly on the western side of the creek. Other land uses in the area include low density housing and forestry, although agriculture remains the predominant land use throughout most of the area.

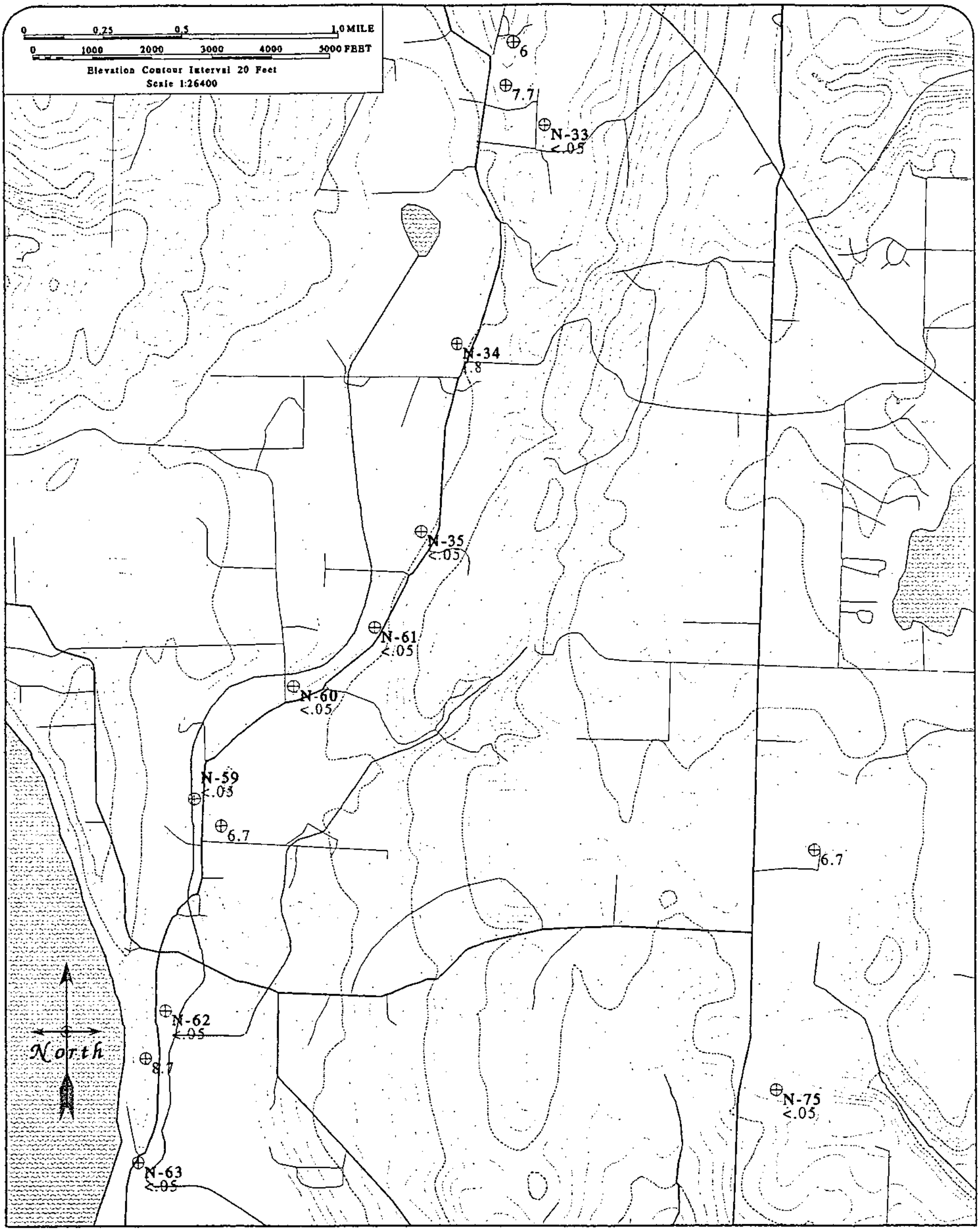
Background data showed elevated nitrate levels at the north end of the Focus Area in the D aquifer (6.0, 7.7 mg/L). Follow-up sampling in the immediate vicinity as well as directly downgradient from these wells did not reveal any nitrate concentrations above 1.8 mg/L (N-33,34). Further sampling extending south along the path of the creek revealed no nitrate concentrations above 0.5 mg/L. This would seem to indicate a small area of contamination, with a source relatively close to the affected wells. The animal pastures in the immediate vicinity provide the most likely source.

In the southern part of the Focus Area are two wells finished in the D aquifer each of which have recorded a nitrate concentration of 6.7 mg/L. One lies just east of Maxwelton Creek, and the other lies approximately two miles due east and directly upgradient from the first. It appears that these wells are hydrologically connected, and it is possible that they share a common nitrate source in the vicinity of the easternmost well, which lies upgradient. A site inspection of this well revealed that it lies in a small closed basin which collects surface water from surrounding animal pastures. Just 1/2 mile south of this well is a large wetland which contains several potential sources of nitrates, such as bird and mammal feces and large quantities of decomposing vegetation. This wetland also collects surface water from numerous animal pastures and small farms in the area. However, widespread contamination of the D aquifer appears unlikely due to the number of apparently unimpacted wells in the area (N-59,62,75).

The highest nitrate concentration recorded in the Focus Area was 8.7 mg/L. This well lies in the southwest corner of the area, just north of Maxwelton Beach. Because this level is higher than any recorded upgradient of this location, it appears likely that an additional nitrate source exists between this well and the upgradient wells. One possible source is an abandoned poultry operation less than 1/2 mile northeast of the well.

Throughout the Focus Area, all wells finished in the C aquifer showed nitrate concentrations below 0.5 mg/L (N-35,59,60,61,62), apparently indicating that contaminants in the D aquifer are not reaching the deeper C aquifer.

This Focus Area includes at least three distinct areas of contamination, each apparently with a separate nitrate source. Each of these areas has a history of agricultural land uses. While population density in the area is low and all recorded levels are below the MCL, the number of wells in the area and the continued prevalence of agriculture create the potential for public health impacts. For those with contaminated wells, the C aquifer apparently provides an unimpacted water supply option.



Legend	
⊕	Well Location
N-17	Sample ID
<.05	Nitrate (mg/L)
15.0	Background NO_3

Figure 2.1
Nitrate Sample Results
Focus Area 1, Maxwelton Valley

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II. Freeland Focus Area

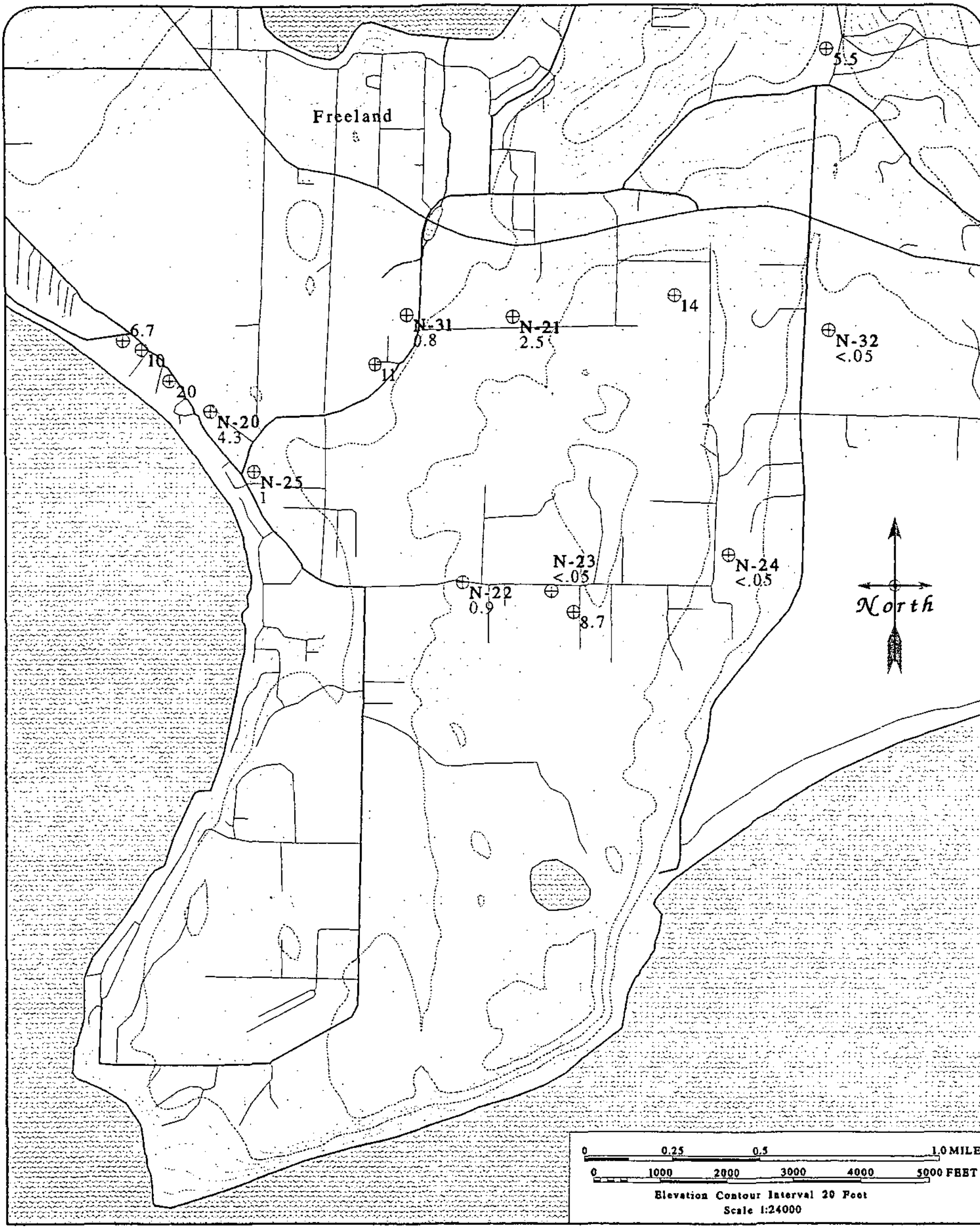
The Freeland Focus Area consists of an area extending south and east from Freeland (Fig. 2.2). It is bounded on the north by Holmes Harbor and on the west by Mutiny Bay. Wooded uplands extend south approximately three miles south from Freeland, and are bounded on the east and northwest by broad, low valleys. Historical land uses range from high density housing in Freeland and along the coast of Mutiny Bay to large forested tracts in the southern part of the Focus Area. Many small to mid-sized animal farms have operated in the area, primarily along the western edge of the Focus Area and immediately south and southeast of Freeland. Many of these farms are still in operation.

The E aquifer appears in the higher elevations on the eastern side of the Focus Area, extending from land surface to depths of less than 60 feet. The D aquifer is typically found at depths of 80 to 120 feet throughout the area, and the C aquifer lies just slightly deeper. The D and C aquifers apparently contact each other throughout much of the area.

Historical data revealed elevated nitrate concentrations throughout the area, with levels ranging from less than 0.5 mg/L to 20.0 mg/L in shallow dug wells along Mutiny Bay. A well just east of Freeland has recorded a nitrate level of 5.5 mg/L. This well lies at the base of a sloping cow pasture, and surface water runoff flows across the pasture to collect and infiltrate within 75' of the well head. A nitrate concentration of 14.0 mg/L was recorded one mile southeast of Freeland, and approximately one mile further south a nitrate level of 8.7 mg/L was recorded. Both of these wells are finished in the D aquifer, although data from surrounding wells (N-21,22,23,24,31,32) seem to indicate that contamination is not widespread in the area. It seems likely that these wells have been impacted by separate nitrate sources in the vicinity of the affected wells, and indeed both wells lie adjacent to small animal farms. One mile south of Freeland lies a well serving a small water system which has recorded a nitrate concentration of 11.0 mg/L. Because this well lies approximately one mile downgradient from the aforementioned well which showed nitrates at 14.0 mg/L, it is possible that these wells share a common nitrate source in the vicinity of the upgradient well. As mentioned above, this well lies adjacent to a cattle farm, which is the most obvious nitrate source in the area.

One half mile further southwest and downgradient lie a number of wells along Mutiny Bay, most of which are shallow dug wells, which have recorded nitrate levels as high as 20.0 mg/L. The source of nitrates impacting these wells is unclear. Because groundwater gradients from the north, east and southeast all converge in this area, these wells may share a common contaminant source with any or all of the upgradient wells which have been impacted. However, it is improbable that these shallow wells are hydrologically connected to the deeper wells inland. Most likely the shallow wells have been impacted by nitrate sources in the immediate vicinity. The most obvious sources are the livestock pasture and topsoil mixing operations directly to the north, as well as the high density of on-site sewage systems in this highly populated area. Previous Health Department studies in this area concluded that domestic wastewater was not the source of nitrates, based upon analyses for other parameters found in wastewater.

The overall pattern of contamination in this Focus Area suggests multiple nitrate sources with areas of localized impacts. While agricultural operations, which appear to be the primary nitrate source in the area, are gradually being replaced by residential land uses, the possibility of further impacts to this highly populated area must be considered. In particular, the proximity of water supply wells for the Freeland Water District to affected wells is cause for concern.



Legend

⊕	Well Location
N-17	Sample ID
<.05	Nitrate (mg/L)
15.0	Background NO

Figure 2.2
Nitrate Sample Results
Focus Area 2, Freeland

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III. Greenbank Focus Area

The Greenbank Focus Area encompasses an area extending from Lake Hancock south to Classic Road (Fig. 2.3). This section of Whidbey Island consists of rolling, wooded uplands dropping steeply to the shorelines on the east and west and sloping more gradually to Lake Hancock to the north. Historically, primary land uses consisted of forest and numerous small animal farms. Low density housing has become the predominant land use, although many small farms still exist, and the area remains heavily forested.

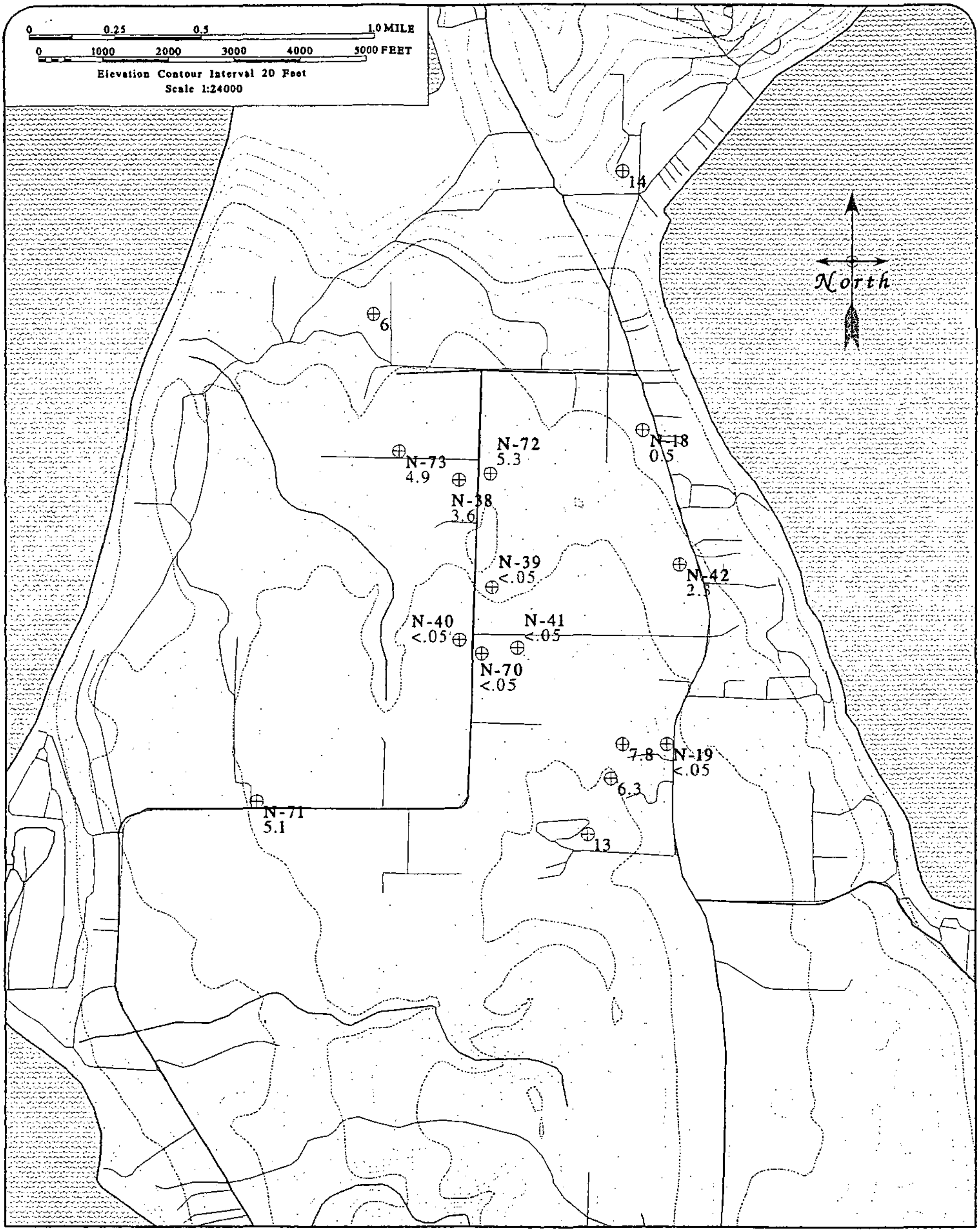
In the uplands in the eastern portion of the Focus Area, the E aquifer appears only sporadically at depths of less than 50 feet. The D aquifer consistently appears at depths ranging from 80 to 140 feet throughout the area, and extends into the lowland areas further west, where it is found at slightly shallower depths. The C aquifer lies just below sea level throughout the area.

Historical data indicated elevated nitrate levels in the D and E aquifers. The area immediately south of Christensen Road and west of Hwy 525 has consistently shown nitrate concentrations above 5.0 mg/L and as high as 13.0 mg/L in the E aquifer. Historical data from the area south and east of this area showed no signs of contamination. To the north and west of this area, however, sampling revealed nitrate concentrations in the range of 4 to 5 mg/L in the D aquifer (N-38, 71,72,73). Because this is the direction of flow in the E aquifer, it is possible that the two aquifers share a common nitrate source in the vicinity of the highest concentrations found in the E aquifer. Past land uses in this area include a dairy farm, so manure is one possible source of nitrate contamination.

Drainage patterns in this area are irregular, and surface water collects in a small closed basin just west of Old County road, directly adjacent to the highest recorded nitrate levels. Throughout the Focus Area, nitrate levels in the C aquifer were below .05 mg/L (N-19,39,40,41,70), indicating that its depth (>250 feet in most areas) and the presence of impermeable layers in the sediment strata have protected it from the contamination that has affected the D and E aquifers.

At the north end of the Focus Area lies a well which has recorded a nitrate concentration of 14.0 mg/L. This well used to serve a berry farm and winery, but is no longer in use due to the nitrate levels. Based upon aquifer configurations and nitrate concentrations, it appears unlikely that this well shares a common nitrate source with the previously mentioned wells to the south. Rather, drainage around the well site and a cracked surface seal indicate that this well may be subject to inundation by stormwater from the berry fields . Another possible nitrate source is a small pond which lies 100 feet east of the well.

Nitrate concentrations above the MCL of 10 mg/L in the E aquifer pose a potential public health threat, although the impacted area is relatively small and is not densely populated. The impact to the D aquifer, while more widespread, consistently shows nitrate levels well below the MCL. Groundwater impacts appear to be related more to the agricultural history of the area than to the more residential land use patterns of the present, so further degradation of the resource may be unlikely. The seemingly unimpacted C aquifer remains a water supply option for those whose sources are above the MCL.



⊕ Well Location
N-17 Sample ID
<.05 Nitrate (mg/L)
15.0 Background NO

Figure 2.3
Nitrate Sample Results
Focus Area 3, Greenbank

IV. Ebey's Prarie Focus Area

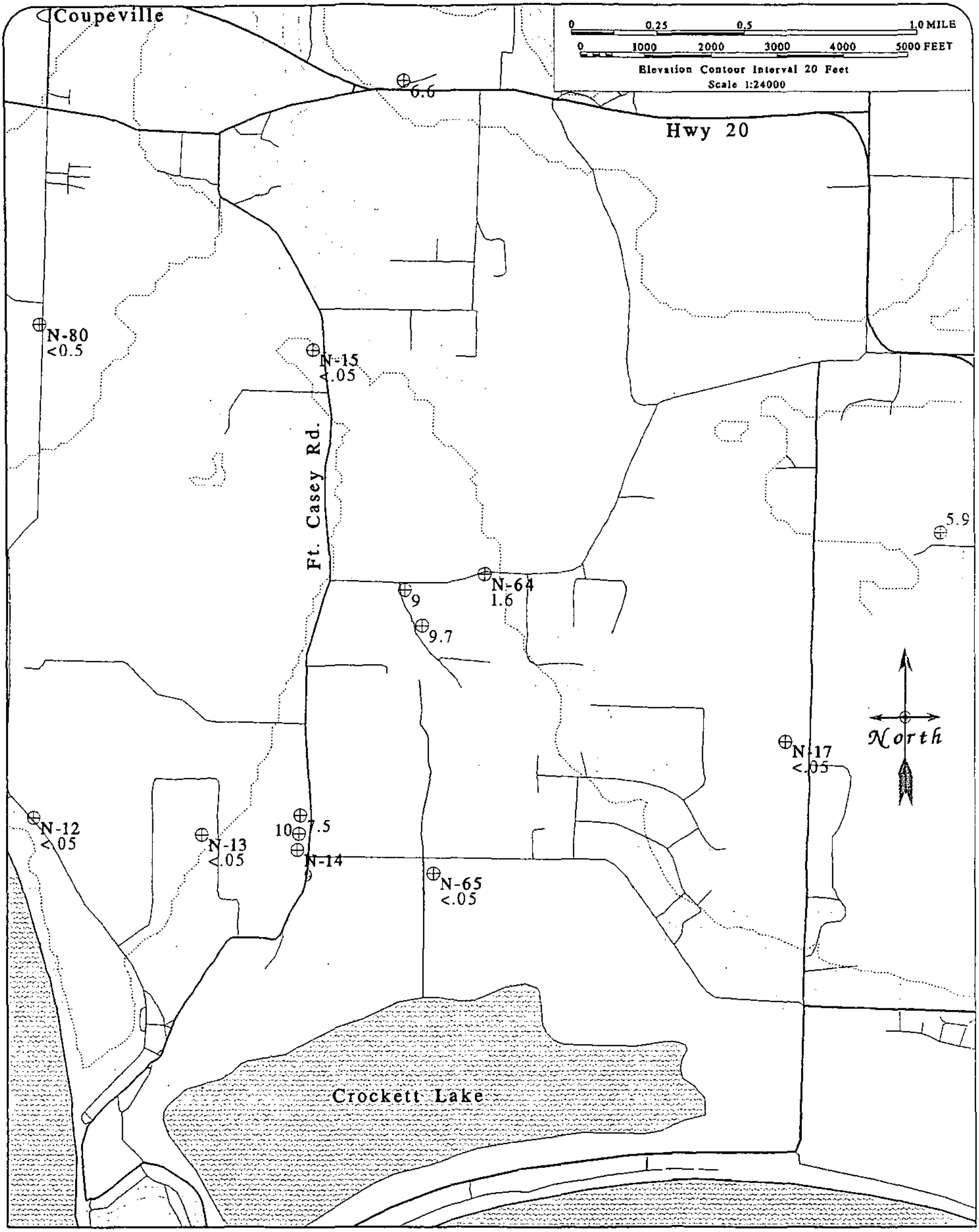
The Ebey's Prarie Focus Area consists of a broad, gently sloping basin bordered by wooded uplands on the east and west, by the town of Coupeville on the north, and by Crockett Lake to the south (Fig. 2.4). The area has historically been the site of extensive agricultural activity, primarily dairy and beef cattle operations. This is still the predominant land use, along with some crop production and low density housing.

In the eastern portion of the Focus Area, the E aquifer extends from the land surface to a depth of approximately 50 feet, and is apparently connected to the D aquifer throughout much of this area. The D aquifer in this area is over 100 feet thick, and contacts the deeper C aquifer in some places. Moving westward across the basin, the E aquifer disappears and the D aquifer becomes thin and discontinuous, with no apparent connection to the C aquifer, which lies approximately 100 feet below sea level.

Water quality data showed elevated nitrate levels in the E aquifer in the central portion of the basin, and in the D aquifer further south and downgradient. Deeper wells in the northern end of the basin showed no contamination (N-15), as did shallow wells in the southern end (N-65). Wells in the uplands to the east and west of the basin (N-13,17) are also apparently unaffected. All of this indicates a contaminant plume originating in the northern end of the basin and appearing at increasing depth as it moves south through the center of the basin. Possible nitrate sources in the area include two cattle operations in the central and northern portions of the basin. Each of these operations includes a manure lagoon and applies manure to surrounding fields.

Elevated nitrate concentrations were also found in the northern part of the Focus Area (6.6 mg/L), and groundwater gradients indicate that this well may share a common nitrate source with those in the basin. A well to the east of the basin which has recorded a nitrate level of 5.9 mg/L does not appear to be influenced by the contaminant plume in the basin, and is likely related to manure application in adjacent fields.

With nitrate concentrations at or near the MCL of 10 mg/L, this Focus Area raises concerns for the health of those who rely upon its groundwater. While the highest nitrate levels are confined to sparsely populated areas, water supply wells for the town of Coupeville in the vicinity create the potential for more widespread public health impacts. Animal feedlots, which are the apparent source of the contamination, continue operation, so further degradation of groundwater quality is a possibility and reason for concern.



Legend	
⊕	Well Location
N-17	Sample ID
<.05	Nitrate (mg/L)
15.0	Background NO

Figure 2.4
Nitrate Sample Results
Focus Area 4, Ebey's Prairie

V. *Hastie Lake Focus Area*

The Hastie Lake Focus Area extends from Oak Harbor west to Admiralty Inlet. It is bounded on the north by Fort Nugent Rd. and extends south almost to Arnold Rd. (Fig 2.5). Most of this area consists of a relatively flat, rolling plateau which descends abruptly to the shoreline. Drainage patterns are poorly developed, and much of the area experiences extensive surface water ponding during the wet season, in addition to numerous year-round ponds and wetlands. Historically, much of this area has been in agricultural production for many decades. Many small to medium sized farms remain today, and low to medium density housing is the other primary land use, with some high density housing along the shorelines.

The E aquifer appears at depths of less than 50 feet in the northern and eastern edges of the Focus Area. Throughout the majority of the area, however, the E aquifer is not found, and the D aquifer appears at depths of over 100 feet. An impermeable layer separates the D aquifer from the deeper C aquifer, which lies approximately 100 feet below sea level.

Water quality data reveals widespread occurrence of elevated nitrate levels within the area. In the northwest portion of the Focus Area lies a well finished in the D aquifer which has recorded a nitrate level of 21.2 mg/L. This well (N-09) lies directly north of a large depression which collects surface water from surrounding horse pastures. It appears likely that this depression is serving as a groundwater recharge area, and that the quality of the water being collected is significantly impacted by the surrounding agricultural activities. Nitrate concentrations drop considerably downgradient (N-36,37,45,7.5mg/L), providing further indication that the contaminant source is in close proximity to the N-09 sample point.

The highest nitrate concentration recorded in this study lies within this Focus Area, approximately one mile south of the city of Oak Harbor (N-77). Because this well is located on a commercial egg farm, chicken manure is a possible nitrate source. Other elevated nitrate concentrations in the area (N-57,69) decrease with distance from the N-77 sample point, suggesting a contaminant plume emanating from the vicinity of N-77 and moving in a northwesterly direction. More elevated nitrate levels were recorded in the shallow E aquifer throughout the broad, flat basin extending west for approximately three miles from this point (N-04,05,07,29,8.3mg/L,11.0mg/L). Again nitrate concentrations decrease with distance from sample point N-77, suggesting a common contaminant source in that vicinity. However, this basin contains many small farms, so the possibility of a separate source or multiple sources must be considered.

Approximately one mile further south lies a well finished in the D aquifer which recorded a nitrate concentration of 13.0 mg/L (N-28). Because other wells in the D aquifer in this area (N-01,02,03,16,27) showed significantly lower levels, it appears that this well lies in close proximity to the nitrate source. As with other impacted wells in the area, agricultural activities and the collection of polluted surface water near the wellhead provide the most likely source for the elevated nitrate levels.

This Focus Area exhibits multiple nitrate sources with localized areas of contamination. Nitrate concentrations well above the MCL in the western portion of the Focus Area give cause for concern. While the contaminant plume lies in a sparsely populated area, nitrate levels are high enough to pose a threat to public health. This threat is compounded by the proximity of densely populated areas to the north and south, as well as by the rapid growth of the general area. Nitrate levels above the MCL in the northern and southern parts of the Focus Area are apparently limited to small areas and affect only a few wells. However, the continuation of agricultural practices, which appear to be the source of the nitrates, presents the possibility of further contamination in the future.

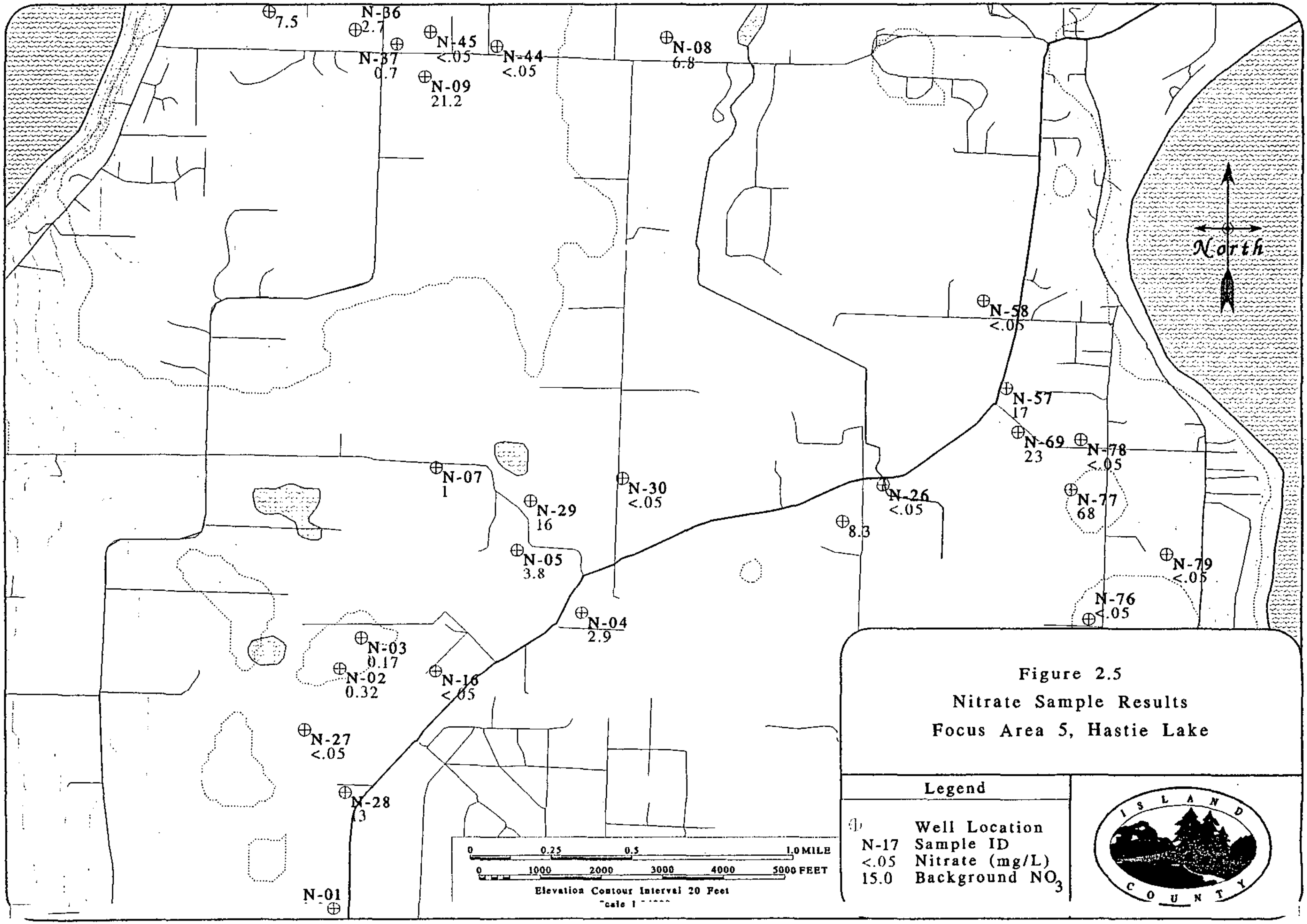


Figure 2.5
Nitrate Sample Results
Focus Area 5, Hastie Lake

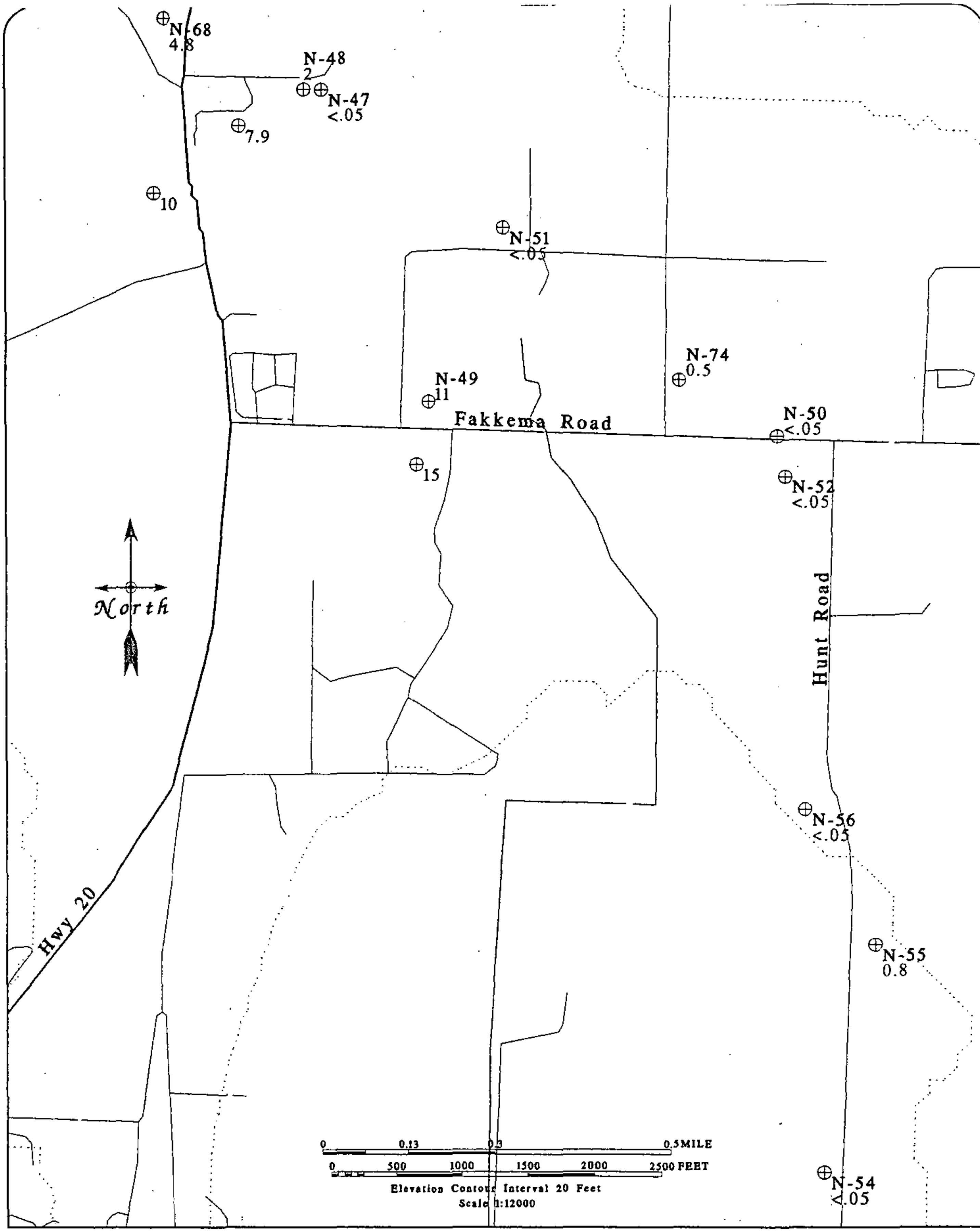
VI. Green Valley Focus Area

The Green Valley Focus Area lies just north of the city of Oak Harbor (Fig. 2.6), and consists primarily of a large basin in the north end with gently sloping woods and pastures extending south. Most of this area has been in agricultural production for many decades. A few farms remain today, and low to medium density housing is the only other significant land use.

The E aquifer exists at shallow depths at the eastern edge of the Focus Area, but disappears as land elevation drops further to the west. Throughout the rest of the area the D aquifer lies just above sea level, at a depth of approximately 50 feet. The depth of the C aquifer is unknown in this vicinity. All of the wells included in this study are apparently finished in the D aquifer, with depths ranging from 60 to 110 feet.

Water quality data indicate a number of wells in the northern part of the Focus Area which have recorded nitrate concentrations near or above the MCL of 10.0 mg/L. These wells lie clustered around a closed basin which has historically been the site of intense agricultural activities, specifically a dairy operation and a livestock arena. This basin is very poorly drained, and exhibits extensive flooding during the wet season. A hydrogeologic investigation performed in this area found that the groundwater gradient in the vicinity places the elevated nitrate levels along State Highway 20 (4.8,7.9,10.0mg/L) directly downgradient from this basin (Rongey and Associates,1995). Wells directly south of the basin have also been impacted (11.0,15.0mg/L). Sampling on the upgradient side of the basin showed nitrate concentrations consistently at or below detection limits (N-50,51,52,56,74). These conditions indicate a contaminant plume emanating from the center of the basin and moving to the south and east. Given the history of the area, livestock manure is the most probable source of the nitrates, and the extensive wet season flooding provides ideal conditions for local aquifers to be recharged by contaminated surface waters.

The D aquifer has apparently been impacted throughout most of the Focus Area. Nitrate levels consistently above the MCL are cause for concern in this area, particularly because of the relatively high population densities nearby. One small water system in the area has been required to install a treatment system to reduce nitrate levels, and another has been forced to blend water from two wells in order to stay below the MCL. Fortunately, the contaminant plume appears to be moving into areas with very low population densities to the south and east. It is hoped that the shift in land use from agriculture to low density housing will result in lower nitrate levels in the future. However, should levels continue to rise, the water system serving the city of Oak Harbor is close enough to be considered as a potential backup water source for residents of the area.



Legend	
⊕	Well Location
N-17	Sample ID
<.05	Nitrate (mg/L)
15.0	Background NO

Figure 2.6
Nitrate Sample Results
Focust Area 6, Green Valley

VII. North Camano Focus Area

This Focus Area is bounded on the north by Utsalady Bay and extends south and east approximately 1.5 miles. (Fig. 2.7). Topography generally rises steeply from the shoreline to rolling, wooded uplands in the western part of the area and pastures in the eastern part. Predominant land uses include high density housing along the shoreline, forestry and some agriculture further inland, and low density throughout. Historically, the eastern portion of this area has been the site of extensive agricultural activities.

In the lower elevations in the eastern portion of the Focus Area, the D aquifer appears within 50 feet of land surface. Further west, as land elevation rises, the D aquifer lies at over 200 feet of depth, and the E aquifer appears at more shallow depths, and actually contacts land surface in places. A continuous impermeable layer up to 200 feet thick separates the D and E aquifers, and a thinner aquitard separates the D aquifer from the deeper C aquifer.

The two wells with the highest recorded nitrate levels (9.9, 6.9mg/L) lie in the eastern half of the area, although they do not appear to share a common nitrate source. While both are finished in the D aquifer, lower nitrate concentrations in the vicinity of these wells seems to indicate nitrate sources relatively close to the wellheads and small areas of contamination. The most apparent nitrate sources in these areas are past and present agricultural activities, namely livestock grazing and dairy operations.

Possible nitrate sources are less apparent in the western portion of the Focus Area. Within the relatively undisturbed wooded upland area lie two wells with nitrate levels at 2.7mg/L. Both of these wells appear to be finished in the C aquifer. Another well just north of these wells near the shoreline is also finished in the C aquifer, and has recorded a nitrate level of 2.8mg/L. It seems probable that these wells share a common nitrate source, although the relatively undeveloped upgradient areas provide no obvious sources. The depth of the C aquifer and the uniformity of the nitrate concentrations could indicate a relic source, such as a buried peat layer.

The two other wells in this area with elevated nitrate levels (2.2, 5.1mg/L) are shallow dug wells which do not appear to be hydrologically connected to the C aquifer. Because of the inherent susceptibility of dug wells to contamination from surface water and shallow groundwater, it is likely that these wells have been impacted by nitrate sources relatively close to the wellhead. Approximately 1/4 mile south of these wells lies a small pond that collects stormwater from surrounding animal pastures. Animal wastes entering this pond and domestic sewage disposal systems in the area are the two most apparent sources for the nitrates appearing downgradient in the shallow aquifer.

While nitrate concentrations in the western part of the Focus Area remain well below the MCL of 10.0mg/L, further contamination could have serious public health impacts due to the high population densities in the area and the number of residents served by the affected wells. The higher levels recorded further east are limited to relatively few wells in sparsely populated areas. However, agricultural activities, which appear to be the source of nitrates, continue today, and the rapid population growth of the area presents the possibility of more impacts in the future.

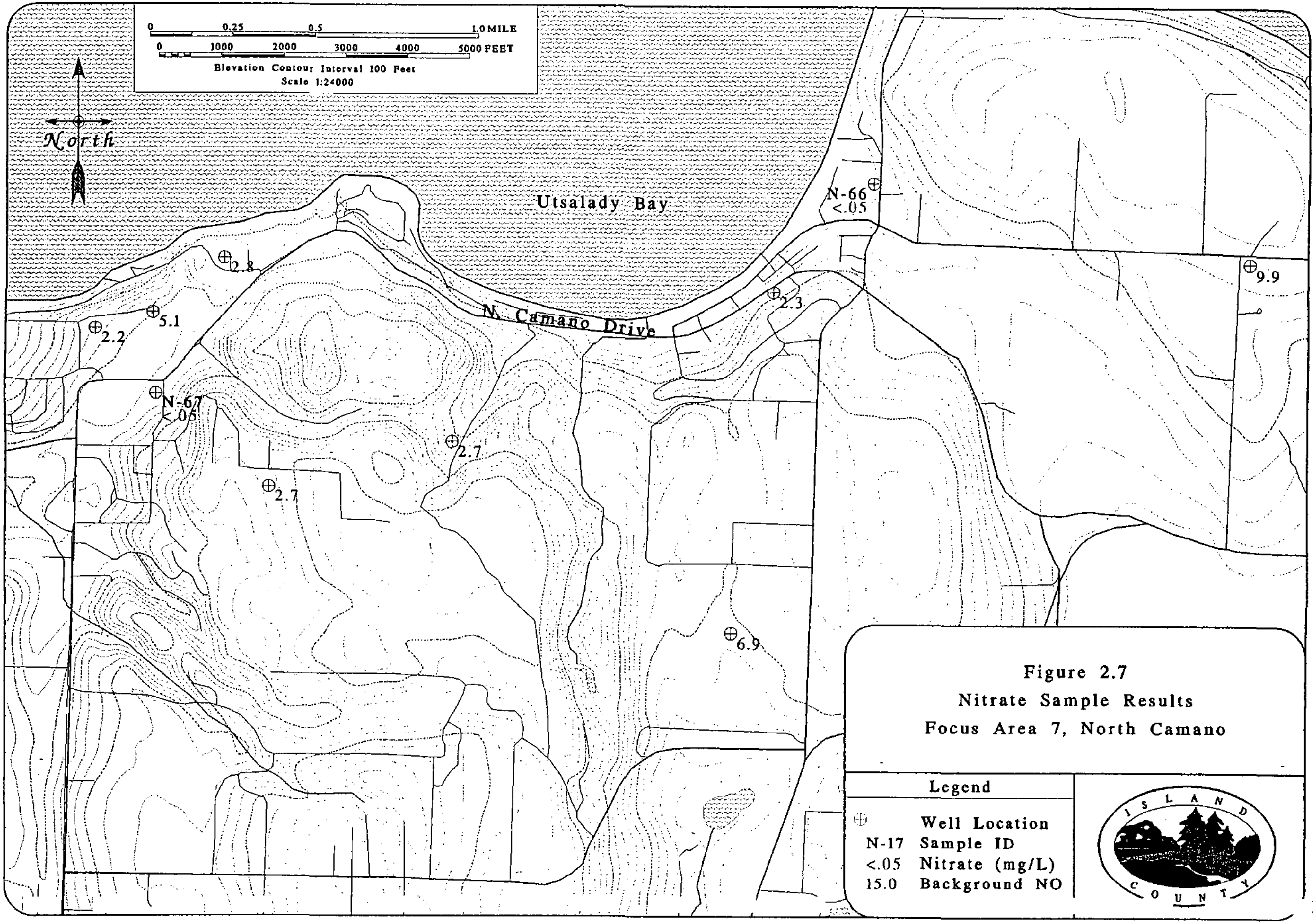


Figure 2.7
Nitrate Sample Results
Focus Area 7, North Camano

Conclusions

The results of this study are generally encouraging. Less than 1% of the wells surveyed had recorded a nitrate concentration above the MCL of 10.0 mg/L. While this does not represent a purely random sampling, the spatial distribution of the sampling is adequate to conclude that nitrate levels above the MCL are not widespread in Island County. Where concentrations above the MCL were found, they were typically limited to relatively small areas with low population densities, indicating that very few residents of the county have been exposed to nitrate levels above the 10.0 mg/L. Nitrate concentrations above 20.0 mg/L were found in only four wells in the study. This is also encouraging, since higher nitrate concentrations are more likely to produce adverse health effects.

However, these results are also cause for concern. While the vast majority of the county's groundwater exhibits nitrate concentrations well below the MCL of 10.0 mg/L, it is apparent that some residents have been exposed to levels above the MCL. It is also apparent that in most or all cases, elevated nitrate concentrations are the direct or indirect result of human activities. This raises the possibility that growing populations will result in still higher concentrations in aquifers that are now below the MCL, as well as impacts to aquifers that were previously unaffected.

Among the primary purposes of this study was to attempt to determine how nitrate contaminated wells became impacted. Specifically, the goal was to identify which activities or conditions at the land surface resulted in the release of nitrates, and what geographic and geologic conditions were likely to result in drinking water wells being affected. Throughout the study, every attempt was made to make direct, firsthand observations of impacted wells and their surroundings. Because it is impossible to know with certainty exactly where a nitrate molecule originated or how it reached a well, a certain degree of conjecture is necessary to draw any conclusions about contamination scenarios. However, the goal of this study was not to provide hard evidence of contaminant sources, but simply to draw sound conclusions about conditions which result in impacts to drinking water wells.

In reviewing the data gathered during the inspections of affected wells, as well as their spatial distribution, depth and degree of contamination, three factors common to a significant number of the wells began to emerge. They shall be discussed separately, under the following headings: Agriculture, Well Isolation, and Well Depth.

I. Agriculture

Throughout Island County, the highest recorded nitrate concentrations are found in areas with a history of agricultural land uses. Indeed, in each individual Focus Area, the highest nitrate levels were found either on a farm or within 1/4 mile of a farm. These areas typically lacked any other obvious nitrate sources. This correlation between agriculture and nitrates is consistent with findings elsewhere in the state of Washington (Ryker et al, 1995), as well as throughout the world(Hallberg et al, 1993).

It is relevant at this time to consider the nutrient balance on a typical farm. Nitrogen is imported to a farm in the form of feed and fertilizer, and becomes concentrated in the form of manure. Unless carefully handled, stored, and applied to crops at agronomic rates, the manure can exceed the capacity of the land to absorb its nitrogen through plant uptake and soil adsorbtion. The resulting excess nitrogen can then be leached in solution beyond the root zone. At this stage almost all excess nitrogen has been oxidized to form a nitrate molecule, which is very stable and mobile. The molecule can then move through the soil strata and, depending upon geologic conditions, may enter the aquifer system.

Unlike crop farms, where an economical nutrient balance is the goal, animal farms typically produce much more manure than can be utilized, and nutrient disposal becomes the goal. Manure is often stockpiled and stored for extended periods in unlined lagoons, providing favorable conditions for nitrate leaching. Land application of manure is often done at many times the agronomic rates, or during winter, when plants and soil microbes are not able to "tie up" excess nitrogen. In some cases wells are simply located too close to manure handling areas, and are impacted by contaminated surface water or shallow groundwater.

Agricultural practices have advanced significantly in the past fifty years, and it is possible that the groundwater impacts witnessed today may be the result of activities which took place decades ago. Anecdotal evidence suggests that this may be the case in some areas. In at least two cases, outdated and improper manure management techniques are the only obvious nitrate source for wells with concentrations above 20.0 mg/L. In several other instances, modern farm management techniques have resulted in no apparent impacts to groundwater. Because of the known pollution potential of agricultural practices, it is prudent to continue to encourage farmers to implement modern techniques for the handling and disposal of manure, as well as the responsible and efficient use of fertilizers.

II. Well Isolation

The majority of impacted wells in this study were isolated in the sense that nearby wells, even those finished in the same aquifer, did not also show elevated nitrate levels. Where contaminant plumes did spread to other wells, nitrate levels typically decreased sharply in wells further from the source. What this indicates is that wells are being impacted by sources close to the wellhead, and that the well shaft itself may be serving as the conduit through which surface water and shallow groundwater reach the aquifer. In most cases, withdrawals from the well appear to be sufficient to contain the contaminant plume, as evidenced by unaffected wells nearby.

While proper well construction techniques are designed to prevent this type of scenario, many older wells were not drilled under current standards. Many of the wells inspected during this study had cracked surface seals or no surface seal at all. The subsurface sanitary seal, which is meant to prevent shallow groundwater from entering the well shaft, was apparently inadequate or nonexistent in some wells. Studies elsewhere have concluded that improper sealing of the well shaft can significantly increase the chances of nitrate contamination.(Kross et al, 1990, Baker et al, 1989)

Another related factor among impacted wells was improper placement of the well in proximity to contaminant sources. Many were located directly downslope from livestock holding areas, and in some cases animals were allowed to graze within ten feet of the wellhead. A number of inspections revealed wellheads that were clearly subject to inundation by stormwater, which can result in the well being impacted by numerous contaminants.

The overall pattern of contamination in Island County is not indicative of a broad, diffuse leaching of nitrates through the soil strata. Rather, nitrate "hot spots" surrounded by unaffected wells seem to indicate that improper siting and construction of wells provides pathways for nitrates to reach the aquifer, and that contaminant plumes typically do not travel far from the source.

III. Well Depth

The findings of this study suggest a correlation between shallow well depths and vulnerability to nitrate contamination. Only one of the dug wells included in this study had a nitrate concentration below 2.0 mg/L. Conversely, in all but one of the Focus Areas, the C aquifer was apparently unaffected by nitrates. In the affected C aquifer, all recorded nitrate concentrations were below 3.0 mg/L.

While the scope of this study does not allow a complete statistical analysis of well vulnerability as a function of depth, the overall pattern observed was one of deeper aquifers being less likely to be impacted by nitrates. This observation is consistent with the findings of numerous other studies throughout the U.S. (Kross et al, 1990. Baker et al, 1989), as well as worldwide (Goldberg, 1989).

These findings support the widely held theories that groundwater nitrates originate at the land surface, and that aquifers are protected from pollutants by the presence of overlying layers of semipermeable deposits. In Island County, it is perhaps not surprising to find that deep deposits of consolidated glacial strata, often hundreds of feet thick, have protected the deeper aquifers from contaminants which ostensibly originated at the ground surface. However, it is also obvious that even the deepest wells can be subject to contamination due to vertical migration of pollutants through the bore hole, and that shallow wells, if properly sited and constructed, can be safe sources of domestic water.

Recommendations

Based upon the findings of this study, it is clear that steps can and should be taken not only to prevent exposure to nitrate levels above the MCL, but to prevent further degradation of groundwater quality. It is also important that the public be educated and warned of the risks associated with drinking untreated and often untested well water. The following recommendations are intended to achieve these goals, and fall under the following headings: Source Protection, Monitoring, and Education.

I. Source Protection

In an area such as Island County, which has been designated a Sole Source Aquifer by the EPA, protection of the groundwater resource is obviously of the utmost importance. Because it can take decades for contaminated aquifers to be "flushed out" by recharge, and treatment for nitrates is very expensive, prevention of contamination is the most prudent approach to preventing exposure to potentially unhealthy nitrate levels.

Perhaps the most important aspect of source protection is that of well siting. In Island County, no new well may be approved for use unless the owner has secured sanitary control over the entire 100 foot radius surrounding the well, either through restrictive covenants or outright ownership. In addition, well sites must be inspected and approved either by a licensed well driller or by the county Health Department. These requirements protect drinking water sources from all types of contaminants and help prevent further impacts to aquifers by keeping a buffer area between pollution sources and well shafts. These measures, which are mandated by state and county health regulations, are vital to ensuring safe drinking water supplies, and should be continued. Along with well construction standards, they provide the first line of defense against well contamination.

Another important aspect of aquifer protection is the treatment and disposal of domestic wastewater. Proper design and construction standards are necessary to ensure that groundwater quality is not degraded by inadequately treated wastewater. In Island County, design standards for on-site sewage systems are actually more stringent than state standards in some instances. It is important that these standards continue to be strictly applied and enforced, particularly in light of the poor soil conditions which exist throughout much of the county. Shallow, slowly permeable soils and perched water tables create conditions unsuitable for conventional gravity systems. In these situations, careful design, construction, and maintenance of systems becomes crucial to ensuring adequate treatment and disposal of wastewater.

It is also important that on-site sewage systems be inspected and maintained to assure proper functioning. Many active systems in the county were installed before current design standards were in effect, and many of these systems do not provide the level of treatment that is required today. For these systems, regular maintenance and pumping are even more important to protect the groundwater resource. The Health Department program of tracking pumping records and mailing reminders to those who have not had their systems pumped for three years should be continued and expanded if possible. In areas where sewage disposal problems are widespread, mandatory maintenance contracts should be considered, and alternative treatment and disposal methods should be explored.

In agricultural areas, proper manure management and disposal are essential to protecting aquifers from contamination. The findings of this study suggest that many of the elevated nitrate levels found within the county are related to past or present agricultural practices. For this reason, it is only prudent to urge farms of all sizes to examine their management of manure and fertilizers, and to make improvements wherever possible. The Washington State University Extension office and the local Conservation District office provide free technical assistance to farmers, and in many cases low interest loans are available for improvements to manure storage and land application systems. These programs should be continued and expanded if possible, and farms of all sizes should be encouraged to participate. In addition, state regulations which address agricultural impacts to water quality must be applied and enforced.

II. Monitoring

In Washington, all water systems of three connections or more are required to test for nitrates prior to approval. Ongoing monitoring for nitrates is also required, with the frequency of testing being determined by the size of the system and the nitrate concentration found in the source or sources. Island County also requires that two-party water systems and individual wells test for nitrates prior to approval. Since 1990, all applicants for new construction in Island County have been required to demonstrate that their drinking water source has a nitrate concentration below the MCL of 10.0 mg/L. Sources with nitrate levels above the MCL are required to install treatment systems to reduce nitrate concentrations to safe levels.

These requirements are absolutely vital to protecting the public from potentially unhealthy water, and should certainly be continued. In addition, the data provided is valuable in tracking the quality of the county's aquifers and identifying problem areas. Indeed, much of the data used in this study was available only because of the county's requirements for building permit issuance, and presumably most individual well owners would not test for nitrates if not required to do so.

Additional sampling requirements for individual well owners should be considered in areas where elevated nitrate concentrations are known to be a problem. Such a program could include periodic testing for individual wells to ensure that nitrate concentrations that rise above the MCL are detected in a timely manner. Also, efforts should be made to include some of the older wells in the county, many of which have never been tested for nitrates. Older wells that were drilled or dug prior to the enactment of current well construction standards are potentially more susceptible to all sorts of contaminants, so including them in a monitoring program could greatly reduce the health risks posed to their users.

III. Education

It is likely that thousands of Island County homes are served by wells which have never been tested for nitrates or for any other contaminants. This places the health of many county residents at risk. At the root of this problem is ignorance, not only of the quality of one's drinking water, but also ignorance of the health risks associated with nitrate contamination of wells. One result of this is a reluctance on the part of some people to have their wells tested simply because they are unaware of the risks they face. Clearly the solution to this problem is to inform people about water quality issues in general, and particularly about the dangers of methemoglobinemia.

From the beginning of this project, every attempt was made to educate the public about the potential health effects of nitrates. But it is evident that more can and should be done to inform county residents about the health risks of drinking untested well water, particularly those who are not served by approved water systems. Printed brochures provide an inexpensive and easy way to disseminate information to the public, and the Health Department should continue to produce and distribute them. The local Conservation District office can also play a valuable role by educating rural homeowners about water quality issues, and by providing technical assistance to small farms with issues such as manure management and fertilizer application. These efforts should be supported and continued, as well as other programs such as informal water quality seminars, where people can bring in water samples to be tested for nitrates. Such seminars have been offered by the Conservation District office in the past, and provide an excellent opportunity for public outreach and education.

Summary

The majority of Island County residents rely upon groundwater for drinking water supplies. The entire county has been designated a Sole Source Aquifer by the EPA due to the lack of water supply options. Available water quality data indicates that most of the county's aquifers exhibit nitrate levels below detection limits, with a few localized areas of elevated nitrate concentrations, typically limited to very small areas. This is likely due to the discontinuous nature of the local aquifers, and to the ability of well withdrawals to contain contaminant plumes. In many cases, it appears that improper well construction practices have allowed surface water and shallow groundwater to enter the aquifer through the well shafts. Areas of the county with more widespread contamination appear to be directly related to past and present agricultural practices. Well depth, well construction standards, and the presence of restrictive strata are apparently important factors in preventing contaminants from reaching aquifers.

State and county regulations such as well siting restrictions, construction standards, and sampling requirements all play an important role in protecting drinking water supplies from nitrate contamination. Educating the public about water quality issues and related health concerns is also crucial to preventing exposure to potentially unhealthy nitrate levels. Programs to gather more data on nitrate concentrations countywide could identify problem areas and detect trends in a timely manner, and reduce health risks posed to the public through exposure to nitrate concentrations above the MCL.

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Table I
Well Data

Easting	Northing	Nitrate	Conductivity	ID	Depth	Name
1541815.4	459637.4	3.3	690	N-01	122	Maddex
1541912.0	463588.1	0.32	700	N-02	160	Prisk
1542262.6	464086.4	0.17	570	N-03	150?	Sanders
1545860.3	464505.7	2.9	860	N-04	83	Webb
1544802.6	465544.9	3.8	930	N-05	60	Eerkes
1547177.3	457378.6	<.05	720	N-06	160	Moses
1543481.8	466894.8	1	1140	N-07	60	Kenworthy
1547235.6	473797.6	6.8	660	N-08	?	Little
1543296.7	473183.7	21.2	630	N-09	250?	Moody
1545061.1	481756.6	1.5	550	N-10	178	Mccormick
1542799	480494	<.05	700	N-11	72	Troyer
1548270.0	435255.8	<.05	1080	N-12	250?	Vonkrusenstiern
1550839.8	434991.4	<.05	1750	N-13	185	Olson
1552325.5	434753.2	9	1370	N-14	70	Keilwitz
1552574.5	442349.2	<.05	820	N-15	100	Paris
1543468.0	463550.2	<.05	680	N-16	110	Lamont
1559821.4	436400.4	<.05	350	N-17	109	Hay
1575304.2	404623.7	0.5	590	N-18	240	Hunter
1575671.8	399851.7	<.05	240	N-19	300+	Hall
1581452.0	369620.6	4.3	670	N-20	?	Smith
1586108.7	371037.9	2.5	510	N-21	127	Walker
1585339.7	367000.8	0.9	590	N-22	260	Gates
1586697.5	366869.6	<.05	620	N-23	250?	Bryant
1589362.7	367419.4	<.05	470	N-24	205	Burrier
1582112	368694	1	530	N-25	120	Piske
1550784.4	466616.9	<.05	480	N-26	110	Sherwood
1541346.0	462588.4	<.05	670	N-27	119	Fisher
1541997.8	461558.8	13	1030	N-28	110	Whitlock
1545025.2	466350.4	16	670	N-29	30	Amsler
1546523.1	466719.6	<.05	470	N-30	168	Prince
1584477.1	371073.9	0.8	240	N-31	96	Thomson
1590865.5	370832.7	<.05	140	N-32	116	Hawley
1613560	366400.8	<.05	220	N-33	?	Hagglund
1612056.8	362783.2	1.8	80	N-34	75?	Fouts
1611448.0	359653.9	<.05	220	N-35	75?	Moseley
1542164.5	473920.9	2.7	350	N-36	145	Harry
1542835.7	473701.8	0.7	450	N-37	137	Turner
1572503.4	403876.3	3.6	200	N-38	210	Olsen
1573009.5	402243.1	<.05	220	N-39	350?	Habeck
1572516	401443.5	<.05	200	N-40	357	Therkildsen
1573396.0	401322.2	<.05	220	N-41	320?	Schricker
1575869.3	402583.8	2.3	210	N-42	37	Horton
1570662.0	421351.3	3.2	200	N-43	75	Therkildsen
1544458.5	473662.2	<.05	470	N-44	150?	Barkhausen
1543381.6	473891.2	<.05	510	N-45	220	Nienhuis
1544943.1	482469	39	1170	N-46	48	Fakkema

Table I continued

Easting	Northing	Nitrate	Conductivity	ID	Depth	Name
1564283.9	491232.7	<.05	100	N-47	?	Walters
1564148.8	491235.8	2	320	N-48	?	Barton, Geo.
1565108.0	488882.2	11	270	N-49	60	Corrigan
1567738.1	488618.6	<.05	490	N-50	111	Dodge
1565679.0	490186.6	<.05	260	N-51	50	Dunn, F.
1567798.7	488313.1	<.05	560	N-52	90	Thompson
1571314.2	488333.6	0.6	330	N-53	158	Voorhees
1568082.5	483035.8	<.05	450	N-54	90	Zimmerman
1568460.1	484750.2	0.8	420	N-55	40	Heard
1567942.9	485775.8	<.05	420	N-56	?	Frank
1552784.6	468190.9	17	450	N-57	>250	Steedman
1552412.7	469618.8	<.05	530	N-58	72	Bjaaland
1607611.7	355172.7	<.05	170	N-59	100	Greeott
1609284.6	357063.6	<.05	150	N-60	100	Cole
1610666.2	358048.5	<.05	260	N-61	?	Larson
1607129.5	351635.6	<.05	180	N-62	?	Benscoten
1606668.4	349111.5	<.05	170	N-63	60	Thorsen
1555204.3	438941.8	1.6	770	N-64	40?	Smith
1554418.7	434399.3	<.05	750	N-65	30	Jefferds
1601992.6	462418.7	<.05	460	N-66	140	Haugen
1590410	459460	<.05	230	N-67	>200	Gilbertson
1563079.8	491767.5	4.8	500	N-68	35	Dickson
1552970.6	467476.9	23	430	N-69	160	Balster
1572850.7	401233.2	<.05	240	N-70	396	Hoyman
1569403.6	398980.7	5.1	220	N-71	234	Lile
1572980.7	403966.8	5.3	200	N-72	?	Jacobson
1571562.5	404303.1	4.9	210	N-73	199	Russell
1567004.3	489041.0	0.5	300	N-74	?	Hoehn
1617451.3	350308.5	<.05	100	N-75	181	Firethorn
1554115.8	464408.8	<.05	420	N-76	263?	Bowen
1553828.2	466544.2	68	1150	N-77	?	Hamernik
1553983	467351	<.05	430	N-78	?	Seekamp
1555359.9	465494.2	<.05	380	N-79	95	Zweltsloot
1548383	442754	<0.5		N-80	125	Sherman
1608120	344660	13.8			60	Strickland
1604850	378520	6.7			146	Demartini
1613040	367780	6			98	Gabelein
1612910	367060	7.7			72	Gabelein
1608060	354720	6.7			72	Suzuki
1618090	354310	6.7			68	Lapole
1571180	406380	6			50	Olsen
1574820	399330	6.3			70	Umbreit
1574470	398480	13			40	Haggan
1571030	387280	7.3			15	Olin
1552370	435280	7.5			65	Wicker
1587880	444500	6.2			432	Reyes
1549540	477840	9.6			?	Balda

Table I continued

Easting	Northing	Nitrate	Conductivity	ID	Depth	Name
1540770	474210	7.5			296	Bentencourt
1608190	461570	9.9			182	Bragonier
1599715	455568	6.9			220	Pollock
1557630	502141	9.9			55	Howes
1557130	502141	7.7			48	Bailey
1551950	482350	7			174	Sebo
1585970	485900	11			230	Kasiewniak
1580050	484470	5.4			54	Dewar
1554248	438166	9.7			35	Boyer
1535030	455070	5.2			50	Silva
1553980	438707	9			32	Engle
1553990	446406	6.6			146	Argent
1588550	371363	14			236	Arnold
1550126	466020	8.3			40	Blue Fox
1575000	408530	14			40?	St. Michelle
1565895	513652	6.2			128	Cornet Bay Hts.
1559570	482040	7.5				Evergreen MHP
1552470	482760	8.4			190	Family Bible Church
1580120	370680	6.7			41	Glo Crest
1606800	350840	8.7			93	Gullson WS
1548880	479320	7.8			187	Hillcrest Village
1569620	414070	6			215	Lake Hancock
1565014	488408	15			91	Jaeger WS
1587030	366550	8.7			111	Lancaster Hts #1
1567870	423190	18			140	Ledge Edge WS
1590850	375080	5.5			140	Maple Glen WS
1572050	485210	7.2			168	Maple Hill Trailer Ct
1580400	370550	10			30	Menlo Beach
1563000	490450	10			61	Midget Mart
1562200	439570	5.9				NAS Whidbey OLF
1580830	370080	20			160	Palmer's Mutiny Bay
1571700	375240	5.8			105	Skewes Ln WS
1548980	477570	8.6			133	Swantown Water
1563650	490960	7.9			78	Thunderbird MHP
1583990	370330	11			98	Wildwood Park WS
1622070	390910	7.8			17	Wilkes Gary
1607590	385880	6.5			160	Winston Well
1552350	435000	10			65	Ballou
1575000	399850	7.8			60	Town
1551950	488408	9			175	Heller Rd. Comm.
1559620	499610	5.4			60	Benedict
1592210	457950	2.7			362	Smith
1595180	458690	2.7			138	Utsalady Pt. WS
1600370	461155	2.3			145	Utsalady Cove Condos
1590350	460790	5.1			40	Maple Grove Hts
1589495	460575	2.2			40	Maple Grove Bch
1591480	461680	2.8			269	Acaladi