VIOLET PRAIRIE SPECIAL AREA STUDY

Thurston County Environmental Health Division

Thurston County Community and Environmental Programs

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I. Elevated Nitrate Levels in Violet Prairie

A. Background: Ground water in the Violet Prairie area is the only source of drinking water for area residents. The permeable nature of the area's soils and shallow depth to ground water make the area's drinking water aquifers susceptible to contamination from land use practices. In fact, well monitoring has found nitrate levels in excess of the state maximum contaminant level (MCL) of 10 parts per million (ppm) [or 10 milligrams per liter (mg/l)] in a few wells in Violet Prairie.

Wells in Violet Prairie have been monitored on a sporadic basis since the 1980's. In response to citizens concerns about safe drinking water, and in an effort to accurately define the public health threat, the Thurston County Commission initiated a special area study in 1993. This monitoring projects goal was to identify elevated nitrate levels in Violet Prairie in a systematic manner (Figure 1). High levels of nitrate in drinking water are a concern because they can cause a blood disorder in newborn babies called methmoglobinemea or "blue baby disease". Methmoglobinemea affects the bloods ability to carry oxygen, causing the body to suffer oxygen deprivation in severe cases. Although methmoglobinemea can affect any age, nitrate contaminated water principally causes this illness in infants under one year of age, and not older children or adults. Some studies have suggested a possible link between high nitrate levels, cancer, and birth defects. These suggestions however, have not been confirmed (WSDOH, 92). Owners of the wells which were found to have high nitrate levels have received information from the health department regarding the possible health risks associated with high nitrate levels in drinking water. Since nitrate in drinking water can be an indicator of overall water quality, elevated nitrates may also indicate the presence of other contaminants which could cause health problems (WSDOH, 92). This report is based on well monitoring data collected between June 1993 and November 1994

VIOLET PRAIRIE MONITORING WELLS

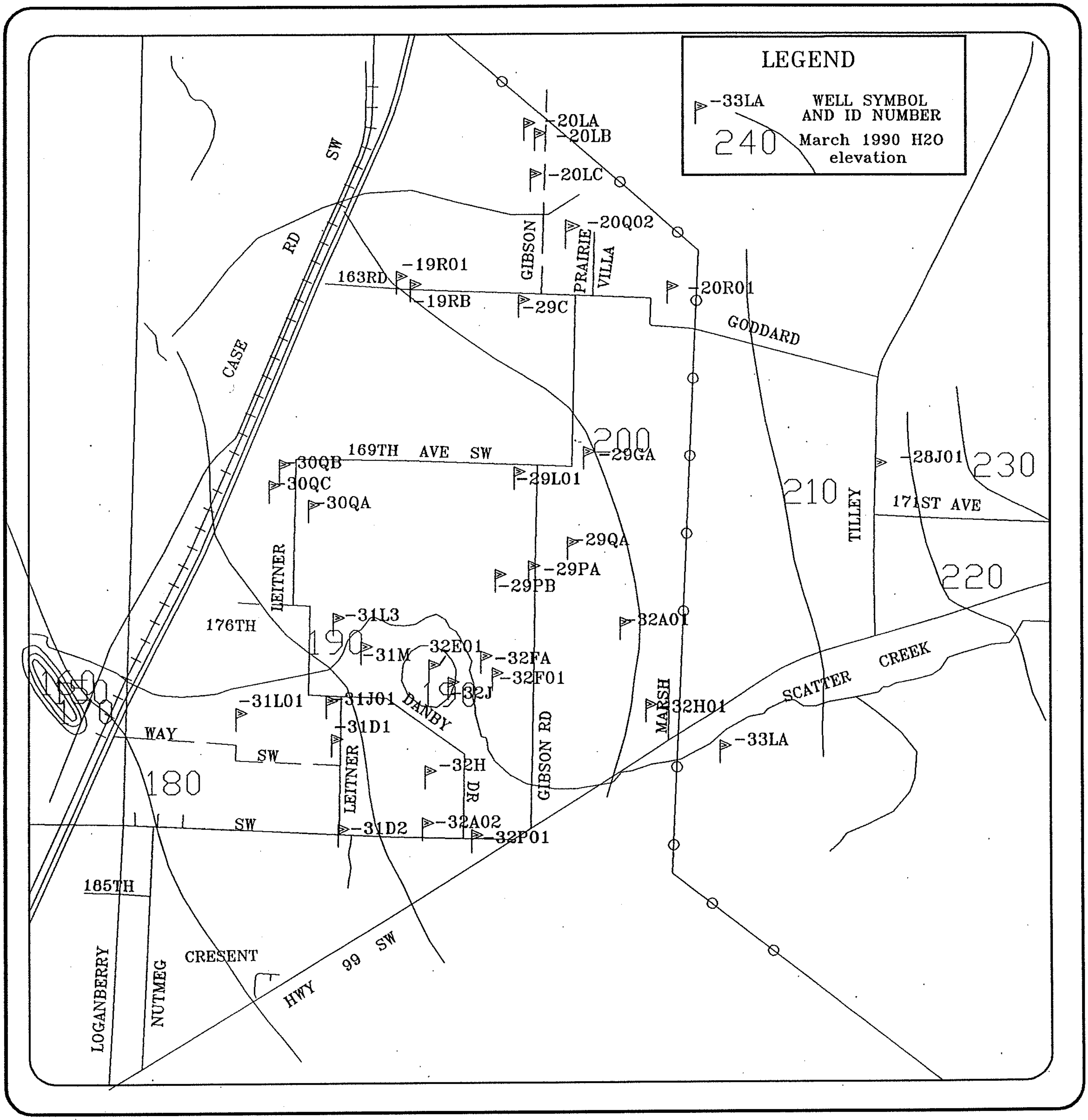


FIGURE 1

by the Thurston County Environmental Health Division.

B. Study Objectives:

- Delineate areas of nitrate levels elevated above background levels (1-2 ppm)
- Identify sources for the elevated nitrate levels
- Verify seasonal fluctuation of nitrate levels
- Track changes in nitrate levels as land use changes

C. Summary: The Department of Ecology conducted ground water monitoring in 1982, 83, and 89 in the Violet Prairie area (Hirschey and Sinclair 1992). Nitrate levels appear to have increased somewhat since then. During the 1993-94 monitoring period, four wells were found to have nitrate levels exceeding the MCL; one as high as 30 ppm. However, a direct statistical comparison between the various data sets is not yet possible due to seasonal data collection differences and the fact that different wells were used for the 1993-94 study. The monitoring data from the 1993-94 study does not indicate a plume of high nitrate levels has spread throughout the aquifer. Nitrate levels near or exceeding the MCL (10 ppm) appear to be clustered in distinct sub-areas.

1. Key Conclusions:

- 23 of 25 wells tested in the area had nitrate levels above background (1-2 ppm) at least once and approximately 14 wells had nitrate levels above 5 ppm at least once.

- Four wells had nitrate levels above the MCL of 10 ppm, one of these wells had a nitrate level of 30 ppm.

- A failing septic system appears to be the source for the well with the highest nitrate level (30 ppm). The Health Dept. is in the process of confirming this via a dye trace of the septic system.

- Since only a few wells in Violet Prairie appear to consistently have nitrate levels near or exceeding the MCL, the area wide public health threat is probably not significant.

- Land application of livestock waste in excess of agronomic rates appears to be the source for the elevated nitrate levels in specific sub-areas of Violet Prairie.

- Land application of livestock waste in excess of agronomic rates occurs up gradient of nearly every high nitrate well (groundwater flow is generally east to west).

- Continued monitoring will be necessary to evaluate the effectiveness of farm conservation plan implementation and track long-term water quality trends in Violet Prairie.

- A long-term monitoring plan will also serve as an early warning system. This will enable county staff to identify possible contamination problems and initiate corrective actions before contaminants have a chance to spread.

- Some elevated nitrate levels could not be associated with specific sources, and a few wells have decreased in nitrate levels.

- Wells that are 80 feet or deeper appear to generally have lower nitrate concentrations than shallower wells.

II. Potential Sources of Nitrate Contamination in the Study Area: In order to correct or remediate the elevated levels of nitrate found in the study area, it is important to determine the potential and probable sources of nitrogen (Figure 2). Lack of time and funding prevents identification of direct cause and effect relationships between sources and well contamination. However, it is possible to identify with a degree of accuracy the main sources of nitrate loading to the aquifer.

For this study, a determination of nitrogen sources was done by inventorying known sources in the study area and quantifying their relative proportions (how much from each source). With this information a qualitative analysis was carried out. This analysis attempts to determine whether a particular source was releasing or discharging nitrogen in ways that could impact nitrate levels in area wells.

III. Inventory of Potential Nitrogen Sources: Nitrogen originates from human and other animal waste, nitrogen based fertilizers, plants that fix nitrogen from the atmosphere, deposition of atmospheric nitrogen, and lightning. The inventory looked at the kinds of land uses and land management practices in the area that might concentrate these different sources of nitrogen in ways that could cause an elevation of nitrates in area wells.

A. Key Features:

- The study area consists of approximately 5 square miles in Violet Prairie. The boundaries are approximately Goddard Road and 163rd to the north, 183rd and Old Highway 99 to the South, Interstate 5 to the west, and Tilley Road to the east.
- Total acreage is roughly 3200 acres.

VIOLET PRAIRIE LAND USE

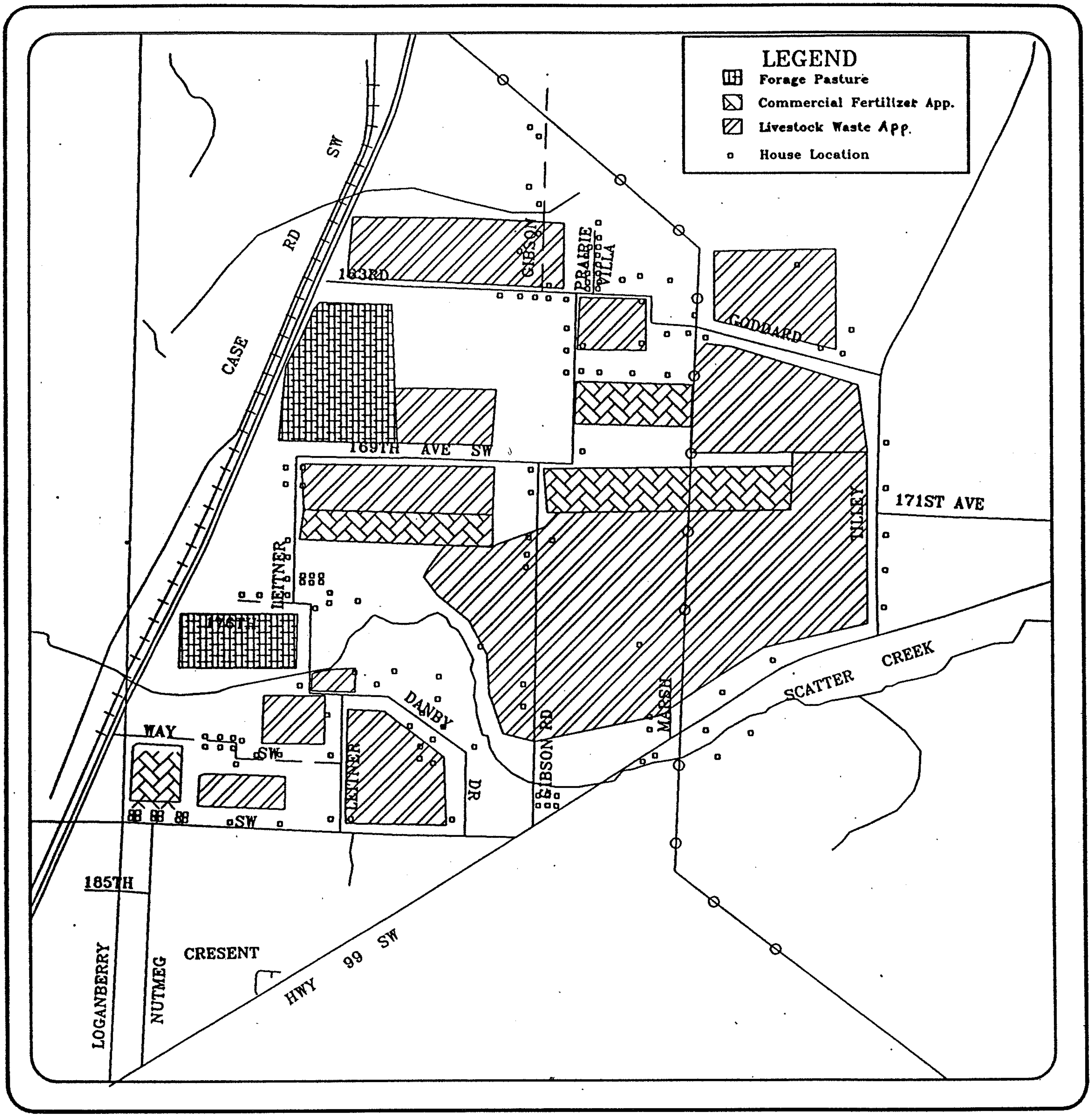


FIGURE 2

- Total human population is roughly 1000 people.
- Total number of commercial livestock is roughly 1750 cattle, 200,000 chickens, and one aquaculture facility (numbers of fish unknown).
- Several horses, goats and other domestic animals.
- Four christmas tree operations (fertilizer quantities used are unknown).
- Nitrogen fixing plants, such as scotch broom, alder trees, and some legumes in pastures, but not considered to be in sufficient number to cause the level of nitrate contamination found in well water samples.

IV. Potential Nitrogen Output From Identified Sources: Table 1 below quantifies the approximate nitrogen production from the primary sources in the study area.

Nitrogen Production From Primary Sources in Violet Prairie

Source	Total Waste Produced	Nitrogen Component
Residential Wastewater	353,400 lbs/day (wet weight)	25 lbs/day
Cattle (manure only)	140,000 lbs/day	788 lbs/day
Poultry (manure only)	13,680 lbs/day	186 lbs/day
Residential Wastewater **Annual Total**	128,991,000 lbs (wet weight)	9125 lbs
Commercial livestock **Annual Total**	56,093,200 lbs	355,510 lbs

Table 1 (USDA, Pub. 210-AWMFH, 92)

V. Qualitative Analysis of How Different Nitrogen Sources Could Impact Groundwater: On-site sewage systems in the study area produce a small but steady portion of nitrogen throughout the year in the study area. The average housing density in the area is very low, about .05 units per acre (The Profile, 1993). Nitrogen removal via soil treatment and plant uptake averages 50% (Banton and Kenrick, 1990). High ground water recharge areas (>24 in/year), such as Violet Prairie, translate into high dilution of infiltrating waste water (Hirschey and Sinclair 1992)(Banton and Kenrick 1990). Additionally, ground water sampled in the study area for Methylene Blue Activated Substance (MBAS) down gradient from areas of high residential development resulted in non-detection. MBAS is a substance found in detergents and is often used to detect ground water contamination from on-site sewage systems. Based on these facts, overall nitrogen input from septic systems in the study area is probably small.

Commercial livestock operations in the study area produce the largest proportion of nitrogen annually. However, It is important to remember that the above figures are based on average book values for as excreted manure. No actual measurements were taken at the facilities in the study area for the purposes of this report. Nitrogen concentrations will usually be reduced by a considerable percentage by the time manure is actually applied to the pasture due to volitization and different handling practices.

Manure actually contains less than 1% nitrate. Organic forms of nitrogen in the manure are converted to nitrate in the soil, and the actual percentage of organic nitrogen converted to nitrate by soil biological activity is variable dependent upon environmental conditions (Mathews,94). Most of the manure solids from the study area are used as soil amendments and fertilizers in other areas of the county. Furthermore, one of the dairies in the study area has been hauling their liquid manure to a storage facility since the fall of 93. It is unknown how much of the manure from that facility comes back into the study area to be spread. Therefore, it is assumed there is a great amount of uncertainty in the actual quantity of livestock waste produced in the study area and the acreage needed to utilize the nitrogen. The annual nitrogen production figure of 355,510 pounds will be considered as a high estimate.

The average forage pasture of improved pasture grass yields 3.5 tons/acre/yr, and each dry ton removes 50 pounds of nitrogen. Based on these figures, roughly 2031 acres of properly managed, improved pasture grass is needed to utilize all the nitrogen produced by commercial livestock in the study area (Mathews, 94). The problem the livestock owners face is having enough pasture area to utilize the nitrogen produced. As it stands now, there probably is enough open ground available if it were properly managed as forage pasture. However, significant portions of the open ground in the study area are planned for residential development. Livestock owners may be faced with having to manage leased land elsewhere.

The aquaculture facility located near Scatter Creek between Gibson Road and Leitner Road discharges wastewater into Scatter Creek. The Health Department has a water quality monitoring station immediately downstream at the Leitner Road bridge. The nutrient input to Scatter Creek from the fish farm is significant enough to increase nitrate concentrations several orders of magnitude over upstream concentrations. The mean nitrate concentration at the Gibson Rd. bridge during water year 1994 monitoring was .872 ppm compared to 3.578 ppm at the Leitner Rd. bridge. However, the volume of recharge from the creek to ground water in the area between the discharge point and the boundary of the study area is minimal (Hirschey and Sinclair, 1992). Therefore, the impact to nearby wells is most likely minimal.

The cumulative impact to ground water nitrate concentrations from all the nitrogen sources in the study area should be considered. Although this has not been quantified, the combined nitrogen input from all livestock, residential wastewater, and nitrogen fixing plants could be significant.

VI. Recommendations: The following recommendations primarily focus on improving management of manure and other sources of nitrogen in the study area.

1. Land application of manure should only occur at agronomic rates. Proper plant utilization of manure nutrients will complete the recycling loop and keep nutrients from becoming pollutants.

2. Livestock operators should seek assistance from the Thurston Conservation District* to develop and implement adequate manure management plans.

*Many of the areas livestock operations are currently in the process of developing and implementing manure management plans with the assistance of the Thurston Conservation District. Measures taken to date include: Cessation of winter time land application in Violet Prairie by two area farms, construction of a manure lagoon to store manure during the winter, and the mitigation of winter time spreading by reducing rates of application, maximizing volitization of nitrogen, and avoiding spreading when it rains.

3. It is essential that these farms continue to implement their manure management plans. As these operations improve their manure management practices, nitrates in area wells should begin to decline.

4. Landowners and operators who use commercial fertilizers and pesticides should exercise caution in their timing and rates of application. Pesticides

that leach should be avoided if possible. Application should take place under proper weather conditions and seasons. Technical assistance is available through WSU Cooperative Extension, the Conservation District, and the manufacturer of the product.

5. Wellhead management: Some of the wells which were used as sample sites should have better buffers from potential contaminant sources. in general, a 100 foot radial buffer should be maintained to exclude application of manure, fertilizers, pesticides, intensive cattle grazing, chemical storage, and on-site sewage disposal systems.

6. Long Term Information and Technical Assistance: Thurston County, Dept. of Ecology, Thurston Conservation District, and WSU Cooperative Extension should work together to provide information, and technical assistance to area residents, land owners, farm operators, and businesses about how they can protect their drinking water.

7. Testing residual soil nitrogen levels is a good monitoring tool to assess the effectiveness of manure and fertilizer application practices*. Currently the Conservation District assists land mangers in taking residual soil nitrate samples.

*Residual soil nitrogen can impact groundwater because it is the nitrogen in the root zone left over after a crop is harvested or stopped growing. The residual nitrogen is converted to nitrate by soil biological activity and if vegetation is not utilizing the nitrate it is available to leach down to ground water. Nearly all soils have some amount of residual soil nitrogen from either natural or agricultural /landscape related activities. Studies in other areas of the United States have identified ranges of residual soil nitrate acceptable for protecting ground water (Mathews, 94). Soil nitrate testing on land application sites can help land managers determine application rates, and identify problem areas.

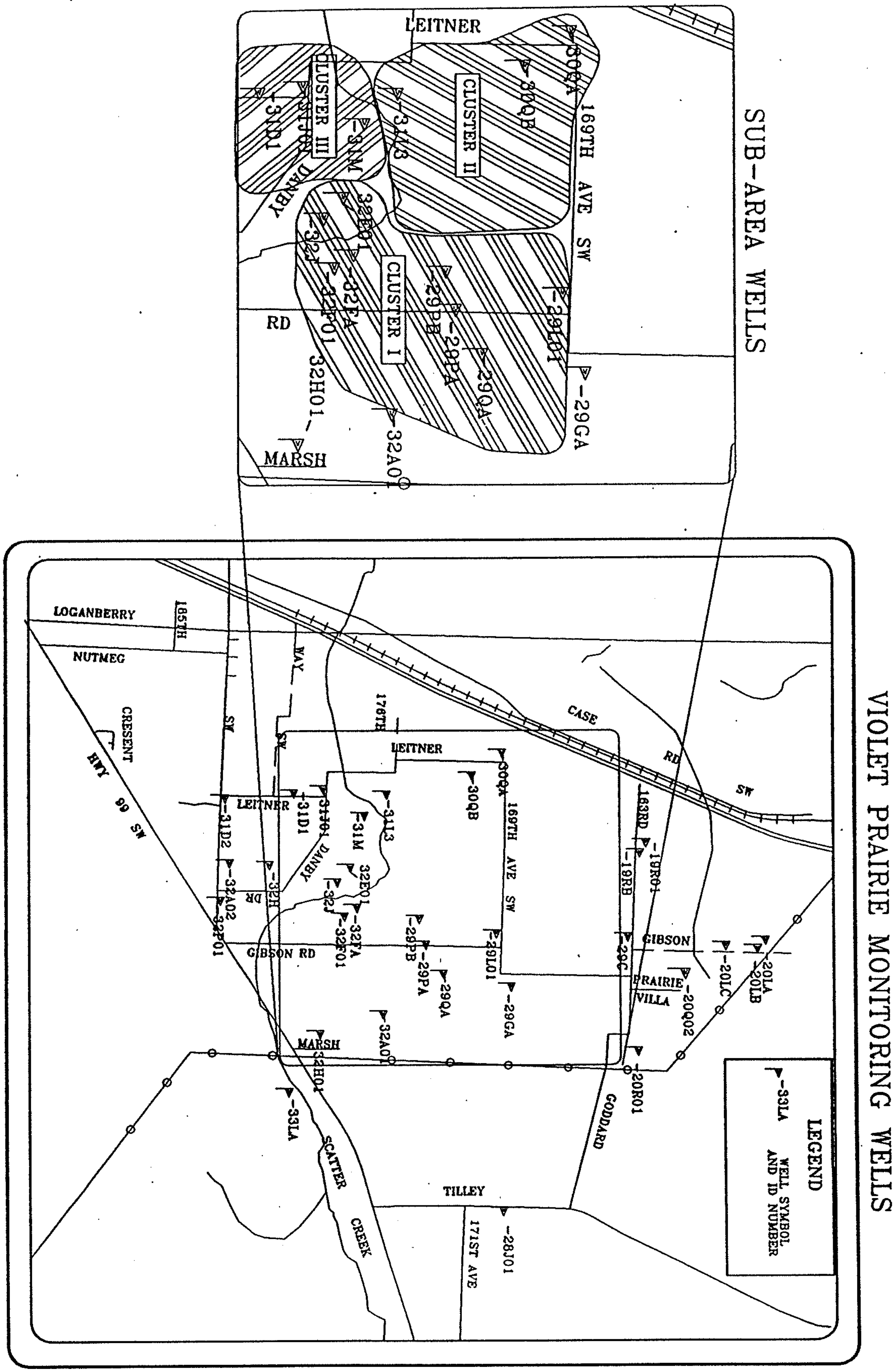
8. Continued ground and surface water monitoring is needed to evaluate the effectiveness of farm conservation plan implementation and track long term water quality trends in the south county. Additionally, a long term monitoring plan will serve as an early warning system. This will enable county staff to identify possible ground water contamination problems and initiate corrective actions before contaminants have a chance to spread.

VII. Analysis of Monitoring Results

A. Sub-Area Results: The different sub-areas found to have nitrate levels near or exceeding the MCL have been separated into three clusters (Figure 3). Many factors can influence nitrate concentrations in ground water including: Type of contamination source, well construction and depth, precipitation patterns, soil types, ground water seepage velocities, and hydraulic conductivity.

<u>Cluster 1 Location:</u> *Gibson Road between Old Highway 99 and 169th and 2 wells on the north side of Danby Drive:* This area is directly down gradient from suspected sources of nitrate loading. These sources are livestock manure application and commercial fertilizer application. Eight wells were monitored in this cluster between June 1993 and November 1994.

Monitoring results from this cluster show elevated nitrate levels in all but two of the wells tested, with three exceeding the MCL at least once. While there seems to be a clear correlation between these elevated levels and livestock manure application up-gradient from these wells, one fact prevents a more conclusive identification of the nitrate sources. Two wells that are directly down gradient from the potential contamination source, and within a few hundred feet of each other, displayed vastly different nitrate levels of 1 ppm and 30 ppm. The wells monitored were: 29 L01. 29QA, 32FA, 32F01, 32E01, 32J, 32PA, and 32PB. The table and graphs labeled Cluster 1 represents the results from the 1993-94 monitoring period.



SUB-AREA WELLS
CLUSTER I
CLUSTER II
CLUSTER III
VIOLET PRAIRIE MONITORING WELLS
LEGEND
WELL SYMBOL AND ID NUMBER

FIGURE 3

Cluster #1 Well Data

Well ID #	Well Depth (ft)	Sample Date(s)	Nitrate Concentration (mg/l)
29L01	80	10/12/93	2.50
"		03/29/94	3.25
"		11/09/94	3.87
29PA	35	06/02/93	16.4
29PB	76	10/12/93	3.15
"		03/28/94	8.89
29QA	50	03/28/94	10.7
"		11/08/94	6.37
32E01	90	10/13/93	0.45
32F01	80	10/13/93	0.90
"		03/28/94	1.09
32FA	35	10/13/93	9.98
"		03/28/94	30.6
"		11/08/94	19.5
32J	74	10/13/93	2.61
"		03/28/94	6.93
"		11/09/94	3.86

Table 2

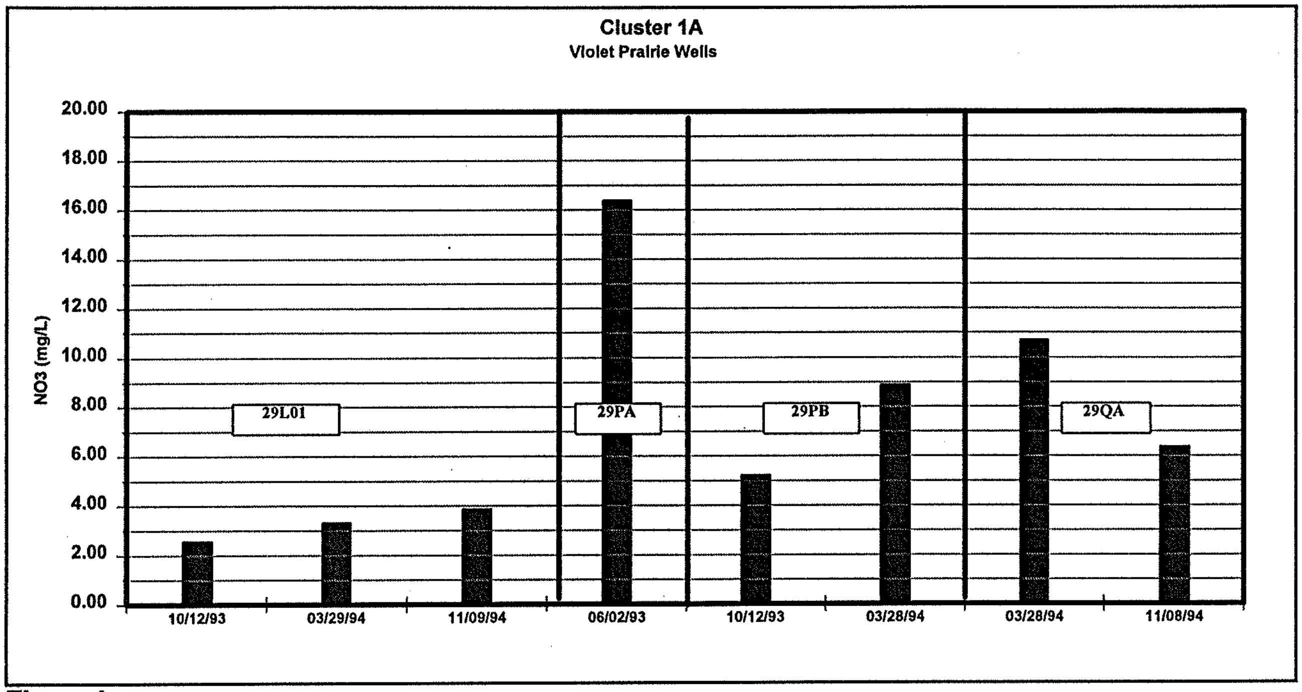


Figure 4

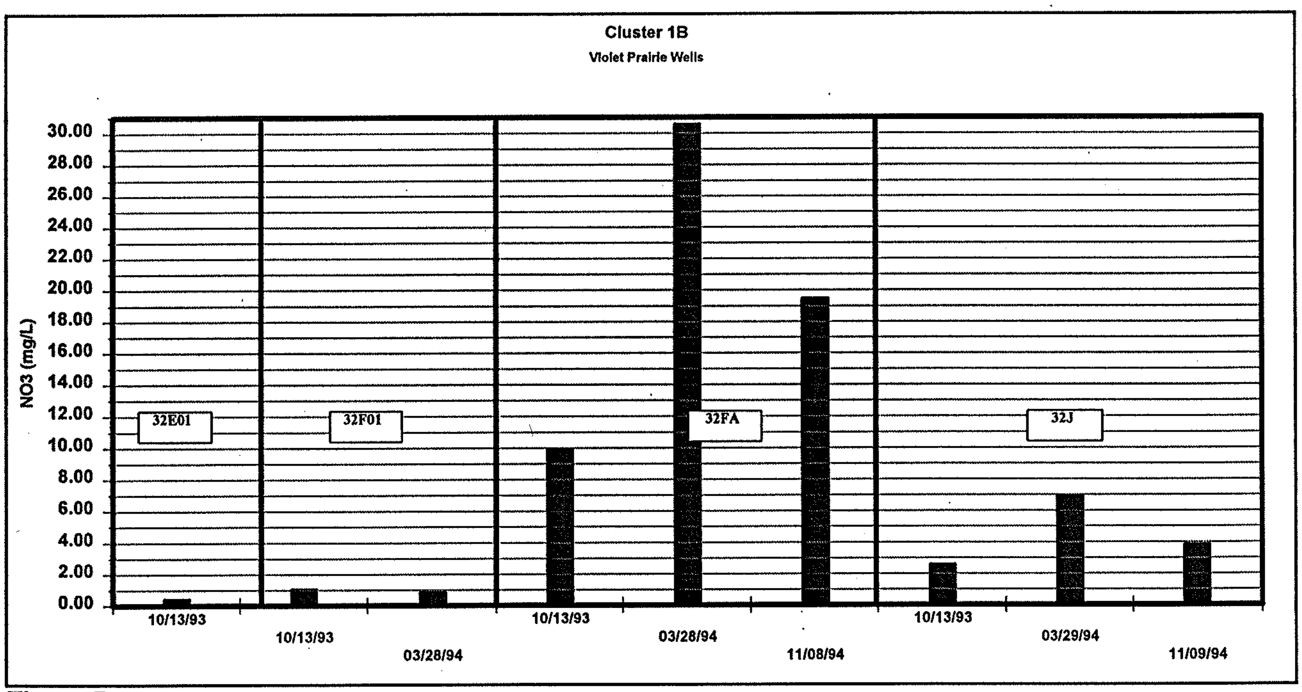


Figure 5

The over-application of livestock manure seems to be the major contributor of elevated nitrates to some of the wells in Cluster 1, however, questions remain. One well down gradient from the livestock manure application site (32F01) has decreased in nitrate concentration since monitoring conducted in 1990. Another well down gradient from a commercial fertilizer application site (29L01) has increased only slightly. This may be a function of well depth, as these two wells are in the 80 + foot range. However, 32F01 and 29PB are approximately the same depth and down gradient from the same source and there results are very different. The March 94 results were .9 ppm and 8.89 ppm respectively. Topographically, 29PB is lower in elevation than 32F01. 29PB could be impacted by surface runoff from up-gradient livestock facilities that infiltrates to ground water.

32FA, which had the highest nitrate level, is most likely being impacted by a failing on-site septic system. This assumption is based upon high chloride and conductivity levels found at this well. The Health Department is currently dye tracing the septic system in an attempt to confirm if a failure is occurring.

Continued monitoring will be needed to gain a clearer understanding of the factors at work in this sub-area. The implementation of best management practices and increasing manure storage at the up-gradient livestock facility will most likely have a positive impact on nitrate concentrations in some of these wells.

<u>Cluster 2 Location:</u> *Leitner Road between 169th and Scatter Creek:* Four wells were monitored in this area. Three are down gradient from pastures that receive heavy livestock manure application and one is down gradient from a christmas tree farm. Nitrate levels were elevated in all of these wells, although, once again two wells very close to one another had very different results. The wells monitored were: 30QA, 30QB, 30QC and 31L3.

Cluster #2 Well Data

Well ID #	Well Depth (ft)	Sample Date(s)	Nitrate Concentration (mg/l)
30QA	88	10/14/93	5.89
"		03/28/94	1.05
"		11/08/94	6.73
30QB	70	03/28/94	10.3
"		11/08/94	8.36
30QC	60	11/09/94	8.98
31L3	40	10/14/93	6.32
"		03/28/94	8.86
"		11/08/94	4.94

Table 3

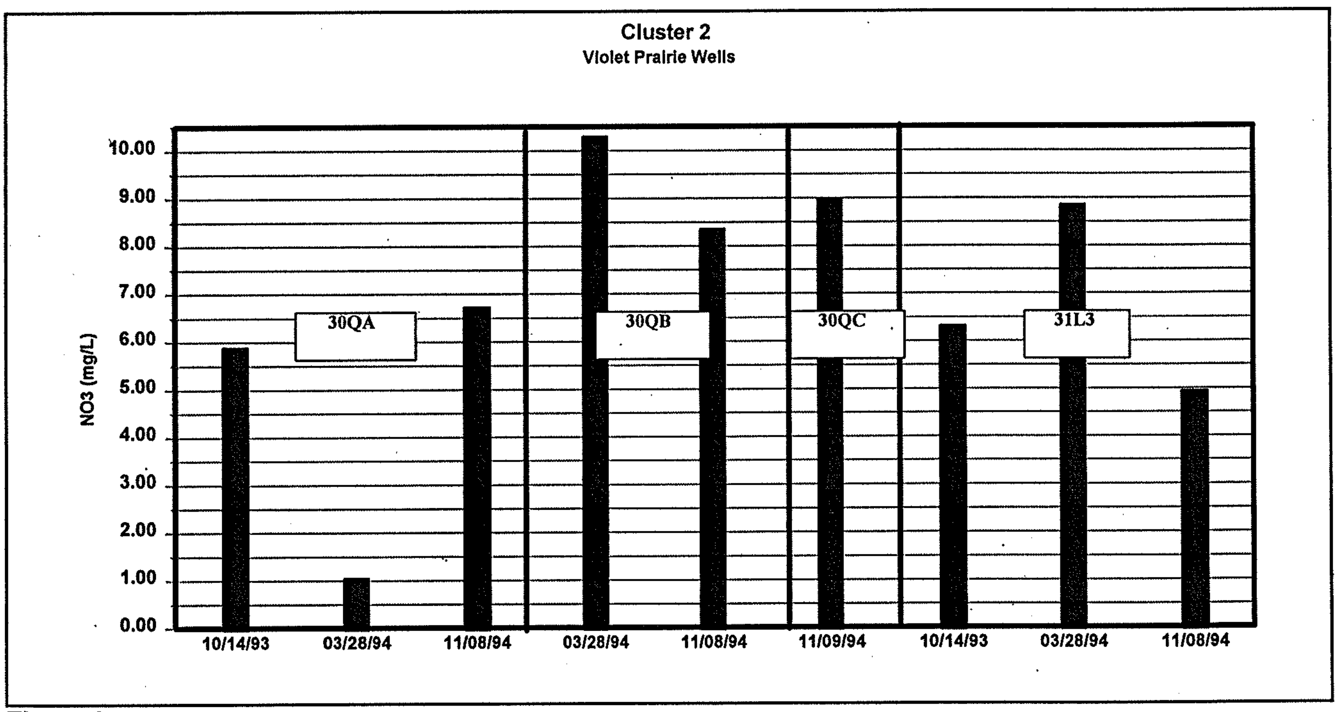


Figure 6

Monitroing on 30QA and 31L3 began in October 93. In order to determine more definitive conclusions, 30QB was added in the spring of 94 and one more well, 30QC, was added for the final monitoring round in November 94.

A christmas tree farm is up-gradient from 31L3, although it is some distance away. Commercial fertilizer application at the tree farm could be impacting this well. At this point the nitrogen source cannot be confirmed. Both of the dairy operators who spread livestock manure on the pastures up-gradient of 30QA, QB, and QC are in the process of developing farm conservation plans and increasing manure storage.

Continued monitoring would be necessary to document the effects on nitrate concentrations in these wells after implementation of best management practices.

<u>Cluster 3 Location:</u> *Leitner Road and Danby Drive, north of 183rd:* Four wells were monitored in this area. Two of the wells, 31J01 and 31D1, are down gradient from a pasture that receives some livestock manure application. 31M does not appear to have an immediate up-gradient nitrate source. 31L02 is west of the Leitner Rd. and Danby Dr. intersection off of 180th Way, and is down gradient of pastures which receive some manure application. All of the wells in this area were found to have elevated nitrate levels. The wells monitored were 31D1, 31JO1, 31L02, and 31M.

Cluster # 3 Well Data

Well ID #	Well Depth (ft)	Sample Date(s)	Nitrate Concentration (mg/l)
31D1	~50	10/14/93	5.09
"		03/29/94	7.32
"		11/09/94	6.61
31J01	80	10/13/93	6.54
"		03/29/94	7.47
"		11/09/94	7.54
31L02	77	11/09/94	4.74
31M	60	10/14/93	1.13
"		03/29/94	4.01

Table 4

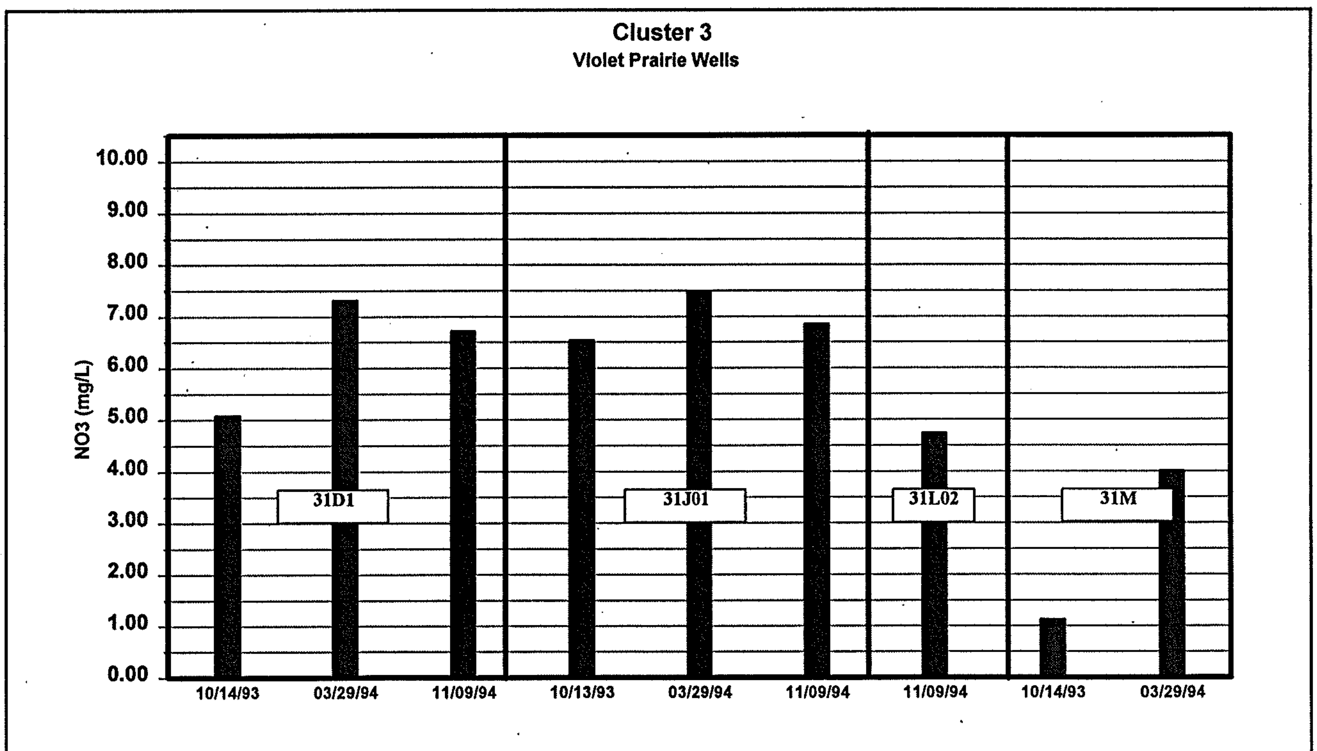
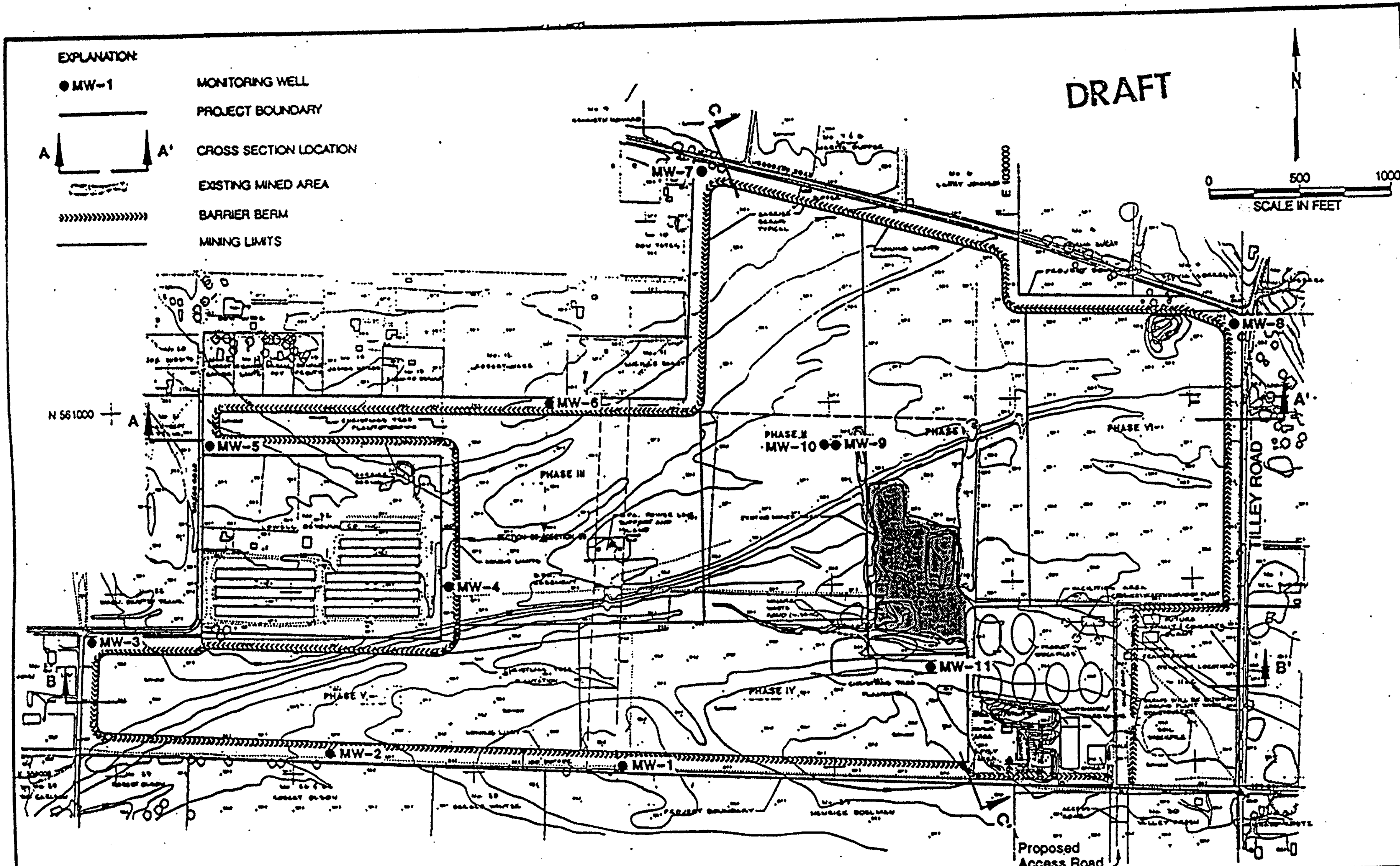


Figure 7

There does not seem to be an obvious nitrate source in close proximity to some of these wells. The pasture east of 31D1, 31J01, and 31L02 do receive some application of livestock manure, although staff has never observed it to be in excess of appropriate agronomic rates. There are some small pastures around 31M which also receives some manure application, although most of the application appears to be down gradient from the well.

B. Lakeside Monitoring Wells: In preparation for the Environmental Impact Statement for Lakeside Industries proposed gravel mine along Tilley Road, GeoEngineers monitored 11 wells on the site property in March of 92 (Figure 8). Seven wells were found to have nitrate levels in the 4 to 13 ppm range. Nitrate levels were in the 4.2 - 6.9 ppm range for wells 1 and 2 and 8.9 - 13 ppm range for wells 5, 6, 9, and 10. Poultry manure has been spread over much of this area for several years. The nitrate levels found in these wells are most likely a response to differing frequencies and rates of application over the area. See Table 3 in the Appendix for more information.

C. Additional Violet Prairie Monitoring Results: A few other wells in the Violet Prairie area had nitrate levels above what would be considered background levels of 1 - 2 ppm. These well are 19RB, 19R01, 29C, 29GA, and 20Q01.



Geo Engineers

SITE PLAN

FIGURE 8

REFERENCE: DRAWING ENTITLED "TILLEY ROAD PROJECT, MINE PLAN," BY ELDON D. STRID, DATED 9/91.

Additional Violet Prairie Monitoring Results

Well ID #	Well Depth	Sample Date(s)	Nitrate Concentration (mg/l)
19RB	40	03/29/94	4.22
19R01	78	03/29/94	1.81
29C	80	03/28/94	7.14
"		11/08/94	5.91
29GA	75	06/02/93	4.71
"		10/12/93	3.25
"		03/28/94	5.09
"		11/08/94	6.52
20Q01	65	11/15/93	5.99
"		1/31/94	5.99
"		11/08/94	7.21
20R01	78	06/01/93	2.26
"		10/12/93	2.07
"		03/29/94	2.77
"		11/08/94	2.58

Table 5

Poultry manure has been spread on pastures up-gradient from 19RB and R01. One of the owners of 29C, a two party well, allowed livestock access to the pastures around the well head. This is the suspected source of nitrates for that well. 29GA serves an active commercial poultry facility, which has spread poultry manure up-gradient from their well. 20Q01, which is on the north side of 163rd between Gibson Road and Prairie Villa (not shown on map), was in the 7, 8, and 9 ppm range in 1990-91. A source has not been identified for the elevated nitrates. A high density of on-site septic systems up-gradient from this well were suspected, but could not be confirmed by monitoring for methylene blue activated substance (MBAS) and chlorides. MBAS is commonly found in detergents and can be an indicator of contamination from an on-site septic system if it is found in well water. There is an active dairy up-gradient from 20R01.

Other wells such as 01B, 20LB, 32H01, and 33LA have displayed very little change, or in some cases, flucuations of less than 1 ppm. See Tables 1 and 2 in the appendix for complete well listings and results.

D. Seasonal Fluctuation: Nitrate levels in ground water will fluctuate seasonally. Many of the wells in Violet Prairie did exhibit this behavior and had higher nitrate levels in the early spring than they did in the early fall. This is probably the lag time between the build up of residual nitrogen in the soil, the conversion to nitrate, and the travel time for the nitrate to reach area wells. It is important to accurately define the seasonal nitrate fluctuation through several monitoring rounds during the same seasons. What appears to be increases or decreases in nitrate levels could simply be seasonal. A long term monitoring plan will define these seasonal trends and track progress of water quality protection efforts.

VII. APPENDIX

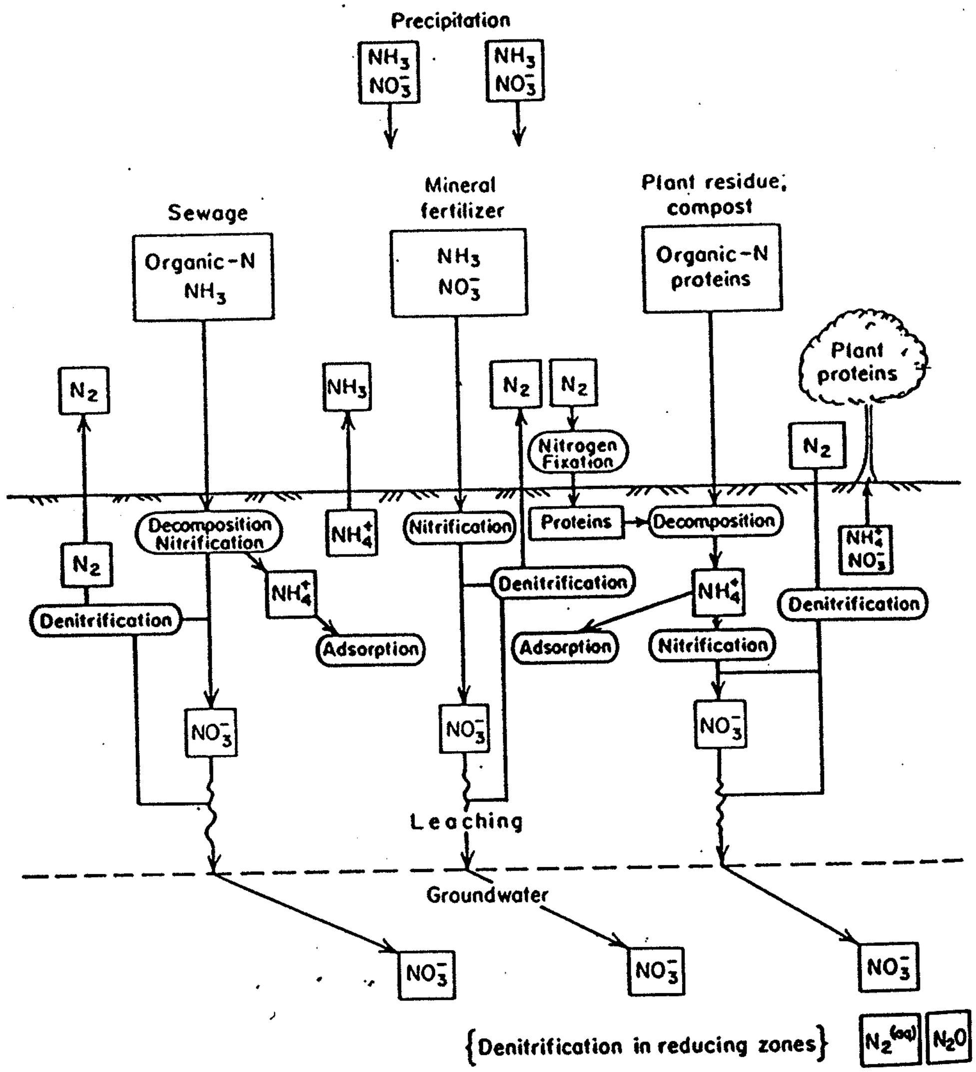
The Nitrogen Cycle

Health Risks of Nitrate in Drinking Water

Water Quality Data Tables

A. Nitrogen Behavior Principals:

1. The Nitrogen Cycle (Freeze and Cherry, 1979)



Sources and pathways of nitrogen in the subsurface environment.

Dissolved nitrogen in the form of nitrate (NO_3^-)is the most common contaminant identified in ground water. Agricultural activity and disposal of sewage on or beneath the land has resulted in this contaminant becoming increasingly widespread in many parts of the world. Although (NO_3^-) is the main form in which nitrogen occurs in ground water, dissolved nitrogen also occurs in the form of nitrite (NO_2^-), nitrogen (N_2), nitrous oxide (N_2O), ammonium (NH_4^+), ammonia (NH_3), and organic nitrogen. Organic nitrogen is nitrogen bound in organic substances (Freeze and Cherry 1979).

NO_3^- originates by the conversion of NH_4^- or organic nitrogen, which occur naturally or are introduced to the soil by human activities. Ammonification is the process of converting organic nitrogen to NH_4^-. Nitrification is the process of converting NH_4^+ to NO_3^- by oxidation. These two processes generally occur above the water surface in the soil zone where organic matter and oxygen are abundant (Freeze and Cherry 1979). Some plants, in particular legumes, capture atmospheric nitrogen and convert it to usable forms in the soil by a process known as nitrogen fixation (Mancl 1987). This is an additional pathway for nitrogen to reach the subsurface environment.

NO_3^- is very mobile in ground water. It can move with no transformation and very little retardation. NO_3^- is usually the stable form of dissolved nitrogen in ground water that is strongly oxidizing. Shallow ground water in highly porous soils or fractured rock contain considerable dissolved O_2. In these hydrogeologic environments, NO_3^- can migrate large distances from source areas (Freeze and Cherry 1979).

Denitrification is the process in which NO_3^- is reduced to N_2O and finally to N_2. These products exist as dissolved species in ground water until the water moves into an unsaturated zone. Here, a portion of the N_2O or N_2 may be lost by volitization to the soil air. From a water quality standpoint, denitrification is a desirable process. Dissolved N_2 and N_2O are not detrimental to drinking water (Freeze and Cherry 1979).

B. Health Risks Nitrates: (From the Washington State Department of Health Toxic Substances Fact Sheet) High levels of nitrate in drinking water can cause a blood disorder in newborn babies called methemoglobinemia. Although methemoglobinemia can affect any age, nitrate contaminated water principally causes this illness in infants under 1 year of age, and not older children or adults. In order for nitrate to cause methemoglobinemia or "blue baby disease", it must first be changed by the body into nitrite. Babies less than four months old have a lower stomach acidity, which allows certain bacteria to grow that are capable of converting nitrate to nitrite.

Nitrite then changes the oxygen carrying hemoglobin to methemoglobin, which does not carry oxygen, causing the body to suffer oxygen deprivation in severe cases. Some studies have suggested a possible link between nitrate and cancer and birth defects. These suggestions however, have not been confirmed. Since nitrate levels in drinking water are a general indicator of overall water quality, elevated nitrates may also indicate the presence of other contaminants which could cause health problems.

Symptoms: An infant with methemoglobinemia shows little distress, but appears ruddy and has a peculiar lavender color generally in the appendages and fingernails. Most often the disease is only recognized in acute stages, when the infant turns blue and has trouble breathing.

Treatment: If the condition is generally not life threatening, no treatment is needed other than to switch to uncontaminated water. The symptoms will improve within two to three days. For severely affected infants, intravenous treatment with methylene blue will convert the methemoglobin back to hemoglobin and bring rapid recovery.

Prevention: Infants under one year of age should not drink water containing nitrate at a concentration greater than the drinking water standard of 10 ppm as nitrogen. The following sub-populations may also be at risk: Individuals with reduced gastric acidity, individuals with hereditary lack of methemoglobin reductase, and women who are pregnant.

In Washington State, laboratories generally report nitrate levels in drinking water as ppm of nitrogen. However, some laboratories may report nitrate levels as ppm of nitrate. If this is the case, then the drinking water standard of 10 ppm is converted to 45 ppm. Three treatment methods commonly used to remove nitrate include: Reverse osmosis, anion exchange, and distillation. These techniques are expensive to install and require frequent, careful maintenance for effective operation. Simple filtering devices do not remove nitrates. If the problem is caused by a poorly constructed or located well, reconstructing or relocating the well may be the best solution.

Violet Prairie Monitoring Data

Table I

LOCAL ID	DATE SAMPLE	SWL	PH	COND	TEMP C[c]	DO	DOSAT	TDS	TURBIDITY	NO3 mg/L	Fe mg/L	Mn mg/L	Cl mg/L
15N/03W-01B	6/1/93		6.450	100.700	12.600			0.065	0.375	2.090			
15N/03W-01B	10/12/93	37.500	6.500	116.700	10.210	0.700	6.300	0.074	1.100	2.320			
16N/02W-19R01	3/29/94		6.470	134.800	8.340	9.200	77.500	0.086	0.380	1.810			
16N/02W-19RB	3/29/94	29.340	6.490	89.300	9.370	10.210	79.500	0.155		4.220			
16N/02W-20LA	6/2/93		6.190	72.500	9.790			0.047	0.400	0.914			
16N/02W-20LA	10/12/93		6.310	113.000	9.660	0.230	2.000	0.072	1.500	0.783			
16N/02W-20LB	6/1/93	35.520	6.340	106.400	9.820			0.068	1.100	1.930			
16N/02W-20LB	10/14/93	43.280	6.310	111.200	9.910	4.230	37.300	0.072		1.330			
16N/02W-20LC	6/1/93	35.000	6.180	70.700	9.430			0.046	0.455	0.967			
16N/02W-20LC	10/12/93	41.750	6.470	146.000	9.610	0.580	7.900	0.094	0.850	0.650			
16N/02W-20LC	11/8/94	46.800	6.580	150.000	9.680	5.770	49.500	0.096	7.100	2.130			4.130
16N/02W-20Q01	11/15/93		6.160	170.000	9.730	6.710	58.200	0.108		5.990			8.060
16N/02W-20Q01	1/31/94		6.250	169.400	10.210	5.840	49.300	0.112		5.990			
16N/02W-20Q01	11/8/94		6.260	176.000	9.860	7.510	66.300	0.114	2.600	7.210			7.750
16N/02W-20R01	6/1/93	36.500	6.400	106.500	10.470			0.068	81.500	2.260			
16N/02W-20R01	10/12/93	46.200	6.370	125.800	9.950	3.080	27.400	0.080	2.500	2.070			
16N/02W-20R01	3/29/94	36.780	6.380	129.900	9.920	5.710	50.100	0.089		2.770			
16N/02W-20R01	11/8/94		6.340	128.200	9.890	7.380	65.000	0.082	8.950	2.580			5.680
16N/02W-28J01	6/1/93		6.150	76.600	10.800			0.049	0.120	2.330			
16N/02W-28J01	10/12/93		6.450	114.700	10.620	0.640	6.600	0.070	0.600	1.630			
16N/02W-29C	3/28/94		6.360	180.000	10.160	6.310	55.700	0.115		7.140			
16N/02W-29C	11/8/94		6.420	178.000	9.890	5.590	49.300	0.114	1.350	5.910			7.230
16N/02W-29GA	6/2/93	29.230	15.510	109.100	11.210			0.070	1.200	4.710			
16N/02W-29GA	10/12/93	43.300	6.180	155.000	13.920	0.090	0.900	0.099	0.950	3.250			
16N/02W-29GA	3/28/94	28.960	5.870	136.100	11.080	0.340	3.100	0.087	1.100	5.090			
16N/02W-29GA	11/8/94		5.970	155.000	10.930	0.730	6.100	0.100	1.100	6.520			5.370
16N/02W-29PA	6/2/93	16.600	6.050	223.000	11.080			0.146	0.310	16.400			
16N/02W-29PA	8/19/93		5.980	169.000	11.040	1.020	10.100	0.108					
16N/02W-29PB	8/19/93		6.410	133.000	10.490	0.810	7.400	0.085		3.150			
16N/02W-29PB	10/12/93		6.180	146.000	11.000	0.100	0.800	0.094	0.550	5.230			
16N/02W-29PB	10/13/93		6.470	143.700	10.430	2.620	22.000	0.092		4.050			
16N/02W-29PB	3/28/94	14.350	6.270	163.000	10.970	4.230	77.200	0.132	0.470	8.890			
16N/02W-29QA	3/28/94		6.140	190.000	10.470	11.340	101.300	0.112	0.870	10.700			
16N/02W-29QA	11/8/94		6.250	146.600	10.430	9.700	87.100	0.094	0.750	6.370			5.680
16N/02W-30QA	10/14/93		6.800	179.000	10.460	5.450	49.100	0.115		5.890			
16N/02W-30QA	3/28/94		6.730	167.000	10.850	7.450	66.200	0.107		1.050			

Violet Prairie Monitoring Data

Table I

LOCAL ID	DATE SAMPLE	SWL	PH	COND	TEMP C°	DO	DOSAT	TDS	TURBIDITY	NO3 mg/L	Fe mg/L	Mn mg/L	Cl mg/L
16N/02W-30QA	11/8/94		6.780	182.000	10.170	9.020	83.600	0.117	2.350	6.730			5.890
16N/02W-30QB	3/28/94	22.380	6.650	188.000	10.390	9.880	88.000	0.120	0.230	10.300			
16N/02W-30QB	11/8/94		6.660	203.000	10.360	9.330	84.100	0.129	2.650	8.360			6.510
16N/02W-30QC	11/9/94		6.670	218.000	10.480	8.720	79.200	0.139	1.700	8.980			6.510
16N/02W-31D1	10/14/93	32.300	6.170	156.000	11.780	5.710	52.500	0.100		5.090			
16N/02W-31D1	3/29/94	17.540	6.460	163.000	11.230	6.230	64.700	0.124		7.320			
16N/02W-31D1	11/9/94	38.200	6.390	157.000	10.510	11.610	104.800	0.102	3.250	6.720			6.610
16N/02W-31D2	10/13/93		6.480	133.500	11.040	2.660	24.100	0.085		2.540			
16N/02W-31J01	10/13/93	37.800	6.690	184.000	10.820	2.420	21.400	0.118		6.540			
16N/02W-31J01	3/29/94	36.100	6.770	199.000	10.590	7.620	67.500	0.126	0.760	7.470			
16N/02W-31J01	11/9/94	43.650	6.740	202.000	10.490	7.250	65.800	0.129	2.650	6.850			7.540
16N/02W-31L02	11/9/94		6.590	153.000	9.660	8.050	69.800	0.098	1.250	4.740			5.160
16N/02W-31L3	10/14/93	37.100	6.360	164.000	10.470	5.120	43.200	0.072		6.320			
16N/02W-31L3	3/28/94	16.680	6.240	156.000	10.260	10.530	93.500	0.100	0.700	8.860			
16N/02W-31L3	11/8/94		6.260	161.000	9.240	5.840	50.600	0.103	0.700	4.940			6.710
16N/02W-31M	10/14/93	27.500		200.000	10.180	4.660	42.100	0.127		1.130			
16N/02W-31M	3/29/94	26.400		207.000	10.230	4.170	39.400	0.131	0.610	4.010			
16N/02W-32A01	2/14/93									1.500			
16N/02W-32A01	3/28/94		6.540	149.000	11.500	6.330	57.500	0.096	0.380	3.560			
16N/02W-32A02	10/13/93		6.350	74.400	12.550	0.890	8.000	0.048		1.500			
16N/02W-32E01	10/13/93		6.500	199.000	10.690	6.310	56.600	0.127		0.447			
16N/02W-32F01	10/13/93		6.360	236.000	11.420	4.120	37.400	0.151		1.090			
16N/02W-32F01	3/28/94	30.280	6.530	267.000	10.340	3.760	46.400	0.169	0.320	0.895			
16N/02W-32FA	5/24/93									22.100			
16N/02W-32FA	10/13/93	36.500	6.320	360.000	11.580	3.910	35.300	0.230		9.980			
16N/02W-32FA	3/28/94	21.130	6.240	415.000	9.820	10.970	96.000	0.265	1.200	30.600			
16N/02W-32FA	11/8/94	42.100	6.440	388.000	10.790	8.600	81.000	0.249	2.450	19.500			18.800
16N/02W-32H	10/14/93		6.140	92.100	10.490	3.100	27.100	0.059		0.774			
16N/02W-32H01	3/30/93									2.600			
16N/02W-32H01	6/21/93							54.000		2.750			
16N/02W-32H01	10/12/93		6.140	128.200	11.550	2.580	23.900	0.082	1.250	2.290			
16N/02W-32H01	10/14/93		6.230	113.200	10.620	5.500	52.300	0.069		2.540			
16N/02W-32J	10/13/93		6.720	165.000	10.640	4.070	36.200	0.103		2.610			
16N/02W-32J	3/29/94	12.910	6.770	204.000	10.470	5.480	47.300	0.130	0.164	6.930			
16N/02W-32J	11/9/94	33.100	6.830	176.000	10.670	6.400	58.400	0.112	1.000	3.860			5.780
16N/02W-32P01	6/2/93	28.360	5.860	66.700	13.140			0.043	1.650	2.020			

Table I

Violet Prairie Monitoring Data

LOCAL ID	DATE SAMPLE	SWL	PH	COND	TEMP C[c]	DO	DOSAT	TDS	TURBIDITY	NO3 mg/L	Fe mg/L	Mn mg/L	Cl mg/L
16N/02W-32P01	10/12/93	47.200	6.100	84.000	10.950	7.430	66.700	0.054	0.500	0.919			
16N/02W-33LA	6/1/93	25.000	6.500	97.600	10.670			0.071	0.830	0.777			
16N/02W-33LA	10/12/93		6.450	114.700	10.620	0.640	6.600	0.073	1.850	0.710			

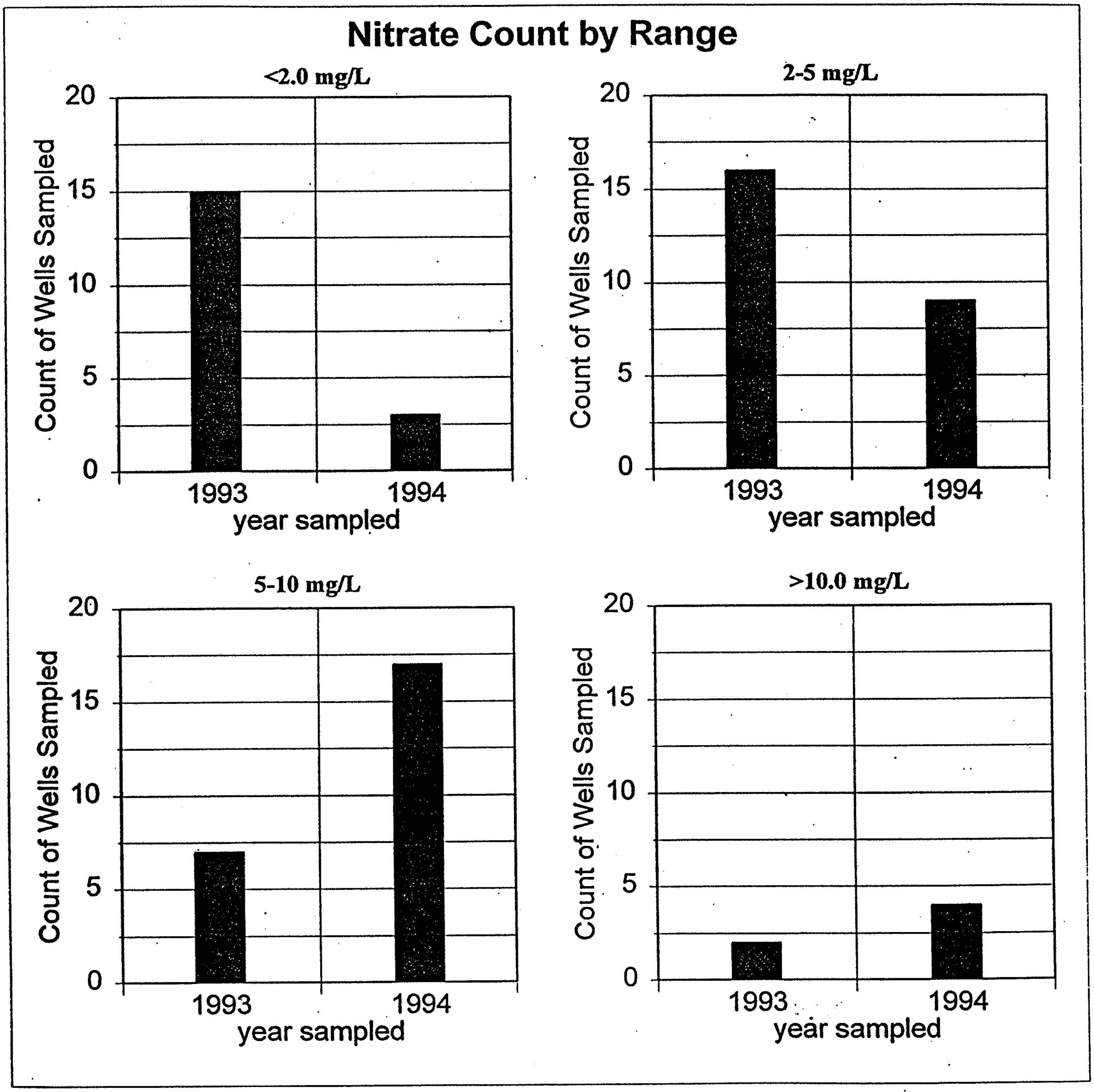

Nitrate Count by Range
<2.0 mg/L
2-5 mg/L
5-10 mg/L
>10.0 mg/L
Count of Wells Sampled
0
5
10
15
20
1993
1994
year sampled

TABLE 3
WATER QUALITY DATA
TILLEY ROAD GRAVEL PIT

Well Number	Date Sampled	Ground Water Elevation (feet)	Temperature (°F)	pH	pH[1]	Conductivity (µmhos)	Salinity (%)	Turbidity (nmu)	Turbidity[1] (mg/l)	Total Dissolved Solids[1] (mg/l)	Nitrates & Nitrites[1] (mg/l)
MW-1	03/04/92	203.0	56.4	7.5		104	-	-	0.2	105	5.4
	03/19/92	202.1	53.6	6.8	6.5	110	1	3.6	0.4	126	6.9
MW-2	03/04/92	199.9	52.5	6.4		97	-	-	0.2	108	4.2
	03/19/92	199.0	53.6	7.4	6.3	110	1	19.6	2.1	108	6.4
MW-3	03/04/92	195.5	53.0	7.3		129	-	-	0.2	123	3.6
	03/19/92	194.6	53.6	6.9	6.2	150	1	2.4	2.8	118	4.8
MW-4	03/04/92	201.7	52.0	7.4		87	-	-	34	78	1.9
	03/18/92	200.9	51.8	7.8	6.4	100	1	21.5	2	91	0.9
MW-5	03/04/92	196.3	58.1	6.8		164	-	-	15	162	9.1
	03/18/92	195.7	52.7	7.8	6.3	165	1	17.5	8.8	179	11.9
MW-6	03/04/92	201.7	52.5	7.8		108	-	-	1.1	120	8.9
	03/18/92	201.2	53.6	7.3	6.1	125	1	9.8	0.7	142	13
MW-7	03/04/92	202.4	59.2	8.6		828	-	-	0.2	74	2.2
	03/19/92	201.9	51.8	7.9	6.5	85	1	18.7	1.9	77	2.4
MW-8	03/04/92	208.3	55.5	7.8		694	-	-	0.4	67	1.3
	03/19/92	207.7	50.9	6.3	6.2	75	1	49.7	16	69	1.4
MW-9	03/04/92	206.4	50.6	7.6		101	-	-	0.8	126	9
	03/19/92	205.7	50.9	6.3	5.9	110	1	2.8	1.1	126	9.7
MW-10	03/04/92	206.3	52.0	7.0		102	-	-	1.4	127	9.2
	03/19/92	205.6	50.9	6.9	5.9	110	1	22.7	2.3	118	9.4
MW-11	03/04/92	207.8	52.1	7.6		88	-	-	20	68	1.9
	03/19/92	206.9	51.8	7.2	6.6	100	1	180.0	87	69	3.2

Notes:
1 Analysis performed by Water Management Laboratories, Inc., Tacoma, Washington.
µmhos = micromhos; nmu = nephelometric units; mg/l = milligrams per liter; - = not tested

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