NOVA SCOTIA

Environment

WELL WATER NITRATE MONITORING PROGRAM

2010 REPORT

Prepared: March 2010

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EXECUTIVE SUMMARY

The Well Water Nitrate Monitoring Program is a long-term study that involves annual testing for nitrate at approximately 150 water wells in Kings County, Nova Scotia. The objectives of the program are to monitor nitrate levels in a group of randomly selected water wells to determine the number of wells that meet the Canadian drinking water guideline for nitrate and to identify any long-term trends in nitrate levels.

The monitoring program was initiated in 2002 as a follow-up to previous water quality studies that collected nitrate samples in 1989, 1999 and 2000. The wells have been sampled on a yearly basis since 2002. In total, the wells have been tested on 11different years during the period between 1989 and 2009.

The monitoring results for the entire period of record indicate that 15% to 25% of the water wells tested exceeded the nitrate drinking water guideline on any given year since 1989. The results from 2009 showed that 21% of the wells exceeded the nitrate drinking water guideline. The results also showed that 5% of the wells had an upward trend in nitrate levels, 29% had a downward trend, and 66% had no trend in nitrate levels.

ACKNOWLEDGMENTS

The Well Water Nitrate Monitoring Program is a collaboration between Nova Scotia Environment (NSE), which oversees the program and collects the well water samples, and the Nova Scotia Agricultural College, which completes the nitrate laboratory analyses. This report was prepared by staff in the Water & Wastewater Branch of the Environment Science and Program Management Division of NSE. Both the report and the operation of the Well Water Nitrate Monitoring Program have benefited from the valuable input of many dedicated individuals. In particular, we gratefully acknowledge the cooperation of the well owners that volunteer their wells to be sampled each year. Their continued participation is vital to the success of this monitoring program.

1.0 INTRODUCTION

1.1 Background and Objectives

The Well Water Nitrate Monitoring Program is a long-term study that involves annual testing for nitrate at approximately 150 water wells in Kings County, Nova Scotia. The program was initiated in 2002 as a follow-up to water quality studies that carried out nitrate sampling in 1989 (Briggins and Moerman, 1995), 1999 and 2000 (Blair, 2001). Since 2002, the nitrate sampling has been completed each year on the same group of water wells.

The objectives of the monitoring program are to monitor nitrate levels in a group of randomly selected water wells to determine the number of wells that meet the Canadian drinking water guideline for nitrate and to identify any long-terms trends in nitrate levels.

This report presents the nitrate results from 1989 up to and including 2009. The report compares the results to the nitrate drinking water guideline, provides summary statistics for each year, presents a map of the 2009 nitrate results and provides statistical trend analyses.

1.2 Description of the Study Area

The study area is located in Kings County, Nova Scotia. It is found in the central part of Nova Scotia on the southern shore of the Bay of Fundy, approximately one hour west of Halifax. The study area and locations of the water wells that were sampled are shown in Figure 1-1. Much of the county is part of the fertile Annapolis Valley, one of the richest agricultural regions in the province. The study area encompasses four watersheds whose rivers ultimately empty into the Minas Basin. These include: the Cornwallis River, the Canard River, the Habitant River, and the Gaspereau River.

The bedrock in the study area is bordered by Triassic basalt of the North Mountain, and granite and Palaeozoic metasediments of the South Mountain. The valley between the North and South Mountains consists of red sandstone, siltstone, conglomerate and shale. These materials are a part of the Blomidon and Wolfville formations that comprise the majority of the land in the study area and where the main bedrock aquifers exist. Most of the surficial geology was deposited during the Pleistocene glaciation and consists of glacial till, glacio-fluvial sand and gravel deposits (Briggins and Moerman, 1995).

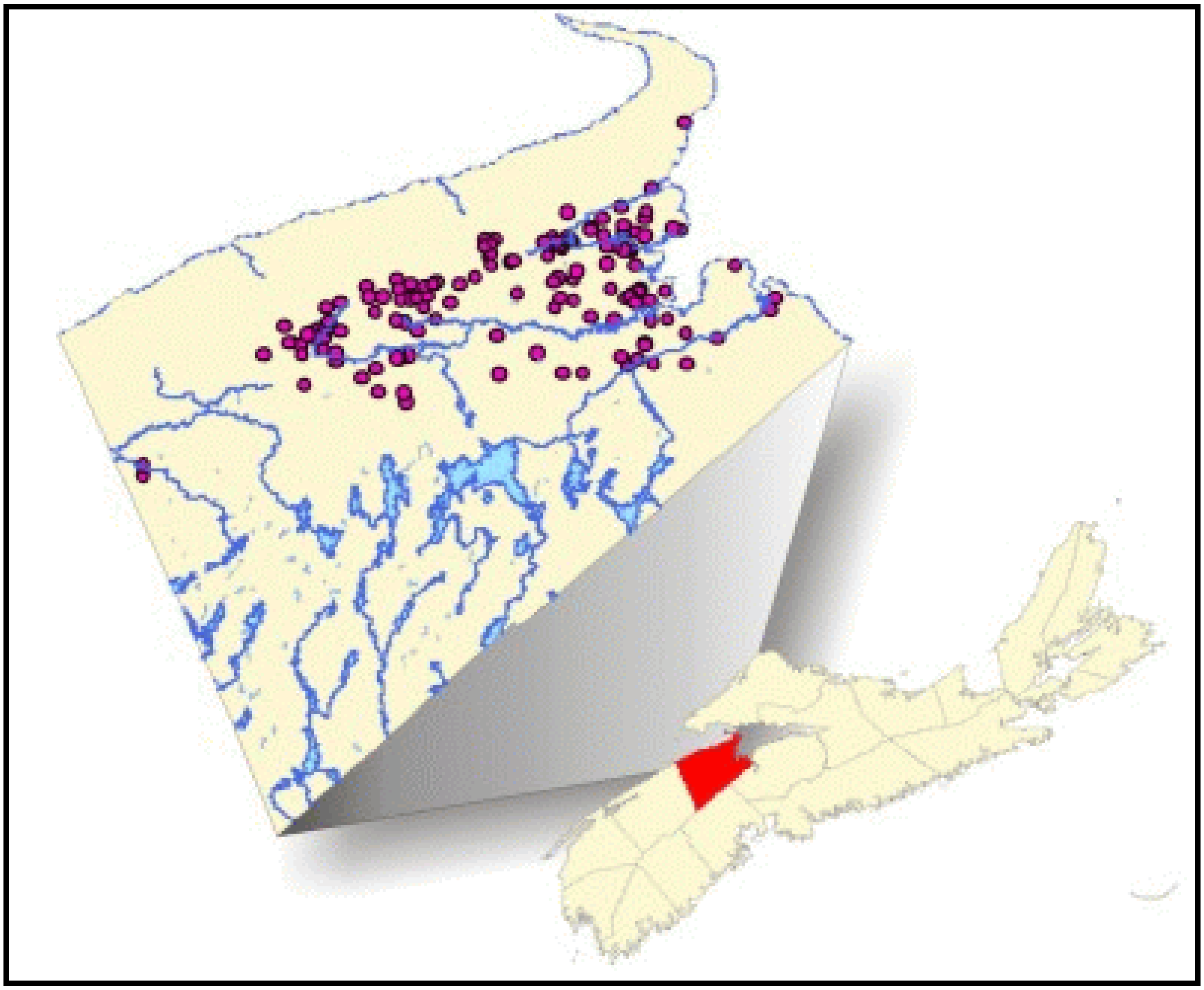

Figure 1-1: Study Area and Well Locations

1.3 Nitrate in the Environment

Nitrate is a naturally occurring ion that is ubiquitous in the environment. Sources of nitrate in groundwater include decaying plant or animal material, agricultural fertilizers, manure, domestic sewage and geological formations containing soluble nitrogen compounds (Health Canada, 1987). Because nitrate salts are very soluble, nitrate is highly mobile in soil and migrates readily to the water table when it is present in excess of the amount utilized by plants.

Nitrogen (N) is an essential nutrient both for plants and animals and it is commonly the limiting nutrient for plant growth. To maintain high yielding crops in agricultural operations it is important to provide non-limiting access to this nutrient, and this has been achieved through the use of fertilizers. Therefore, agricultural fertilizers and manures are often the most significant anthropogenic sources of nitrate in the environment.

Nitrate-impacted groundwater will migrate in an aquifer and can be captured by a water well or discharged to a surface water body as baseflow. Nitrate is a health concern in water wells used for drinking water if the nitrate concentration exceeds the Canadian drinking water guideline of 10 mg/L (expressed as nitrate-nitrogen). Nitrate itself is not highly toxic, as the normal acidity of the adult human stomach will minimize the reduction of nitrate (NO_3^-) to nitrite (NO_2^-), which is highly toxic. However, nitrate levels greater than 10 mg/L can be toxic to human babies. Infants six months and younger who are fed water, or formula made with water that contains a high concentration of nitrate, can develop methaemoglobinaemia (blue baby syndrome). Microbes within the infant's immature digestive system, naturally convert nitrate to nitrite. Nitrite reacts with hemoglobin to form methaemoglobin, which can diminish the oxygen-carrying capability of the infant's blood. This causes the skin to turn a bluish colour, and in cases where the nitrate level in the water is very high, the baby essentially suffocates as its body receives insufficient oxygen (Atlas and Bartha, 1998).

In addition to the direct health concerns associated with nitrate, elevated nitrate levels in well water can indicate that other contaminants may be present, such as microbial pathogens, which can also cause health problems.

Elevated nitrate levels are more commonly observed in shallow groundwater and, therefore, wells that draw shallow groundwater are more likely to have high nitrate levels. Wells that draw shallow groundwater include: dug wells, well points, shallow drilled wells, and deep drilled wells with insufficient casing lengths.

If nitrate-impacted groundwater is not captured by a water well, it will continue to migrate in the aquifer and eventually either naturally attenuate, or discharge to a surface water body as base flow. High nitrate levels in surface water contributes to eutrophication, which results in a reduction of available oxygen for aquatic life.

2.0 METHODS

2.1 Field Methods

There are a total of 153 water wells in the Well Water Nitrate Monitoring Program. The majority of the wells are private water wells that are used as domestic or barn water supplies, however, the program also includes 10 municipal water wells. The wells were randomly selected during the initial 1989 study (Briggins and Moerman, 1995) and the same group of wells is now sampled each year, normally in August. Although sampling is attempted at all 153 wells each year, on any given year there are usually several wells that cannot be accessed because well owners cannot be reached when the sampling is being carried out. As a result, the total number of water wells sampled each year usually ranges between 130 and 140.

There is a general lack of information on well construction for the wells in the monitoring program, however, based on information provided from the initial 1989 study, the majority are drilled wells (approximately 69%), and the remainder are dug wells or sand points (16%), or unknown/other (15%). Most of the well depths are unknown (i.e., 76% unknown). However, of the 24% of wells with known well depths, approximately 14% are shallow (<31 m), 8% are moderately deep (31 m to 61 m), and 2% are deep (>61 m).

The initial water quality study in 1989 tested well water for a variety of parameters, including: nitrate, general chemistry, bacteria and pesticides. The current monitoring program has been refined to focus on nitrate because the results of the 1989 study indicated that nitrate was the parameter that most commonly exceeded its guideline for Canadian drinking water quality.

For the current monitoring program, the well water samples were collected by Nova Scotia Environment staff at an outdoor water tap, if possible. Prior to collecting the sample, the water was run for approximately five minutes to clear the lines of stagnant water to ensure a fresh sample. The samples were collected in 100 ml laboratory-supplied bottles and kept refrigerated for a maximum of three weeks until they were delivered to the Nova Scotia Agricultural College laboratory in Truro, Nova Scotia, for nitrate analysis.

During sample collection, field duplicates were also collected at approximately 5% of the wells. For wells where field duplicates were taken, the relative percent difference was calculated. For the 2009 monitoring event, the average relative percent difference of the duplicate samples was 5% and the maximum was 15%.

2.2 Data Assessment Methods

The nitrate concentration at each water well was assessed by comparing the result to the Canadian drinking water guideline for nitrate, which is 10 mg/L (expressed as nitrate-nitrogen). Each well was also assessed for changes and trends for the period of record, up to and including data collected in 2009. For those wells where over 95% of samples taken exceeded the drinking water guideline, graphs were generated and visually assessed for trends.

The Mann-Kendall trend test (Gilbert, 1987) was used to determine whether a statistically significant trend was present in the nitrate concentrations at each well (i.e. upward trend, downward trend or no trend). This test is one of the most commonly used statistical methods to evaluate trends in environmental data and has been used in other water studies in Nova Scotia. Trends for individual wells were considered "statistically significant" if there was at least a 95% confidence level. Note that "statistically significant" means there is statistical evidence that there is a trend present, but does not indicate whether the trend is large or small.

For all statistical analyses presented in this report, non-detect results were included in the calculations by dividing the detection limit by two.

3.0 RESULTS

A summary of the nitrate data available from 1989 to 2009 is presented in Table 3-1 and Figure 3-1. There is a total of 11 years of data available. The maximum nitrate concentration during the period of record has varied between 25.5 and 46.9 mg/L, consistently exceeding the nitrate drinking water guideline of 10 mg/L. The percentage of wells exceeding the nitrate drinking water guideline has ranged from 15% to 25% and the median nitrate concentration has always remained below the drinking water guideline. Approximately 8% of wells exceeded the nitrate drinking water guideline in every year of the study.

Table 3-1: Summary of Nitrate Concentrations in Well Water (1989-2009)

Year	Number of Wells Sampled	Nitrate Concentration (mg/L, expressed as NO_3-N)			Number of Wells Exceeding Drinking Water Guideline (10 mg/L)	% of Wells Exceeding Drinking Water Guideline (10 mg/L)
		Minimum	Median	Maximum		
1989	135	0.30	3.6	46.1	27	20%
1999	142	0.33	4.2	43.0	34	24%
2000	137	0.05	3.4	46.9	27	20%
2002	139	0.21	4.1	33.1	28	20%
2003	138	0.32	4.7	42.5	25	18%
2004	134	0.19	5.1	46.7	34	25%
2005	130	<0.30	2.2	39.3	19	15%
2006	133	<0.06	3.0	38.5	29	22%
2007	132	<0.08	2.9	34.9	28	21%
2008	135	<0.08	2.6	25.5	26	19%
2009	135	<0.04	3.7	33.3	29	21%

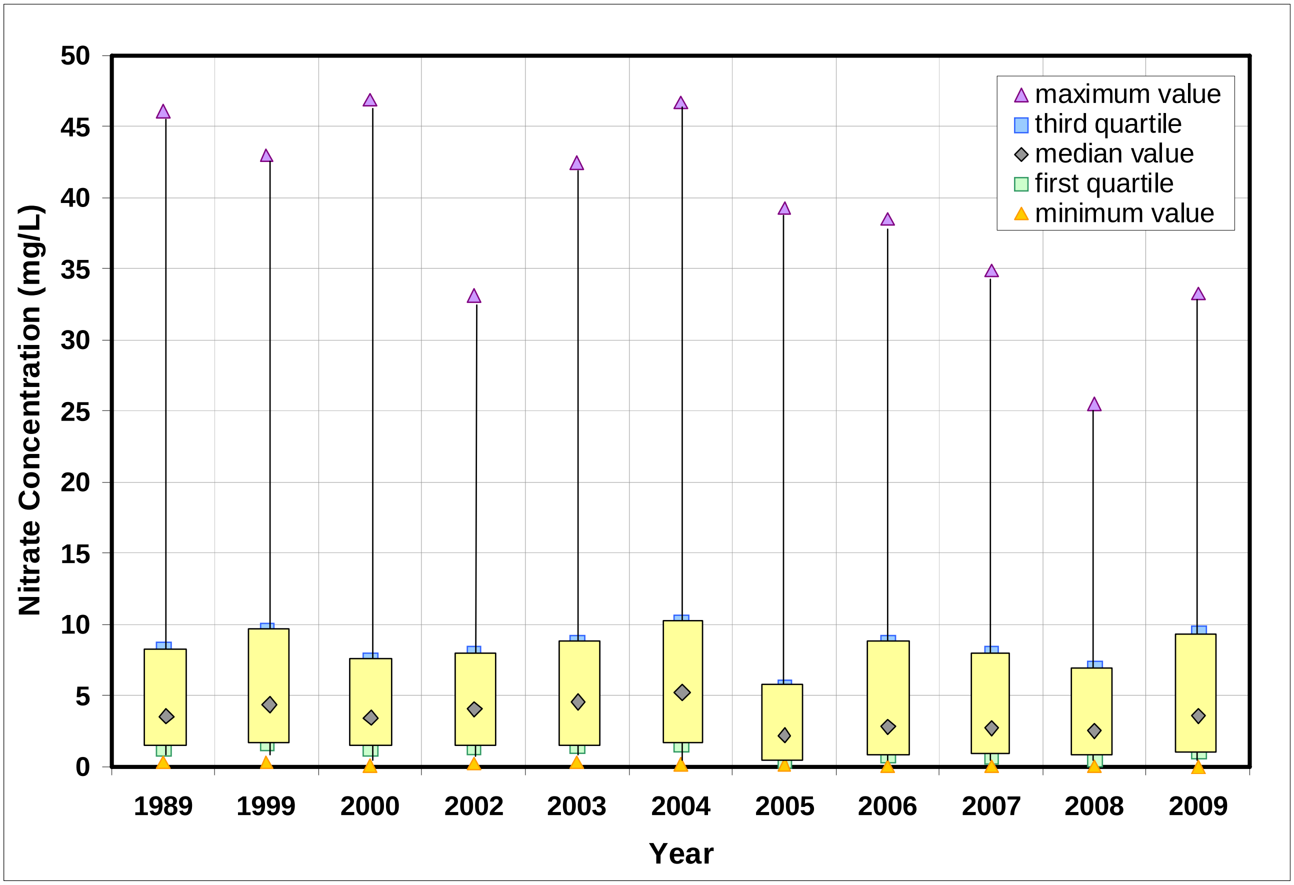

Figure 3-1: Box-Whisker Plots of Nitrate Concentrations in Well Water (1989 - 2009)

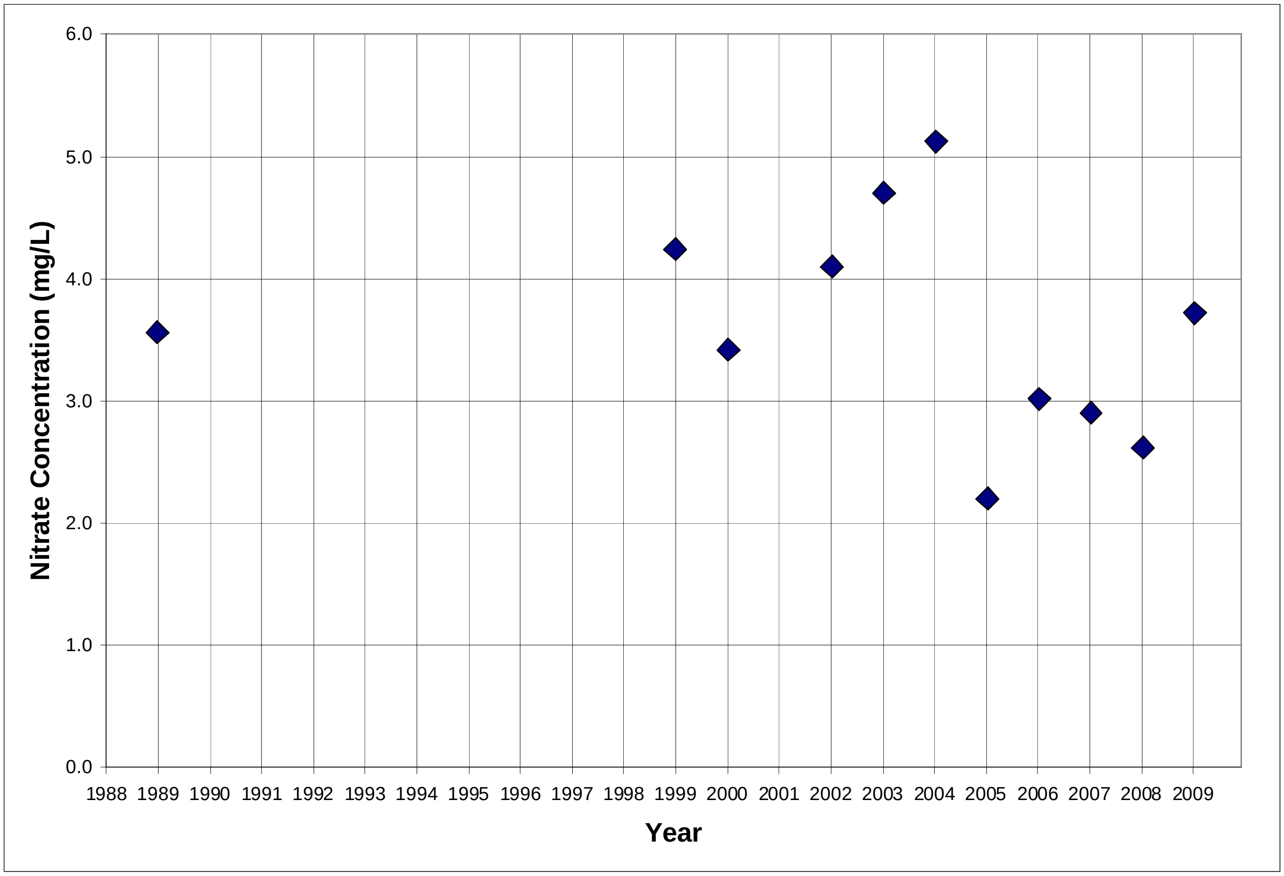

Figure 3-2: Annual Median Nitrate Concentration in Well Water (1989 - 2009)

A trend analysis was carried out on the annual median nitrate concentrations in Figure 3-2. The purpose of this analysis was to determine if there was an overall trend in nitrate levels in the entire dataset. One trend analysis was carried out for the period of 1989 to 2009 and another analysis was carried out for the period of 1999 to 2009. No statistically significant trends were identified at the 95% confidence level. The results of the trend analyses are presented in Appendix A.

A trend analysis was also carried out on each individual well to determine if nitrate concentrations were changing over time on a well-by-well basis. The trend analyses were completed for all wells that had at least four years of data available, which was a total of 144 wells. The trend analyses indicated that 5% of the wells had an upward trend, 29% had a downward trend, and 66% had no statistically significant trend present. The results of the trend analyses are presented in Appendix A.

The 2009 nitrate data are presented Figure 3-3 and Figure 3-4. The 2009 data indicate that 21% of the wells (i.e. 29 of 135 wells) exceeded the nitrate drinking water guideline. This is within the range of exceedances that has been observed historically (i.e., the range since 1989 is from 15% to 25%).

The map in Figure 3-4 shows that the majority of elevated nitrate results were detected in eastern portion of the study area. The elevated results also tend to occur in areas located near the centre of the valley.

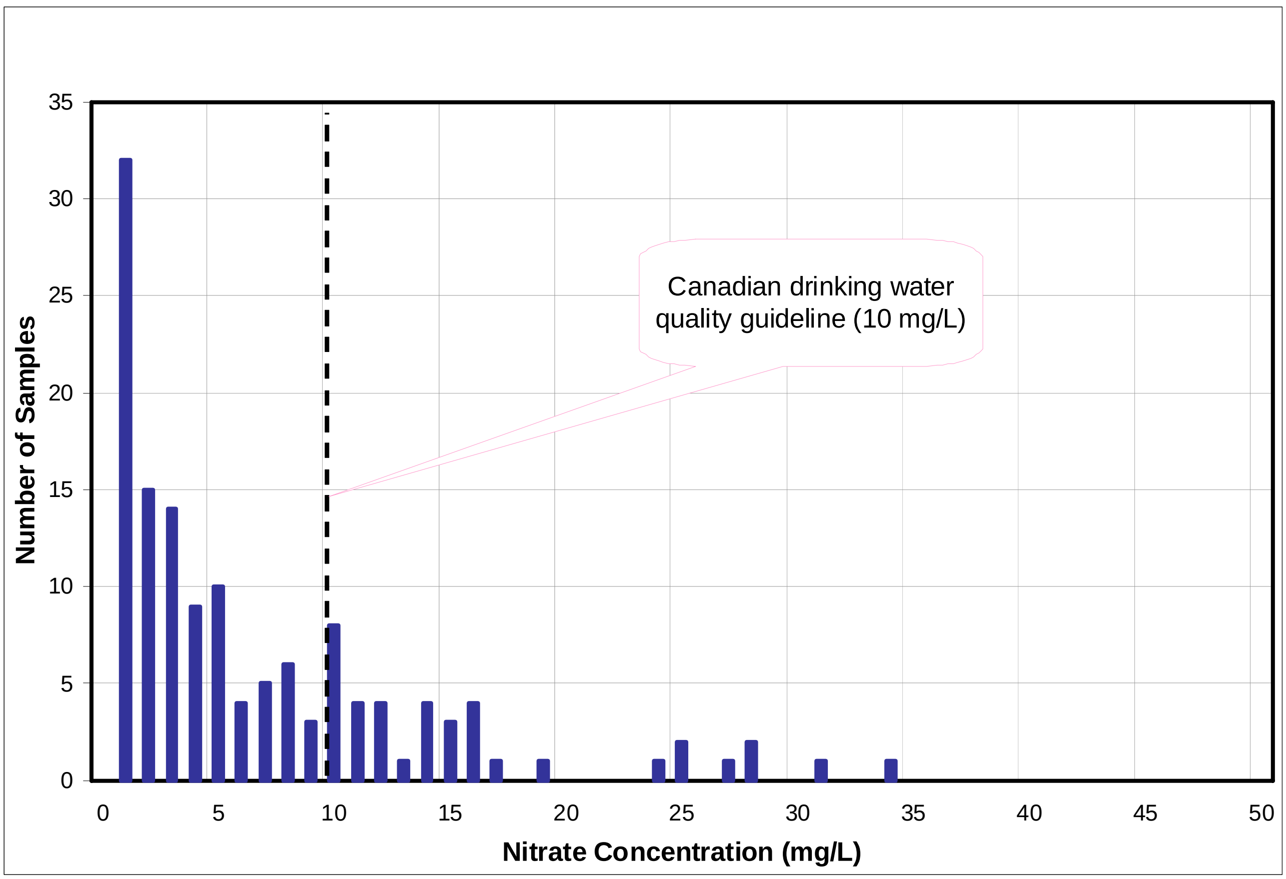

Figure 3-3: Summary of Nitrate Concentrations in Well Water for 2009

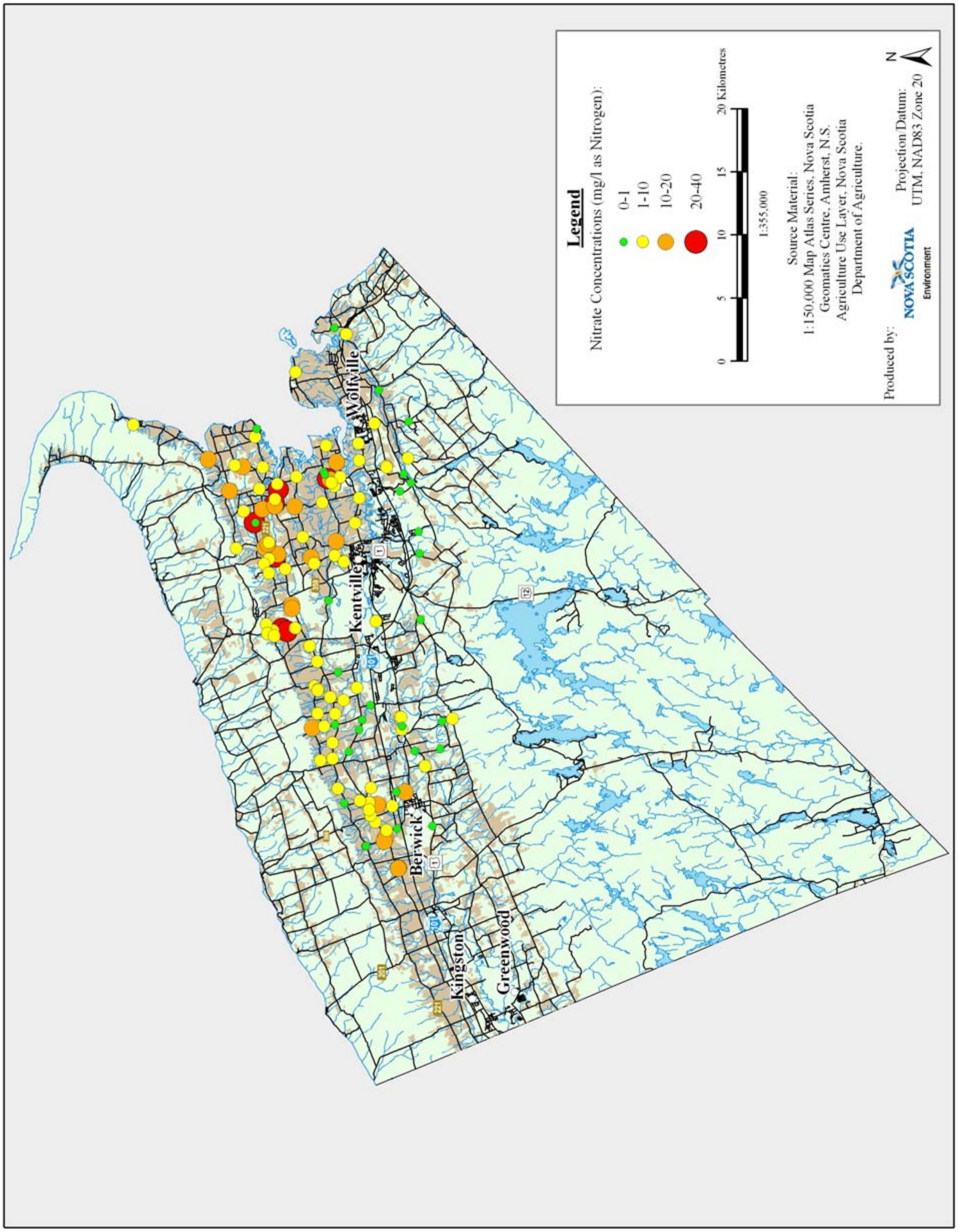

Figure 3-4: Map of Nitrate Concentrations in Well Water for 2009

4.0 REFERENCES

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APPENDIX A

NITRATE TREND ANALYSES

No.	Well No.	First year	Last Year	Q	n	S	VAR(S)	Z	significance
1	*1*	*1989*	*2009*	0.38	*10*	*11*	*125*	0.89	81%
2	*3*	*1989*	*2009*	-0.42	*11*	*-5*	*165*	-0.31	62%
3	*4*	*1989*	*2009*	0.10	*10*	*5*	*125*	0.36	63%
4	*6*	*1989*	*2009*	-1.74	*11*	*-33*	*165*	-2.49	**99%**
5	*7*	*1989*	*2009*	0.58	*11*	*11*	*165*	0.78	78%
6	*9*	*1989*	*2009*	0.16	*11*	*7*	*165*	0.47	67%
7	*10*	*1989*	*2009*	-0.08	*11*	*-14*	*165*	-1.01	84%
8	*17*	*1989*	*2009*	-0.01	*11*	*-13*	*165*	-0.93	82%
9	*18*	*1989*	*2009*	-0.30	*11*	*-32*	*165*	-2.41	**99%**
10	*19*	*1989*	*2009*	-0.21	*10*	*-12*	*125*	-0.98	83%
11	*22*	*1989*	*2009*	-0.16	*11*	*-26*	*165*	-1.95	**97%**
12	*25*	*1999*	*2009*	0.75	*9*	*16*	*92*	1.56	94%
13	*29*	*1989*	*2009*	-0.05	*10*	*-35*	*125*	-3.04	**99%**
14	*32*	*1989*	*2009*	-0.09	*11*	*-7*	*165*	-0.47	67%
15	*34*	*1989*	*2009*	0.19	*9*	*14*	*92*	1.36	91%
16	*35*	*1989*	*2009*	-0.32	*11*	*-17*	*165*	-1.25	89%
17	*37*	*1989*	*2009*	-0.05	*11*	*-6*	*165*	-0.39	65%
18	*38*	*1989*	*2009*	-0.04	*10*	*-16*	*125*	-1.34	91%
19	*39*	*1989*	*2009*	-0.07	*10*	*-11*	*125*	-0.89	81%
20	*40*	*1989*	*2009*	-0.23	*9*	*-16*	*92*	-1.56	94%
21	*41*	*1989*	*2009*	-0.03	*10*	*-20*	*125*	-1.70	**95%**
22	*42*	*1989*	*2009*	-0.92	*11*	*-34*	*165*	-2.57	**99%**
23	*43*	*1989*	*2009*	0.03	*11*	*3*	*165*	0.16	56%
24	*45*	*1989*	*2009*	-0.48	*11*	*-15*	*165*	-1.09	86%
25	*46*	*1989*	*2009*	-0.07	*11*	*-36*	*165*	-2.72	**99%**
26	47	*1989*	*2009*	-0.41	11	-11	*165*	-0.78	78%
27	51	*1989*	*2009*	-0.04	11	-13	*165*	-0.93	82%
28	55	*1989*	*2009*	-0.15	11	-17	*165*	-1.25	89%
29	57	*1989*	*2009*	-0.35	11	-21	*165*	-1.56	94%
30	58	*1989*	*2009*	-0.02	4	-4	*9*	-1.02	84%
31	59	*1989*	*2009*	0.11	11	9	*165*	0.62	73%
32	60	*1989*	*2009*	-0.19	11	-17	*165*	-1.25	89%
33	61	*1989*	*2009*	-0.10	11	-21	*165*	-1.56	94%
34	64	*1989*	*2009*	0.12	11	9	*165*	0.62	73%
35	65	*1989*	*2009*	0.21	6	5	*28*	0.75	77%
36	66	*1989*	*2009*	-0.88	11	-23	*165*	-1.71	**95%**
37	67	*1989*	*2009*	0.00	11	-3	*165*	-0.16	56%
38	70	*1989*	*2009*	-0.12	11	-15	*165*	-1.09	86%
39	71	*1989*	*2006*	-0.21	7	-13	*44*	-1.80	**96%**
40	74	*1989*	*2009*	-0.10	6	-7	*28*	-1.13	87%
41	75	*1989*	*2009*	-0.01	7	-1	*44*	0.00	50%
42	76	*1989*	*2009*	0.03	11	3	*165*	0.16	56%
43	78	*1989*	*2009*	-0.02	11	-7	*165*	-0.47	67%
44	82	*1989*	*2009*	0.02	11	7	*165*	0.47	67%
45	84	*1989*	*2009*	-0.12	11	-34	*165*	-2.57	**99%**
46	87	*1989*	*2009*	-0.05	11	-39	*165*	-2.96	**99%**
47	88	*1989*	*2009*	-0.02	11	-3	*165*	-0.16	56%
48	90	*1989*	*2009*	-0.20	11	-31	*165*	-2.34	**99%**
49	92	*1989*	*2009*	-0.01	7	-1	*44*	0.00	50%
50	93	*1989*	*2009*	0.66	11	13	*165*	0.93	82%
51	94	*1989*	*2009*	-0.40	11	-26	*165*	-1.95	**97%**
52	98	*1989*	*2009*	-0.31	11	-38	*165*	-2.88	**99%**
53	100	*1989*	*2009*	0.04	10	5	*125*	0.36	63%
54	101	*1989*	*2009*	0.02	10	1	*125*	0.00	50%
55	102	*1989*	*2009*	-0.02	9	-16	*92*	-1.56	94%
56	103	*1989*	*2009*	0.05	11	5	*165*	0.31	62%
57	107	*1989*	*2009*	-0.33	8	-14	*65*	-1.61	94%

No.	Well No.	First year	Last Year	Q	n	S	VAR(S)	Z	significance
58	108	*1989*	*2008*	-0.12	9	-18	*92*	-1.77	**96%**
59	109	*1989*	*2009*	0.10	10	19	*125*	1.61	94%
60	112	*1989*	*2009*	0.03	11	1	*165*	0.00	50%
61	113	*1989*	*2009*	0.02	11	2	*165*	0.08	53%
62	114	*1989*	*2009*	-0.10	11	-21	*165*	-1.56	94%
63	116	*1989*	*2009*	-0.08	11	-50	*165*	-3.81	**99%**
64	117	*1989*	*2009*	-0.05	11	-39	*165*	-2.96	**99%**
65	119	*1989*	*2009*	0.12	10	21	*125*	1.79	**96%**
66	120	*1989*	*2009*	-0.05	11	-38	*165*	-2.88	**99%**
67	125	*1989*	*2009*	-0.03	11	-28	*165*	-2.10	**98%**
68	126	*1989*	*2009*	0.18	10	5	*125*	0.36	63%
69	127	*1989*	*2009*	-0.12	10	-20	*125*	-1.70	**95%**
70	128	*1989*	*2009*	0.09	10	11	*125*	0.89	81%
71	132	*1989*	*2009*	-0.10	11	-13	*165*	-0.93	82%
72	137	*1989*	*2009*	0.17	10	3	*125*	0.18	57%
73	140	*1989*	*2009*	0.96	11	39	*165*	2.96	**99%**
74	141	*1989*	*2009*	0.21	11	11	*165*	0.78	78%
75	142	*1989*	*2009*	-0.08	11	-17	*165*	-1.25	89%
76	144	*1989*	*2008*	-0.02	10	-18	*125*	-1.52	93%
77	148	*1989*	*2009*	-0.31	11	-25	*165*	-1.87	**96%**
78	149	*1989*	*2008*	-0.65	10	-17	*125*	-1.43	92%
79	150	*1989*	*2009*	0.93	11	25	*165*	1.87	**96%**
80	153	*1989*	*2009*	-0.07	11	-35	*165*	-2.65	**99%**
81	208	*1989*	*2009*	0.04	11	12	*165*	0.86	80%
82	212	*1989*	*2009*	-0.11	11	-11	*165*	-0.78	78%
83	217	*1989*	*2009*	-0.07	11	-13	*165*	-0.93	82%
84	224	*1989*	*2009*	-0.12	11	-29	*165*	-2.18	**98%**
85	225	*1989*	*2009*	-0.40	10	-8	*125*	-0.63	73%
86	231	*1989*	*2008*	-0.44	10	-17	*125*	-1.43	92%
87	250	*1989*	*2009*	-0.03	11	-36	*165*	-2.72	**99%**
88	251	*1989*	*2009*	-0.03	11	-40	*165*	-3.04	**99%**
89	255	*1989*	*2009*	-0.11	11	-19	*165*	-1.40	91%
90	256	*1989*	*2009*	-0.15	9	-7	*92*	-0.63	73%
91	257	*1989*	*2009*	-0.14	11	-25	*165*	-1.87	**96%**
92	258	*1989*	*2009*	-0.01	11	-3	*165*	-0.16	56%
93	262	*1989*	*2009*	-0.04	11	-40	*165*	-3.04	**99%**
94	270	*1989*	*2009*	-0.04	11	-23	*165*	-1.71	**95%**
95	271	*1989*	*2009*	0.09	11	19	*165*	1.40	91%
96	301	*1989*	*2009*	0.22	10	13	*125*	1.07	85%
97	302	*1989*	*2009*	-0.01	10	-1	*125*	0.00	50%
98	303	*1989*	*2009*	-0.02	10	-16	*125*	-1.34	91%
99	308	*1989*	*2009*	-0.66	11	-33	*165*	-2.49	**99%**
100	309	*1989*	*2009*	0.34	11	32	*165*	2.41	**99%**
101	310	*1989*	*2008*	-0.18	10	-23	*125*	-1.97	**97%**
102	312	*1989*	*2009*	-0.05	11	-25	*165*	-1.87	**96%**
103	313	*1989*	*2009*	-0.07	11	-38	*165*	-2.88	**99%**
104	316	*1989*	*2009*	-0.08	11	-9	*165*	-0.62	73%
105	317	*1989*	*2009*	-0.17	11	-21	*165*	-1.56	94%
106	318	*1989*	*2009*	-0.38	11	-35	*165*	-2.65	**99%**
107	330	*1989*	*2009*	0.19	11	17	*165*	1.25	89%
108	331	*1989*	*2009*	0.08	10	13	*125*	1.07	85%
109	333	*1989*	*2009*	-0.04	11	-28	*165*	-2.10	**98%**
110	335	*1989*	*2009*	-0.16	10	-24	*125*	-2.06	**98%**
111	350	*1989*	*2009*	-0.74	11	-17	*165*	-1.25	89%
112	364	*1989*	*2009*	-0.04	11	-30	*165*	-2.26	**98%**
113	380	*1989*	*2009*	0.14	10	15	*125*	1.25	89%
114	402	*1989*	*2009*	-0.18	10	-15	*125*	-1.25	89%
115	403	*1989*	*2009*	-0.29	11	-39	*165*	-2.96	**99%**

No.	Well No.	First year	Last Year	Q	n	S	VAR(S)	Z	significance
116	405	*1989*	*2009*	0.06	11	24	*165*	1.79	**96%**
117	407	*1989*	*2009*	0.03	11	5	*165*	0.31	62%
118	409	*1989*	*2009*	-0.03	10	-5	*125*	-0.36	63%
119	411	*1989*	*2009*	-0.15	11	-9	*165*	-0.62	73%
120	412	*1989*	*2009*	-0.36	10	-25	*125*	-2.15	**98%**
121	415	*1989*	*2009*	-0.05	11	-11	*165*	-0.78	78%
122	420	*1989*	*2009*	-0.17	11	-7	*165*	-0.47	67%
123	422	*1989*	*2009*	0.06	8	8	*65*	0.87	80%
124	423	*1989*	*2009*	-0.04	11	-8	*165*	-0.54	70%
125	424	*1989*	*2009*	-0.14	10	-23	*125*	-1.97	**97%**
126	428	*1989*	*2009*	0.44	10	33	*125*	2.86	**99%**
127	429	*1989*	*2009*	-0.39	11	-23	*165*	-1.71	**95%**
128	435	*1989*	*2009*	-0.11	11	-1	*165*	0.00	50%
129	437	*1989*	*2009*	0.15	11	7	*165*	0.47	67%
130	439	*1989*	*2009*	-0.07	11	-11	*165*	-0.78	78%
131	500	*1999*	*2009*	-0.03	10	-26	*125*	-2.24	**98%**
132	501	*1999*	*2009*	-0.13	9	-14	*92*	-1.36	91%
133	502	*1999*	*2007*	-0.05	8	-7	*65*	-0.74	77%
134	503	*1999*	*2005*	-0.04	6	-5	*28*	-0.75	77%
135	504	*1999*	*2003*	0.03	4	2	*9*	0.34	63%
136	505	*1999*	*2009*	-0.09	9	-10	*92*	-0.94	82%
137	506	*1999*	*2009*	-0.12	9	-24	*92*	-2.40	**99%**
138	507	*1999*	*2009*	-0.26	10	-13	*125*	-1.07	85%
139	508	*1999*	*2009*	0.38	10	5	*125*	0.36	63%
140	509	*1999*	*2009*	-0.24	9	-8	*92*	-0.73	76%
141	510	*1999*	*2009*	0.33	10	32	*125*	2.77	**99%**
142	511	*1999*	*2009*	-0.09	10	-17	*125*	-1.43	92%
143	512	*2002*	*2009*	-0.38	8	-12	*65*	-1.36	91%
144	513	*1989*	*2009*	-2.62	11	-18	*165*	-1.32	90%
Annual Median Nitrate Concentration									
1	All Wells	*1989*	*2009*	-0.06	11	-15	*165*	-1.09	**86%**
2	All Wells	*1999*	*2009*	-0.12	10	-13	*125*	-1.07	**85%**

Where:

Q is Sen's slope

$$Q = \frac{x_{i'} - x_i}{i' - i}$$

n is the number of records

S is the Mann-Kendall statistic

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k)$$

VAR (S) is the variance of S

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5) \right]$$

Z is the test statistic

$$Z = \frac{S-1}{\left[VAR(S)\right]^{1/2}} \quad if \;\; S > 0$$

$$Z = 0 \qquad if \;\; S = 0$$

$$Z = \frac{S+1}{\left[VAR(S)\right]^{1/2}} \quad if \;\; S < 0$$

Significance is the confidence level of the statistical trend