NOVA SCOTIA

Environment and Labour

**WELL WATER NITRATE
MONITORING PROGRAM**

2008 REPORT

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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 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-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 nine different years during the period between 1989 and 2007.

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 also show that nitrate levels have remained relatively consistent over time, with 77% of the wells showing no trend in nitrate levels, 4% showing an increasing trend and 19% showing a decreasing trend.

The results from 2007 show that 22 % of the wells exceeded the nitrate drinking water guideline. This is the same percentage of exceedances that was observed in 2006 and is within the range of guideline exceedances that has been historically observed since the study began (i.e., 15% to 25%) .

ACKNOWLEDGMENTS

The Well Water Nitrate Monitoring Program is a collaboration between Nova Scotia Environment and Labour (NSEL), 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 and Natural Areas Management Division of NSEL. 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 (Moerman and Briggins, 1994), 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 2007. The report compares the results to the nitrate drinking water guideline, provides nitrate summary statistics for each year, presents a map of the 2007 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 (Moerman and Briggins, 1994).
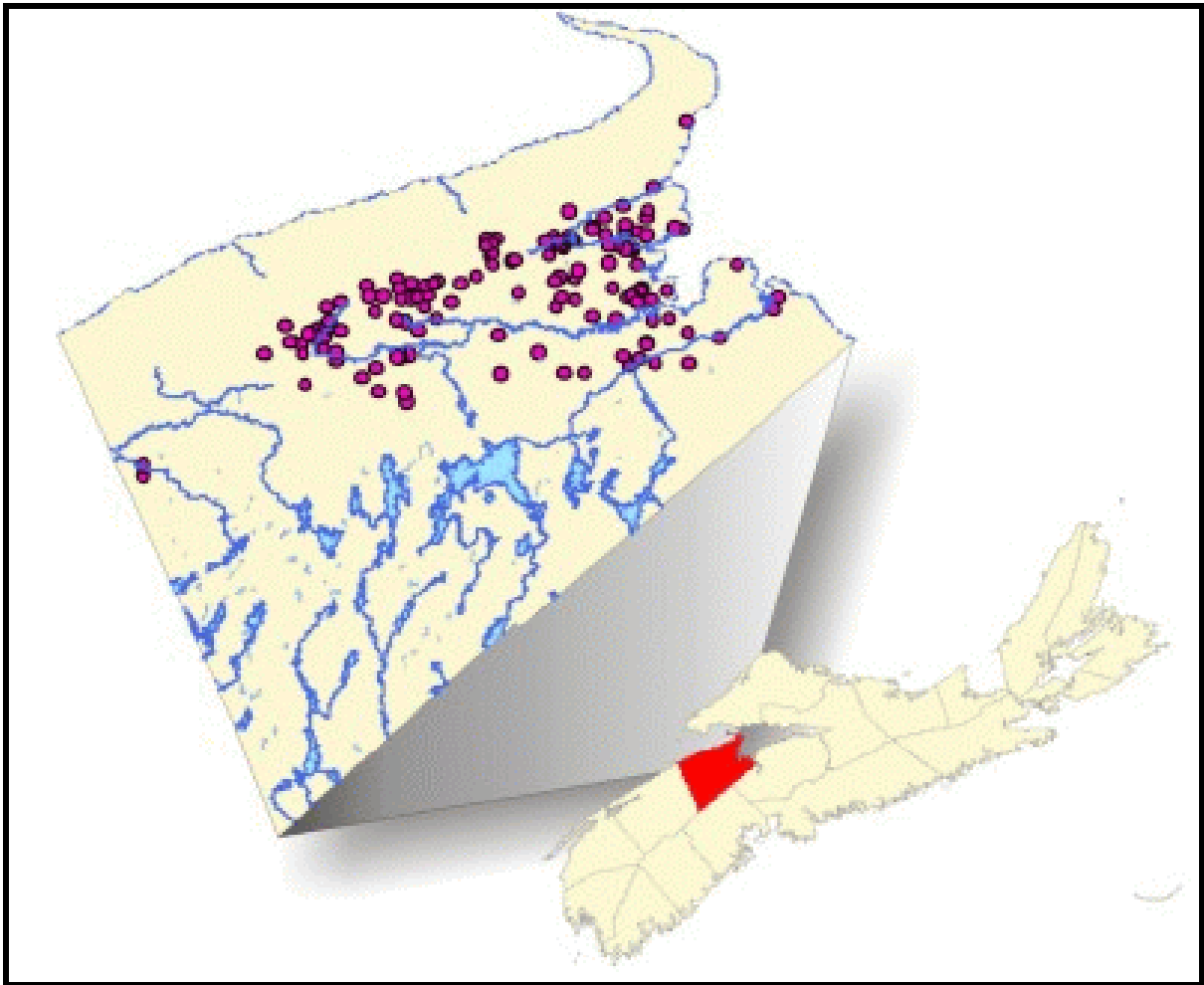
Figure 1-1: Study Area and Well Locations

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 (Moerman and Briggins, 1994) 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 the guideline for Canadian drinking water quality.

For the current monitoring program, the well water samples were collected by Nova Scotia Environment and Labour 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 2007 monitoring event, the relative percent difference of the duplicate samples was less than 10%.

2.2   Data Assessment Methods

The nitrate concentration at each water well was assessed by comparing the result to the nitrate drinking water guideline (10 mg/L for nitrate-nitrogen). Each well was also assessed for changes and trends for the period of record, up to and including data collected in 2007. 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 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 2007 is presented in Table 3-1 and Figure 3-1. In total there are nine years that have data available. The maximum nitrate concentration during the period of record has varied between 33.1 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 6% of wells which have been sampled since 1989 exceeded the nitrate drinking water guideline in every year of the study.

Table 3-1: Summary of Nitrate Concentrations in Well Water (1989-2007)

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	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	26	19%
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	29	22%
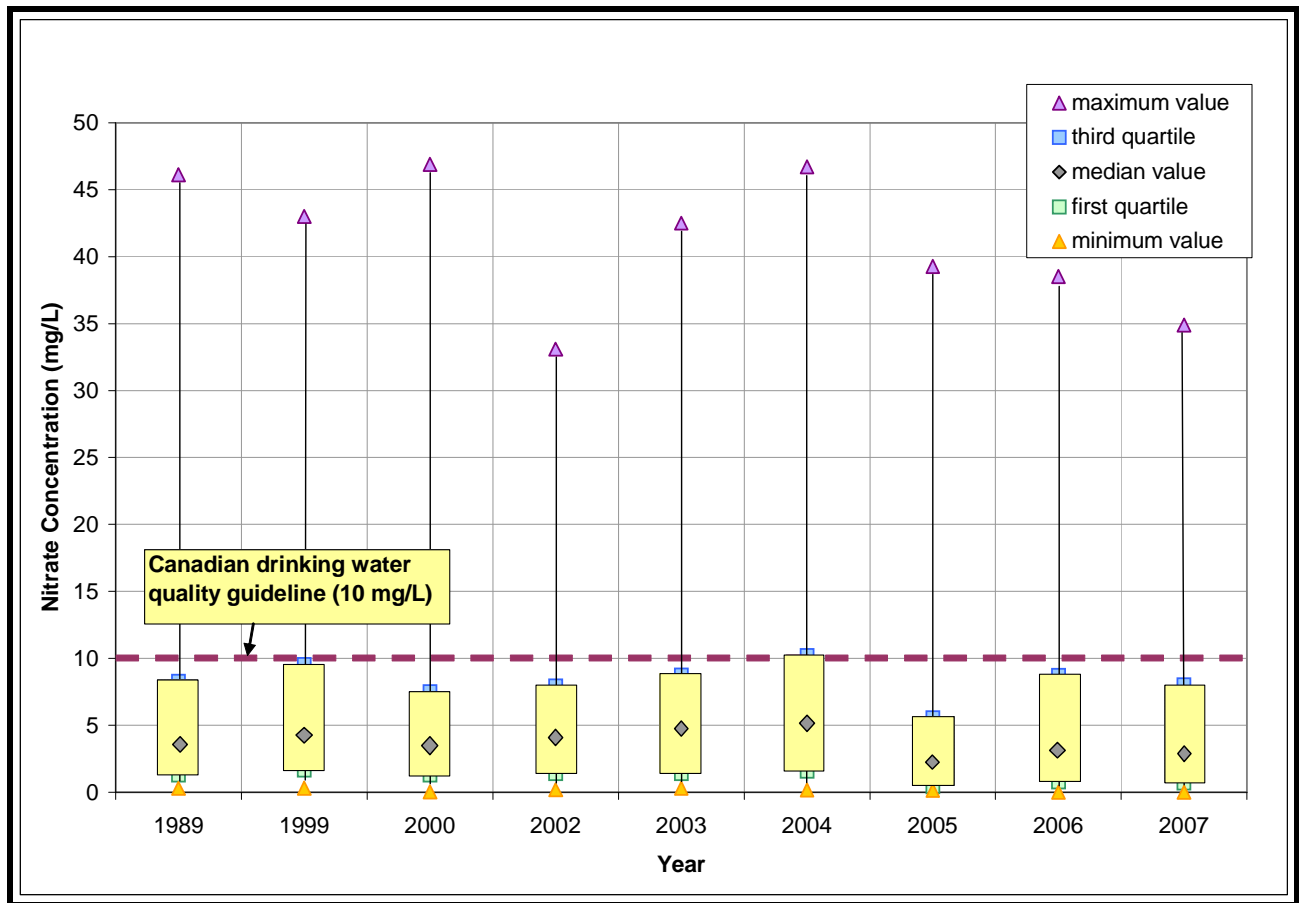
Figure 3-1: Box-Whisker Plots of Nitrate Concentrations in Well Water (1989 - 2007)

The 2007 nitrate data are presented Figure 3-2 and Figure 3-3. The 2007 data show that 22 % of the wells (i.e. 29 of 132 wells) exceeded the nitrate drinking water guideline. This is within the range that has been observed historically (i.e., the range since 1989 is from 15% to 25%).

The Mann-Kendall trend test was used to determine whether a statistically significant trend was present in the nitrate concentrations at each well over time. The results of the statistical trend analyses are presented in Appendix A. The trend analyses were completed for all wells that had at least four years of data available, which was a total of 143 wells. The trend analyses indicated that 4% of the wells had an upward trend, 19% had a downward trend, and 77% well had no statistically significant trend.
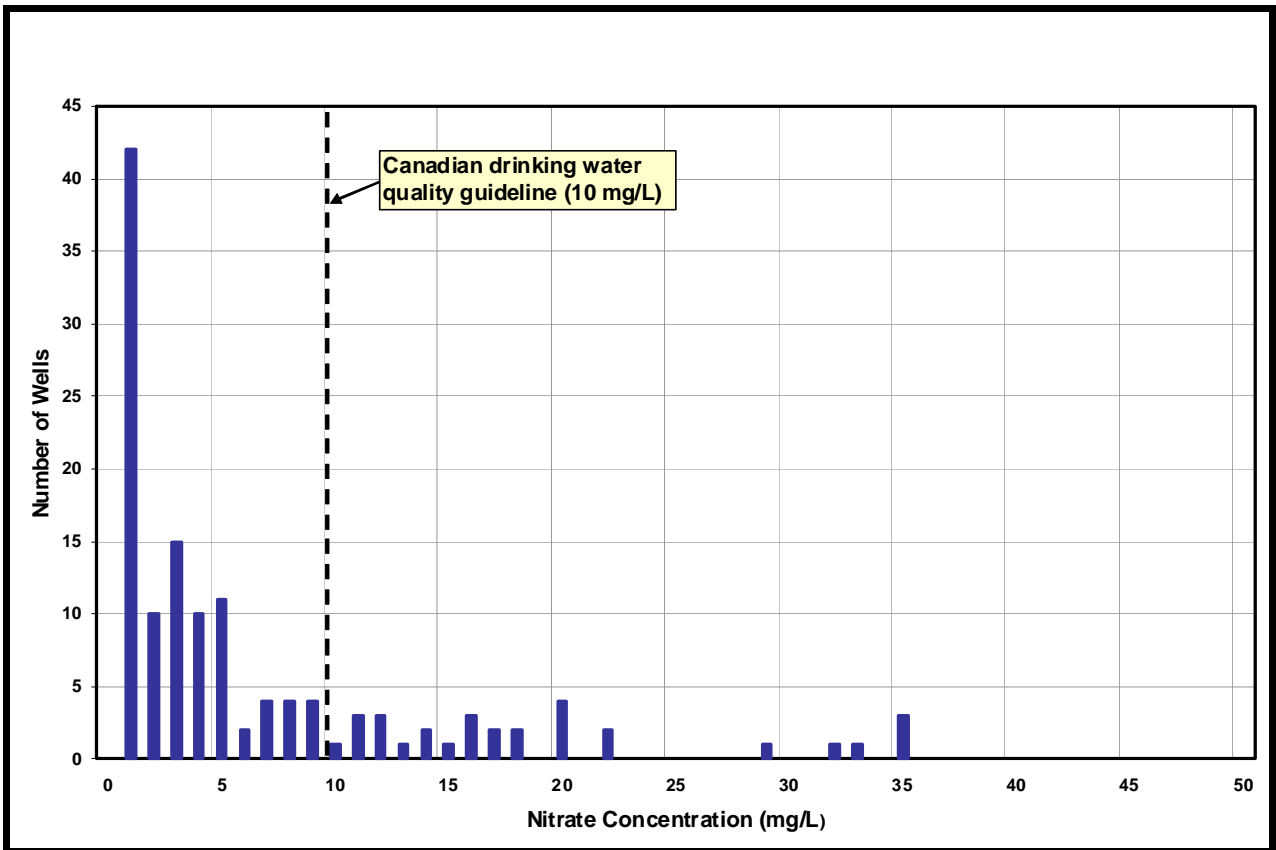
Figure 3-2: Summary of Nitrate Concentrations in Well Water for 2007
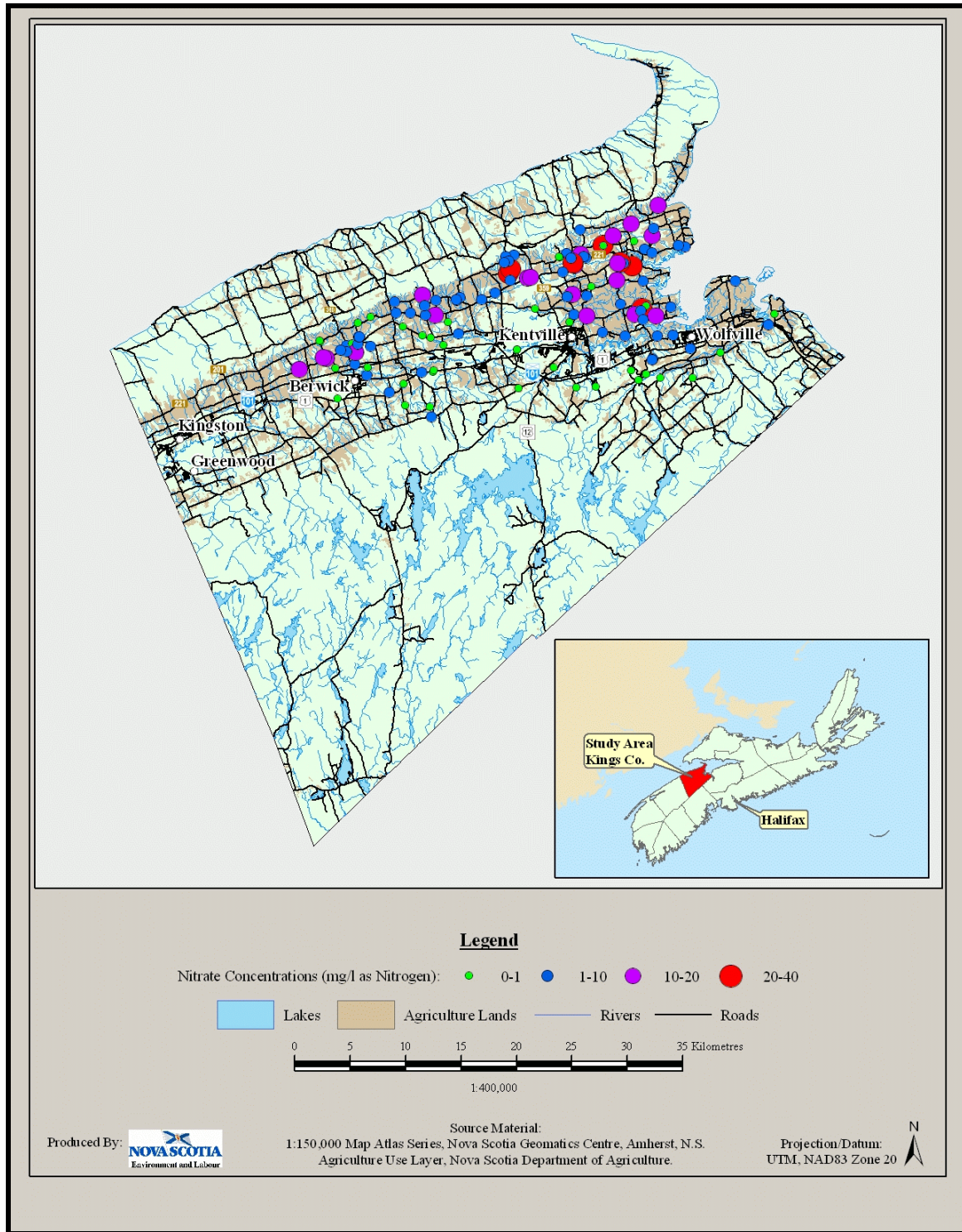
Figure 3-3: Map of Nitrate Concentrations in Well Water for 2007

4.0   REFERENCES

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APPENDIX A

NITRATE TREND ANALYSES

No.	Well number	First year	Last Year	Q	n	S	VAR(S)	Z	Significance
1	1	1989	2007	0.223	8	2	65.333	0.12	54%
2	3	1989	2007	-0.101	9	0	92	0.00	50%
3	4	1989	2006	0.428	8	8	65.333	0.87	80%
4	6	1989	2007	-1.891	9	-16	92	-1.56	94%
5	7	1989	2007	1.191	9	16	92	1.56	94%
6	9	1989	2007	0.697	9	12	92	1.15	87%
7	10	1989	2007	0.014	9	1	92	0.00	50%
8	17	1989	2007	-0.010	9	-8	92	-0.73	76%
9	18	1989	2007	-0.470	9	-27	92	-2.71	**99%**
10	19	1989	2007	-0.165	8	-6	65.333	-0.62	73%
11	22	1989	2007	-0.334	9	-26	92	-2.61	**99%**
12	25	1999	2007	1.200	7	13	44.333	1.80	**96%**
13	29	1989	2007	-0.050	8	-24	65.333	-2.85	**99%**
14	32	1989	2007	-0.064	9	-2	92	-0.10	54%
15	34	1989	2006	0.456	7	7	44.333	0.90	81%
16	35	1989	2007	-0.146	9	-2	92	-0.10	54%
17	37	1989	2007	0.133	9	4	92	0.31	62%
18	38	1989	2007	-0.033	8	-6	65.333	-0.62	73%
19	39	1989	2007	-0.079	8	-8	65.333	-0.87	80%
20	40	1989	2006	-0.232	8	-12	65.333	-1.36	91%
21	41	1989	2007	-0.033	8	-10	65.333	-1.11	86%
22	42	1989	2007	-0.374	9	-17	92	-1.67	**95%**
23	43	1989	2007	-0.495	9	-12	92	-1.15	87%
24	45	1989	2007	-0.458	9	-6	92	-0.52	69%
25	46	1989	2007	-0.074	9	-24	92	-2.40	**99%**
26	47	1989	2007	-0.48	9	-6	92	-0.52	69%
27	51	1989	2007	-0.05	9	-10	92	-0.94	82%
28	55	1989	2007	-0.12	9	-8	92	-0.73	76%
29	57	1989	2007	-0.38	9	-12	92	-1.15	87%
30	59	1989	2007	0.12	9	4	92	0.31	62%
31	60	1989	2007	-0.21	9	-10	92	-0.94	82%
32	61	1989	2007	-0.12	9	-12	92	-1.15	87%
33	64	1989	2007	0.21	9	10	92	0.94	82%
34	65	1989	2003	0.36	5	2	16.667	0.24	59%
35	66	1989	2007	-0.75	9	-10	92	-0.94	82%
36	67	1989	2007	0.01	9	2	92	0.10	54%
37	70	1989	2007	0.03	9	4	92	0.31	62%
38	71	1989	2006	-0.21	7	-13	44.333	-1.80	**96%**
39	74	1989	2002	-0.23	4	-2	8.6667	-0.34	63%
40	75	1989	2007	0.00	5	0	16.667	0.00	50%
41	76	1989	2007	0.15	9	12	92	1.15	87%
42	78	1989	2007	-0.04	9	-6	92	-0.52	69%
43	82	1989	2007	0.01	9	2	92	0.10	54%
44	84	1989	2007	-0.15	9	-18	92	-1.77	**96%**
45	87	1989	2007	-0.06	9	-27	92	-2.71	**99%**
46	88	1989	2007	0.06	9	10	92	0.94	82%
47	90	1989	2007	-0.22	9	-22	92	-2.19	**98%**
48	92	1989	2007	-0.23	6	-7	28.333	-1.13	87%
49	93	1989	2007	1.21	9	12	92	1.15	87%
50	94	1989	2007	-0.53	9	-23	92	-2.29	**98%**
51	98	1989	2007	-0.36	9	-26	92	-2.61	**99%**
52	100	1989	2007	0.09	8	4	65.333	0.37	64%
53	101	1989	2006	-0.03	8	-6	65.333	-0.62	73%
54	102	1989	2007	-0.01	7	-2	44.333	-0.15	55%
55	103	1989	2007	0.35	9	12	92	1.15	87%
56	107	1989	2007	-0.10	6	-3	28.333	-0.38	64%
57	108	1989	2007	-0.11	8	-12	65.333	-1.36	91%

No.	Well number	First year	Last Year	Q	n	S	VAR(S)	Z	Significance
58	109	1989	2007	0.15	8	12	65.333	1.36	91%
59	112	1989	2007	0.89	9	14	92	1.36	91%
60	113	1989	2007	0.10	9	11	92	1.04	85%
61	114	1989	2007	-0.15	9	-14	92	-1.36	91%
62	116	1989	2007	-0.09	9	-34	92	-3.44	**99%**
63	117	1989	2007	-0.05	9	-27	92	-2.71	**99%**
64	119	1989	2007	0.11	8	10	65.333	1.11	86%
65	120	1989	2007	-0.06	9	-26	92	-2.61	**99%**
66	125	1989	2007	-0.03	9	-16	92	-1.56	94%
67	126	1989	2007	0.30	8	4	65.333	0.37	64%
68	127	1989	2007	-0.14	8	-9	65.333	-0.99	83%
69	128	1989	2007	0.11	8	10	65.333	1.11	86%
70	132	1989	2007	-0.16	9	-14	92	-1.36	91%
71	137	1989	2007	0.50	8	14	65.333	1.61	94%
72	140	1989	2007	0.97	9	28	92	2.81	**99%**
73	141	1989	2007	0.37	9	14	92	1.36	91%
74	142	1989	2007	-0.03	9	-6	92	-0.52	69%
75	144	1989	2007	0.00	9	-9	92	-0.83	79%
76	148	1989	2007	-0.34	9	-20	92	-1.98	**97%**
77	149	1989	2007	-0.57	9	-12	92	-1.15	87%
78	150	1989	2007	1.01	9	24	92	2.40	**99%**
79	153	1989	2007	-0.07	9	-22	92	-2.19	**98%**
80	208	1989	2007	0.00	9	1	92	0.00	50%
81	212	1989	2007	-0.07	9	-4	92	-0.31	62%
82	217	1989	2007	-0.11	9	-16	92	-1.56	94%
83	224	1989	2007	-0.13	9	-20	92	-1.98	**97%**
84	225	1989	2007	-0.22	8	-4	65.333	-0.37	64%
85	231	1989	2007	-0.78	9	-22	92	-2.19	**98%**
86	250	1989	2007	-0.04	9	-24	92	-2.40	**99%**
87	251	1989	2007	-0.03	9	-28	92	-2.81	**99%**
88	255	1989	2007	-0.14	9	-14	92	-1.36	91%
89	256	1989	2007	-0.18	7	-7	44.333	-0.90	81%
90	257	1989	2007	-0.17	9	-16	92	-1.56	94%
91	258	1989	2007	-0.06	9	-16	92	-1.56	94%
92	262	1989	2007	-0.04	9	-28	92	-2.81	**99%**
93	270	1989	2007	-0.06	9	-20	92	-1.98	**97%**
94	271	1989	2007	0.11	9	14	92	1.36	91%
95	301	1989	2007	0.31	8	10	65.333	1.11	86%
96	302	1989	2007	-0.05	8	-4	65.333	-0.37	64%
97	303	1989	2007	-0.02	8	-10	65.333	-1.11	86%
98	308	1989	2007	-0.52	9	-16	92	-1.56	94%
99	309	1989	2007	0.31	9	18	92	1.77	**96%**
100	310	1989	2007	-0.17	9	-16	92	-1.56	94%
101	312	1989	2007	-0.04	9	-10	92	-0.94	82%
102	313	1989	2007	-0.08	9	-20	92	-1.98	**97%**
103	316	1989	2007	-0.07	9	-6	92	-0.52	69%
104	317	1989	2007	-0.23	9	-14	92	-1.36	91%
105	318	1989	2007	-0.39	9	-24	92	-2.40	**99%**

No.	Well number	First year	Last Year	Q	n	S	VAR(S)	Z	Significance
106	330	1989	2007	0.28	9	12	92	1.15	87%
107	331	1989	2007	0.08	8	8	65.333	0.87	80%
108	333	1989	2007	-0.03	9	-10	92	-0.94	82%
109	335	1989	2007	-0.23	8	-17	65.333	-1.98	**97%**
110	350	1989	2007	0.05	9	2	92	0.10	54%
111	364	1989	2007	-0.03	9	-14	92	-1.36	91%
112	380	1989	2007	0.09	8	6	65.333	0.62	73%
113	402	1989	2007	-0.04	8	-2	65.333	-0.12	54%
114	403	1989	2007	-0.30	9	-26	92	-2.61	**99%**
115	405	1989	2007	0.06	9	13	92	1.25	89%
116	407	1989	2007	-0.02	9	-2	92	-0.10	54%
117	409	1989	2007	0.00	9	0	92	0.00	50%
118	411	1989	2007	-0.04	9	-2	92	-0.10	54%
119	412	1989	2007	-0.35	8	-12	65.333	-1.36	91%
120	415	1989	2007	-0.05	9	-4	92	-0.31	62%
121	420	1989	2007	0.11	9	2	92	0.10	54%
122	422	1989	2007	0.01	6	1	28.333	0.00	50%
123	423	1989	2007	-0.09	9	-9	92	-0.83	79%
124	424	1989	2007	-0.12	8	-14	65.333	-1.61	94%
125	428	1989	2007	0.29	8	16	65.333	1.86	**96%**
126	429	1989	2007	-0.39	9	-14	92	-1.36	91%
127	435	1989	2007	-0.38	9	-6	92	-0.52	69%
128	437	1989	2007	0.74	9	8	92	0.73	76%
129	439	1989	2007	-0.04	9	-2	92	-0.10	54%
130	500	1999	2007	-0.03	8	-10	65.333	-1.11	86%
131	501	1999	2006	-0.13	7	-7	44.333	-0.90	81%
132	502	1999	2007	-0.05	8	-7	65.333	-0.74	77%
133	503	1999	2005	-0.04	6	-5	28.333	-0.75	77%
134	504	1999	2003	0.03	4	2	8.6667	0.34	63%
135	505	1999	2007	-0.09	8	-6	65.333	-0.62	73%
136	506	1999	2007	-0.17	7	-19	44.333	-2.70	**99%**
137	507	1999	2007	0.05	8	0	65.333	0.00	50%
138	508	1999	2007	-0.13	8	-12	65.333	-1.36	91%
139	509	1999	2006	-0.11	7	-1	44.333	0.00	50%
140	510	1999	2007	0.23	8	15	65.333	1.73	95%
141	511	1999	2007	-0.10	8	-14	65.333	-1.61	94%
142	512	2002	2007	-0.50	6	-9	28.333	-1.50	93%
143	513	2000	2007	-3.61	7	-11	44.333	-1.50	93%

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

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

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

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

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

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

Sigificance is the confidence level of the statistical trend