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Rural Well Water Survey

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ABSTRACT:

During the summer of 1991, a survey of rural wells in Huron County was carried out. Information was gathered on 400 wells, water samples were collected from 301 of these wells. 30.5% of the dug/bored wells exceeded the drinking water recommendation of 10 mg/L for nitrate-N. This compares to 4% for the drilled wells. 37% of the wells tested had bacteria levels that would be considered unsafe based on the current standards (however only one test was performed). Once again, the dug/bored wells had significantly higher levels of bacteria than the drilled wells. Only two of the five pesticides measured were detected in any of the water samples. Atrazine was detected most often, although at concentrations well below the drinking water standard of 60 μg/L. Information was gathered on agricultural practices carried out near the wells. In general, there was poor correlation between most of these practices and water quality in the wells.

RURAL WELL WATER SURVEY

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BACKGROUND

Groundwater is very important to Ontario farmers. It has been estimated that about 90% of farms use groundwater for household purposes and about 80% use it for livestock watering (OMAF 1989). It is only logical that as the interest in environmental issues has grown in society over the past years, so also has the interest in water quality.

The fact remains though that many rural residents have no idea of the quality of water that they're drinking. A service is available through most Health Units in Ontario to sample water for total coliform and fecal coliform bacteria. This service is offered free of charge. Many farmers have taken advantage of this. However, very few farmers have sent water samples to private labs to have them tested for chemicals and pesticides.

A survey of 91 wells conducted in 1984 in Southern Ontario found that 11 wells had atrazine residues in concentrations of 0.1 µg/L or greater (Frank et al, 1987). Other studies have been done which have measured pesticide levels in wells where contamination was suspected. Frank et al (1987) found that spills of pesticide concentrates, back-siphoning of spray solutions and/or spills from overfilling, emptying or rinsing spray equipment were the causes of most of the contamination.

A study of rural wells in Ohio in 1987 found that the average concentration of nitrate-N was 1.32 mg/L and that 2.7% of the wells surveyed exceeded the drinking water standard of 10 mg/L (Baker, 1990). This study concluded that the nitrate contamination was not due solely to agricultural contamination of groundwater. Some of the problem was due to poor well construction or poor maintenance of older wells. In the same study, atrazine was the most frequently detected herbicide with 9.2% of the supplies containing atrazine at levels greater than 0.05 µg/L. Only 0.8% of the wells had atrazine levels greater than 1.0 µg/L.

Various studies have been done which have tried to establish relationships between agricultural activities and quality of groundwater. Ritter and Chirnside (1987) found high levels of nitrate in groundwater in areas of excessively well drained soils. They also found that poultry manure seemed to cause a greater increase in groundwater nitrates than did commercial fertilizer. Milburn et al (1990) found that nitrate-N leaching was occurring under potato production practices in New Brunswick.

There are many farm practices that can have an impact on groundwater quality. While some of these are related to field management practices, others deal with farmstead management. Jones and Jackson (1990) listed the following farmstead activities which could impact groundwater quality: a) pesticide handling and storage, b) nitrogen fertilizer storage and handling, c) petrolium product storage and handling, d) farm and home hazardous waste disposal, e) milkhouse waste water disposal, f) household waste water treatment system design and maintenance, g) silage storage, h) livestock manure storages, i) livestock yards, j) location and condition of well. They suggested a farmstead assessment be made which would consider all of these potential sources.

OBJECTIVES

1. To determine typical levels of certain water quality parameters in Huron County rural wells.
2. To determine what, if any, farm practices have a detrimental effect on well water quality.
3. To pass on as much information as possible on water quality to the participants in the study.

DESCRIPTION OF SURVEY

Sampling sites were selected at random. There are 16 townships in Huron County. For convenience, all of the wells in each township were done at one time. The farm visits were all made between May and August, 1991. During the site visit, a series of questions was asked to gain information on the well and on farming practices in the area and water samples were taken.

Collecting water samples - The following procedure was used to collect water samples at each site:

1. A tap was chosen as close to the water source as possible. In some cases, this was outside the house in a pump room. Often, it was in the basement of the house, near the pump, and in other cases the water had to be taken from a kitchen tap. When the water was taken from a tap with an aerator, the aerator was first removed, if possible.
2. Water was run through the tap for three minutes before any samples were taken.
3. Bottles used for chemical analysis of water were rinsed with the tap water before they were filled. The bottles used for the bacterial analysis were simply filled and capped.
4. All bottles were stored in a refrigerated cooler.
5. At the end of the day the water samples destined for bacterial analysis were delivered to the local health unit where they were immediately taken to the lab for analysis. The water samples for pesticide and chemical analysis were refrigerated until they could be delivered to the testing labs involved.

Laboratory analysis - Testing of the water was done at as many as four different labs. The local health unit delivered the water samples for bacterial analysis to the laboratory at Palmerston. Analysis was started within 24 hours of taking the water sample. Total coliform and fecal coliform levels were measured. The Pesticide Laboratory Section of the Agricultural and Food Laboratory Services Branch, OMAF, in Guelph, analyzed the samples for alachlor, metolachlor, atrazine, D-ethylatrazine, cyanazine, nitrate-N, and pH. At Centralia College the levels of nitrate-N, conductivity and pH were measured. Selected samples were sent to the Ontario Ministry of the Environment (MOE) regional lab in London. The participation of MOE in this study was limited to analyzing water from selected wells for calcium, magnesium, total hardness, sodium, potassium, chloride, sulphur and alkalinity.

RESULTS AND DISCUSSION

Well information - accuracy - In some cases, the well survey was completed by people having only a minimal knowledge of their water supply or of the farming practices near the well. As much as possible, the information on the actual well was cross checked with well records available from the Ontario Ministry of the Environment. Sometimes, especially with older wells, this was not possible. Measurements to other land uses such as to septic systems and to manure storages were made by the technician working on the study. The technician rated each visit as to the confidence in the information received on that visit. The rating system ranged from 1, meaning very low, to 5, meaning very high. The average rating for the study was 4.0 (high).

In many cases, the well owner was not sure of the diameter, depth or age of the well. This was simply treated as missing data. There are several other cases where this happened in filling out the survey. In the following sections, where there are results given, the sample number will generally be given. The reason why these sample numbers will not add up to the same number from one comparison to the next is because of the amount of missing data.

Well information - general - The number of well owners who participated in the survey was 281. Information was gathered on 400 wells. Water samples were taken from 301 wells. Many of the sites contained more than one water supply. Figure 1 shows the number of farms having one and more water supplies. Forty percent of the people surveyed had more than one water supply. In some cases, these were no longer being used but were not sealed. None of the survey sites used well water for irrigation and only six percent had wells designated specifically for barns or livestock watering. The majority used at least some of the water for household needs.

Not all of the people surveyed lived on farms. All lived in rural areas but 95 of the 281 sample sites were rural residences only. Some of the rural residences included houses that were severed off of farms or houses rented to nonfarm families. In the latter case, none of the water was used for farming.

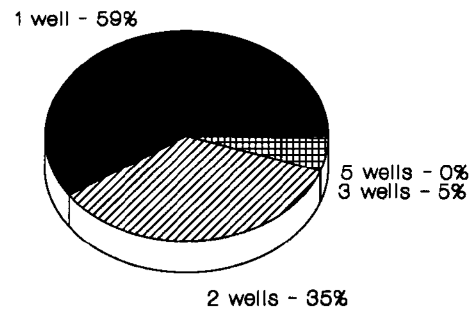


Figure 1 Number of survey sites having one or more wells.

For the purposes of this report, the wells will be grouped into three categories: 1) dug or bored wells, 2) drilled wells, and 3) other. There were no sand points (jetted or driven wells). "Other" consists of wells where the construction was not known by the person answering the survey questions. It also includes springs and surface water sources. The relative proportion of dug/bored, drilled, and other in the survey was 41%, 56%, and 3% respectively. Some pertinent information about the dug/bored and the drilled wells is found in Table 1. In interpreting these numbers, it is important to remember that some of the survey respondents had a minimal knowledge about their water supply. The reported ages of wells over 100 years old are usually just estimates. Table 2 gives the average distances between the wells and various land uses.

In most cases, the average values for separation distances appear to be reasonable. However, the minimum distances are a cause for concern. It appears as though many wells are likely located very close to a potential source of contamination.

Water quality - general - The quality of water from most wells was quite good. Certain wells had values of parameters which exceeded the maximum allowable or maximum desirable concentrations. This happened most frequently for bacteria and nitrates. These will be discussed in more detail in later sections. Table 3 gives a summary of the statistics for all of the water samples. There were a total of 301 wells surveyed. Unfortunately, seven of the sample bottles were broken in transit to the pesticide lab, leaving results for 294. As mentioned earlier, certain parameters were measured for only 90 targeted wells.

Where the parameters were not detected in the water sample, the lab report simply stated "not detected". For data analysis, these results were entered as 0. The minimum detection limits are listed in Table 3 to give an idea of the sensitivity of the various tests.

Table 1: Selected information on well characteristics.			
		Dug / Bored Wells	Drilled Wells
Age (yrs.)	Average	66.3	27.6
	S.D.	33.6	22.6
	Maximum	150	107
	Minimum	12	0
	Number	86	185
Diameter (in.)	Average	44.1	4.8
	S.D.	13.2	0.9
	Maximum	96	8
	Minimum	24	2.5
	Number	115	172
Depth (ft.)	Average	24.5	148.2
	S.D.	11.1	72.1
	Maximum	54	405
	Minimum	4	20
	Number	118	193

Table 2: Distances (ft.) between wells and various land uses.

Land Use	Average	S.D.	Maximum	Minimum	Number
Cultivated Crop	78	110	1000	0	351
Fuel Storage	102	96	500	8	169
Septic System	103	95	500	1	261
Silo	168	127	500	1	111
Manure Storage	174	125	500	0	142
Feedlot	130	133	600	2	72
Pesticide Filling/Mixing	106	127	500	0	18
Pesticide Storage	131	84	300	35	32

Table 3: Average water quality parameter values for all wells.						
Parameters	**Units**	**MDL**	**Average**	**S.D.**	**Number**	**MAC**
pH	pH units	—	7.36	0.34	301	6.5-8.5 D
nitrate-N	mg/L	0.04	3.15	5.6	301	10
conductivity	μmhos/cm	0.05	605	306	301	—
total coliform bacteria	#/100 mL	1	20.1	30.9	301	10
fecal coliform bacteria	#/100 mL	1	6.0	15.9	301	0
alachlor	μg/L		0	0	294	350 *
metolachlor	μg/L		0	0	294	50
atrazine	μg/L		0.187	1.62	294	60
d-ethyl atrazine	μg/L		0.098	0.319	294	—
cyanazine	μg/L		0	0	294	10
calcium	mg/L	0.1	78.1	29.7	90	—
magnesium	mg/L	0.1	23.7	8.01	90	—
hardness	mg/L	0.1	294	94.9	90	500 D
sodium	mg/L	0.1	19.8	40.0	90	200 D
potassium	mg/L	0.1	3.66	6.82	90	—
alkalinity	mg/L	10	264	60.2	90	—
chloride	mg/L	0.1	27.3	62.2	90	250 D
sulphate	mg/L	0.5	49.1	45.2	90	500 D

MDL Minimum Detection Limit
SD Standard Deviation
MAC Maximum Acceptable Concentration - Ontario Ministry of Environment, and Health and Welfare Canada (D denotes maximum desirable concentration)
* EPA

Water quality - nitrates - In Ontario, the maximum allowable concentration of nitrate-N in drinking water is 10 mg/L (MOE, 1984). The dug and bored wells had significantly higher concentrations of nitrate-N than the drilled wells. The average concentrations, listed in Table 4, were 7.42 mg/L of nitrate-N for the dug/bored wells and 1.46 for the drilled wells. 30.5% of the dug/bored wells exceeded the drinking water recommendation. This is compared to four percent for the drilled wells. Figure 2 shows the distribution of concentrations for the different well water samples.

Table 4: Levels of nitrate-N in wells.		
	Dug/Bored Wells	**Drilled Wells**
Average concentration (mg/L)	7.42	1.46
SD	7.78	3.34
Max.	40.7	26.4
Min.	0.04	0.04
Number	80	205
Number exceeding 10 mg/L	24 (30.5%)	9 (4%)

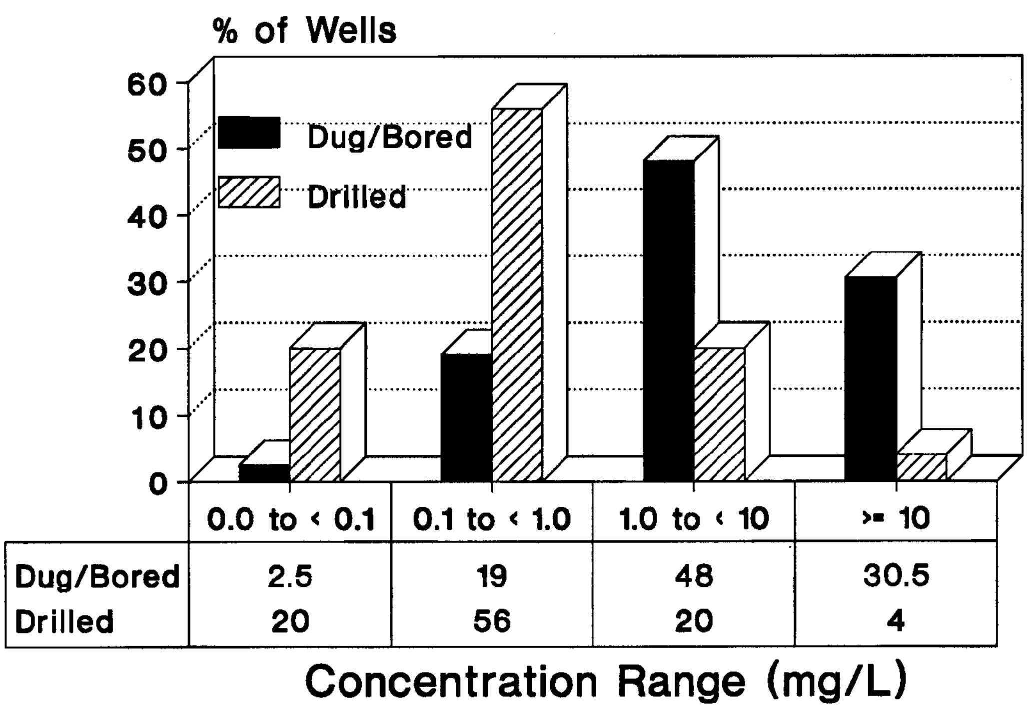


Figure 2 Percentage of wells, by type, having concentrations of nitrate-N in various ranges.

There was no significant difference in nitrate levels in the wells for those using fertilizer compared to those who didn't use fertilizer. The average of 141 wells where fertilizer was used was 2.90 mg/L nitrate-N. The average for the 137 sites where fertilizer was not used was 3.02 mg/L. Interestingly, the farms where soil testing was performed had significantly lower levels of nitrate in the wells. The average for the 109 farms where soil testing was routinely carried out was 2.23 mg/L. This compares to 5.12 mg/L for the 32 farms where soil testing was not routinely carried out. The reasons for this difference are not obvious since the soil test does not actually measure levels of nitrogen in the soil. It is possible that farmers who routinely soil test are more conscious of efficient use of nutrients, including nitrogen. This would result in lower soil reserves of nitrogen at the end of the growing season and therefore less nitrate available to be leached into the groundwater.

Farmers reported on the tillage system used. There was no significant difference in nitrate levels for the farms using conventional, reduced, and no-till systems. A linear regression analysis was performed to determine if nitrate levels in wells were related to a variety of other considerations. The highest R^2 value relates nitrate levels to depth. This value is only .16. There is no good linear relationship between nitrate levels and depth, age, distance to: crop land, fuel storage, septic system, silo, manure storage, or feedlot.

Another consideration often used in discussions concerning nitrate is the soil type and the geology of an area. The predominant soil textural class was recorded for each of the well sampling sites. As one might expect, the sandy soil had the highest mean nitrate-N level (4.5 mg/L nitrate-N). However, there was no significant difference between any of the soil types in the study.

Figure 3 shows a map of the county but with circles to represent ranges in nitrate-N levels. Each of the wells sampled is represented on the map. The large diameter circles show the locations of wells where the nitrate-N levels exceeded 10 mg/L. Similarly, the dots on the map represent wells where nitrate-N levels were less than the detection limit of 0.10 mg/L. While there appear to be some areas where nitrate levels tend to be low and other areas where the levels tend to be high, it also appears that no strong pattern emerges.

Water quality - bacteria Total coliform and fecal coliform bacteria levels were measured in all 301 water samples. Normally, well owners are advised to take more than one water sample for a bacteria test, due to the fact that bacteria levels in water tend to vary over time. If there is any suspicion that a water supply is contaminated, it should be sampled three times at intervals of between one and three weeks. Due to the limitations of this study, each of the wells was sampled only once. The maximum detection limit for total coliform bacteria was 80 organisms per 100 mL, and for fecal coliform it was 60. These values were used for data analysis in all cases where the bacteria numbers exceeded the maximum detection limit.

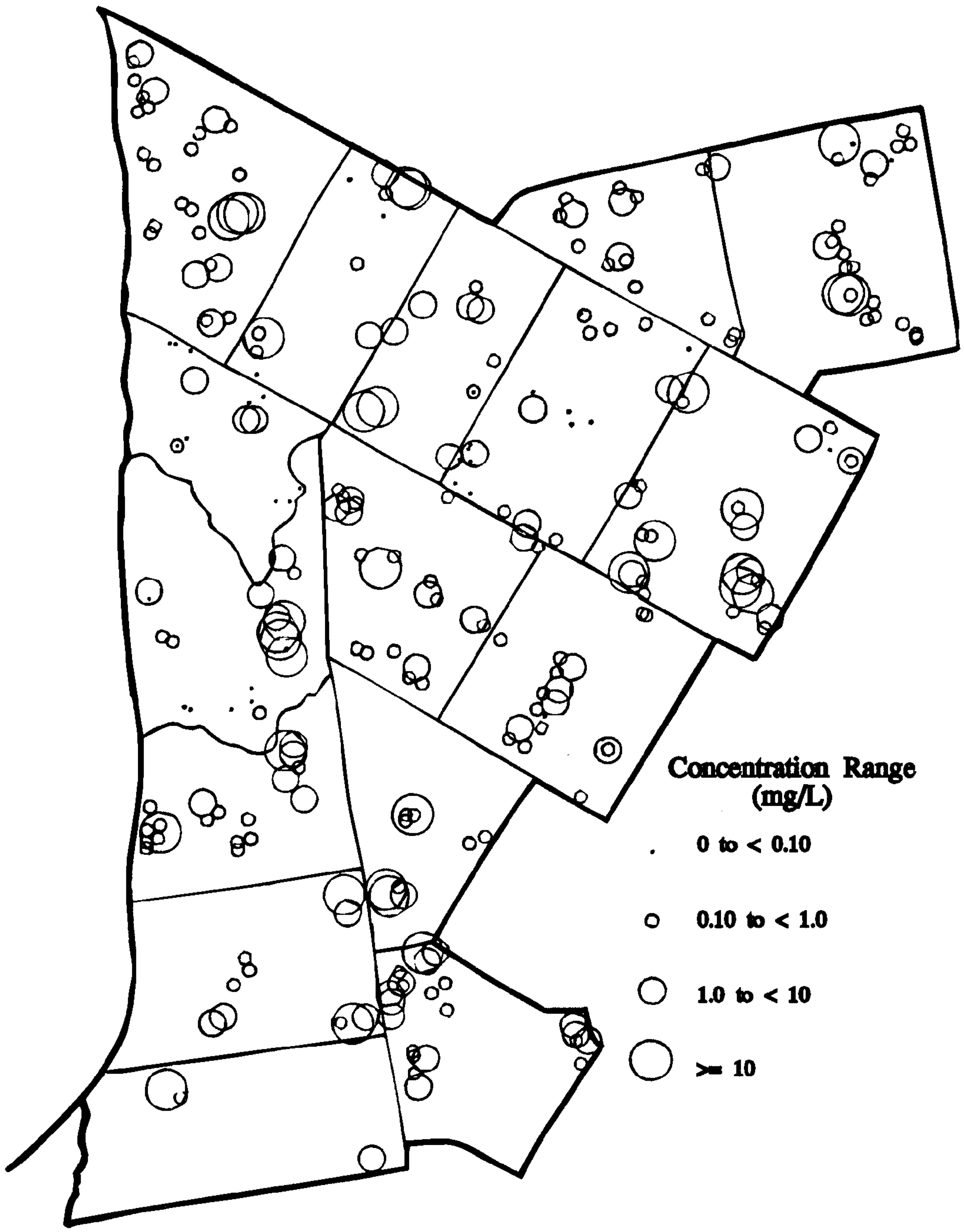


Figure 3 Nitrate-N levels and locations of wells in study.

Of the 301 samples, 198 had levels of total coliform at or below 10 organisms per 100 mL. This is the maximum acceptable concentration for drinking water. Similarly, 224 water samples had no measurable fecal coliform organisms. In other words, 34.2% of the wells had unsafe levels of total coliform bacteria and 25.6% of all wells had unsafe levels of fecal coliform bacteria (based on one test only). A total of 190 wells had safe levels of both types of bacteria (i.e. 36.9% had unsafe levels of one or both types of bacteria). This information is graphically depicted in Figure 4.

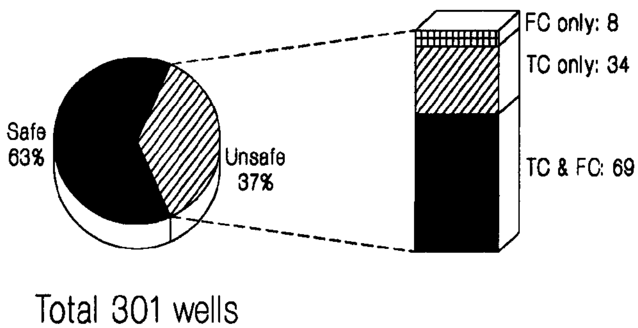
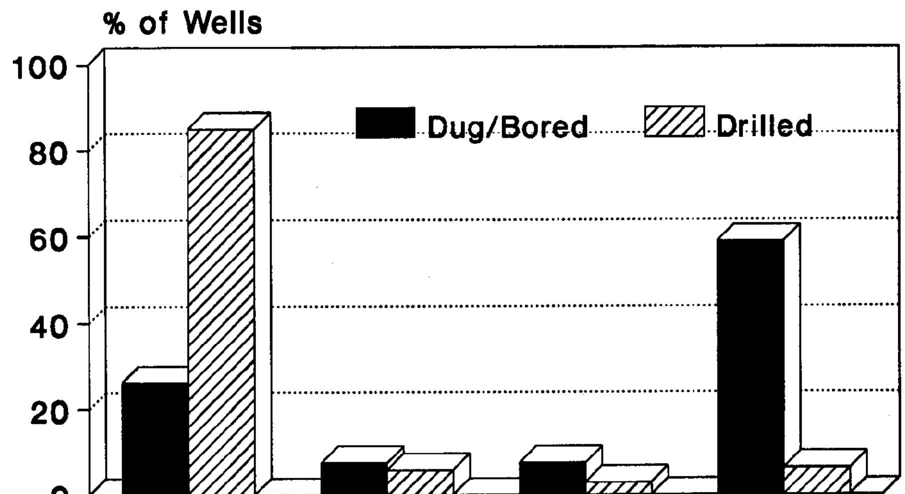


Figure 4 Wells with "safe" and "unsafe" levels of total coliform (TC) and fecal coliform (FC) bacteria, showing the number of "unsafe" conditions caused by each bacteria (one sample per well)

The difference between dug/bored wells and drilled wells was highly significant (at $p < 0.001$) for total coliform and fecal coliform levels. The average total coliform level for dug/bored wells was 50.0 organisms per 100 mL, and for drilled wells was 8.0. Figure 5 shows the percentage of wells having bacteria counts in various ranges. It is obvious that there is a much greater problem with bacteria levels in the dug/bored wells than in the drilled wells.

The well type proved to be the single most important factor concerning bacteria levels in the well water. Whether the water was used for house, barn, or a combination of the two, seemed to make no difference in the bacteria levels. Whether the top of the well was elevated above the ground or not made no difference in bacteria levels. The 253 wells where the surface water was diverted away from the well had the same bacteria levels as the 43 wells where there was no surface water diversion. There were no significant differences between wells installed in various soil types. The study included a good cross section of farm types. There were several dairy, hog, beef, cash crop, and other types of farms. However, there was no significant difference in bacteria levels in the well water for the different types of farms. One might have expected that the livestock farms would have high levels. This was not the case.

No significant correlation was found between bacteria levels and any of the following parameters: depth of well (R^2 = .25), age of well (R^2 = .15), distance to crop land, distance to septic system, distance to manure storage, and distance to feedlot.

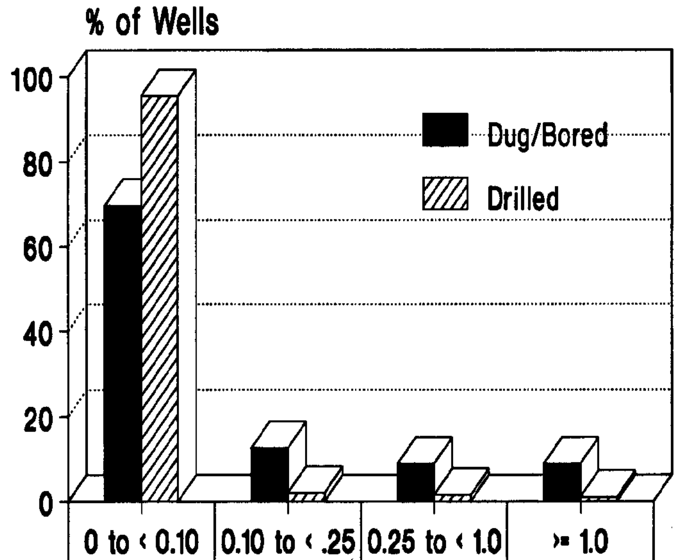


	0 to <10	10 to <25	25 to <50	>=50
Dug/Bored	26.2	7.5	7.5	58.8
Drilled	84.9	5.8	2.9	6.3

Density Range (#/100 mL)

Figure 5 Percentage of wells, by type, having densities of total coliform bacteria in various ranges.

Water quality - pesticides - None of the water samples had measurable levels of alachlor, metolachlor, or cyanazine. Table 3 gives the average concentrations of atrazine and d-ethyl atrazine in the wells. The highest detected level of atrazine in the water was less than half of the maximum acceptable concentration of 60 µg/L. Only 1.0% of drilled wells and 8.9% of dug/bored wells had atrazine concentrations exceeding 1 µg/L. The comparison of concentration ranges for dug/bored and drilled wells is found in Figure 6.



	0 to < 0.10	0.10 to < .25	0.25 to < 1.0	>= 1.0
Dug/Bored	69.6	12.6	8.9	8.9
Drilled	95.5	2	1.5	1

Concentration Range (ug/L)

Figure 6 Percentage of wells, by type, having concentrations of atrazine in various ranges.

Unlike nitrates and bacteria, there was no significant difference in atrazine levels between the types of wells. The average concentration for dug/bored wells was 0.25 µg/L and for drilled wells was 0.17. Likewise, the levels of atrazine seemed to be unaffected by type of farm operation, use of inorganic fertilizers, type of tillage system, age of the well, depth of the well, and distance to crop land. Wells on farms where pesticides were used did not have significantly different levels of pesticides in the wells than those on farms where no pesticides were used. Wells used to fill sprayers had no higher levels than wells that were not used for this purpose. Distances to the pesticide filling area and to the pesticide storage seemed to have no bearing on levels of contamination of well water.

The distribution of wells within the county is shown in Figure 7. This map shows the locations of wells having various atrazine concentration ranges. It is difficult to find any pattern to these results.

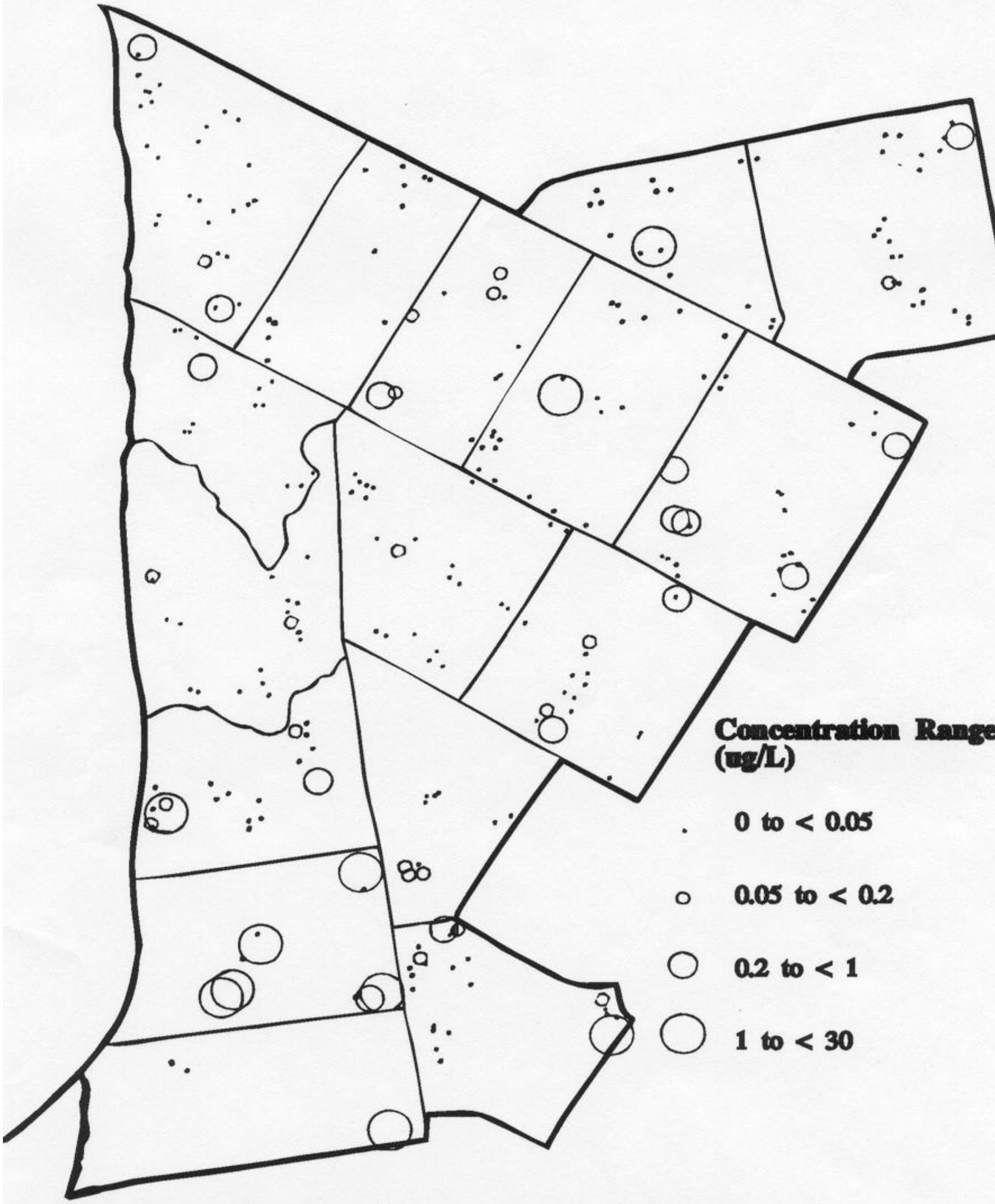


Figure 7 Levels of atrazine in wells - showing location of wells

Water quality - other chemical parameters - As mentioned earlier, several chemical parameters were measured in only selected wells. Selection was based on whether or not the well was located in an area designated as having a high susceptibility to contamination of groundwater. It is interesting to note that the average hardness level for dug/bored wells of 342 mg/L is considerably higher than the average of 220 for drilled wells.

Survey acceptance by well owners - For the most part, well owners were quite interested in the survey and very helpful in completing the questionnaire. Although many of the well owners had previously had their water analyzed for levels of bacteria, there were many who had not. Very few had ever analyzed their water for anything other than bacteria.

Some well owners did not want to participate in the study. The most common reason was a fear that if their water was contaminated, some legal action might be taken against them. In one case, the well owner was afraid that the survey was part of a plan to force people to connect to the pipeline.

SUMMARY AND RECOMMENDATIONS

Based on the information from the 400 wells in the survey and the water samples taken from 301 of these wells, the following can be said about rural well water in Huron County:

1. Rural well owners have a keen interest in the quality of their drinking water even though very few have taken any steps to assess the quality of the water.

2. Of the 281 sites visited, 41% had more than one source of water.

3. The relative proportion of dug/bored, drilled and other types of water sources in the survey was 41%, 56% and 3% respectively. Many of the wells were located close to potential sources of contamination (such as septic system, silo, manure storage, pesticide filling/mixing areas).

4. 30.5% of dug/bored wells and 4% of drilled wells exceeded the water quality guideline of 10 mg/L of nitrate-N. Besides the type of well, the only other factor which seemed to have any significance relating to nitrate-N levels was the use of soil testing. On those farms where soil testing was routinely carried out, the levels of nitrate-N in the wells was lower then on the farms where no soil testing was carried out.

5. The soil type of the farm did not seem to play a significant role in the levels of any of the measured parameters in the wells. 37% of all wells had unsafe bacteria levels (defined as greater than 10 organisms per 100 mL for total coliform and/or greater than 0 organisms per 100 mL for fecal coliform). This

number is based on only one test and normally the well owner would perform more than one to get a more accurate assessment for bacteria. The dug/bored wells had significantly higher levels of bacteria than the drilled wells.

6. No residues of alachlor, metolachlor, or cyanazine were detected in any of the water samples. The pesticide which showed up most frequently was atrazine even though the concentrations were very low. None of the wells had atrazine levels exceeding the drinking water standard of 60 µg/L. 8.9% of dug/bored wells and 1% of drilled wells had atrazine concentrations exceeding 1.0 µg/L.

This study has identified the need for a much greater effort in the area of education. Well owners and groundwater users need to be aware of water quality standards, especially as they relate to health. They need to be aware of the variety of factors that can lead to poor water quality. Some excellent technical publications have been produced by various agencies and give helpful information on water quality treatment options, testing, programs, etc.

ACKNOWLEDGEMENTS
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