# **WATER QUALITY** OF BARRON COUNTY, **WISCONSIN**

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The Wisconsin Geological and Natural History Survey (WGNHS) conducted a random sampling of private wells in Barron County from July 1983 to October 1985 to define the current quality of groundwater in the county and to identify potential problem areas. During that period, 383 samples were collected from randomly selected private wells in all of the 25 townships of the county (fig. 1). In addition, the county zoning administration ordered analyses of 98 samples that had been collected at the request of county homeowners. These 481 samples were analyzed in the University of Wisconsin Soil Science Department Laboratory in Madison for chloride, total solids, specific conductivity, and all species of nitrogen and phosphorus. Samples collected in 1984 and 1985 were also analyzed for hardness. Ninety of the 481 samples were also analyzed for calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and chemical oxygen demand (COD). In addition, 241 nitrate analyses were gathered from the county and Wisconsin Department of Natural Resources (DNR) files.

Sixty complete chemical analyses were available for determining basic characteristics of groundwater quality in the county (Holt and Skinner, 1973); nine additional samples were collected by WGNHS and analyzed by the U.S. Geological Survey (USGS) laboratory. The complete analysis included all major cations (Na, K, Ca, Mg, Fe, Mn) and anions (CI, SO<sub>4</sub>, HCO<sub>3</sub>, F, NO<sub>3</sub>) and basic properties of water (specific conductivity alkalinity, pH, total dissolved solids, and hardness). Data on trace and minor constituents were compiled from the results of the National Uranium Resource Evaluation (NURE) program (Arendt and others, 1978). Sixty-two well-water samples were taken for this program from August to November 1977 in the county area covered by the 1:250,000 Rice Lake quadrangle (a part of the county east of the 92° latitude). The wells selected for sampling formed a more or less regular grid, with wells approximately 5 miles apart.

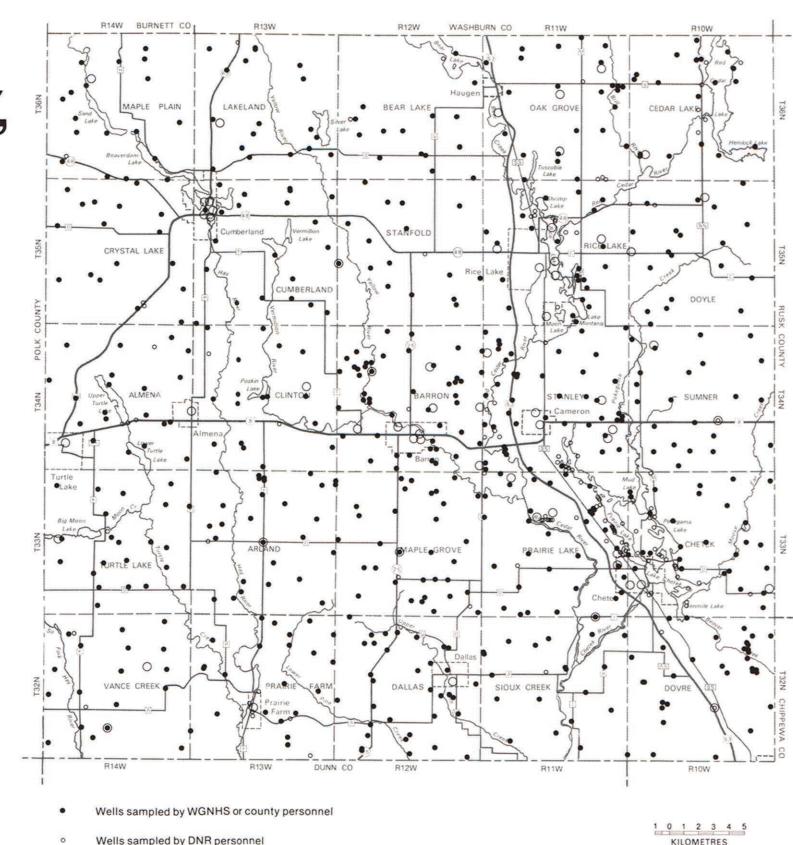
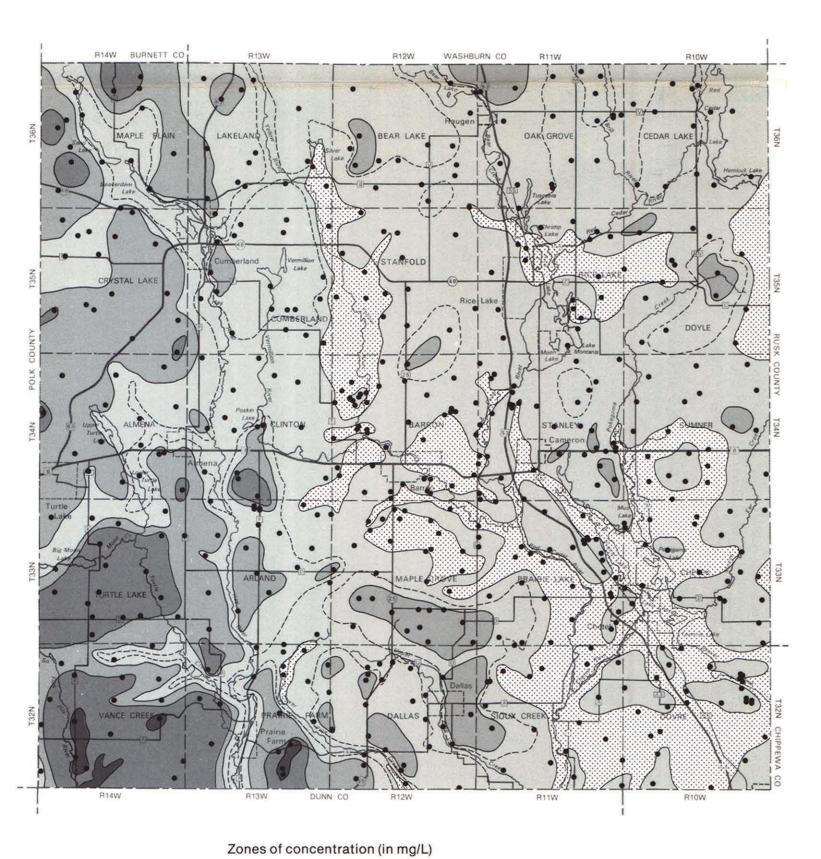


Figure 1. Well-water sampling locations in Barron County, 1983-85.

Samples taken for complete analysis



Supplemental contour Sampling point

Figure 2. Generalized mineral concentration of groundwater in Barron County.

Map 87-2f A part of the Barron County Atlas

Cartography by K.M. Campbell

# Current quality of groundwater

The overall natural quality of groundwater in Barron County is good, and the water is suitable for most purposes. The composition of groundwater in the county is primarily a result of its movement through and interaction with the unconsolidated deposits and sedimentary rocks that contain large amounts of carbonate minerals. Therefore, the groundwater is predominantly of the calcium-magnesium-bicarbonate type. Regional differences in the quality of water are due to the composition, solubility, and physical properties of soil and rock particles through which the water moves, and to the length of time the water is in contact with these materials

0 1 2 3 4 5

Total dissolved solids (TDS) in a water sample is a measure of dissolved mineral constituents derived from the solution of rocks and soils. The total concentration of minerals dissolved in water is a general indication of the overall suitability of water for various types of uses. If the water contains less than 500 milligrams per liter (mg/L) TDS, it is generally satisfactory for domestic and many industrial uses. Mineralization of groundwater in Barron County is low under natural conditions. More than 80 percent of samples collected during the study contained less than 300 mg/L TDS; most samples had between 100 and 200 mg/L TDS, which is normal for the sand-and-gravel and sandstone aquifers in this part of Wisconsin (Devaul, 1975a; b). Groundwater is more mineralized (more than 300 mg/L TDS) in the western part of the county underlain by dolomite (fig. 2). The lowest concentrations of TDS are in areas of outwash, where rapid movement of groundwater through the coarse-grained material results in low mineralization. The median concentration of dissolved solids in water from 566 wells sampled for analysis was 164 mg/L (table 1). The lowest concentration was 27 mg/L in a well in the town of Doyle, and the highest was 1,041 mg/L in a well in the town of Prairie Farm. Only 17 samples exceeded the limit of 500 mg/L recommended by the U.S. Environmental Protection Agency (EPA) for drinking water. These higher concentrations can be considered anomalies in this area, and may indicate degradation of natural water quality. However, higher mineralization itself does not pose any health hazard, but the water may have a disagreeable taste and may be corrosive.

The number of major dissolved constituents of groundwater is quite small, and the natural variations are not as great as might be expected from the complex mineral and organic materials through which the water has passed. Six ions included in figure 3 calcium (Ca), magnesium (Mg), sodium (Na), bicarbonate (HCO<sub>3</sub>), sulfate (SO<sub>4</sub>), and chloride (CI) - form more than 95 percent of all the dissolved substances in water. Major chemical constituents shown in figure 3 indicate that the quality of water differs only slightly between aquifers. Water in the sandstone aquifer is generally more mineralized and harder than water in the sand-and-gravel aquifer. Common chemical constituents of groundwater in Barron County and their maximum, minimum, and average values are summarized in table 1.

Besides these common constituents, groundwater in Barron County contains a number of minor, or trace, elements. The concentrations summarized in table 2 are the result of sampling done during the NURE program in 1977 (Arendt and others, 1978). Almost all the samples taken from 62 wells in the county contained only small quantities of these elements, well below the limits recommended for drinking water. Limits included in table 2 were set by the U.S. EPA and accepted by the state only for those elements that in the greater quantities may have toxic effects on humans (Wisconsin Administrative Code, 1982). More than 60 percent of samples analyzed for copper and all samples analyzed for zinc had detectable amounts of each. Only one sample exceeded the established limits - a well in the town of Stanfold had 6.2 mg/L (6,249 µg/L) of zinc in the water sample. In addition, samples taken from two wells in the town of Barron at the request of homeowners had concentrations of copper higher than the standard for drinking water: 1,800 and 4,000 µg/L, respectively. Many water distribution systems use copper pipes, galvanized well casing, or galvanized pressure tanks. Dissolution from copper pipe or galvanized casing may be a source of copper or zinc in some water samples.

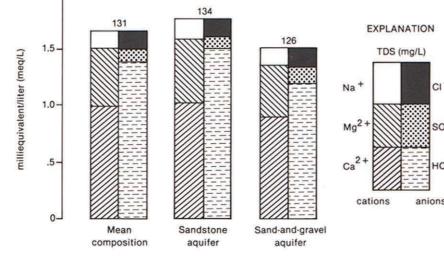


Figure 3. Mean composition of water in Barron County, by aquifer.

## General water-quality problems

The quality of Barron County groundwater is much better than required by drinkingwater standards (Wisconsin Administrative Code, 1982). Only a few of the properties and constituents of groundwater listed in table 1 have caused or have a potential to cause water-quality problems.

Minor water-use problems can be caused by hardness. Groundwater in Barron County is, on the average, moderately hard. The countywide median hardness for 198 samples was 84 mg/L as CaCO3 (table 1). Hardness increases across the county from the east (less than 60 mg/L) to the west (more than 180 mg/L) (fig. 4). The federal or state regulations of drinking water do not include a limit for hardness because no serious health problems are known to result from consumption of hard water. Hardness of water is caused by calcium and magnesium, two of the major dissolved constituents found in the county's groundwater. Hard water is objectionable for domestic and industrial uses because the insoluble residue collects in kettles and boilers used for heating water and a curd forms when hard water comes into contact with soap. The residue in water distri oution systems causes premature deterioration of pipes and water heating equipment. Hardness problems can be reduced easily by using water softeners. On the other hand, depending on factors such as the pH and alkalinity of the water, naturally soft water may cause corrosion in water distribution systems, and consequently, dissolution of copper pipes in the systems. This problem can be removed by the installation of a water hardener, which will increase the CaCO3 content of the water.

## Table 1. Summary of chemical and physical characteristics of groundwater in **Barron County** (all in milligrams per liter, mg/L, unless indicated otherwise)

Constituent or property	No. of samples	Maximum	Minimum	Median	Mean	No. over limit*
Alkalinity, total, lab (as CaCO <sub>3</sub> )	71	242	11	51	58	÷,
Bicarbonate (HCO <sub>3</sub> )	54	246	13	68	85	¥1
Calcium (Ca)	58	57	3.5	19.5	21	¥:
Chloride (CI)**	65	32	0	4.3	6.9	0
Fluoride (F)	57	0.6	0	0.1	0.1	0
Hardness (as CaCO <sub>3</sub> )**	66	215	14	78	84	-
ron and Manganese, total dissolved (Fe + Mn)	65	32	0	0.1	0.8	5
Magnesium (Mg)	57	19	1.1	6.6	7.1	*:
litrate-nitrogen (NO <sub>3</sub> -N)**	62	80	0	6.2	10.2	19
H, lab (no units)	64	8.3	6.0	6.9	7.0	-
otassium (K)	45	3.5	0.1	0.7	0.9	*
Sodium (Na)	51	14	0.9	3.6	4.0	2
Specific conductance (in micromhos)	54	457	31	133	171	-
Sulfate (SO <sub>4</sub> )	65	33	0.5	6.3	6.8	0
otal dissolved solids (TDS)**	66	270	45	119	131	0
Chloride	657	167	0.04	7.0	6.4	0
Hardness	198	468	16	84	94	.e. 2
Nitrate-nitrogen	722	42	0	2.5	4.3	76
otal dissolved solids	566	1,041	27	164	208	17

\*For limits, see Wisconsin Administrative Code, 1982.

\*Includes only results of the complete chemical analyses. Values from the analyses of samples collected during

Source: Holt and Skinner, 1973; recent USGS analyses; analyses of samples collected in 1983-85.

### Table 2. Concentrations of minor and trace constituents in goundwater in **Barron County** (in micrograms per liter, μg/L)

Constituent	No. of samples	Maximum	Minimum	Median	Maximum limit*
Aluminum (AI)	62	37	<10.0	<10.0	VE.
Arsenic (As)	62	2.2	< 0.5	< 0.5	5
Barium (Ba)	62	261	< 2.0	< 5.5	1,000
Beryllium (Be)	62	< 1.0	< 1.0	< 1.0	-
Boron (B)	62	270	< 5.0	< 8.0	-
Chromium (Cr)	62	8.0	< 4.0	< 4.0	50
Cobalt (Co)	62	17.0	< 2.0	< 2.0	-
Copper (Cu)	62	302	< 2.0	< 4.0	1,000
Lithium (Li)	62	4.0	< 2.0	< 2.0	3.55
Molybdenum (Mo)	62	9.0	< 4.0	< 4.0	
Nickel (Ni)	62	9.0	< 4.0	< 4.0	-
Scandium (Sc)	62	< 1.0	< 1.0	< 1.0	120
Selenium (Se)	62	3.0	< 0.2	< 0.2	10
Silver (Ag)	62	< 2.0	< 2.0	< 2.0	50
Titanium (Ti)	62	< 2.0	< 2.0	< 2.0	J.E.
Zinc (Zn)	62	6,249	5.0	60.0	5,000

\*From: Wisconsin Administrative Code (1982). Source: Arendt and others (1978)

The concentration of nitrate in groundwater in Barron County generally was low during this study. Nitrate-nitrogen (NO<sub>3</sub>-N) concentrations ranged from 0 to 42 mg/L and averaged 3.0 mg/L (table 1). Concentrations of nitrate in groundwater vary widely with respect to season, depth to water, location of wells, type of soil or sediment in the unsaturated zone, and available sources of nitrate. Because of the variability, it is impossible to show zones of nitrate in the groundwater of Barron County on a map. However, a map showing all sampled wells and determined nitrate values is on file at the Barron County Zoning Office. General distribution of nitrate is illustrated in figure 5 by average nitrate concentrations by town. The lowest observed concentrations in individual wells (less than 2.0 mg/L) generally were limited to the northernmost and westernmost tiers of townships. The higher concentrations, more than 10 mg/L, can be found especially in the irrigated areas of outwash plains in the southeast and in the areas of shallow bed-

An unusually large amount of nitrate in well water may indicate pollution from septic tanks, privies, manure pits, or barnyards. Even though nitrate is not a problem in itself, it may serve as an indicator that the water may contain harmful bacteria, which also may be carried into the aquifer from these sources of pollution.

High concentrations of nitrate can result in a serious, though easily treated, blood disorder in infants called infantile methemoglobinemia (or cyanosis). Under certain conditions, nitrate can be reduced to nitrite (NO2) by denitrifying bacteria in the upper digestive tract of some infants. The reaction of nitrite with the hemoglobin of the blood reduces the capability of the blood to carry oxygen to the body tissues. Because the skin of affected infants takes on a blue tone, similar to that which would occur from suffocation, such infants are called blue babies. Prompt medical treatment normally re-

Infants under 6 months of age are most susceptible to this disease, but not all infants are affected. Many infants have drunk water with nitrate concentration higher than 10 mg/L and have not developed the disease. In Wisconsin no fatalities associated with nitrate in drinking water have been reported, and the actual occurrence of the disease is thought to be quite rare (Wisconsin Department of Natural Resources, 1980). The standard of 10 mg/L NO<sub>3</sub>-N is based on the medical observation that no known cases of methemoglobinemia have been reported when water contained less than 10 mg/L. Older children, adults, and animals can consume water with larger concentrations with no known ill effects because their stomach juices are more acidic than those of infants and do not promote the growth of denitrifying bacteria.

To determine the nitrate concentrations in Barron County, 722 analyses were collected from various sources. Table 3 shows that about 10 percent of the samples (76 samples) exceeded the established limit for drinking water (10 mg/L NO<sub>2</sub>-N) and that only 20 of the 76 samples contained more than 20 mg/L. About 55 percent of the samples (391 samples) contained less than 3.0 mg/L, and of that amount, 195 samples contained less than 1.0 mg/L NO<sub>3</sub>-N.

Nitrate in groundwater is derived from a variety of natural and human sources. The principal natural sources are soil nitrogen (product of decaying vegetation, growth of certain plants, and wild-animal waste) and atmospheric deposition. Principal humanrelated sources include barnyards, feedlots, animal waste disposal, septic systems, and nitrogen fertilizers on irrigated fields. Nonpoint sources (that is, dispersed over wide areas) - such as soil nitrogen and leaching of commercial fertilizers - are very difficult to distinguish from other sources. The level of nitrate concentration that is considered to be above natural or background levels and thus, the result of human activities, has not been clearly defined. The U.S. Geological Survey evaluated existing nitrate data for the United States and concluded that a concentration of more than 3.0 mg/L indicates possible human inputs (Madison and Brunnett, 1985). Rural areas have greater potential for nitrate pollution than urban areas because of barnyard drainage, inadequate storage of animal waste, and use of fertilizers.

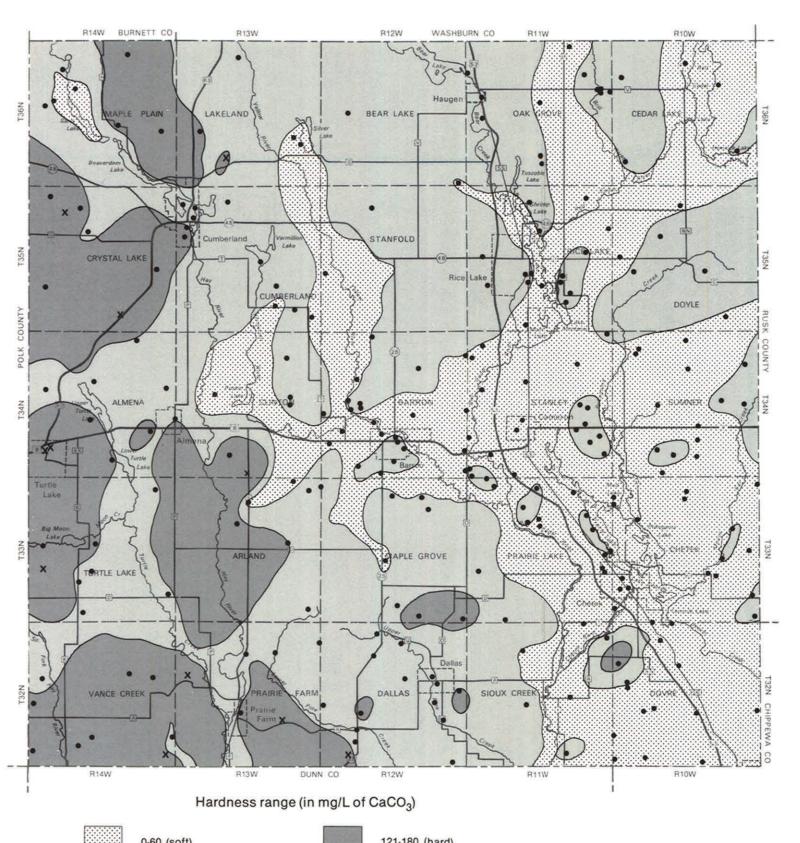


Figure 4. General distribution of hardness of groundwater in Barron County.

Sampling point

Greater than 180 (very hard

1 0 1 2 3 4 5

# Table 3. Barron County nitrate survey, 1983-85

	Nitrate-nitrogen (NO <sub>3</sub> -N) in mg/L									Wells sampled		Highest value			
Township	0-0.9		1.0-2.99		3.0-9.99		10.0-19.9		20.0 & more		Total	% of wells	mg/L	Date	Township
	No. of samples	%	No. of samples	%	No. of samples	%	No. of samples	%	No. of samples	%	no.	w/NO <sub>3</sub> -N 10.0 mg/L or more			average
Almena	8	33.3	7	29.2	7	29.2	2	8.3	0	0	24	8.3%	13.2	7/8/83	2.49
Arlano	12	42.8	8	28.6	7	25.0	1	3.6	0	0	28	3.6%	19.9	8/17/83	2.79
Barron	21	44.7	7	14.9	15	31.9	3	6.4	1	2.1	47	8.5%	26.3	8/22/83	3.77
Bear Lake	10	58.8	4	23.5	3	17.6	0	0	0	0	17	0%	4.7	7/21/83	1.44
Cedar Lake	11	45.8	8	33.3	5	20.8	0	0	0	0	24	0%	8.5	10/8/85	1.76
Chetek	7	13.5	10	19.2	29	55.8	5	9.6	1	1.9	52	11.5%	22.5	11/5/85	4.75
Clinton	4	21.0	5	26.3	9	47.4	0	0	1	5.3	19	5.3%	24.0	10/21/85	4.36
Crystal Lake	8	42.1	4	21.1	5	26.3	0	0	2	10.5	19	10.5%	26.2	7/18/83	4.31
Cumberland	7	33.3	6	28.6	7	33.3	1	4.8	0	0	21	4.8%	13.7	9/25/84	2.86
Dallas	5	14.7	5	14.7	14	41.2	6	17.6	4	11.8	34	29.4%	28.8	8/16/83	8.34
Dovre	5	14.3	13	3.7	10	28.6	4	11.4	3	8.6	35	20.0%	42.3	8/18/83	6.89
Doyle	4	19.0	10	47.6	6	28.6	1	4.8	0	0	21	4.8%	18.6	3/7/83	3.37
Lakeland	12	63.2	5	26.3	2	10.5	0	0	0	0	19	0%	5.5	1/31/83	1.19
Maple Grove	4	12.1	13	39.4	13	39.4	3	9.1	0	0	33	9.1%	13.6	2/22/83	4.42
Maple Plain	9	47.3	6	31.6	2	10.5	1	5.3	1	5.3	19	10.6%	32.2	5/21/84	2.55
Oak Grove	8	28.6	9	32.1	11	39.3	0	0	0	0	28	0%	6.8	6/17/85	2.61
Prairie Farm	6	22.2	7	25.9	8	29.6	4	14.8	2	7.4	27	22.2%	29.1	10/3/84	4.99
Prairie Lake	4	6.3	14	22.2	28	44.4	13	20.6	4	6.3	63	26.9%	30.8	8/18/83	7.59
Rice Lake	7	22.6	11	35.5	11	35.5	2	6.5	0	0	31	6.5%	14.5	9/12/84	3.57
Sioux Creek	1	5.0	8	40.0	8	40.0	3	15.0	0	0	20	15.0%	17.7	1/16/84	4.95
Stanfold	5	31.3	6	37.5	5	31.3	0	0	0	0	16	0%	8.1	4/20/83	2.34
Stanley	11	18.6	10	16.9	32	54.2	6	10.2	0	0	59	10.2%	18.0	9/15/83	4.86
Sumner	8	34.8	8	34.8	6	26.1	0	0	1	4.3	23	4.3%	30.3	10/5/84	3.55
Turtle Lake	8	34.8	6	26.1	8	34.8	1	4.3	0	0	23	4.3%	18.1	8/29/84	2.80
Vance Creek	10	50.0	6	30.0	4	20.0	0	0	0	0	20	0%	4.5	8/3/83	1.37
TOTALS*	195	27.0	196	27.2	255	35.3	56	7.7	20	2.8	722	10.5%	42.3		

Data from: 1983-85 survey, county files, DNR noncommunity water supply and aldicarb monitoring programs.

61-120 (moderately hard)

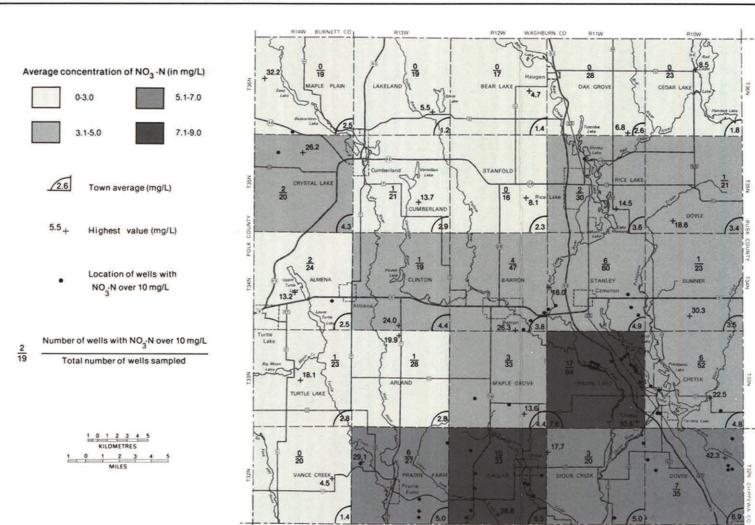


Figure 5. Nitrate distribution in Barron County, 1983-85, by town.

Twenty-two wells that exceeded 10 mg/L NO3-N during the first round of random sampling in 1983 were resampled in 1984 and showed essentially the same nitrate concentrations. The continuing presence of high amounts of nitrate indicated the presence of a pollution source. Therefore, the location of these wells - together with another 11 wells that tested high in nitrate during the second round of random sampling in 1984 were field-checked for pollution sources in 1985. The on-site inspection showed that leakage from septic tanks, runoff from barnyards and temporary manure storage areas, and overapplication of fertilizer, in combination with deficiencies in well construction, were probably the major sources of nitrate in the inspected wells.

Nitrate concentrations vary in space and time. Areal distribution of nitrate in Barron County was described previously. However, nitrate varies not only horizontally, but also vertically. In most instances, elevated nitrate concentrations can be found in water from relatively shallow wells (less than 50 ft deep). The relationship between well depth (specifically, well-casing depth) and nitrate concentration is shown in table 4. From the 383 wells randomly selected for testing during 1983-85, only 176 (46%) had available data about well construction. Table 4 shows less nitrate at greater depth, indicating that the shallow wells are more likely to be polluted by nitrate than the deeper wells.

		Nitrate-Nitrogen Concentration (mg/L)								
Casing depth (ft)	No. of	0 -	0.9	1.0 -	9.9	10.0 & more				
	wells	No. of wells	%	No. of wells	%	No. of wells	%			
0-49	57	6	10.6	34	59.6	17	29.8			
50- 74	44	15	34.1	27	61.4	2	4.5			
75- 99	27	7	25.9	19	70.4	1	3.7			
100-149	22	12	54.5	9	40.9	1	4.6			
150-199	20	13	65.0	6	30.0	1	5.0			

33.0

In an attempt to investigate long-term variations in nitrate concentrations over time nitrate data were compiled for 232 samples taken by various agencies during 1964-82. These analyses are not directly compatible with the results of the 1983-85 sampling because the samples were not taken from the same wells and were not randomly distribut ed. The concentration of NO3-N varied from 0 to 80 mg/L, and about 25 percent of the samples exceeded 10 mg/L. Eleven of 33 wells that contained higher concentrations of nitrate during 1964-72 were resampled in 1983-85. All of them except one had nitrate concentrations lower than those from the previous samplings.

96

54.5

A comparison of two DNR studies from 1980 and 1986 shows that the nitrate concentration has not changed significantly during the last 5 years. Noncommunity public water supply systems in Barron County (i.e., systems serving at least 25 people per day at least 60 days per year) are being periodically sampled for nitrate by the DNR. First sampling was done during 1979-80, when 125 systems were tested for nitrate (Wisconsin Department of Natural Resources, 1980). The sampling revealed that four (3.2%) noncommunity facilities out of the total 125 had average nitrate-nitrogen levels of 10 mg/L or greater. Median nitrate value was 1.1 mg/L NO<sub>3</sub>-N. In 1985, all noncommunity facilities in the county with detectable levels of nitrate (more than 0.5 mg/L) in 1979-80 were resampled (Strous, 1986). A comparison of the results of the two sampling periods shows no statistically significant trend. In 1985, the limit (10 mg/L) was exceeded in four (2.4%) of the total 166 facilities tested; the median was 2.6 mg/L. Compared to other Wisconsin counties, Barron County ranked 20th in 1980 and 24th in 1985 in median nitrate values; and 33rd in 1980 and 19th in 1985 in the percentage of wells that exceeded

There are two basic options in dealing with the nitrate problem: 1) reduce the nitrate intake at the source and 2) develop an alternative source of water. The first option includes proper location, construction, and maintenance of water wells (strict adherence to the Wisconsin well code); protection of fertilizers stored on land surface against rainfall and runoff; control of runoff from barnyards, feedlots, and manure-storage areas; and proper application of fertilizers based on soil tests, recommended rates of application, and proper timing. The removal of nitrate from water is difficult and can be accomplished only by demineralizing or distilling water; boiling water does not remove nitrate. hus, if a reduction in nitrate concentration is desired, the second option is to use water from an unaffected source or to reconstruct or relocate the well.

Three wells in the county were sampled frequently during our study to investigate short-term, seasonal variations of nitrate concentrations (fig. 6). Wells 49 and 4, both in Prairie Lake Township next to irrigated fields, were initially sampled quarterly during the DNR aldicarb monitoring. Starting in 1984, they were sampled monthly by the WGNHS for a period of 18 months. Well Br 661 in Maple Grove Township, one of the randomly selected wells, was first sampled in summer 1983 and then monthly from October 1984 to April 1986. Two springs in the town of Dovre were sampled during the same period to provide a comparison with natural fluctuations of nitrate levels. The springs fluctuated between 0.2 and 1.0 mg/L and 1.2 and 1.9 mg/L, respectively, showing a slightly increasing trend. No apparent annual cycles have been detected on monitored wells. However, all three wells showed significant decrease in nitrate levels from the peak in 1983, indicating possible impact of fertilizer-application patterns at surrounding fields. By 1985, nitrate levels dropped about 22 percent on well 49, 42 percent on well Br 661. and 66 percent on well 4. The peak on well 49 apparently followed planting of potatoes on a field across the road in 1981. In the subsequent years, other crops that demand less nitrogen were planted and nitrate concentration in the well decreased. Similar explanation applies to trends on well 4. Less clear is the trend on well Br 66l. Because of time and funding limits, no attempt was made in this study to correlate nitrate concentration with various soil types and with proximity to common sources of nitrate in wells, such as barnyards, feedlots, manure pits, and septic tanks. Continued monitoring of wells and analysis of land uses on surrounding fields will be necessary for a better understanding of seasonal variations in nitrate and their relation to crop rotation.

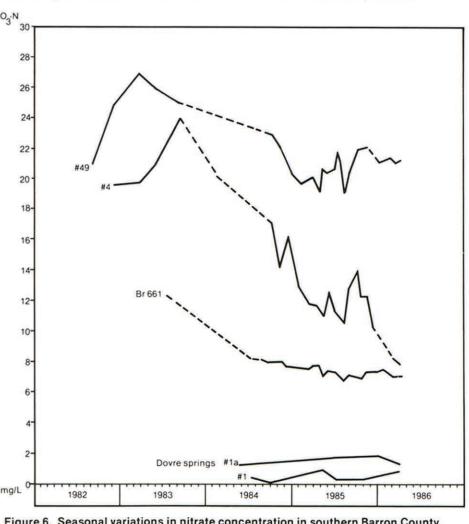


Figure 6. Seasonal variations in nitrate concentration in southern Barron County. REFERENCES

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