

Presence and Distribution of Nitrate and Selected Pesticides in Surficial-Sand Aquifers and Selected Lakes, 1993-94, East Otter Tail County, Minnesota

By Shannon E. Smith and James F. Ruhl

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Conversion Factors

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
degree Fahrenheit (°F)	$5/9 \times (°F - 32)$	degree Celsius (°C)

Chemical concentrations are given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Definition of Terms

Alkalinity: The sum of carbonate species in water; commonly reported as an equivalent amount of calcium carbonate; attributed mostly to dissolved forms of carbon dioxide if the pH of the water is less than 9.5.

Aquifer: Geologic or stratigraphic unit that contains sufficient saturated, permeable material to yield usable quantities of water to wells or springs.

Dissolved: The amount of a given constituent carried in solution that passes through a 0.45 micron membrane filter.

Ground water: Subsurface water that is in the saturated zone beneath the water table.

Hardness: The soap-consuming capacity of water; generally attributable to calcium and magnesium; commonly reported as an equivalent concentration of calcium carbonate. Water that ranges in hardness from 0 to 60 mg/L (as calcium carbonate) is soft, from 61 to 120 mg/L is moderately hard, from 121 to 180 mg/L is hard, and greater than 180 mg/L is very hard (Hem, 1985).

Metabolite: Decomposition product of a compound, such as a pesticide, after it begins to degrade in the environment.

Outwash: Sorted and stratified sand and gravel deposited by flowing meltwater from glacial ice.

Pesticides: A general term for agricultural chemicals used to kill crop pests; these chemicals include herbicides, insecticides, and fungicides. Only herbicides and insecticides were analyzed for in this study.

pH: A measure of the acidity (or alkalinity) of a solution; the negative logarithm of the concentration of hydrogen ions in solution. A pH of 7.0 indicates a neutral solution. pH values less than 7.0 indicate an acid solution and pH values greater than 7.0 indicate an alkaline solution.

Saturated zone: The part of a surficial or unconfined aquifer where all of the pore space is filled with water. The water table is the upper limit of this zone. Water in the saturated zone is under pressure equal to or greater than atmospheric.

Specific conductance: The capacity of water to conduct an electrical current; generally proportional to the dissolved solids concentration in most dilute natural water.

Unconfined aquifer: A water-bearing formation that is not completely saturated with water; an aquifer that has a water table. Also referred to as a surficial or water-table aquifer.

Water table: The level in the saturated zone where the water pressure is atmospheric; in an unconfined aquifer this level is the same as the top of the saturated zone.

Presence and Distribution of Nitrate and Selected Pesticides in Surficial-Sand Aquifers and Selected Lakes, 1993-94, East Otter Tail County, Minnesota

By S.E. Smith and J.F. Ruhl

Abstract

This report presents selected data collected during the first year (December 1993 to September 1994) of a three year water-quality study of surficial-sand aquifers and selected lakes in east Otter Tail County, Minnesota. The objectives of the study are (1) to determine the presence and distribution of nitrate-nitrogen and selected pesticides in ground water from the surficial-sand aquifers; and (2) to characterize the water quality of selected lakes and the Otter Tail River.

Ground water was sampled from 73 wells. The concentration of nitrate nitrogen in ground water was above 10 mg/L (milligrams per liter) in 30 of the sampled wells (38 percent). The concentration of triazine herbicide compounds, as determined by immunoassay, was above the detection limit 0.10 µg/L (micrograms per liter) in water from 17 of the sampled wells (24 percent). The nitrate-nitrogen concentration in water from 14 wells, compared to data collected during a previous study in 1979-81, increased in water from 4 wells and decreased in water from 4 wells.

Lake water was sampled from 11 sites on Little Pine, Big Pine, Rush, and Otter Tail Lakes. Nitrate-nitrogen concentrations were all below the detection limit (0.05 mg/L). The concentration of triazine herbicide compounds, as determined by immunoassay, was at or below the detection limit (0.10 µg/L) at all 11 sites. Dissolved oxygen concentrations at the sites ranged from 7.3 to 10.1 mg/L at the water surface, and from 5.3 to 9.7 mg/L at depth. Secchi disk transparency readings ranged from 4.0 to 7.4 feet. Total phosphorus concentrations were generally near or below the detection limit (0.01 mg/L) except at one site where the water had a total phosphorus concentration of 0.06 mg/L.

INTRODUCTION

The presence of nitrates and pesticides in ground and surface water is a source of concern in Minnesota. Nitrogen fertilizers and pesticides applied to agricultural land are potential sources of contamination to ground and surface water. Agriculture is a major land use in east Otter Tail County, Minnesota, which is underlain by unconfined surficial-sand aquifers and overlain by lakes. Lakes and rivers are vulnerable to contaminants transported in runoff or in ground-water discharge. Contaminants may leach into aquifers by water percolating from the land surface to the water table. The use of irrigation systems may increase the concentrations of contaminants in surface and ground water. An investigation of the presence and distribution of nitrates and pesticides in ground and surface water in east Otter Tail County is being conducted by the U.S.

Geological Survey in cooperation with the East Otter Tail County Soil and Water Conservation District and the Minnesota Department of Natural Resources (MDNR). This investigation will benefit local water resource managers and citizens by providing them information about ground- and surface-water quality in the county.

The maximum permissible level of nitrate and pesticides in a public water supply system is the maximum contaminant level (MCL) established by the U.S. Environmental Protection Agency (USEPA). The MCL for nitrate-nitrogen is 10 mg/L (U.S. Environmental Protection Agency, 1991). Most pesticides and pesticide metabolites do not have an established MCL. Pesticides that do have established MCLs include atrazine (3 µg/L), alachlor (2 µg/L), aldicarb (3 µg/L), aldicarb sulfone (2 µg/L), aldicarb

sulfoxide (4 µg/L), carbofuran (40 µg/L), 2,4-D (70 µg/L), lindane (0.2 µg/L), and silvex (50 µg/L) (U.S. Environmental Protection Agency, 1991).

Objectives and Purpose

The objectives of the study are: (1) to determine the presence and distribution of nitrate-nitrogen and selected pesticides in ground water from the surficial-sand aquifers; and (2) to characterize the water quality of selected lakes and the Otter Tail River. This report: (1) presents selected data collected during the first year of a three-year study, including ground-water quality data collected from 73 wells completed in the surficial-sand aquifers and surface-water quality data collected at 11 sites on Little Pine, Big Pine, Rush, and Otter Tail Lakes (fig. 1, in the back of this report) and (2) compares nitrate-nitrogen concentrations to results from a previous study conducted in this area during 1979-81.

Description of Study Area

East Otter Tail County, in west-central Minnesota, is typical of many areas in the glaciated Upper Midwest that are comprised of surficial-glacial outwash. Surficial-glacial outwash consists of sand and gravel, and generally are unconfined, or water-table aquifers, hereinafter referred to as surficial-sand aquifers.

Approach and Methods

Ground-water samples were collected from 73 wells. Sampled wells include 21 monitoring wells installed by the U.S. Geological Survey, 5 monitoring wells installed by the MDNR, and 47 privately owned wells used mostly for domestic and livestock supplies. Well depths were obtained from three sources: (1) well logs recorded by the driller for the 26 monitoring wells; (2) a report published by Myette (1982) for 14 privately owned wells resampled in this study; and (3) the well owner's descriptions for the other 33 privately owned wells (many of these wells were hand-driven sand point wells that were assumed to have a depth of 30 feet or less).

Prior to collection of ground-water samples, the sampled wells were pumped for about 20 minutes while the water was monitored for temperature, specific conductance, pH, and dissolved oxygen. The quality of sampled water was assumed to be representative of the quality of ground water in the aquifer when these properties stabilized.

Lake-water samples were collected at 11 sites on Little Pine, Big Pine, Rush, and Otter Tail Lakes.

Samples were collected by depth integration from the lake surface to a depth equal to about 1.5 times the secchi disk transparency reading. Secchi disk transparency readings and vertical profiles of temperature, specific conductance, pH, and dissolved oxygen were measured at each lake site.

Measurements of water-quality characteristics including temperature, specific conductance, pH, dissolved oxygen, and transparency were made in the field with portable meters that were calibrated at the start of each sampling day. Water samples were analyzed for nutrients, chloride, and pesticides at the U.S. Geological Survey National Water-Quality Laboratory in Arvada, Colorado. Quality control replicate, blank, and spiked water samples for nutrients and pesticides were analyzed at the U.S. Geological Survey National Water-Quality Laboratory.

Water samples from the wells and lakes were analyzed to determine the concentrations of nitrogen and phosphorous nutrients, chloride, and triazine herbicide compounds. The combined concentration of nitrite nitrogen and nitrate nitrogen is considered to be equivalent to the concentration of nitrate nitrogen because the concentration of nitrite nitrogen generally was negligible.

Triazine concentrations were determined by immunoassay method (Millipore¹, Marlborough, Massachusetts; Thurman and others, 1990) at the Minnesota District laboratory in Mounds View, Minnesota. A triazine concentration greater than or equal to 0.10 µg/L indicates that a combination of one or more triazine herbicide compounds or metabolites are present in the water sample. Triazine herbicide compounds detected by this method include ametryn, atrazine, cyanazine, de-ethyl atrazine, prometon, prometryn, propazine, simazine, simetryn, terbuthylazine, terbutryn, and trietazine. The results are reported as µg/L as atrazine. Water from 11 wells was analyzed for commonly used herbicides and insecticides by gas chromatography/mass spectrometry (GC/MS).

Well-Location System

The system used to locate wells in this report is based on the Federal system of land subdivision (township, range, and section) (fig. 2, in the back of this report). In this system, the first number of a location number

¹ The use of brand names in this report is for identification purposes only and does not constitute an endorsement by the U.S. Geological Survey.

indicates the township; the second, the range; and the third, the section in which the well is located. Uppercase letters after the section number indicate location within the section. Letters A, B, C, and D are assigned in a counterclockwise direction, beginning in the northeast corner of each tract. The first letter denotes the 160-acre tract; the second, the 40-acre tract; and the third, the 10-acre tract. For example, the well location T136NR39W16ADC indicates a well in the SW 1/4 of the SE 1/4 of the NE 1/4 of section 16, township 136 north, range 39 west.

Acknowledgments

We are grateful to the many land owners in east Otter Tail County who gave us permission to obtain samples of their well water, or who allowed us to install a monitoring well on their property.

Ground-Water Quality

The concentration of nitrate nitrogen ranged from less than the detection limit (0.05 mg/L) to 50 mg/L (table 1, in the back of this report). Twenty-eight of the sampled wells (38 percent) had water with a nitrate-nitrogen concentration higher than the MCL of 10 mg/L (fig. 3, in the back of this report).

The wells were grouped into two total depth categories: deep wells with a depth greater than 40 feet below the land surface (15 wells) or shallow wells with a depth less than or equal to 40 feet (58 wells). Five of the deep wells (33 percent of the deep wells) had water with a nitrate-nitrogen concentration higher than 10 mg/L. Twenty-three of the shallow wells (40 percent of the shallow wells) had water with a nitrate-nitrogen concentration higher than 10 mg/L.

Fourteen wells sampled in 1993-94 also were sampled in 1979-81 as a part of an earlier study (Myette, 1982 and 1984) (table 2). The nitrate-nitrogen concentration in water from five of these wells was higher than 10 mg/L in 1993-94. Water from four wells had a nitrate-nitrogen concentration that increased between 1.4 and 8.9 times from the 1979-81 period to the 1993-94 period (wells 19, 37, 60, 72). The concentration in water from 4 wells decreased from the 1979-81 period to the 1993-94 period (wells 7, 31, 41, 54).

The estimated concentration of triazine herbicide compounds determined by immunoassay in water from 72 of the wells ranged from less than the detection limit (0.10 µg/L) to 3.71 µg/L (table 1). Seventeen of these wells (24 percent) had a triazine concentration greater

Table 2.-- Nitrate-nitrogen concentration in water from 14 wells for 1979-81 (Myette, 1982) and 1993-94, east Otter Tail County, Minnesota [mg/L, milligrams per liter; (2), number of samples used for calculation of mean, where number of wells is greater than one; <, less than]

Local identifier	Nitrogen, nitrite plus nitrate, dissolved (mg/L as nitrogen) 1979-81	Nitrogen, nitrite plus nitrate, dissolved (mg/L as nitrogen) 1993-94
6	0.04	0.14
7	9.1	3.0
19	14.6 (5)	28.0
31	.49 (6)	<.05
37	5.6	50.0
39	12.0	13.0
41	.32 (6)	<.05
44	7.2 (5)	7.1 (2)
45	.42 (15)	.14
54	.72	<.05
57	.04	<.05
59	.04 (6)	<.05
60	2.1 (6)	15.5 (2)
72	10.2 (5)	14.0 (2)

than the detection limit (fig. 4, in the back of this report). Two of these wells were deep wells (13 percent of the deep wells) and 15 were shallow wells (26 percent of the shallow wells).

Water from 11 wells was analyzed by GC/MS for selected pesticides (table 3, in the back of this report). The concentrations of most of these compounds were below their respective detection limits. Atrazine, cyanazine, de-ethyl atrazine, and metribuzin were detected at or near the detection limit (0.02, 0.01, 0.01, and 0.01 µg/L, respectively) in a total of six wells. Water from wells 1, 3, and 23 had atrazine concentrations of 0.01 µg/L and water from wells 9 and 28 had atrazine concentrations of 0.02 µg/L. Water from well 23 had a cyanazine concentration of 0.02 µg/L. Water from wells 3, 9, and 28 had de-ethyl atrazine concentrations of 0.05, 0.02, and 0.01 µg/L, respectively. Water from well 5 had a metribuzin concentration of 0.05 µg/L. These concentrations are below the MCLs for any herbicide.

Lake-Water Quality

Water samples were collected at 11 sites on Little Pine, Big Pine, Rush, and Otter Tail Lakes in September 1994 (fig. 1). The nitrate-nitrogen concentration was below the detection limit of 0.05 mg/L at each of the 11 sites (table 4, in the back of this report). The concentration of triazine herbicide compounds, as determined by immunoassay, was at or below the detection limit (0.10 µg/L) at all 11 sites. Site L10, near the outlet of Otter Tail Lake, had trace amounts of triazine herbicide compounds detected at 0.10 µg/L.

Vertical profiles of specific conductance, pH, temperature, and dissolved oxygen were measured at 11 sites. Table 4 shows water-quality data at the water surface and at the deepest point for each site. The values for these properties changed very little with depth except for two sites (L3 and L7). The dissolved oxygen concentrations generally ranged from 7.1 to 10.1 mg/L throughout the water column. The dissolved oxygen concentration decreased with depth at site L3 on Big Pine Lake, where the concentration decreased from 9.2 mg/L at the surface to 5.3 mg/L at a depth of 10.7 feet, and at site L7 on Rush Lake, where the concentration decreased from 10.1 mg/L at the surface to 6.8 mg/L at a depth of 21.6 feet.

The measured and analyzed values for transparency and phosphorus are also listed in table 4. The secchi disk transparency readings were: 4.1 feet on Little Pine Lake, 4.0-5.4 feet on Big Pine Lake, 4.4-5.0 feet on Rush Lake, and 4.3-7.4 feet on Otter Tail Lake. The total phosphorus concentrations ranged from less than 0.01 to 0.02 mg/L at all sites except L7 on Rush Lake, where total phosphorus concentration was 0.06 mg/L.

References

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- Thurman, E.M., Meyer, Michael, Pomes, Michael, Perry, C.A., and Schwab, A.P., 1990, Enzyme-linked immunosorbent assay compared with gas chromatography/mass spectrometry for the determination of triazine herbicides in water: *Analytical Chemistry*, v. 62, no. 18, p. 2043-2048.
- U.S. Environmental Protection Agency, 1991, Is your drinking water safe?: Washington D.C., U.S. Environmental Protection Agency Report 570/09-91-005, 24 p.

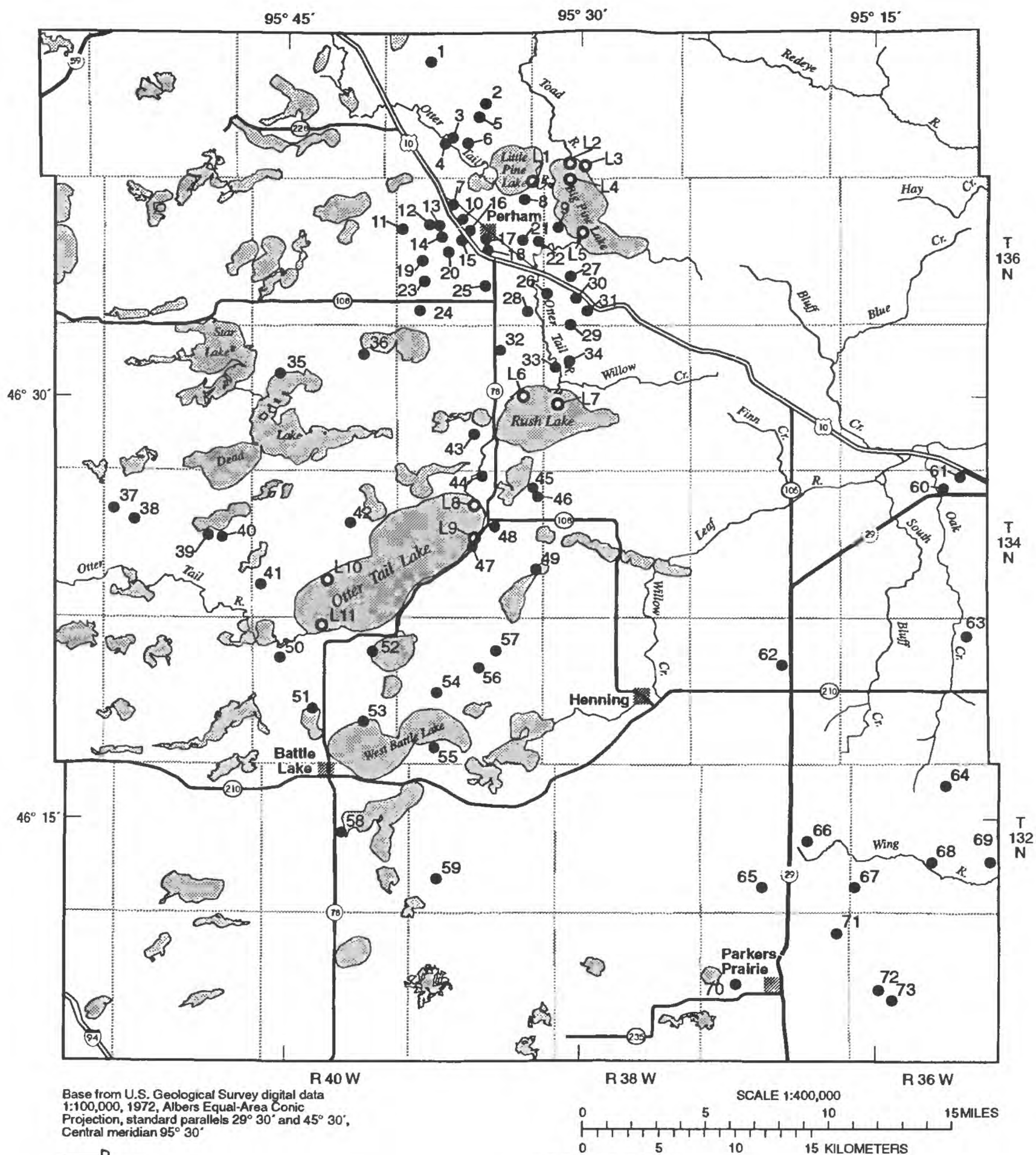


Figure 1. Location of wells and lake sites where water-quality data were collected, east Otter Tail County, Minnesota.

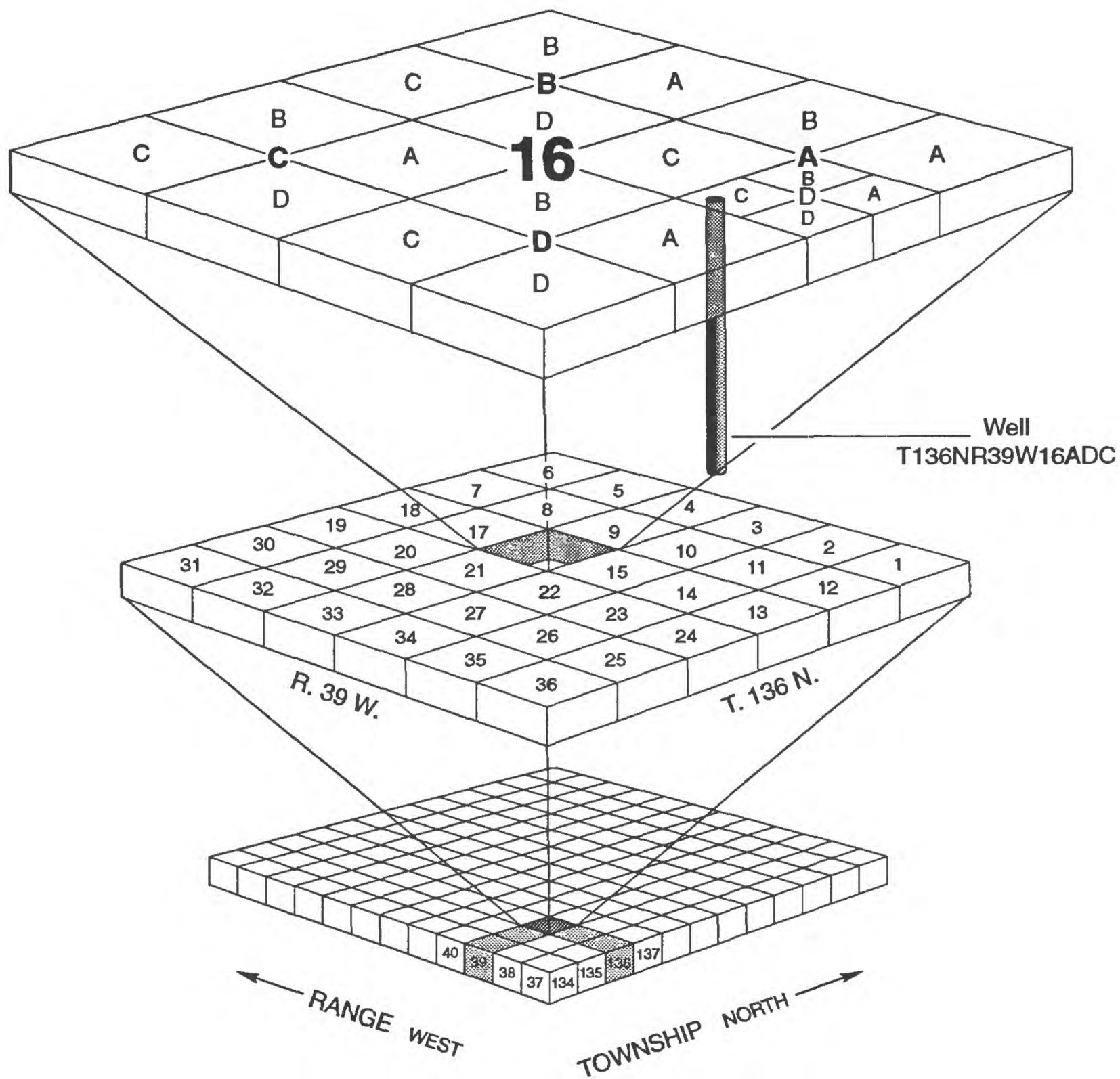
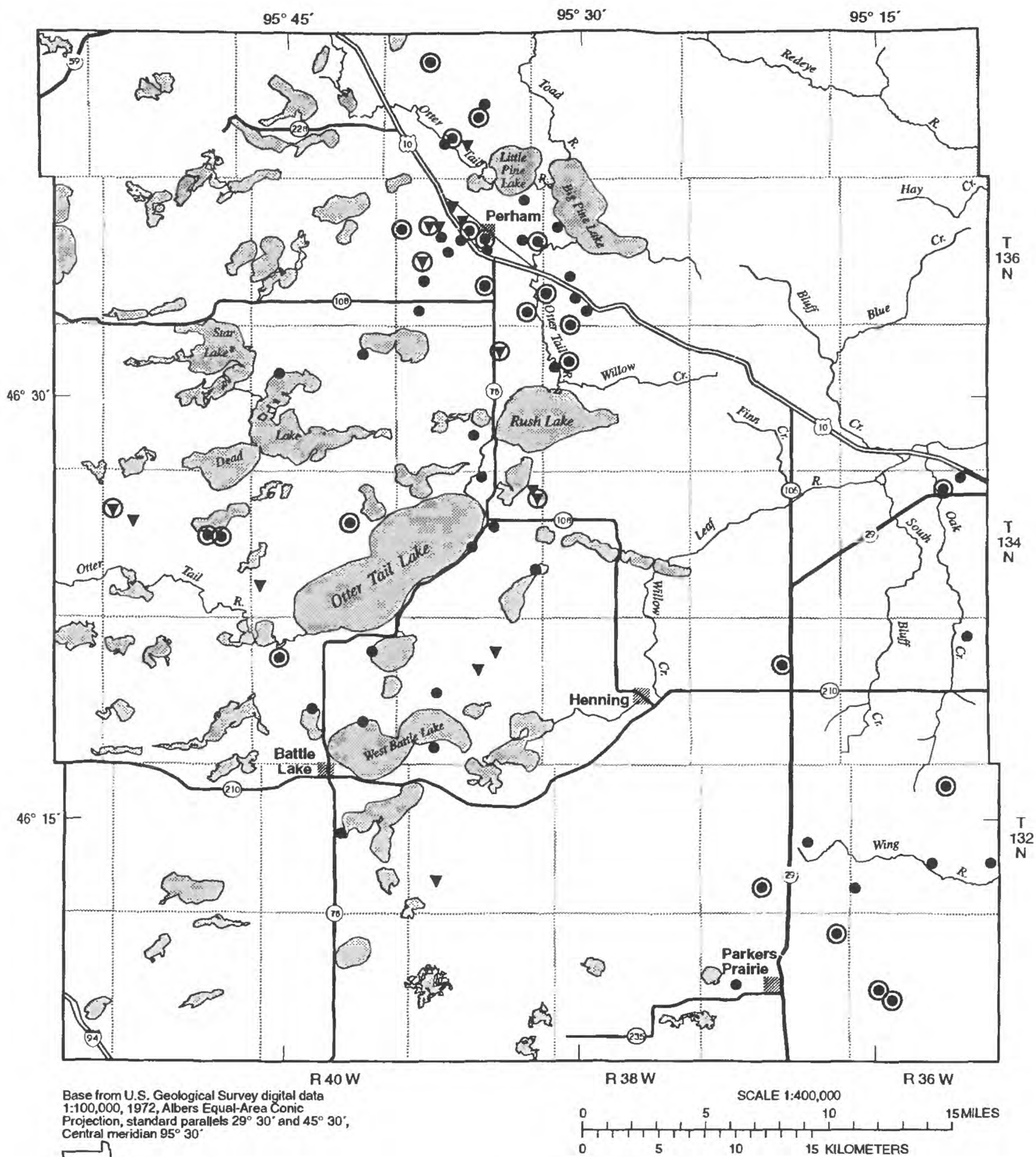


Figure 2. Well-location system.



- EXPLANATION**
- ▼ Deep wells (depth greater than 40 feet)
 - Shallow wells (depth less than or equal to 40 feet)
 - ▼ Wells with nitrate-nitrogen concentrations greater than 10 milligrams per liter

Figure 3. Location of wells sampled and analyzed for nitrate nitrogen, 1993-94, east Otter Tail County, Minnesota.

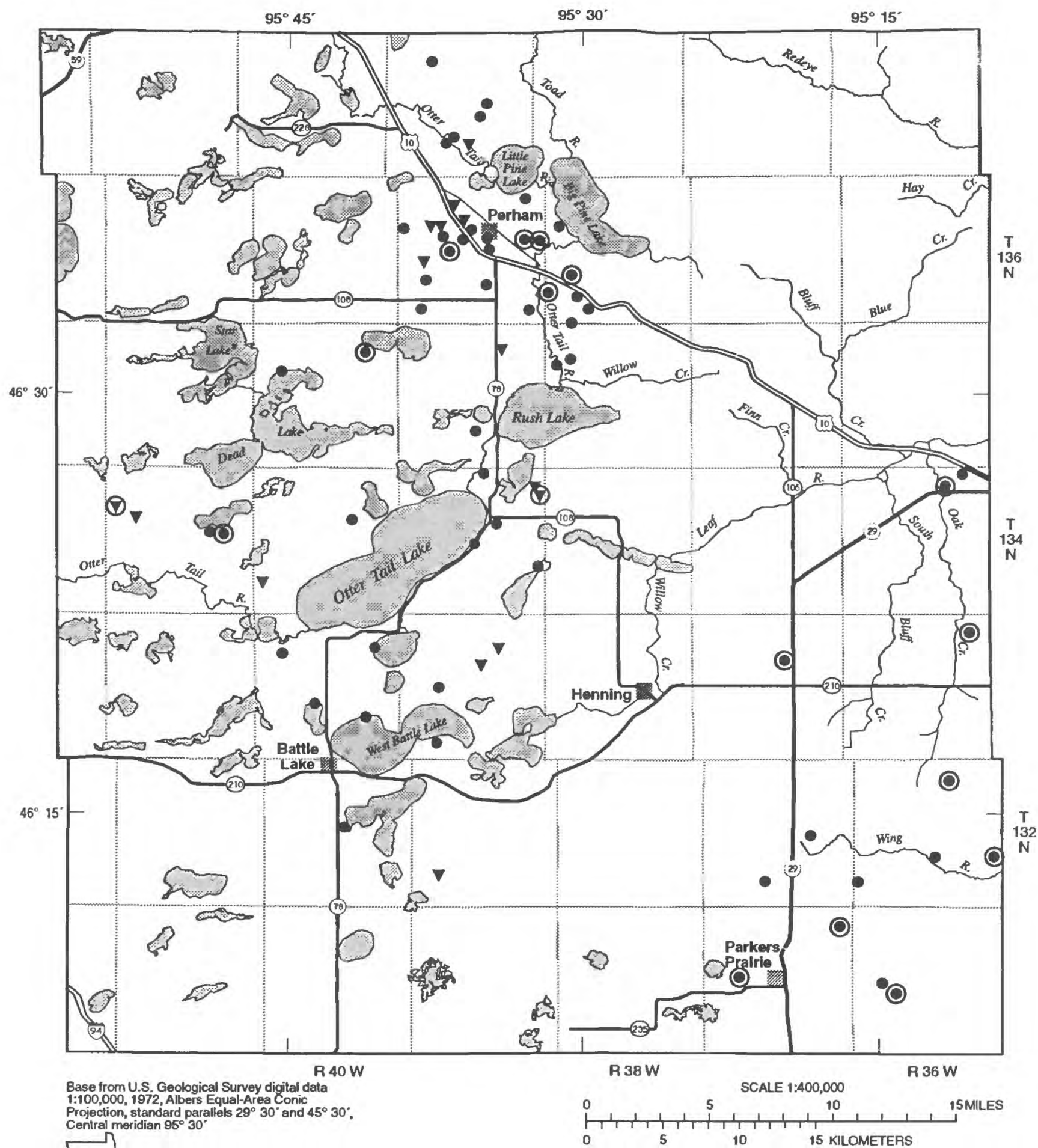


Figure 4. Location of wells sampled and analyzed for triazine herbicide compounds by immunoassay, 1993-94, east Otter Tail County, Minnesota.

Table 1.--Water-quality data for wells sampled in 1993-94, east Otter Tail County, Minnesota
[(mm/dd/yy), month/day/year; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than]

Location	Local identifier	Date (mm/dd/yy)	Depth of well below land surface ¹ , (feet)	pH, field (standard units)	Oxygen, dissolved (mg/L)	Chloride, dissolved (mg/L as Cl)	Nitrogen, nitrite, dissolved (mg/L as N)				Nitrogen, nitrate, dissolved (mg/L as N)		Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Triazine herbicide compounds (µg/L as atrazine)
T137NR39WS08AAC	1	06/21/94	29.0	7.5	9.1	56	<0.01	<0.01	29.0	0.02	<0.01	<0.01	<0.01	<0.10	<0.10
T137NR39WS15DDA	2	06/16/94	14.0	7.3	<.3	4.2	.04	.04	<.05	.02	.04	.04	.04	<.10	<.10
T137NR39WS28ACA	3	06/14/94	10.5	7.2	<.1	17	<.01	<.01	12.0	.02	.04	.04	.03	<.10	<.10
T137NR39WS28CAB	4	06/16/94	12.1	7.6	<.1	2.8	<.01	<.01	.39	.30	.03	.03	.02	<.10	<.10
T137NR39WS22ACC	5	06/02/94	24.0	7.4	.6	51	.09	.09	13.0	<.01	<.01	<.01	<.01	--	--
T137NR39WS27BDD	6	12/15/93	68.0	7.3	.2	3.1	.02	.02	.14	2.6	--	--	.07	<.10	<.10
T136NR39WS04CCD	7	12/15/93	90.0	7.3	.2	4.9	.03	.03	3.0	.04	--	--	<.01	<.10	<.10
T136NR39WS01CCB	8	06/29/94	9.0	7.7	7.0	5.6	<.01	<.01	6.7	.02	.01	.01	.02	<.10	<.10
T136NR38WS07CDD	9	07/25/94	31.0	7.9	9.8	.70	<.01	<.01	3.2	.03	<.01	<.01	<.01	<.10	<.10
T136NR39WS09DDC	10	06/17/94	80.0	7.3	1.7	4.7	<.01	<.01	2.3	.03	--	--	.01	<.10	<.10
T136NR39WS18BBB	11	06/16/94	<30.0	7.4	5.1	7.4	<.01	<.01	14.0	<.01	--	--	.04	<.10	<.10
T136NR39WS08CCD	12	07/14/94	50.0	7.6	.3	44	.02	.02	14.0	.02	.02	.02	.01	<.10	<.10
T136NR39WS08CCD	13	06/14/94	91.0	7.3	.2	37	<.01	<.01	.84	.01	--	--	.06	<.10	<.10
T136NR39WS17ABA	14	06/15/94	25.0	7.3	0	16	<.01	<.01	<.05	.03	--	--	.07	<.10	<.10
T136NR39WS16ADC	15	06/14/94	30.0	7.1	10.1	14	.01	.01	.37	.02	--	--	<.01	<.10	<.10
T136NR39WS16AAA	16	07/18/94	33.8	7.2	9.5	1.7	.01	.01	14.0	.02	--	--	.01	<.10	<.10
T136NR39WS15BDD	17	07/20/94	32.7	7.5	9.9	1.9	.03	.03	14.0	.02	--	--	<.01	<.10	<.10
T136NR39WS15CAA	18	06/09/94	<30.0	7.3	6.0	13	<.01	<.01	9.9	.02	--	--	<.01	<.10	<.10
T136NR39WS19ABD	19	06/17/94	90.0	7.3	6.1	28	<.01	<.01	28.0	<.01	--	--	<.01	<.10	<.10
T136NR39WS17DDD	20	07/12/94	8.5	7.2	3.1	14	<.01	<.01	.12	.03	.02	.02	<.01	.26	.26
T136NR39WS13CBB	21	06/15/94	32.0	7.6	10.1	4.9	<.01	<.01	5.6	<.01	--	--	<.01	.71	.71
T136NR39WS13DBB	22	06/15/94	30.0	7.0	9.3	240	<.01	<.01	35.0	<.01	--	--	.01	2.73	2.73
T136NR39WS29BBB	23	06/30/94	9.0	7.0	.9	3.8	<.01	<.01	<.05	.14	.07	.07	.05	<.10	<.10
T136NR39WS31ADC	24	07/14/94	24.5	7.4	3.2	15	<.01	<.01	.01	1.5	.08	.08	.06	<.10	<.10
T137NR39WS27ADD	25	07/25/94	18.0	7.5	7.7	50	<.01	<.01	46.0	.02	<.01	<.01	<.01	<.10	<.10

Table 1.--Water-quality data for wells sampled in 1993-94, east Otter Tail County, Minnesota--Continued

Location	Local identifier	Date (mm/dd/yy)	Depth of well below land surface, (feet)	pH, field (standard units)	Oxygen, dissolved (mg/L)	Chloride, dissolved (mg/L as Cl)	Nitrogen, nitrite, dissolved (mg/L as N)			Nitrogen, nitrate, dissolved (mg/L as N)			Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Triazine herbicide compounds (µg/L as atrazine)
T136NR39WS25DAD	26	07/12/94	25.0	7.5	9.3	41	<0.01	43.0	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	2.92
T136NR38WS29BBB	27	07/13/94	33.0	7.4	6.7	--	--	--	--	--	--	--	--	--	.17
T136NR39WS36BCD	28	06/28/94	28.7	7.4	9.2	15	<.01	12.0	.02	.01	.01	.01	.01	.01	<.10
T136NR38WS31DDD	29	07/13/94	13.5	7.6	8.9	1.0	<.01	13.0	<.01	<.01	<.01	<.01	<.01	<.01	<.10
T136NR38WS29CCA	30	06/29/94	24.3	7.5	1.0	16	<.01	<.05	.02	<.01	<.01	<.01	<.01	<.01	<.10
T136NR38WS32ABB	31	12/15/93	20.0	7.3	.7	21	.02	<.05	.12	--	--	.04	.04	.04	<.10
T135NR39WS11BBB	32	07/11/94	41.0	7.4	6.4	53	<.01	16.0	.01	.02	.02	<.01	<.01	<.01	<.10
T135NR38WS07CAC	33	07/13/94	9.0	7.6	1.1	39	<.01	<.05	.03	.05	.05	.04	.04	.04	<.10
T135NR38WS07ADD	34	07/13/94	10.0	7.1	3.8	2.3	<.01	15.0	.01	.20	.20	.20	.20	.20	<.10
T135NR40WS08CCC	35	06/13/94	<30.0	7.4	.2	1.0	<.01	.11	.29	--	--	.06	.06	.06	<.10
T135MR40WS02DDC	36	06/13/94	<30.0	7.3	7.2	26	<.01	2.7	<.01	--	--	<.01	<.01	<.01	.31
T134NR41WS07CAA	37	12/17/93	80.0	6.6	.3	160	.04	50.0	1.0	--	--	<.01	<.01	<.01	3.71
T134NR41WS08CCC	38	06/17/94	43.0	6.6	6.9	12	.10	5.9	.11	--	--	<.01	<.01	<.01	<.10
T134NR41WS14CAA	39	12/16/93	16.0	7.3	10.1	19	<.01	13.0	.04	--	--	.02	.02	.02	<.10
T134NR41WS14DAB	40	06/14/94	23.0	7.1	6.8	10	<.01	20.0	.02	--	--	<.01	<.01	<.01	.25
T134NR40WS30CAB	41	12/16/93	70.0	7.1	.1	4.8	<.01	<.05	.28	--	--	.04	.04	.04	<.10
T134NR40WS15AAD	42	06/09/94	37.0	7.3	3.0	22	<.01	16.0	.02	--	--	.08	.08	.08	<.10
T135NR39WS28ADD	43	07/20/94	13.1	7.7	4.8	1.0	<.01	4.9	.03	--	--	.04	.04	.04	<.10
T134NR39WS03BAD	44	12/15/93	25.0	7.1	3.7	6.8	.02	6.5	.03	--	--	.02	.02	.02	<.10
T134NR39WS03BAD	44	07/20/94	25.0	9.1	2.5	7.7	<.01	7.6	.01	--	--	.01	.01	.01	<.10
T134NR39WS01ACD	45	12/15/93	60.0	7.0	.1	17	.02	.14	.27	--	--	<.01	<.01	<.01	<.10
T134NR39WS01ACD	46	06/16/94	52.5	7.1	.1	29	.30	33.0	.02	--	--	<.01	<.01	.28	.28
T134NR39WS15CCD	47	07/20/94	<30.0	7.0	3.2	70	<.01	3.8	.03	--	--	<.01	<.01	<.01	<.10
T134NR39WS15AAC	48	06/10/94	<30.0	7.2	.4	19	.02	7.0	.03	--	--	.01	.01	.01	<.10
T134NR39WS24DCC	49	07/20/94	<30.0	7.1	4.5	3.0	<.01	5.0	.02	--	--	<.01	<.01	<.01	<.10
T133NR40WS08CBC	50	06/14/94	<30.0	7.2	3.8	15	<.01	13.0	.01	--	--	<.01	<.01	<.01	<.10

Table 1.--Water-quality data for wells sampled in 1993-94, east Otter Tail County, Minnesota--Continued

Location	Local identifier	Date (mm/dd/yy)	Depth of well below land surface, (feet)	pH, field (standard units)	Oxygen, dissolved (mg/L)	Chloride, dissolved (mg/L as Cl)	Nitrogen, nitrite, dissolved (mg/L as N)				Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)		Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Triazine herbicide compounds (µg/L as atrazine)
T133NR40WS21CAD	51	06/08/94	<30.0	8.1	0.6	6.4	<0.01	<0.01	<0.01	<0.01	<0.05	0.19	--	0.02	<0.10
T133NR40WS11ADC	52	06/14/94	<30.0	7.3	.1	9.3	<.01	<.01	<.01	.13	.13	.01	--	.01	<.10
T133NR40WS26BDA	53	07/20/94	<30.0	7.4	.1	10	<.01	<.01	<.01	.03	.03	.05	--	.05	<.10
T133NR39WS17CDD	54	07/19/94	38.0	7.5	.1	--	<.01	<.01	<.01	1.0	1.0	.07	--	.07	<.10
T133NR39WS32BDA	55	07/19/94	34.7	7.4	10.1	1.8	<.01	<.01	<.01	.01	.01	.01	--	.01	<.10
T133NR39WS10CCD	56	06/16/94	42.0	7.4	.9	1.0	<.01	<.01	<.01	.13	.13	<.01	--	<.01	<.10
T133NR39WS10ADC	57	12/16/93	83.0	7.6	.2	.90	<.01	<.01	<.01	.16	.16	.07	--	.07	<.10
T132NR40WS15CCD	58	06/08/94	32.0	7.3	5.7	4.4	<.01	<.01	<.01	.02	.02	<.01	--	<.01	<.10
T132NR39WS29CBB	59	12/16/93	45.0	7.5	.1	3.9	<.01	<.01	<.01	1.2	1.2	.03	--	.03	<.10
T134NR36WS02CCD	60	12/15/93	20.0	7.3	10	46	.02	.02	.02	.03	.03	<.01	--	<.01	.29
T134NR36WS02CCD	60	07/21/94	20.0	7.4	8.5	48	<.01	<.01	<.01	.03	.03	<.01	--	<.01	.16
T134NR36WS01BBA	61	06/17/94	39.0	7.2	.1	7.7	<.01	<.01	<.01	.62	.62	.07	--	.07	<.10
T133NR37WS10CDD	62	07/19/94	14.3	7.0	6.4	16	.04	.04	.04	.03	.03	<.01	--	<.01	.12
T133NR36WS01CBC	63	07/19/94	17.0	7.1	.6	7.1	<.01	<.01	<.01	.02	.02	.01	--	.01	.40
T132NR36WS03DCA	64	06/09/94	<30.0	7.3	5.5	17	<.01	<.01	<.01	.01	.01	<.01	--	<.01	.14
T132NR37WS28CDC	65	06/08/94	<30.0	7.4	8.8	13	<.01	<.01	<.01	<.01	<.01	.01	--	.01	<.10
T132NR37WS23BBA	66	06/07/94	<30.0	7.4	.1	1.2	<.01	<.01	<.01	.43	.43	.06	--	.06	<.10
T132NR36WS30CCC	67	06/09/94	<30.0	6.8	.1	5.1	.01	.01	.01	.13	.13	.04	--	.04	<.10
T132NR36WS22CBB	68	06/09/94	<30.0	7.2	8.2	5.6	<.01	<.01	<.01	.02	.02	<.01	--	<.01	<.10
T132NR36WS24DDDD	69	06/07/94	28.0	7.0	.3	16	<.01	<.01	<.01	.56	.56	.07	--	.07	.14
T131NR37WS17BDB	70	06/09/94	<30.0	7.1	2.3	12	<.01	<.01	<.01	.02	.02	.01	--	.01	.16
T131NR37WS01CDB	71	06/10/94	<30.0	7.2	.1	8.2	.08	.08	.08	.03	.03	.20	--	.20	3.12
T131NR36WS19AAA	72	12/16/93	18.0	7.3	.7	23	<.01	<.01	<.01	.04	.04	<.01	--	<.01	<.10
T131NR36WS19AAA	72	06/07/94	18.0	7.2	1.6	22	<.01	<.01	<.01	.02	.02	<.01	--	<.01	<.10
T131NR36WS20ACC	73	06/07/94	<30.0	7.2	.8	22	<.01	<.01	<.01	.01	.01	<.01	--	<.01	.16

¹ Wells with a depth below land surface of <30.0 feet are sand point wells where the depth is unknown.

Table 3.--Selected pesticides analyzed in 1994, east Otter Tail County, Minnesota--Continued

Location	Local identifier	Date (mm/dd/yy)	Diazinon, dissolved (µg/L)	Dieldrin, dissolved (µg/L)	Lindane, dissolved (µg/L)	Malathion, dissolved (µg/L)	MCPA, dissolved (µg/L)	Metolachlor, dissolved (µg/L)	Metribuzin, dissolved (µg/L)	Parathion, dissolved (µg/L)	Pemethrin, dissolved (µg/L)
T137NR39WS08AAC	1	06/21/94	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.02	<0.02
T137NR39WS15DDA	2	06/16/94	--	--	--	--	--	--	--	--	--
T137NR39WS28ACA	3	06/14/94	<0.01	<0.01	<0.01	<0.01	--	<0.01	<0.01	<0.02	<0.02
T137NR39WS28CAB	4	06/16/94	--	--	--	--	<0.05	--	--	--	--
T137NR39WS22ACC	5	06/02/94	<0.01	<0.01	<0.01	<0.01	--	<0.01	.05	<0.02	<0.02
T136NR39WS01CCB	8	06/29/94	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.02	<0.02
T136NR38WS07CDD	9	07/25/94	<0.01	<0.01	<0.01	<0.01	--	<0.01	<0.01	<0.02	<0.02
T136NR39WS08CCD	12	07/14/94	<0.01	<0.01	<0.01	<0.01	--	<0.01	<0.01	<0.02	<0.02
T136NR39WS29BBB	23	06/30/94	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.02	<0.02
T136NR39WS36BCD	28	06/28/94	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.02	<0.02
T136NR38WS29CCA	30	06/29/94	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.02	<0.02

Table 3.--Selected pesticides analyzed in 1994, east Otter Tail County, Minnesota--Continued

Location	Local identifier	Date (mm/dd/yy)	Triazine herbicide compounds				Trifluralin, dissolved ($\mu\text{g/L}$)
			Prometon, dissolved ($\mu\text{g/L}$)	Propanil, dissolved ($\mu\text{g/L}$)	Simazine, dissolved ($\mu\text{g/L}$)	Terbufos, dissolved ($\mu\text{g/L}$)	
T137NR39WS08AAC	1	06/21/94	<0.01	<0.02	<0.01	<0.01	<0.01
T137NR39WS15DDA	2	06/16/94	--	--	--	--	--
T137NR39WS28ACA	3	06/14/94	<0.01	<0.02	<0.01	<0.01	<0.01
T137NR39WS28CAB	4	06/16/94	--	--	--	--	--
T137NR39WS22ACC	5	06/02/94	<0.01	<0.02	<0.01	<0.01	<0.01
T136NR39WS01CCB	8	06/29/94	<0.01	<0.02	<0.01	<0.01	<0.01
T136NR38WS07CDD	9	07/25/94	<0.01	<0.02	<0.01	<0.01	<0.01
T136NR39WS08CCD	12	07/14/94	<0.01	<0.02	<0.01	<0.01	<0.01
T136NR39WS29BBB	23	06/30/94	<0.01	<0.02	<0.01	<0.01	<0.01
T136NR39WS36BCD	28	06/28/94	<0.01	<0.02	<0.01	<0.01	<0.01
T136NR38WS29CCA	30	06/29/94	<0.01	<0.02	<0.01	<0.01	<0.01

Table 4.--Water-quality data for lakes sampled in 1994, east Otter Tail County, Minnesota
 [(mm/dd/yy), month/day/year; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data; <, less than;
 µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius]

Location	Local identifier	Date (mm/dd/yy)	Transparency (feet)	Sampling depth (feet)	Temperature (°C)	Specific conductance (µS/cm)	pH, field (standard units)	Oxygen, dissolved (mg/L)
T136NR39WS01BAB Little Pine Lake	L1	09/21/94	4.1	0-6.0	--	--	--	--
		09/21/94	--	0	19.7	340	8.6	9.6
		09/21/94	--	11.6	19.7	340	8.3	9.5
T137NR38WS31ADA Big Pine Lake	L2	09/21/94	4.0	0-5.2	--	--	--	--
		09/21/94	--	0	19.8	330	8.5	9.3
		09/21/94	--	4.8	19.8	330	8.4	8.5
T137NR38WS32BDA Big Pine Lake	L3	09/21/94	4.8	0-7.2	--	--	--	--
		09/21/94	--	0	19.7	330	8.4	9.2
		09/21/94	--	10.7	19.7	330	8.0	5.3
T136NR38WS06ACB Big Pine Lake	L4	09/21/94	5.4	0-10.0	--	--	--	--
		09/21/94	--	0	19.6	330	8.3	7.3
		09/21/94	--	10.8	19.6	330	8.1	6.8
T136NR38WS17BAD Big Pine Lake	L5	09/21/94	5.4	0-8.1	--	--	--	--
		09/21/94	--	0	19.4	330	8.5	8.0
		09/21/94	--	19.8	19.3	330	8.1	7.1
T135NR39WS13CCC Rush Lake	L6	09/20/94	5.0	0-7.5	--	--	--	--
		09/20/94	--	0	20.6	310	8.6	9.7
		09/20/94	--	5	20.5	320	8.5	9.7
T135NR38WS19BAD Rush Lake	L7	09/20/94	4.4	0-6.6	--	--	--	--
		09/20/94	--	0	20.2	300	8.6	10.1
		09/20/94	--	21.6	19.6	310	8.4	6.8
T134NR39WS10BCC Otter Tail Lake	L8	09/22/94	7.4	0-13.6	--	--	--	--
		09/22/94	--	0	18.9	350	8.5	7.9
		09/22/94	--	13.6	19.0	350	8.2	7.6

Table 4.--Water-quality data for lakes sampled in 1994, east Otter Tail County, Minnesota--Continued

Location	Local identifier	Date (mm/dd/yy)	Transparency (feet)	Sampling depth (feet)	Temperature (°C)	Specific conductance (µS/cm)	pH, field (standard units)	Oxygen, dissolved (mg/L)
T134NR39WS15CBC	L9	09/22/94	4.3	0-4.3	--	--	--	--
Otter Tail Lake		09/22/94	--	0	18.7	340	8.6	8.4
		09/22/94	--	3.9	18.7	340	8.4	8.3
T133NR40WS04ACA	L10	09/22/94	5.7	0-8.5	--	--	--	--
Otter Tail Lake		09/22/94	--	0	18.2	350	8.6	8.3
		09/22/94	--	7.4	18.2	350	8.2	8.3
T134NR40WS28ADD	L11	09/22/94	4.7	0-4.7	--	--	--	--
Otter Tail Lake		09/22/94	--	0	17.2	350	8.4	8.3
		09/22/94	--	4	17.2	350	8.3	8.3

Table 4.--Water-quality data for lakes sampled in 1994, east Otter Tail County, Minnesota--Continued

Location	Local identifier	Date (mm/dd/yy)	Chloride ¹ , dissolved (mg/L as Cl)	Nitrogen ¹ , nitrite, dissolved (mg/L as N)	Nitrogen ¹ , nitrite plus nitrate, dissolved (mg/L as N)	Nitrogen ¹ , ammonia, dissolved (mg/L as N)	Phosphorus ¹ , total (mg/L as P)	Phosphorus ¹ , ortho, dissolved (mg/L as P)	Triazine ¹ , immuno- assay screen (µg/L as atrazine)
T136NR39WS01BAB Little Pine Lake	L1	09/21/94	--	<.01	<.05	0.01	<.01	<.01	<.10
		09/21/94		--	--	--	--	--	--
		09/21/94		--	--	--	--	--	--
T137NR38WS31ADA Big Pine Lake	L2	09/21/94	--	<.01	<.05	.01	<.01	<.01	<.10
		09/21/94		--	--	--	--	--	--
		09/21/94		--	--	--	--	--	--
T137NR38WS32BDA Big Pine Lake	L3	09/21/94	--	<.01	<.05	.01	.02	<.01	<.10
		09/21/94		--	--	--	--	--	--
		09/21/94		--	--	--	--	--	--
T136NR38WS06ACB Big Pine Lake	L4	09/21/94	--	<.01	<.05	.03	<.01	<.01	<.10
		09/21/94		--	--	--	--	--	--
		09/21/94		--	--	--	--	--	--
T136NR38WS17BAD Big Pine Lake	L5	09/21/94	--	<.01	<.05	.02	<.01	<.01	<.10
		09/21/94		--	--	--	--	--	--
		09/21/94		--	--	--	--	--	--
T135NR39WS13CCC Rush Lake	L6	09/20/94	--	<.01	<.05	<.01	.01	<.01	<.10
		09/20/94		--	--	--	--	--	--
		09/20/94		--	--	--	--	--	--
T135NR38WS19BAD Rush Lake	L7	09/20/94	--	<.01	<.05	<.01	.06	<.01	<.10
		09/20/94		--	--	--	--	--	--
		09/20/94		--	--	--	--	--	--
T134NR39WS10BCC Otter Tail Lake	L8	09/22/94	--	<.01	<.05	.02	<.01	<.01	<.10
		09/22/94		--	--	--	--	--	--
		09/22/94		--	--	--	--	--	--

Table 4.--Water-quality data for lakes sampled in 1994, east Otter Tail County, Minnesota--Continued

Location	Local identifier	Date (mm/dd/yy)	Chloride ¹ , dissolved (mg/L as Cl)	Nitrogen ¹ , Nitrogen ¹ , Nitrogen ¹ , nitrite, nitrate plus ammonia, dissolved			Phosphorus ¹ , ortho, dissolved (mg/L as P)	Phosphorus ¹ , total (mg/L as P)	Triazine ¹ , immuno- assay screen (µg/L as atrazine)
				(mg/L as N)	(mg/L as N)	(mg/L as N)			
T134NR39WS15CBC	L9	09/22/94	--	<0.01	<0.05	0.01	<0.01	<0.01	<0.10
Otter Tail Lake		09/22/94		--	--	--	--	--	--
		09/22/94		--	--	--	--	--	--
T133NR40WS04ACA	L10	09/22/94	--	<0.01	<0.05	.02	.02	<.01	.10
Otter Tail Lake		09/22/94		--	--	--	--	--	--
		09/22/94		--	--	--	--	--	--
T134NR40WS28ADD	L11	09/22/94	--	<0.01	<0.05	.02	<.01	<.01	<.10
Otter Tail Lake		09/22/94		--	--	--	--	--	--
		09/22/94		--	--	--	--	--	--

¹ Samples were composited over depth range shown in Sampling Depth column.