Prepared in cooperation with the
UPPER REPUBLICAN NATURAL RESOURCES DISTRICT

Ground-Water Quality in the Upper Republican Natural Resources District, Southwestern Nebraska, 1998-99

—By Jill D. Frankforter, A.D. Druliner, and Sonya A. Jones

In 1998, the U.S. Geological Survey began a 3-year study in cooperation with the Upper Republican Natural Resources District to characterize ground-water quality with respect to major ions, nitrate, coliform bacteria, and triazine herbicides within the Upper Republican Natural Resources District, in southwestern Nebraska. In 1998, 368 irrigation wells and 101 domestic wells were sampled as part of the study. This fact sheet presents the results of water-quality analyses of these samples and results from follow-up sampling of 150 irrigation wells in 1999

INTRODUCTION

The Upper Republican Natural Resources District (URNRD) includes Chase, Dundy, and Perkins Counties in southwestern Nebraska (fig. 1). Ground water in much of the URNRD is found in the loosely cemented sandstone, caliche, sand, gravel, and volcanic ash of the Ogallala Formation (Engberg and Druliner, 1988). Along the Republican River Valley and many of the tributary valleys, ground water is found in alluvial deposits of sand and gravel that are underlain by the Pierre Shale (Bradley and Johnson, 1957). The depth to water ranges from about 5 ft (feet) below land surface (bls) in the valleys of Frenchman, Spring, and Stinking Water Creeks, and the Republican River, to more than 290 ft bls in southeastern Chase County (Heimes and others, 1987). Soil types in the uplands vary from sandy soils with permeabilities (rates at which water moves through the soil) ranging from 6 to 20 in/hr (inches per hour), to loamy and silty soils with permeabilities ranging from 0.6 to 2.0 in/hr (Soil Conservation Service, 1963;

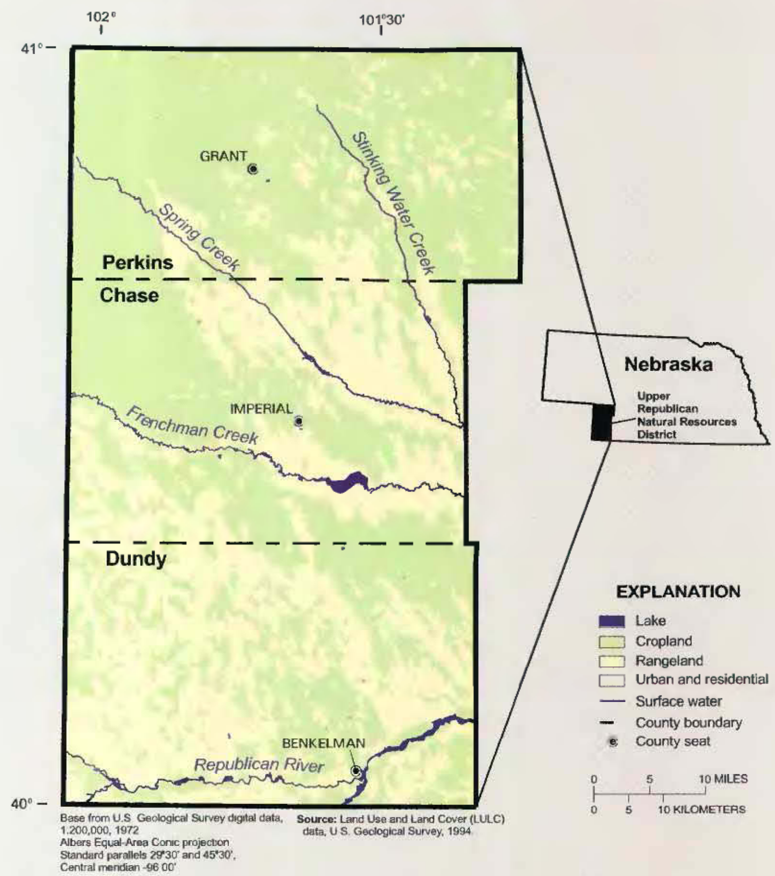

Figure 1. Location of and land uses in the Upper Republican Natural Resources District, southwestern Nebraska.

Land used for the production of corn and sunflowers in the Upper Republican Natural Resources District

1982; and 1991). Bottomland soils also are generally silty and loamy with permeabilities ranging from 0.6 to 2.0 in/hr.

By the 1950s, about 50 percent of land in the URNRD was used for crop production. The percentage of cropland has remained relatively stable since that time (fig. 1). However, production in the area has changed from wheat and sorghum to corn. The change in crop type was, in large part, the result of development of ground-water irrigation in the 1960s. By 1995, more than 25 percent of the land in the URNRD was irrigated using ground water from the more than 3,300 irrigation wells registered in the three-county area (Nebraska Natural Resources Commission, 1998). With irrigation water available, large quantities of fertilizers and other chemicals were used to increase, and sustain, crop yields. The development of ground-water irrigation and the associated use of fertilizer and other chemicals increased the potential for leaching of these compounds into the ground water. Therefore, characterization of ground-water quality provides basic information that is important to the understanding and use of water resources in the URNRD area. Ground-water sampling was conducted in 1998 and 1999 (selected results are presented herein), and additional sampling is intended in 2000.

SAMPLING METHODS

Irrigation and domestic wells that were sampled for water-quality analyses were selected randomly with adjustments to ensure a wide distribution of sampling sites throughout the URNRD. When possible, water-quality samples were collected from spigots or faucets located close to the wellhead. Producers often apply fertilizers, or other chemicals, to the fields with the irrigation water using chemical injection (chemigation) systems. Water samples from irrigation wells with chemigation systems were collected from faucets or spigots located between the water source and the chemigation injection point. If a spigot was not available on an irrigation well, water for field measurements and water-quality samples was collected from openings in the irrigation pipes or from the pivot/sprinkler itself, provided a chemigation system had not been used recently. Field measurements consisted of monitoring the specific conductance, pH, temperature, and dissolved oxygen of the water until the measurements had stabilized. Once the field measurements were stable, water-quality samples were collected.

Technician monitoring field measurements of specific conductance, pH, water temperature, and dissolved oxygen at an irrigation well in the Upper Republican Natural Resources District.

In 1998, ground-water samples were collected from 368 irrigation wells, and were analyzed for nitrite plus nitrate as nitrogen (hereinafter referred to as nitrate) by Olsen's Agricultural Laboratory in McCook, Nebraska. Of the 368 irrigation wells sampled, samples from 116 wells, or 32 percent, also were analyzed for major ions by the U.S. Geological Survey's National Water Quality Laboratory (NWQL) in Arvada, Colorado.

In 1999, 150 of the 368 irrigation wells were selected randomly and resampled to confirm the results from the 1998 sampling and to screen samples for selected triazine herbicides. If the herbicide screen indicated the presence of triazine herbicides at a concentration of 0.10 μg/L (micrograms per liter) or greater, the sample was analyzed by the NWQL to identify the specific compounds and concentrations present. Ground-water samples from 20 of the 150 irrigation wells (13 percent) also were analyzed for major ions.

In 1998, ground-water samples were collected from 101 domestic wells, and were analyzed for nitrate and coliform bacteria by Olsen's Agricultural Laboratory. In 1999, 32 of the 101 domestic wells were resampled, with water samples again analyzed for nitrate and coliform bacteria. Selection of the domestic-well sampling sites in 1999 was not random, but was based on the detection of nitrate at concentrations of 6.0 mg/L (milligrams per liter) or greater, or the presence of coliform bacteria, in the 1998 sample. The water-quality results from the 1999 domestic-well sampling were not included in the data analyses.

MAJOR IONS

In 1998, ground-water samples from 116 of the 368 irrigation wells were analyzed for major dissolved ions. Natural water commonly contains 8 to 10 major dissolved ionic constituents that can be grouped by similarities in chemical properties (cations and anions) to approximate the overall chemical composition of the water (Briel, 1993). The chemical composition of the water can be useful when considering the suitability of water for certain purposes, such as consumption (Hem, 1989). In figure 2, each sample analyzed for major ions is plotted in the lower left triangle by percentage (in milliequivalents per milliliter) of total cations, and in the lower right triangle by percentage of total anions. Straight lines drawn from these two points are used to generate a third point in the diamond field indicating the

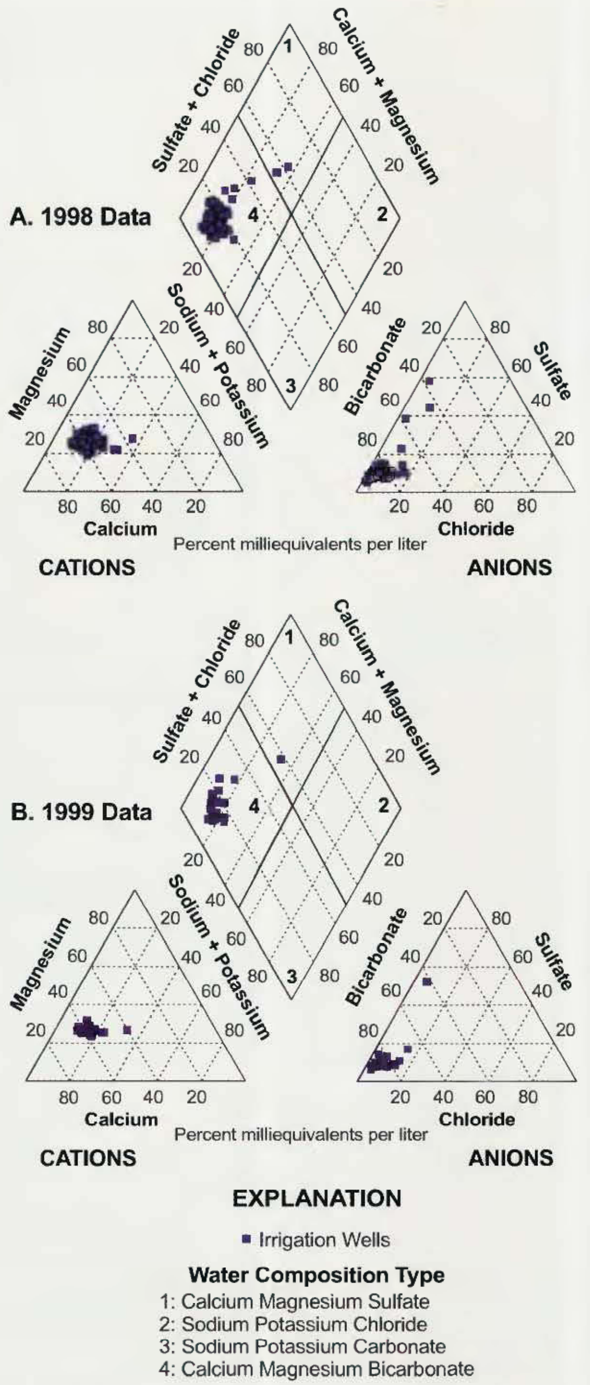

Figure 2. Chemical composition, based on relative concentrations of the major ions, of water from irrigation wells sampled in the Upper Republican Natural Resources District, Nebraska, 1998 and 1999.

overall chemical composition of the water. The midpoints of opposite sides of the diamond can be connected to form four smaller diamonds, with each subarea representing a type of water composition (Briel, 1993). Plots of the ionic constituents in all but two samples collected in 1998 fell in the leftmost subarea of the diamond field (fig. 2A), and were of a calcium-magnesium-bicarbonate composition typical of water from the Ogallala Formation (Engberg and Druliner, 1988). Plots for water collected from the other two wells fell in the uppermost subarea (fig. 2A), and were of a calcium-magnesium-sulfate composition. Both wells are near the Republican River in Dundy County, and the presence of elevated sulfate concentrations detected in water from the wells may be the result of influence of the underlying Pierre Shale (Bradley and Johnson, 1957). Ground water collected from irrigation wells in 1999 and analyzed for major ions showed a similar distribution, 19 samples having a calcium-magnesium-bicarbonate composition, and one having a calcium-magnesium-sulfate composition (fig. 2B).

NITRATE

Nitrates were detected in 364 of the 368 irrigation-well samples (98 percent) collected in 1998. Concentrations ranged from less than the method-reporting limit of 0.03 mg/L to 25 mg/L. Given that nitrate concentrations of 3.0 mg/L or less may be assumed to be naturally occurring (Madison and Brunett, 1985), it is reasonable to expect that detectable levels of nitrates may be found in all of the

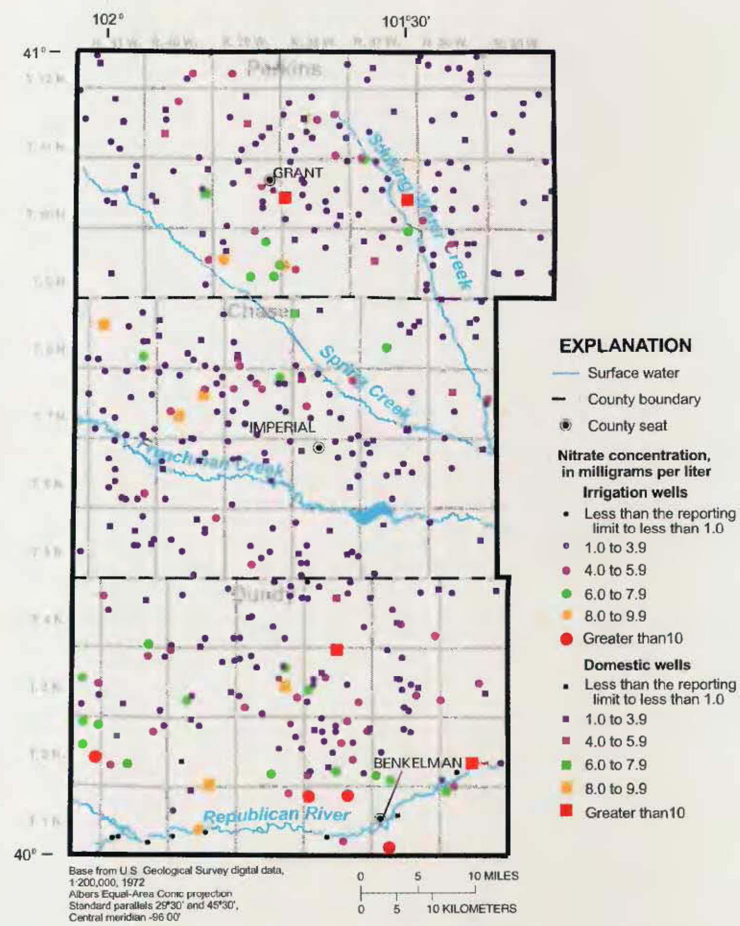

Figure 3. Approximate locations and concentrations of nitrates detected in water from irrigation and domestic wells sampled in the Upper Republican Natural Resources District, Nebraska, June–August 1998.

samples. Ground-water samples with nitrate concentrations less than the method-reporting limit were from wells in the Republican River Valley (fig. 3). The absence of detectable concentrations of nitrates in these samples may be the result of denitrification occurring as a result of the availability of organic matter and the presence of anaerobic conditions in an area with a shallow water table (Starr and Gillham, 1993).

Wells with nitrate concentrations ranging from less than 1.0 to almost 6.0 mg/L were distributed throughout the URNRD. Areas with nitrate concentrations from 6.0 to more than 10 mg/L were found predominantly in western and south-central Dundy, south-central Perkins, and north-central Chase Counties (fig. 3). Nitrate concentrations from four samples exceeded the drinking-water maximum contaminant level (MCL) of 10 mg/L established by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 1999). Nitrate concentrations greater than than 6.0 mg/L commonly correspond with upland areas with sandy and sandy/loamy soils that have soil permeabilities ranging from 6 to 20 in/hr (Soil Conservation Service, 1963; 1982; and 1991) or regions of relatively shallow depths to water as measured at the time of well completion. The median depth to water was 51 ft bls for 31 wells with nitrate concentrations greater than 6.0 mg/L compared with a median depth to water of 72 ft bls for all wells sampled.

The 1998 median nitrate concentration for the 368 samples was 2.5 mg/L. Comparing the nitrate data for irrigation-well samples by county, the median concentrations varied from 2.3 mg/L and 2.4 mg/L in Chase and Perkins Counties to 3.2 mg/L in Dundy County (fig. 4). The median concentration in Dundy County was significantly larger (99-percent confidence level; Wilcoxon rank-sum test (Helsel and Hirsch, 1992)) than the median nitrate concentrations in the other two counties. Although land uses are similar in the three counties, the median depth to water (42 ft bls) is significantly less (95-percent confidence level; Wilcoxon rank-sum test) for the wells in Dundy County than the medians for depth to water in Chase (64 ft bls) and Perkins (151 ft bls) Counties. Shallow depth to water may increase the probability that nitrates will leach into the ground water. Samples collected and analyzed in 1999 verify results of the 1998 sampling (fig. 4). Nitrates were detected in all of the 150 ground-water samples collected from selected irrigation wells. Nitrate concentrations in these samples ranged from 0.09 to 26 mg/L (fig. 4), with a median nitrate concentration for the URNRD of 2.6 mg/L.

Nitrates were detected in all of the 101 domestic-well samples collected in 1998. Nitrate concentrations detected ranged from the method-reporting limit of 0.03 mg/L to 23 mg/L (figs. 3 and 4). The median concentration for the

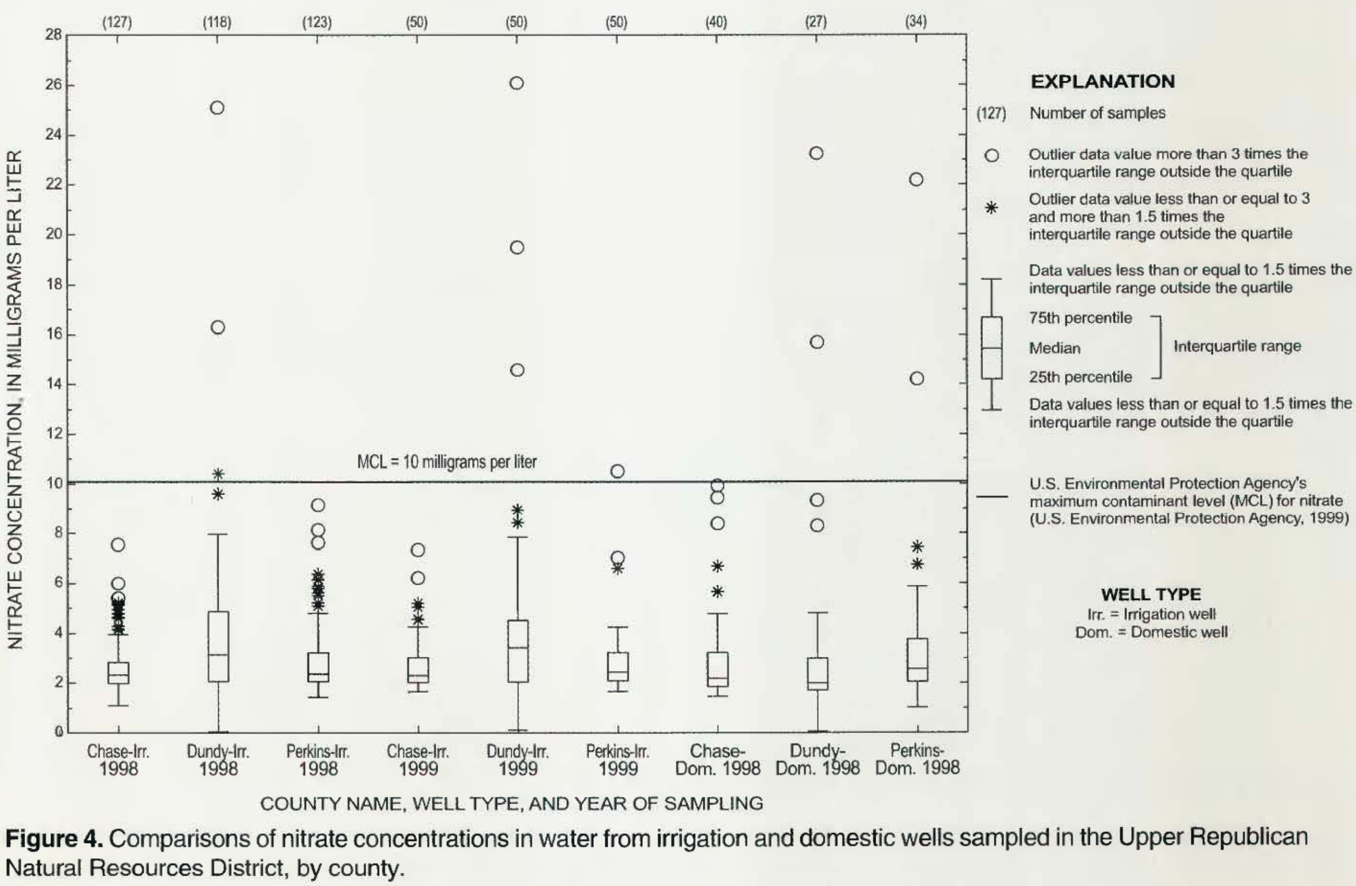

Figure 4. Comparisons of nitrate concentrations in water from irrigation and domestic wells sampled in the Upper Republican Natural Resources District, by county.

101 samples was 2.2 mg/L. Concentrations of nitrate in water from two wells in Dundy County and two wells in Perkins County exceeded the MCL. Because the 1999 domestic-well sample sites were not selected randomly, the nitrate analytical results for these wells were not included in the data analysis.

COLIFORM BACTERIA

Of the 101 domestic-well samples analyzed in 1998, 24 percent tested positive for total coliform bacteria, exceeding the MCL of zero colonies (U.S. Environmental Protection Agency, 1999). The number of colonies ranged from 1 to greater than 200 per 100 mL (milliliter) of water. The presence of bacteria in water from the domestic wells in 1998 does not appear to be related to elevated nitrate concentrations. Water from just eight of the wells that tested positive for total coliform bacteria had nitrate concentrations greater than 3.0 mg/L, the level that may be considered indicative of influence from human sources (Madison and Brunett, 1985).

In 1999, samples were collected from 32 domestic wells that either tested positive for coliform bacteria, or had nitrate concentrations above 6.0 mg/L in 1998. Of the domestic wells resampled, 14 of 28 wells again tested positive for total coliform bacteria. Also, water from three additional wells, which had no coliform bacteria in the 1998 sample, tested positive in 1999.

TRIAZINE HERBICIDES

In 1999, all 150 irrigation-well samples were screened for atrazine and other triazine herbicides. As a result of the screening process, 31 samples were sent to the NWQL for further analysis. Triazine herbicides (atrazine, metolachlor, and (or) the atrazine degradation product, deethylatrazine) were detected in 19 of the samples. Concentrations less than the method reporting limit (0.05 µg/L) were reported as estimated values. Atrazine was detected most frequently (in 18 samples) with concentrations ranging from 0.004 (estimated) to 0.22 µg/L. Metolachlor was detected in 5 samples at concentrations ranging from 0.01 (estimated) to 0.05 µg/L, and deethylatrazine was detected in 16 samples at concentrations ranging from 0.01 (estimated) to 0.96 µg/L. All concentrations of atrazine were less than the 3.0 µg/L MCL established by the U.S. Environmental Protection Agency (1999). The other two compounds do not have established MCLs. Although most of the triazine herbicide concentrations detected were less than the method reporting limit, their presence indicates that leaching of these compounds into the ground water is occurring in some areas.

SUMMARY

The results of the major-ion analyses indicate that most ground water sampled in the URNRD is of calcium-magnesium-bicarbonate composition. Some water from wells near the Republican River is of a calcium-magnesium-sulfate composition, with elevated sulfate levels possibly resulting from influences of the underlying Pierre Shale.

Nitrates were detected in 98 percent of the irrigation wells sampled in 1998, and in all of the samples collected in 1999. Nitrates were detected in all of the domestic wells sampled in 1998 and 1999. While many samples had nitrate concentrations less than 3.0 mg/L, samples from 121 irrigation (1998 and 1999) and 16 domestic wells (1998) had nitrate concentrations ranging from 3.0 to 10 mg/L. Nitrate concentrations exceeded the 10 mg/L nitrate MCL in samples from four irrigation wells and four domestic wells. Areas with nitrate concentrations ranging from 6.0 to more than 10 mg/L were predominantly in western and south-central Dundy, but also in south-central Perkins and north-central Chase Counties. The areas of increased nitrate concentrations commonly correspond with regions of relatively shallow depths to water or upland areas with sandy and sandy/loamy soils.

Total coliform bacteria was present in water from 24 percent of the domestic wells sampled in 1998. When these wells were resampled in 1999, water from 17 wells tested positive for coliform bacteria (14 of the wells that tested positive in 1998, plus three additional wells).

Triazine herbicides were detected in 19 of the 31 samples submitted for laboratory analysis; however, many of the herbicides were detected at concentrations below the method reporting limit, and were reported as estimated values. Atrazine was detected in almost half of the samples submitted for laboratory analysis, indicating leaching of triazine compounds into the ground water has occurred. However, no concentrations exceeded the MCL of 3.0 µg/L.

REFERENCES

Bradley, Edward and Johnson, C.R., 1957, Geology and ground-water hydrology of the valleys of the Republican and Frenchman Rivers, Nebraska: U.S. Geological Survey Water-Supply Paper 1360-H, p. 589–713.

Briel, L.I., 1993, Documentation of a multiple-technique computer program for plotting major-ion composition of natural waters: U.S. Geological Survey Open-File Report 93–74, 88 p.

Engberg, R.A., and Druliner, A.D., 1988, Nebraska ground-water resources, *in* U.S. Geological Survey, National water summary 1986—Hydrologic events and ground-water resources: U.S. Geological Survey Water-Supply Paper 2325, p. 347–354.

Heimes, F.J., Ferrigno, C.F., Gutentag, E.D., Luckey, R.R., Stephens, D.M., and Weeks, J.B., 1987, Comparison of irrigation pumpage with change in ground-water storage in the High Plains aquifer in Chase, Dundy, and Perkins Counties, Nebraska, 1975–83: U.S. Geological Survey Water-Resources Investigations Report 87–4044, 34 p.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: Amsterdam, The Netherlands, Elsevier Science Publishers B.V., 522 p.

Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Madison, R.J. and Brunett, J.O., 1985, Overview of the occurrence of nitrate in ground water of the United States, *in* U.S. Geological Survey National water summary 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, p. 93–105.

Nebraska Natural Resources Commission, 1998, Estimated water use in Nebraska, 1995: Lincoln, Nebraska Natural Resources Commission, 64 p.

Soil Conservation Service, 1963, Soil survey of Dundy County, Nebraska: U.S. Department of Agriculture, Soil Conservation Service, 86 p.

___ 1982, Soil survey of Chase County, Nebraska: U.S. Department of Agriculture, Soil Conservation Service, 187 p.

___ 1991, Soil survey of Perkins County, Nebraska: U.S. Department of Agriculture, Soil Conservation Service, 178 p.

Starr, R.C. and Gillham, R.W., 1993, Denitrification and organic carbon availability in two aquifers: Ground Water, v. 31, no. 6, p. 934–947.

U.S. Environmental Protection Agency, 1999, Drinking water regulations and health advisories: U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, accessed September 5, 2000 at URL http://www.epa.gov/safewater/mcl.html.

For more information, contact:

District Chief
U.S. Geological Survey
Federal Building, Room 406
100 Centennial Mall North
Lincoln, NE 68508
http://www-ne.cr.usgs.gov/

Crop production in the Upper Republican Natural Resources District has changed from wheat and sorghum to corn.

Printed on recycled paper