science for a changing world

GEOHYDROLOGY AND WATER QUALITY OF THE NORTH PLATTE RIVER ALLUVIAL AQUIFER, GARDEN COUNTY, WESTERN NEBRASKA, 1993-94

U.S. Geological Survey
Water-Resources Investigations Report 98-4033

Prepared in cooperation with
NORTH PLATTE NATURAL RESOURCES DISTRICT

GEOHYDROLOGY AND WATER QUALITY OF THE NORTH PLATTE RIVER ALLUVIAL AQUIFER, GARDEN COUNTY, WESTERN NEBRASKA, 1993-94

By G.V. Steele, *U.S. Geological Survey*, J.C. Cannia, *North Platte Natural Resources District*, and J.S. Stanton, *U.S. Geological Survey*

U.S. Geological Survey
Water-Resources Investigations Report 98-4033

Prepared in cooperation with the
NORTH PLATTE NATURAL RESOURCES DISTRICT

Lincoln, Nebraska
1998

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
THOMAS J. CASADEVALL, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
406 Federal Building
100 Centennial Mall North
Lincoln, NE 68508

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Federal Center
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

TABLES

TABLES--Continued

Page

CONVERSION FACTORS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot	1,233	cubic meter
foot (ft)	0.3048	meter
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)
cubic feet per day (ft^3/d)	0.02832	cubic meters per day
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Geohydrology and Water Quality of the North Platte River Alluvial Aquifer, Garden County, Western Nebraska, 1993-94

By G.V. Steele[1], J.C. Cannia[2], *and* J.S. Stanton[1]

ABSTRACT

In 1993, the U.S. Geological Survey and the North Platte Natural Resources District began a 3-year study to describe the geohydrology and water quality of the North Platte River alluvial aquifer near Oshkosh, Garden County, Nebraska. The objectives of the study were to describe the geohydrology of the alluvial aquifer near Oshkosh, to establish a well network for long-term monitoring of concentrations of agricultural chemicals including nitrate and herbicides, and to describe the water quality of the aquifer emphasizing agricultural chemicals.

Fourteen monitor wells were installed at 11 sites near Oshkosh. The geohydrologic properties of the aquifer were estimated from water-level measurements plus short-term constant-discharge aquifer tests near two monitor wells. Water samples were collected approximately bimonthly and analyzed for specific conductance, pH, water temperature, dissolved oxygen, and nutrients including dissolved nitrate. Samples were collected semiannually for analysis of major ions, and annually for triazine and acetamide herbicides.

Aquifer tests indicated hydraulic conductivities ranging from 169 to 183 feet per day and transmissivities ranging from 12,700 to 26,600 feet-squared per day. The average specific yield was 0.20. Ground-water flow velocities were estimated to be about 1 foot per day.

Ground water in the study area varied between a calcium and sodium bicarbonate type. Calcium was the predominant cation in wells in Lost Creek Valley and generally just downgradient from it, whereas sodium was the predominant cation in a few scattered wells.

Nitrate concentrations in water samples from the monitor wells ranged from 1.5 to 56 milligrams per liter as N, with median concentrations, by well, ranging from 1.7 to 50 milligrams per liter as N. Nitrate concentrations exceeded the U.S. Environmental Protection Agency's Maximum Contaminant Level of 10 milligrams per liter for drinking water in at least one sample from 7 of the 14 monitor-well sites. In addition, ground water from Lost Creek Valley, north of the study area, may be diluting concentrations of nitrate near Oshkosh.

Nitrate concentrations in water samples from wells near the upgradient and downgradient ends of the study area generally did not exceed the Maximum Contaminant Level of 10 milligrams per liter. Results of rank-sum tests indicate that there is a significant difference between nitrate concentrations in the North Platte River and water samples collected from the farthest upgradient well. This indicates that nitrates in the ground water probably were not derived from the North Platte River. Nitrate concentrations increased in water samples collected from most sampling intervals of the three multilevel sampling wells from May 1989 to February and August 1994.

Analyses for eight triazine and acetamide herbicides and two atrazine metabolites showed that atrazine was detected in 10 of 34 ground-water samples (29 percent). The atrazine metabolite deethylatrazine was detected in 18 of 34 ground-water samples (53 percent).

INTRODUCTION

Nitrate concentrations exceeding the U.S. Environmental Protection Agency (USEPA) (1996) Maximum Contaminant Level (MCL) of 10 mg/L (milligrams per liter) as N for drinking water, in the alluvial aquifer near Oshkosh, Garden County,

[1]U.S. Geological Survey, Lincoln, Nebraska.
[2]North Platte Natural Resources District, Gering, Nebraska.

Nebraska, are a major concern for both the citizens of the area and the North Platte Natural Resources District (NPNRD). Nitrate concentrations exceeding the MCL were first identified near Oshkosh in samples collected by the NPNRD in 1988. A nitrogen isotope study completed in 1989 by the Conservation and Survey Division of the University of Nebraska-Lincoln (Mary Exner-Spalding, University of Nebraska-Lincoln, written commun., 1991) determined the source of the nitrate concentrations greater than the MCL to be commercial fertilizer applied to irrigated fields. The alluvial aquifer is used as a source of water for the municipal supply of Oshkosh, as well as for rural supplies. Nitrate in water poses a potential health threat; however, the extent of the nitrate, as well as basic geohydrologic characteristics of the aquifer near Oshkosh, were poorly defined. In 1993, the U.S. Geological Survey (USGS) and the NPNRD began a 3-year cooperative study to determine the geohydrology of the alluvial aquifer near Oshkosh; to establish a network of wells for long-term monitoring of agricultural chemicals in the aquifer; and to describe water quality of the aquifer, emphasizing agricultural chemicals (nitrate and herbicides). Results will provide an improved understanding of geohydrology and water quality in alluvial aquifer settings.

Purpose and Scope

The purpose of this report is to document the geohydrology and water quality of the alluvial aquifer near Oshkosh, Garden County, Nebraska. The geohydrology aspect focuses on hydraulic properties and ground-water flow. The water-quality aspect focuses mainly on major ions, nitrate, and triazine and acetamide herbicides. Most of the geologic nomenclature used in this report is that used by the USGS; however, some terms, such as Ogallala Group, are based on nomenclature used by the University of Nebraska-Lincoln.

Site Identification

Three different methods of site identification are used to identify ground-water stations in this report. The first method, USGS site identification, is a 15-character number derived from the international system of latitude and longitude. This number contains no blanks or alphabetic characters and generally is used as an internal control number. Although the station identification number is initially derived from the site location, the number is an IDENTIFIER and not a LOCATOR. The station identification number is a pure number and has no locational significance (Mathey, S.B., ed., 1990, p. 2-10).

The second method, field identification, is based on the aquifer in which the well is developed, or for existing monitor wells installed by the University of Nebraska-Lincoln, a modified version of the previous field identification. In the field identifications for all new monitor wells, the first two letters denote the aquifer in which they were developed—NP for North Platte River Valley and LC for Lost Creek Valley. The next two letters, GC, were used to designate Garden County. Numerical designations generally were assigned from northwest (01) to southeast (11). If the site contained two wells, a succeeding letter was used, S for shallow and D for deep.

Multilevel monitor wells installed by the University of Nebraska-Lincoln in 1989 kept modified versions of the field identifications originally assigned by Mary Exner-Spalding (University of Nebraska-Lincoln, written commun., 1991)—1 OSH, 2 OSH, and 3 OSH. For this study, two additional letters, ML, were added to indicate a multilevel well, and Exner-Spalding's numerical designation was placed after the five letter designation. Thus, Exner-Spalding's 1 OSH became OSHML1. In addition, a succeeding number (1 through 8) was added to denote the shallowest (1) through deepest (8) monitor wells.

The third method, well location, was assigned on the basis of land subdivisions in the U.S. Bureau of Land Management's survey of Nebraska. The numeral preceding N (north) indicates the township, the numeral preceding W (west) indicates the range, and the numeral preceding the terminal letters indicates the section in which the well is located (fig. 1). The terminal letters, designated A, B, C, and D, denote the quarter section, the quarter-quarter section, the quarter-quarter-quarter section, and the quarter-quarter-quarter-quarter section. The designation is given in a counter-clockwise fashion beginning with "A" in the northeast corner of each subdivision. If two or more wells exist in the same subdivision, they are distinguished by adding a sequential number to the well number. Sequential numbers are assigned by the order in which the wells are inventoried.

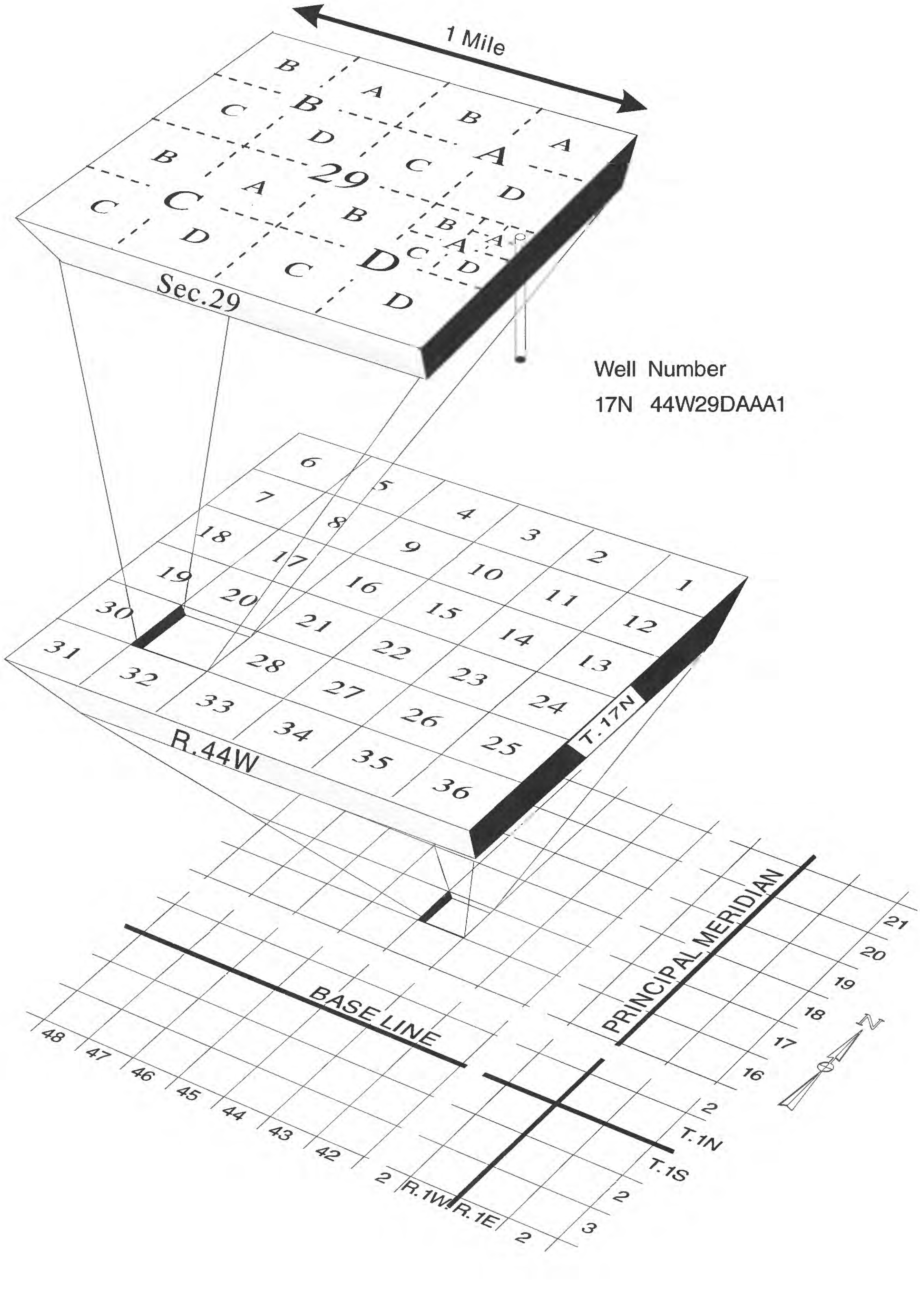


Figure 1. Well-numbering system.

Previous Investigations

Previous investigations described the geology and topography of the paleovalley underlying the present day North Platte River. Darton (1903) described the alluvium overlying the older incised bedrock formations. Darton also reported on flow characteristics in the alluvial deposits and in the underlying Brule Formation. The Missouri Basin State Association (1982) drew maps of the transmissivities and stream depletion factors in the North Platte River Valley. Diffendal (1982, 1983), Diffendal and others (1985), and Swinehart and others (1985) reported on the general features of paleovalleys in western Nebraska.

Other investigations described the water quality in Garden County. LaBaugh (1986) described the water quality of the lakes in the western Sandhills of Nebraska. In 1990 Mary Exner-Spalding (University of Nebraska-Lincoln, written commun., 1991) studied nitrogen isotopes in the ground water of the alluvial aquifer near Oshkosh, Nebraska. Gosselin and others (1994) reported that the alkali lakes region of the Nebraska Sandhills, Garden County, is diverse in water quality. Verstraeten and others (1995) described the ground-water quality in the NPNRD.

Acknowledgments

The authors acknowledge and extend special appreciation to Howard, Charles, and Jerry Ardissono for their assistance and for the use of their irrigation well and discharge pipes during the first aquifer test. Acknowledgment and special appreciation also are extended to the City of Oshkosh for the use of their municipal well, and to Darrell Zorn, William Patterson, and William Campbell for their help prior to and during the second aquifer test. The authors thank all the other land owners for their assistance and cooperation in the study.

Special thanks are extended to Milt Moravek of the Central Platte Natural Resources District, to the Central Platte Natural Resources District, and to Mel Noffke of Great Plains Meter, Inc. The Central Platte Natural Resources District provided an ultrasonic flow meter and ultrasonic micrometer used during the aquifer tests, and Mr. Moravek and Mr. Noffke provided instruction on their usage.

DESCRIPTION OF STUDY AREA

The study area lies in the North Platte River Valley, flanking the town of Oshkosh in southern Garden County, Nebraska, extending from approximately 5 mi (miles) northwest to 7 mi southeast of the town (fig. 2). The regional slope of the land surface is from northwest to southeast, which also characterizes the predominant direction of ground- and surface-water flow. Land use is predominantly rangeland and irrigated and nonirrigated agriculture.

The study area lies in the Highlands Plains Section of the Great Plains Province (Fenneman, 1946). Well-developed drainageways have been incised in the underlying bedrock by perennial streams, the North Platte River, and ephemeral or seasonal streams. Most of the study area is well drained.

Climate

The climate of the study area is semiarid. The area is characterized by severe winters and hot summers, with less annual precipitation than areas lying farther to the east. In the study area, the agricultural growing season is about 130 days, generally from mid-April to late September. The 30-year average annual precipitation, as of 1993, was 17.04 in. (inches) (National Oceanic and Atmospheric Administration, 1994), which occurs mainly as rainfall from storms during May and June. July generally is the hottest month of the year when the temperature ranges from 50 °F (degrees Fahrenheit) to 90 °F. January generally is the coldest month of the year when the temperature ranges from 10 °F to 40 °F (Olsson Associates, 1993).

Hydrologic Setting

The aquifers described in this report are those in unconsolidated Quaternary alluvial and eolian deposits and in the bedrock formations directly underlying the Quaternary deposits (table 1; figs. 3 and 4). The principal aquifers in the study area are in the undifferentiated alluvial deposits in the valleys of the North Platte River and Lost Creek. These aquifers are part of the regional High Plains aquifer and generally are unconfined. Localized clay lenses are commonly found in these aquifers, but are not sufficiently extensive to confine the aquifers.

The varied landforms in the study area are controlled by the geologic units from which they were

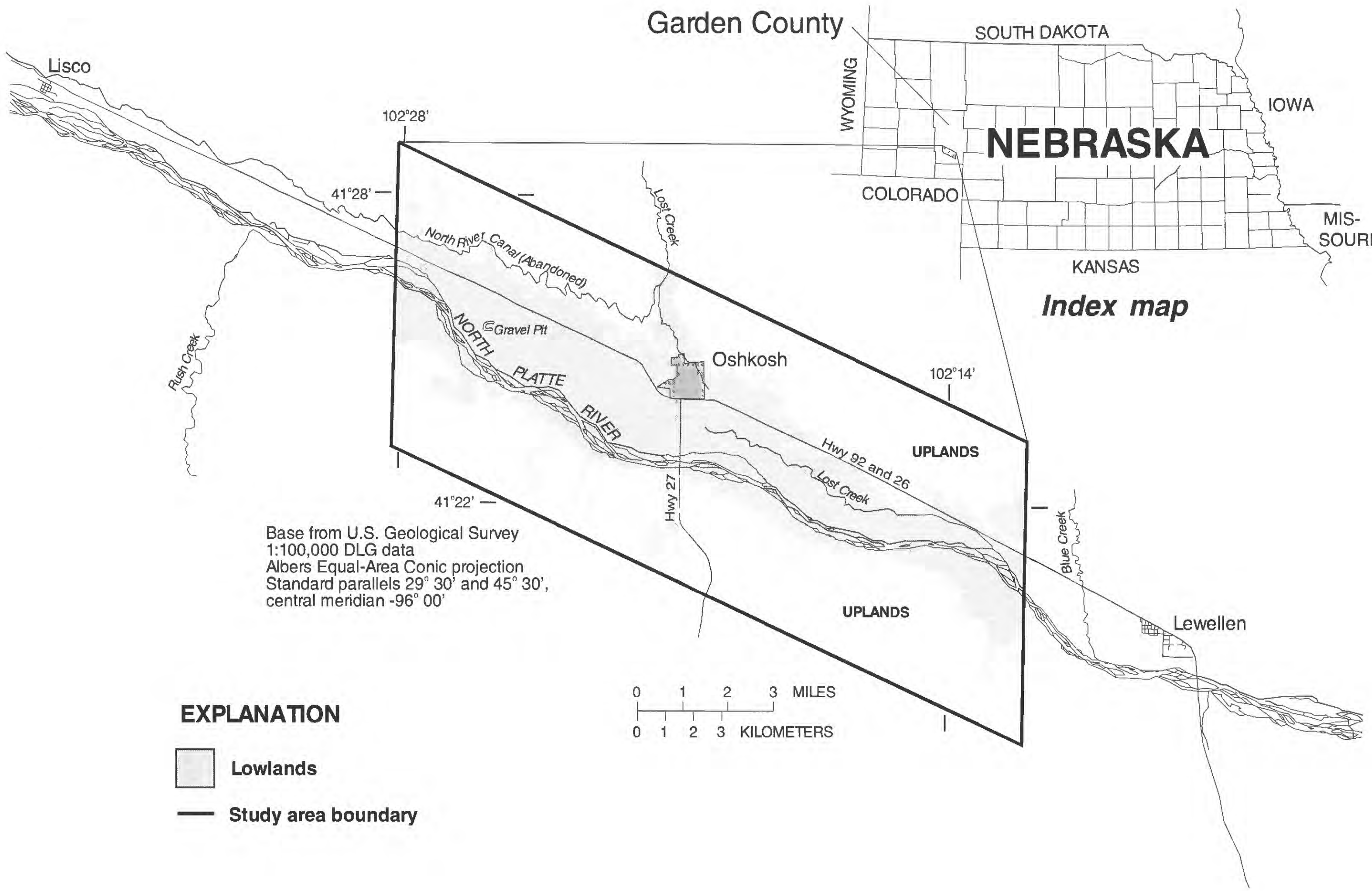


Figure 2. Location of study area, Garden County, western Nebraska.

Table 1. Aquifers in Cenozoic-age stratigraphic units, Garden County, western Nebraska

[Modified from Swinehart and others, 1985; >, greater than; <, less than]

System	Series	Hydrogeologic unit	Maximum thickness, in feet	Hydrogeologic characteristics
Quaternary	Holocene, Pleistocene	Aquifer in undifferentiated alluvial deposits	>200	Undifferentiated sands and gravels in the North Platte River and Lost Creek Valleys; sands, silts, and minor amounts of gravel from locally derived colluvium. Transmissivity ranges from 2,700 to 67,000 feet squared per day. Wells are capable of yielding up to several thousand gallons per minute.
Tertiary	Miocene	Aquifer in Ogallala Group, Ash Hollow Formation	<100	Generally gray, brown, and reddish-brown fine- to coarse-grained sandstones, silty sandstones, sandy gravels, siltstones, and locally occurring ash beds. Some sediments are poorly sorted. Some carbonate cement. Transmissivity ranges from less than 6,700 to 13,500 feet squared per day. Wells are capable of yielding up to 1,000 gallons per minute.
	Oligocene	Aquifer in brown siltstone unit, Brule Formation, White River Group		Massive brown volcaniclastic sandy siltstones and silty very fine-grained sandstones. Mudstones and fine- to medium-grained sandstones occur locally and generally at or near the base. Ash occurs in lower part. Water is unconfined and transmissivity rates are highly variable due to local or regional fractures and fissures. Wells are capable of yielding up to 1,000 gallons per minute locally.
		Aquifer in Whitney Member, Brule Formation, White River Group	450 total	Massive brown volcaniclastic siltstones, mudstones and locally occurring fine- to medium-grained sandstones. Contains two regionally correlative ash beds. Water is unconfined and transmissivity rates are highly variable due to local or regional fractures and fissures. Wells are capable of yielding up to 1,000 gallons per minute locally.
		Aquifer in Orella Member, Brule Formation, White River Group		Brown to greenish-gray volcaniclastic mudstones and siltstones to fine- to medium-grained sandstones. Upper part contains thinly bedded mudstones. Lower part contains regionally correlative ash bed. Water is unconfined and transmissivity rates are highly variable due to local or regional fractures and fissures. Wells are capable of yielding up to 1,000 gallons per minute locally.
	Eocene	Aquifer in Chadron Formation, White River Group	300	Gray and greenish-gray bentonitic claystones and mudstones. Fine- to coarse-grained sandstones with locally occurring conglomerates. Generally, a confined aquifer. Wells completed in the Chadron Formation can yield up to 1,000 gallons per minute. Water from the Chadron Formation is confined, considered hard, and generally not used for human consumption.

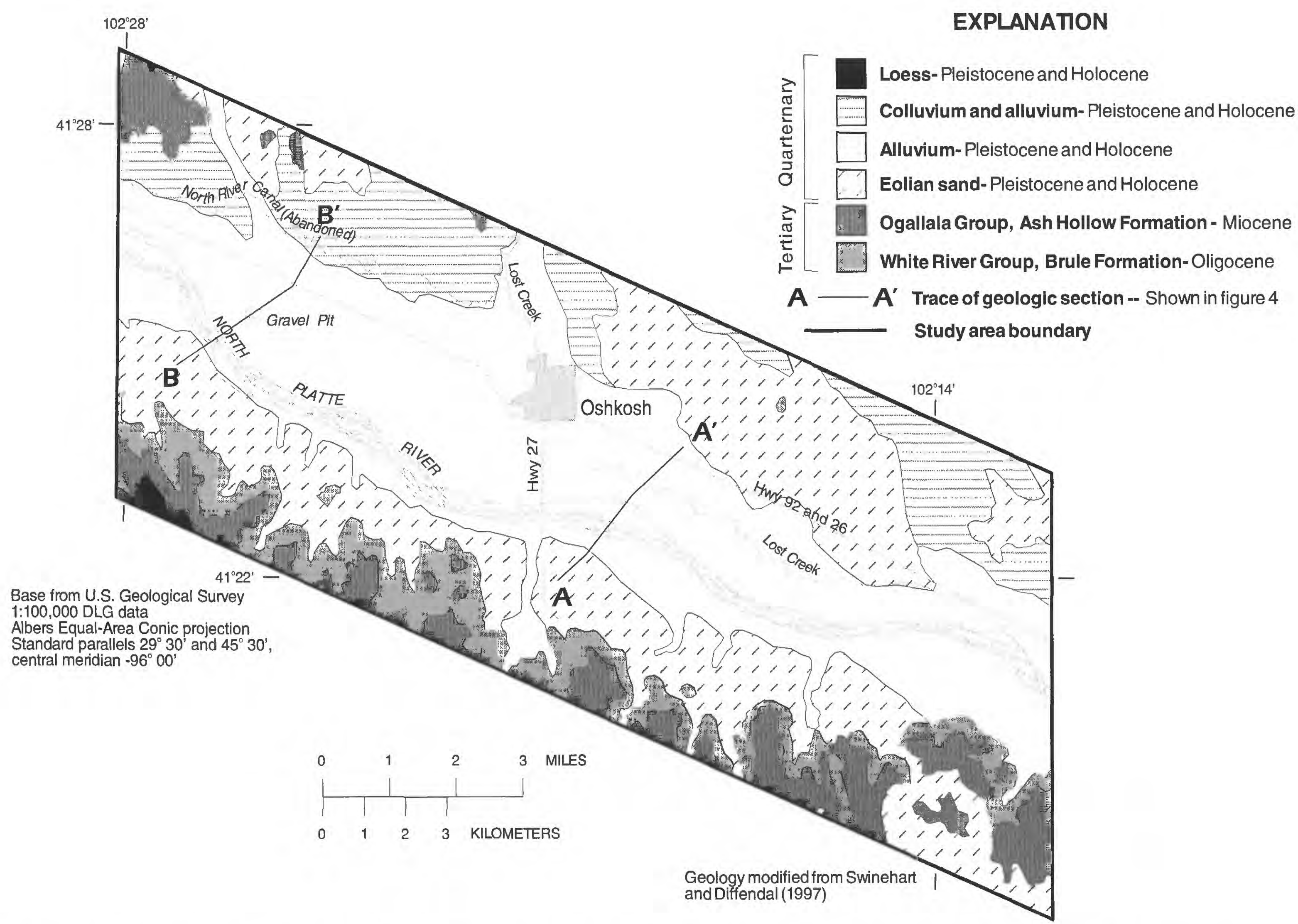


Figure 3. Areal distribution of Tertiary and Quaternary deposits and generalized geologic sections A-A′ and B-B′ in the study area, western Nebraska.

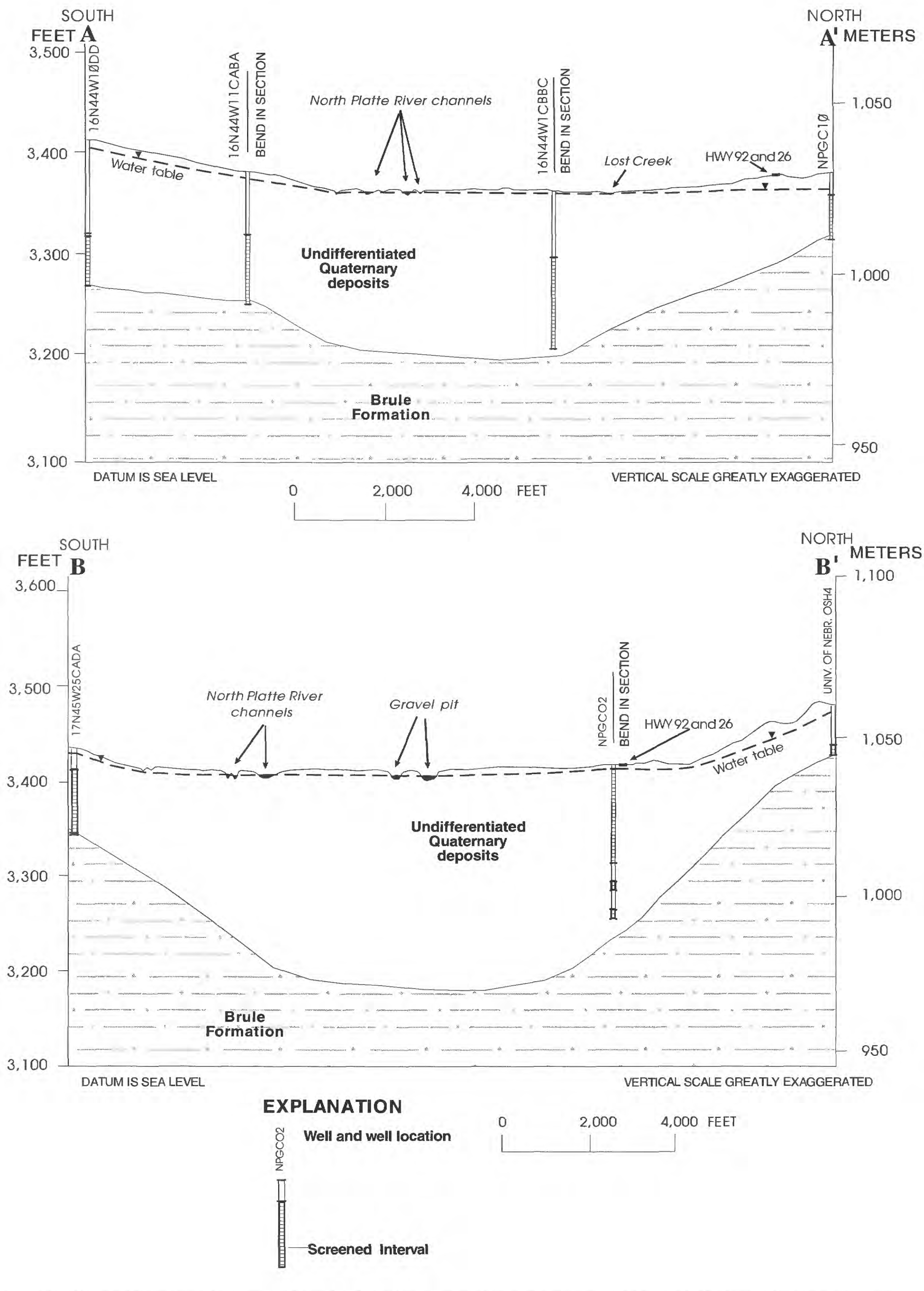


Figure 4. Generalized hydrogeologic sections in the study area, western Nebraska. Trace of sections shown in figure 3.

made. These units are limited to the unconsolidated alluvial deposits of Quaternary age and the bedrock formations of Tertiary age directly underlying the unconsolidated alluvial deposits (table 1). The Eocene and Oligocene White River Group is the oldest group of water-bearing rocks that are present surficially in the study area. The White River Group is made up of the Chadron Formation, and the Orella Member, Whitney Member, and brown siltstone unit of the Brule Formation (Swinehart and others, 1985; Swinehart and Diffendal, 1997). The Miocene Ash Hollow Formation of the Ogallala Group overlies the Brule Formation on the uplands. Quaternary alluvial sediments fill the present North Platte River Valley that incised the Ogallala and White River Groups. An anticline and syncline trending to the northeast also are present in these groups in the western half of the study area.

The alluvial aquifers in the North Platte River and Lost Creek Valleys contain similar sizes and distributions of sands and gravels, are hydraulically connected, and are used for domestic use and irrigation. Because the two alluvial aquifers are hydraulically connected and are similar in both composition and use, for this report they are considered a single unit, hereinafter referred to as the alluvial aquifer.

Locally, the part of the Brule Formation that underlies the alluvial aquifer is up to 450 ft (feet) thick. The Brule Formation overlies and generally serves as the upper confining layer for ground water in the Chadron Formation. The clay content of the Brule Formation, predominantly montmorillonite, influences some of the water-bearing properties of the formation. In particular, the montmorillonite clay commonly swells, resulting in reduced permeability (Tychsen, 1954, p. 172). Most of the water in the Brule Formation is in fissures and crevices (Darton, 1903). The water yielded to wells from the Brule Formation is generally only sufficient for domestic and stock uses; however, some wells can yield up to 1,000 gal/min (gallons per minute) locally.

Ground-water supplies in the alluvial aquifer are sufficient to yield large quantities of water for domestic, irrigation, and municipal wells. This is evident from the many irrigation wells in the North Platte River Valley. The alluvial aquifer is the source of all municipal water in the North Platte River Valley in Garden County.

Soils

Soils in the study area are derived from alluvial and colluvial deposits. Soils found along the valley floors are predominantly represented by the Las-Las Animas-McCook and Lawet-Elsmere-Gannet Associations (Dugan, 1984). These associations are generally loams to fine sands with permeabilities from 5 to 10 in. per hour and very gentle slopes of 0 to 3 percent. The soils are generally well drained and extensively used for agricultural purposes. The soils found on the uplands to the south and north are predominantly represented by the Bazile-Paka-Thurman and the Jayem-Sarben-Valent Associations. These associations are fine sandy loams to fine sands with permeabilities similar to the associations along the valley floors. The slopes generally are 3 to 10 percent; however, in areas classified as the Epping-Rock outcrop complex, the very fine sandy loam slopes can vary from 30 to 60 percent. The slopes from the uplands to the valley floors generally are 9 to 30 percent.

Land Use

Land use in the study area is predominantly agriculture and rangeland (table 2; fig. 5). Agriculture is predominantly irrigated and nonirrigated row crops in the valleys. The crops grown in the study area include corn, dry beans, wheat, alfalfa, and hay. Records of fertilizer and pesticide use are not available for Garden County, but manure and commercial fertilizers, such as anhydrous ammonia and liquid and dry nitrogen mix, and many types of pesticides are used throughout the study area. Rangelands are located mainly north of the North Platte River, in the western end of the study area, and on the uplands to the north and south.

Table 2. Land use in the study area, Garden County, western Nebraska, 1991

[U.S. Department of Agriculture, Consolidated Farm Services Agency, written commun., 1992]

Land use	Number of acres	Percentage of area
Cropland	12,400	47
Pastureland/hay	8,500	32
Rangeland	4,500	17
Urban	900	4
Total	26,300	100

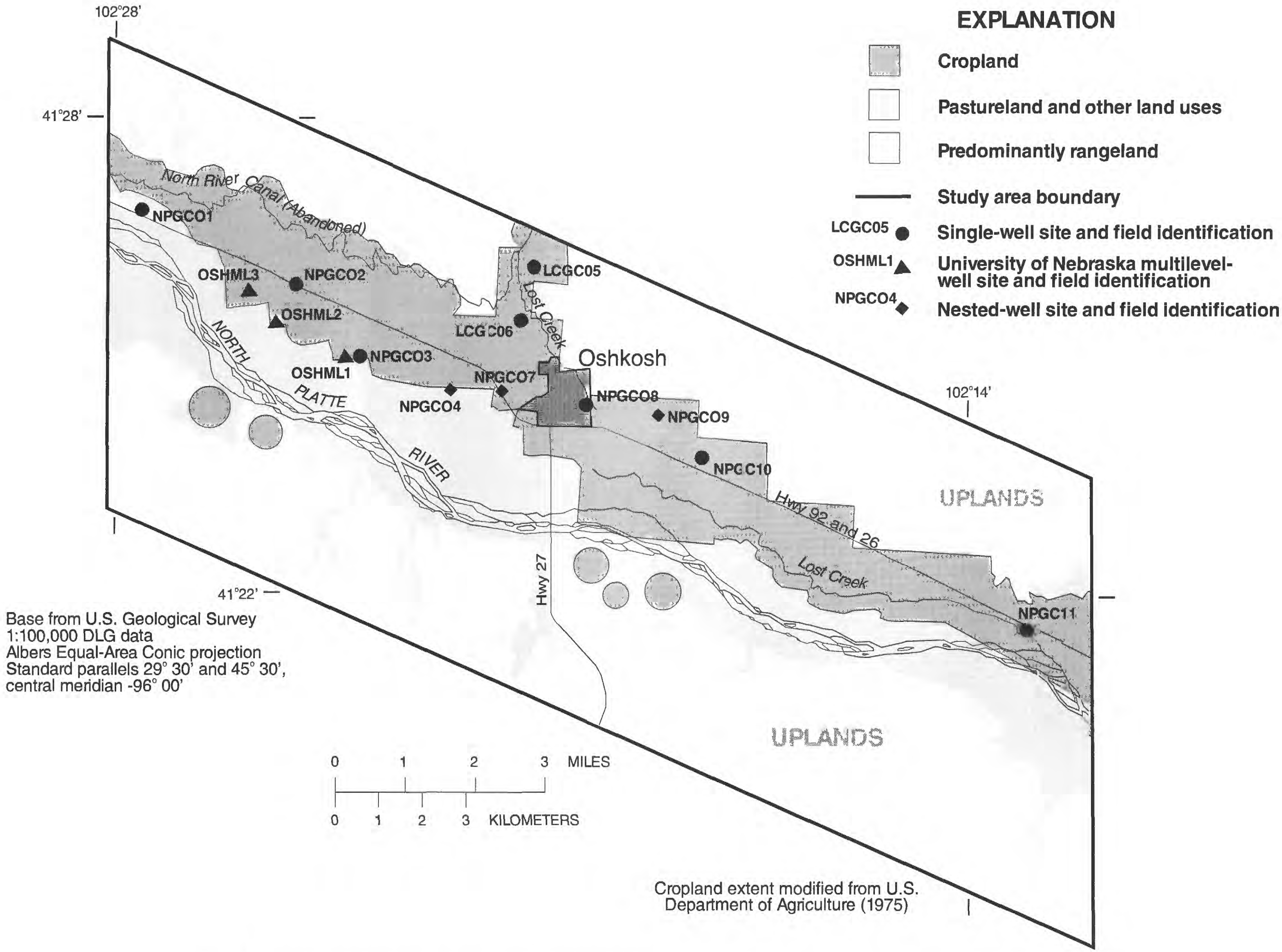


Figure 5. Location of monitor wells and general land use in the study area, western Nebraska.

METHODS

Installation of Monitor Wells

Locations for ground-water-quality monitor wells were selected on the basis of the NPNRD's water-table map, monitor wells previously installed by the University of Nebraska-Lincoln, historical and spatial distribution of nitrate concentrations, land use, and irrigation-well density. Specific criteria for location of monitor wells included proximity to agricultural lands, depth to water table, and the spatial distribution of elevated nitrate concentrations detected in water samples previously collected by the NPNRD. In addition, four sites were specifically located to monitor ground water entering and leaving the study area. After site selection, permission to install wells was obtained from the land owners.

In April 1993, 14 monitor wells were installed at 11 sites. The 11 new sites, along with 3 of the University of Nebraska-Lincoln's previously installed, multilevel monitor wells, compose the long-term monitor network (fig. 5; tables 3 and 4). The 11 new sites have either a single well screened throughout the saturated thickness of the alluvial aquifer, or two nested wells screened in the upper and lower halves of the alluvial aquifer. Each well was constructed of 2.5-in., schedule-40 polyvinyl chloride (PVC) pipe. The well screens also were made of PVC with number 10 slot. In addition to the four sites located to monitor concentrations of nitrate in ground water flowing into or out of the study area, two sites were located near supply wells and were used for water-quality monitoring as well as water-level monitoring during the aquifer tests.

Monitor wells NPGC01 and NPGC11 were located the farthest upstream and downstream in the portion of the study area lying in the North Platte River Valley. These two wells were used to determine nitrate concentrations in ground water flowing into and out of the study area. Monitor wells LCGC05 and LCGC06 are north of Oshkosh and were used to determine if the ground-water inflow from the moderately irrigated Lost Creek Valley contained elevated nitrate concentrations.

All new monitor wells were drilled using direct rotary methods and completed to the top of the bedrock surface with the exception of the shallow nested wells and the three deepest wells: NPGC02, NPGC03, and NPGC11. Monitor wells NPGC02, NPGC03, and NPGC11 were all completed within the alluvial sands and gravels, but only to depths of 163 ft, 145 ft, and 130 ft, respectively.

Hydrologic Data Collection and Analysis

A water-table map, historical data, and two aquifer tests were used to determine the hydrologic properties of the alluvial aquifer. Historical data included lithologic logs from test wells, well registrations from registered irrigation wells, and previous reports and maps. In 1994, two constant-discharge aquifer tests also were conducted to better determine the properties of the alluvial aquifer. Lithologic logs from the University of Nebraska test-hole data and registrations of irrigation and municipal wells were used to obtain depth to bedrock and lithologic features of the alluvial aquifer.

Review of a transmissivity map (Missouri Basin States Association, 1982) of the alluvial aquifer in the lower North Platte River provided an estimate of the range of transmissivity in the alluvial aquifer. This map (scale 1:250,000), developed by the U.S. Army Corp of Engineers with assistance from the University of Nebraska-Lincoln (Vern Souders, University of Nebraska-Lincoln, written commun., 1997), was based on the computation of specific capacity of irrigation wells in the North Platte River Valley. Although limited in detail, the transmissivity map provided useful information to substantiate other estimates of the hydraulic properties of the alluvial aquifer.

In April 1994, two 24-hour constant-discharge aquifer tests were performed to define the hydraulic conductivity, transmissivity, and specific yield of the alluvial aquifer better. Each constant-discharge aquifer test was set up and analyzed using standard methods described by Dawson and Istok (1991), Domenico and Schwartz (1990), Driscoll (1986), Freeze and Cherry (1979), Kruseman and de Ridder (1990), Lohman (1972), Moench (1993, 1994), and Neuman (1975). Prior to the tests, in October 1993 and March 1994, electronic water-level monitoring instrumentation was installed at the two sites used to monitor the water levels, NPGC03 and NPGC08, respectively. This equipment recorded hourly water-level measurements to document water-level trends prior to and following the aquifer tests. In addition, before the start of each test, an additional set of water-level monitoring equipment was installed in the same monitor wells to define the drawdown cone (at logarithmic intervals of 15 seconds to 1 hour) during the actual test.

Table 3. Site identification, field identification, well location, depth, screened interval, and mean water level for single and nested monitor wells, Garden County, western Nebraska

[Diameter of all wells is 2.5 inches; USGS, U.S. Geological Survey]

USGS site identification	Field identification	Well location	Depth below land surface (feet)	Screened interval (feet)	Mean 1993-94 water level (feet below land surface)
412648102274001	NPGC01	17N 45W13BCCD1	34	14 - 34	31.16
412553102250701	NPGC02	17N 44W20BDCC1	163	[1]3 - 163	15.35
412500102240301	NPGC03	17N 44W28CBAA1	145	5 - 145	6.83
412435102223301	NPGC04D	17N 44W27DCCC1	48	28 - 48	4.17
412435102223302	NPGC04S	17N 44W27DCCC2	28	8 - 28	4.14
412605102211001	LCGC05	17N 44W23ACAA1	70	10 - 70	14.93
412526102212301	LCGC06	17N 44W26ABBB1	38	18 - 38	5.75
412434102214201	NPGC07D	17N 44W35BBAA1	48	28 - 48	10.29
412434102214202	NPGC07S	17N 44W35BBAA2	28	8 - 28	10.31
412424102201801	NPGC08	17N 44W36BADD1	87	7 - 87	12.58
412416102182301	NPGC09D	17N 43W31BDAD1	115	55 - 115	19.32
412416102182302	NPGC09S	17N 43W31BDAD2	65	15 - 65	19.15
412345102182301	NPGC10	17N 43W32CCCA1	58	18 - 58	17.25
412137102130101	NPGC11	16N 43W14ACCB1	130	10 - 130	8.24

[1]Includes two sections of solid casing, 103 to 123 feet and 133 to 153 feet below land surface.

Table 4. Site identification, field identification, well location, and depth for multilevel monitor wells, Garden County, western Nebraska

[Well diameter was 0.125 inch; screened interval is discrete; USGS, U.S. Geological Survey]

USGS site identification	Field identification	Well location	Depth below land surface (feet)[1]
412500102241801	OSHML1-1	17N 44W29DAAA1	10
412500102241802	OSHML1-2	17N 44W29DAAA2	15
412500102241803	OSHML1-3	17N 44W29DAAA3	20
412500102241804	OSHML1-4	17N 44W29DAAA4	25
412500102241805	OSHML1-5	17N 44W29DAAA5	30
412500102241806	OSHML1-6	17N 44W29DAAA6	40
412500102241807	OSHML1-7	17N 44W29DAAA7	50
412500102241808	OSHML1-8	17N 44W29DAAA8	60
412526102252701	OSHML2-1	17N 44W19DDDD1	10
412526102252702	OSHML2-2	17N 44W19DDDD2	15
412526102252703	OSHML2-3	17N 44W19DDDD3	20
412526102252704	OSHML2-4	17N 44W19DDDD4	25
412526102252705	OSHML2-5	17N 44W19DDDD5	30
412526102252706	OSHML2-6	17N 44W19DDDD6	40
412526102252707	OSHML2-7	17N 44W19DDDD7	50
412526102252708	OSHML2-8	17N 44W19DDDD8	60
412549102255401	OSHML3-1	17N 44W19DBBA1	10
412549102255402	OSHML3-2	17N 44W19DBBA2	15
412549102255403	OSHML3-3	17N 44W19DBBA3	20
412549102255404	OSHML3-4	17N 44W19DBBA4	25
412549102255405	OSHML3-5	17N 44W19DBBA5	30
412549102255406	OSHML3-6	17N 44W19DBBA6	40
412549102255407	OSHML3-7	17N 44W19DBBA7	50
412549102255408	OSHML3-8	17N 44W19DBBA8	60

[1]From Conservation and Survey Division, University of Nebraska-Lincoln.

Furthermore, hand measurements using electronic measuring tapes were taken to supplement and back up the data recorded by the water-level monitoring instrumentation.

Hydrographs of the data collected prior to and during the two aquifer tests indicate that natural variations in water levels in monitor wells NPGC03 and NPGC08 were minimal during each test, approximately 0.01 ft/d (ft per day) (fig. 6); therefore, no correction was used to adjust the aquifer-test drawdown curve.

The two constant-discharge aquifer tests involved a 24-hour pumping period for each pumped well followed by a 24-hour recovery period. These aquifer-test data were used to define the hydraulic properties of the alluvial aquifer at the well sites, and estimate the hydraulic properties of the alluvial aquifer in the study area.

The first constant-discharge aquifer test was performed during April 4-6, 1994 at the irrigation well adjacent to and 23 ft southwest of monitor well NPGC03. Monitor well NPGC03 is fully screened through the alluvial aquifer, 5 to 145 ft below land surface. The irrigation well, installed in June 1975, is 143 ft deep, has a 16-in. diameter casing, and is screened from 52 to 143 ft below land surface. Discharge from the irrigation well during the aquifer test was about 318,600 ft^3/d (cubic ft per day).

The second aquifer test was performed during April 6-8, 1994 at the Oshkosh municipal well adjacent to and 24 ft north of monitor well NPGC08. Monitor well NPGC08 was used to monitor water-level changes caused by pumping of the municipal well. NPGC08, like NPGC03, also is fully screened through the aquifer, 7 to 87 ft below land surface. The Oshkosh municipal well, installed in December 1974, is 91 ft deep, has an 18-in. diameter casing, and is screened from 39 to 91 ft below land surface. Discharge from the municipal well during the aquifer test was about 193,300 ft^3/d.

Following the data collection, each test was analyzed by determining a matching point on a log-log plot of drawdown as a function of time to a type-curve as described by Boulton (1963). This match point was used in Stallman's (1965) method of analysis for an unconfined, compressible aquifer as described by Lohman (1972) and Neuman (1975). Because the transmissivity and hydraulic conductivity values for the discharge and recovery tests are nearly equal, the transmissivity and hydraulic conductivity values described in this report will be for the discharge test. However, the average value of the specific yield is used in this report because of the wider variance in specific yield values determined from the discharge and recovery tests.

Major assumptions required for the aquifer-test analysis include a fully penetrating production well, a homogeneous, anisotropic aquifer of infinite areal extent, and radial flow to the well screen. Other assumptions include continuous and constant discharge from the pumped wells, constant ground-water density and viscosity, an unconfined aquifer that shows a delayed water table response, negligible head losses through the well screen, and ground-water flow as described by Darcy's Law (Dawson and Istok, 1991).

Water-Quality Sample Collection and Analysis

For this study, procedures modified from Kolpin and Burkart (1991) were used for water-quality sampling and quality assurance. The following describes water-quality sampling techniques and analytical methods.

Water samples for nitrate analysis were collected approximately bimonthly from 23 of the 38 single, nested, and multilevel monitor wells and quarterly from the remaining 15 multilevel monitor wells. Water samples to be analyzed for major ions were collected semiannually and samples to be analyzed for triazine and acetamide herbicides were collected annually. Water levels in all single and nested monitor-well sites were measured prior to lowering a submersible stainless-steel pump into the well. At all single and nested monitor wells, the submersible pump was lowered to about 10 ft below the water surface. The discharge hose from the submersible pump then was connected to a flow-through chamber holding the water-quality field measurement probes (specific conductance, pH, temperature, and dissolved oxygen). Pumping continued until all field measurements stabilized to tolerances described by Kolpin and Burkart (1991) or until three well-casing volumes of water were extracted from the well. Stabilization of the field measurements occurred following approximately 15 to 20 minutes (min) of pumping, sufficient time to flush the equivalent of at least three well-casing volumes from the wells. Water samples from the multilevel monitor wells were collected using a peristaltic pump with polypropylene tubing. These wells were pumped about 1 min prior to collecting the field measurements and water-quality samples.

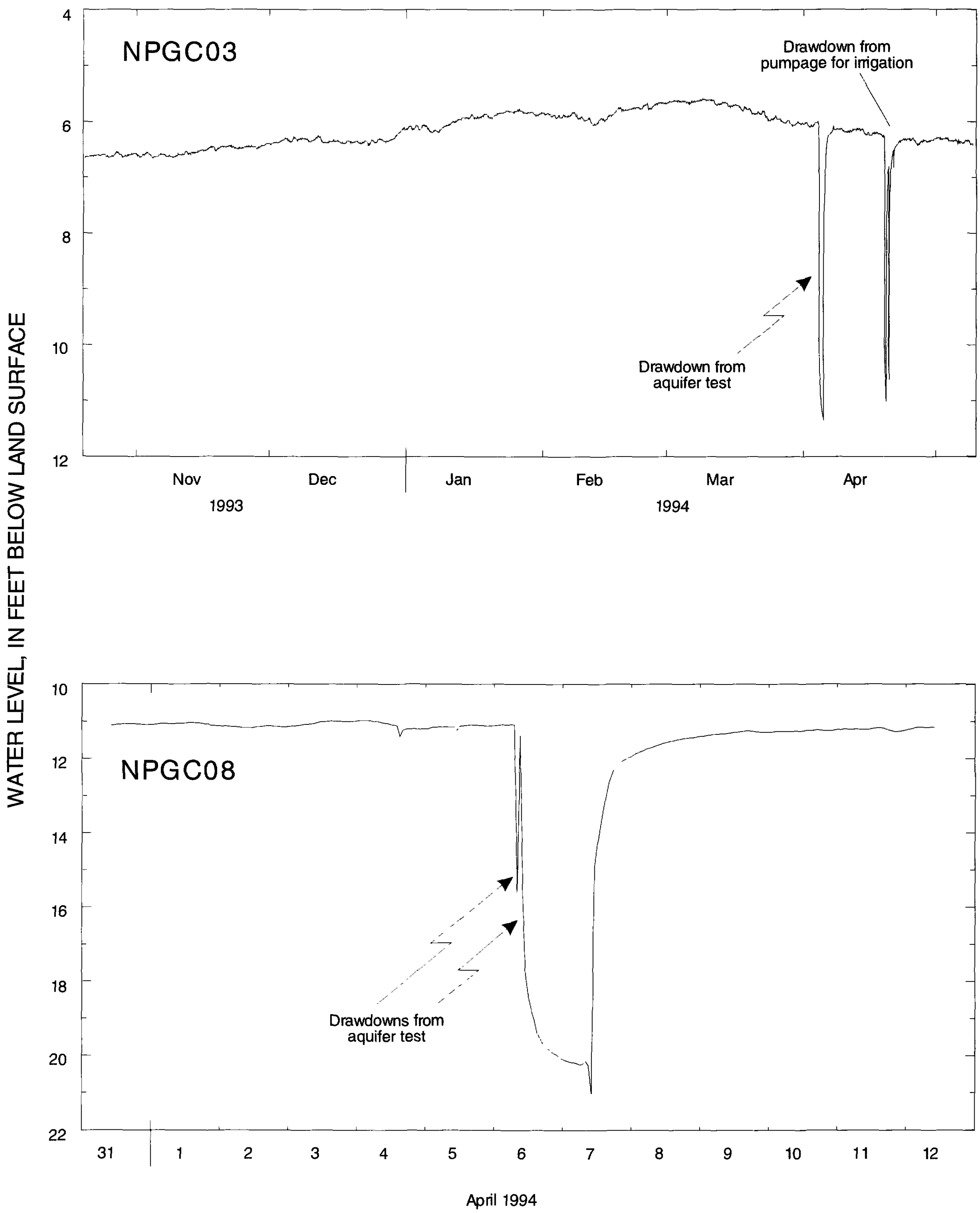


Figure 6. Water levels preceding, during, and following constant-discharge aquifer tests, April 1994, in the study area, western Nebraska.

All unfiltered samples were collected directly into polyethylene jars. Samples requiring filtration, excluding those for triazine herbicide analysis, were collected in a 9-liter polypropylene churn splitter and pumped through a 0.45-micron membrane filter using a peristaltic pump with polypropylene tubing. Samples for triazine and acetamide herbicide analysis were collected in a 1-liter baked-glass jar, pumped through the peristaltic pump and a 1.0-micrometer glass-fiber filter into a 125-milliliter (mL) baked-glass jar, and immediately chilled to 4 °C (degrees Celsius).

Samples for major metal analysis were filtered and immediately adjusted to a pH of 2 or less using 1.0 mL of nitric acid and stored at ambient temperature. Samples for major anion analysis did not require filtration and were stored at ambient temperature. Samples for nutrient analysis were preserved immediately with 0.5 mL mercuric chloride and hydrochloric acid, and then chilled to 4 °C.

Water samples generally were collected in a 2- to 3-day period and shipped to the USGS National Water-Quality Laboratory (NWQL) in Arvada, Colorado. Triazine herbicide samples collected in 1993 were screened at the USGS Nebraska District laboratory using an immunoassay technique. Triazine and acetamide herbicide samples collected in 1994 all were sent to the NWQL.

Measurements for specific conductance, pH, air and water temperature, barometric pressure, and dissolved oxygen were made onsite. However, occasional equipment failures, especially during the winter months, prevented collection of all field measurements for all sample periods (table 9, Supplemental Data section). Samples were analyzed for major cations and anions, nitrate plus nitrite and other nutrients, and selected triazine and acetamide herbicides using standard methods at the NWQL (Fishman and Friedman, 1989). Nitrite (NO_2^-) is unstable in aerated water (Hem, 1985) and usually is oxidized to nitrate in aerobic conditions; therefore, because nitrite is seldom detected, all analyses for nitrate plus nitrite were reported as N.

A triazine herbicide immunoassay kit was used to screen an aliquot of each water sample collected during 1993 for triazine herbicides (Thurman and others, 1990). Samples containing 0.1 microgram per liter (µg/L) or more of triazine herbicides, and 10 percent of the samples with nondetections, were sent to the NWQL for analysis using gas chromatography/mass spectrometry (GC/MS). GC/MS was used to analyze all water samples collected in 1994 for triazine and acetamide herbicides.

Nonparametric statistical analysis of the data was performed to compare subsets of water-quality data. In nonparametric tests, inference is not made on the parameter of the original data, but on the parameter of the new scale of measurement (Dowdy and Wearden, 1991). For these tests the new scale was the "ranking" of the data.

For nonparametric testing, data were grouped into appropriate subgroups and "censored data" (values that are below the reporting limit of the analytical procedure) were assigned a value equal to one-half the reporting limit. Because the tests performed are nonparametric and are performed on ranked values, fabrication of the censored data does not affect the test results (Helsel and Hirsch, 1992).

The Wilcoxon rank-sum test (Helsel and Hirsch, 1992) was used to evaluate the data. The Wilcoxon rank-sum test compares populations whose data are independent of each other, such as data collected from monitor wells screened at the bottom of the aquifer compared with data collected at the top of the aquifer. All statistical analyses used a confidence level of 95 percent ($\alpha = 0.05$). A confidence level is the probability that the test statistic generated for that test accurately defines the populations being tested. The p-value associated with this particular test is the probability of getting a test statistic equal to, or more extreme than, the value computed from the data when the null hypothesis (differences in the medians of the populations is zero) is true. If the p-value is less than or equal to 0.05, the null hypothesis is rejected and there is a significant difference between the medians of the two populations. If the p-value is greater than 0.05, the null hypothesis is accepted and a significant difference between the medians of the two populations cannot be concluded.

Quality Assurance and Quality Control

Quality-assurance (QA) and quality-control (QC) procedures described by Kolpin and Burkart (1991) were employed during all sampling periods. These procedures involved randomly choosing a monitor well from which a replicate sample was collected, and running an equipment blank using deionized water. About 7 percent of the samples collected were for QA/QC analyses and procedures. The values for all replicate analyses for nitrates and other constituents were within 7 percent of the values for the original analysis.

The QA program at the NWQL includes participation in an interlaboratory evaluation with the USEPA, and submission of blind standard reference water samples into the NWQL sample stream (Friedman and Fishman, 1982; Jones, 1987). Bottles and preservatives used for sampling were subjected to QA tests to reduce the chance of contamination. Cation-anion balances were calculated for each complete analysis to ensure major-ion balance and internally consistent data. Samples were reanalyzed by the NWQL if the cation-anion ionic charges did not balance within 5 percent of each other.

GEOHYDROLOGY OF THE ALLUVIAL AQUIFER

Hydraulic Properties

The hydraulic properties of the alluvial aquifer were determined by evaluation of historical data—drillers logs, well registrations, previous reports—and data collected during this study—lithologic logs from the monitor wells and results of the two constant-discharge aquifer tests. Historical data and lithologic logs of wells drilled by the USGS and the University of Nebraska-Lincoln indicate the thickness of the alluvial aquifer varies with location (fig. 7). The saturated thickness of the alluvial aquifer varies generally from 0 to more than 200 ft and is largely dependent upon the altitude of the bedrock (fig. 8).

Water-level data also were used to estimate some of the hydraulic properties of the alluvial aquifer. A water-table map (fig. 9), constructed from spring 1993 ground-water level data collected from all 14 monitor-well sites and about 65 registered irrigation wells in the North Platte and Lost Creek Valleys, was used to determine the hydraulic gradient in the study area. The regional hydraulic gradient in the alluvial aquifer, as defined by spring 1993 data, was estimated to be about 0.0012 ft/ft or about 6.5 ft/mi.

In general, substantial variations in the hydraulic properties exist throughout the alluvial aquifer. These variations largely are due to the horizontal and vertical differences in size, distribution, and thickness of the sand and gravel deposits. Any or all of these differences can, and do, occur within hundreds of feet. Moreover, reports on alluvial systems in western Nebraska by Darton (1903) and western and central Kansas by Sophocleous (1991) suggest that hydraulic conductivities in alluvial aquifers vary vertically as well as areally.

Similar to the systems described by Darton (1903) and Sophocleous (1991), lithologic logs of the monitor wells (tables 13-23, Supplemental Data section) show evidence that the alluvial aquifer probably contains highly transmissive channels. These inferred, localized, highly transmissive channels could greatly affect the overall hydraulic conductivity and transmissivity of the aquifer. However, no attempt was made in this report to differentiate hydraulic conductivities of individual sand and gravel lenses. The transmissivities of the clay lenses were not considered to be part of the regionalized transmissivity.

Analysis of the aquifer-test data at both test sites showed that water-level changes in each monitoring well occurred almost instantaneously with the start-up of the production well. In addition, most of the drawdown in the monitor wells at each test site occurred during the first ten minutes following the start of the tests (figs. 10 and 11). Likewise, at both test sites, most of the recovery occurred during the first ten minutes after pumping ceased. Indications that the alluvial aquifer is unconfined were determined from analysis of the aquifer-test data. The start of a delayed-yield curve appeared at both test sites after about 100 minutes of pumping and recovery (figs. 10 and 11). This curve, which is typical of water-table conditions, represents Boulton's (1963) delayed yield type-B curve for aquifer tests in unconfined systems.

Evaluation of the aquifer-test data also indicates that the hydraulic properties of the alluvial aquifer differ between the two test sites (table 5). The horizontal hydraulic conductivity for the alluvial aquifer varied slightly, 169 ft/d at NPGC08 and 183 ft/d at NPGC03 (table 5). Because the saturated thickness at monitor well NPGC08 (75 ft) is about half that of NPGC03 (145 ft), the transmissivity determined at NPGC08, 12,700 ft^2/d (ft-squared per day), is about half that determined at NPGC03 (26,600 ft^2/d) (table 5).

Results of the two aquifer tests are in agreement with historical data. Published historical data show some transmissivity values greater than 26,000 ft^2/d in the deeper parts of the alluvial aquifer (Missouri River Basin Association, 1982). These transmissivities are similar to the transmissivities determined by analysis of the aquifer-test data at monitor well NPGC03.

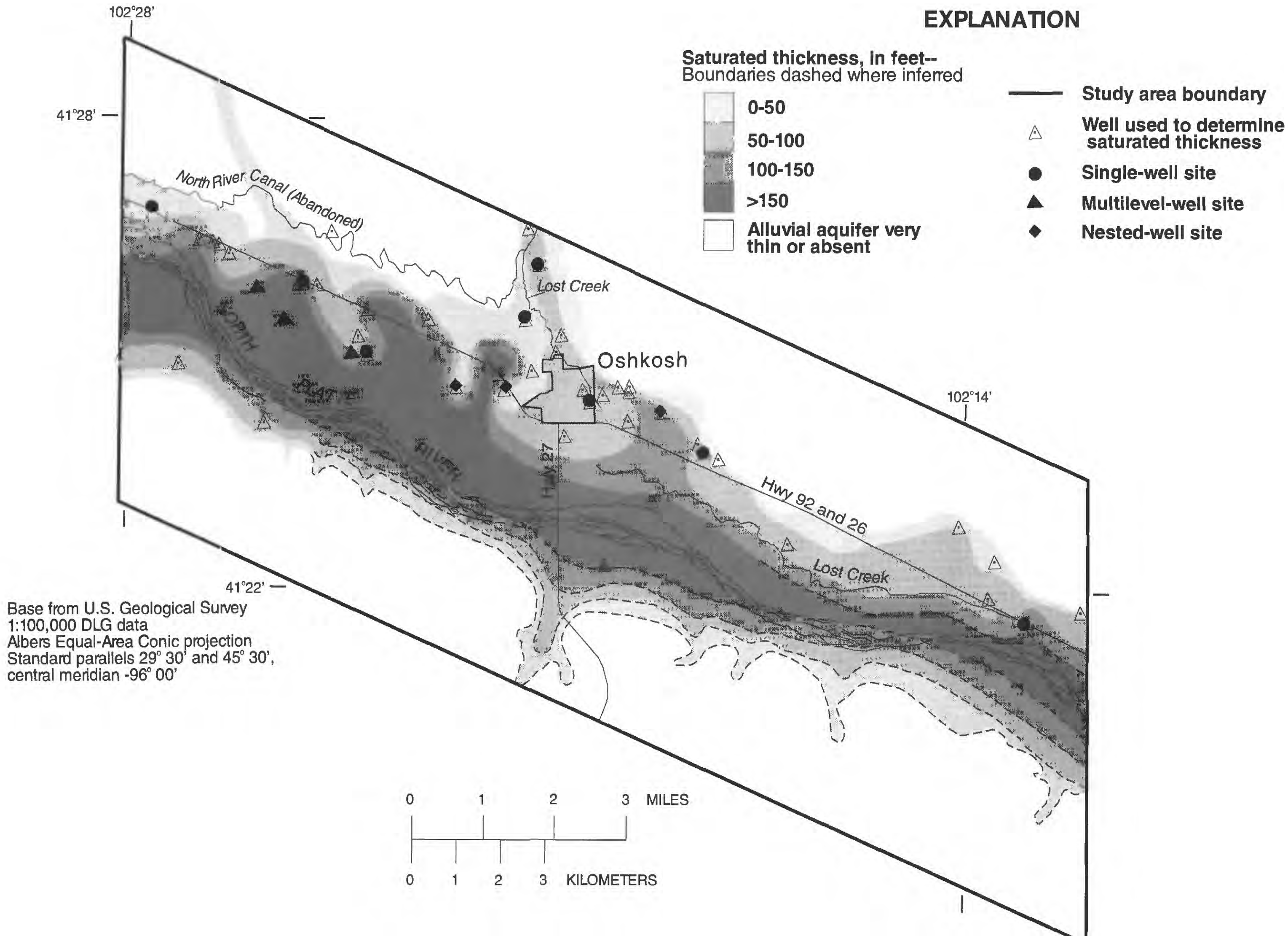


Figure 7. Generalized saturated thickness of alluvial aquifer in the study area, western Nebraska.

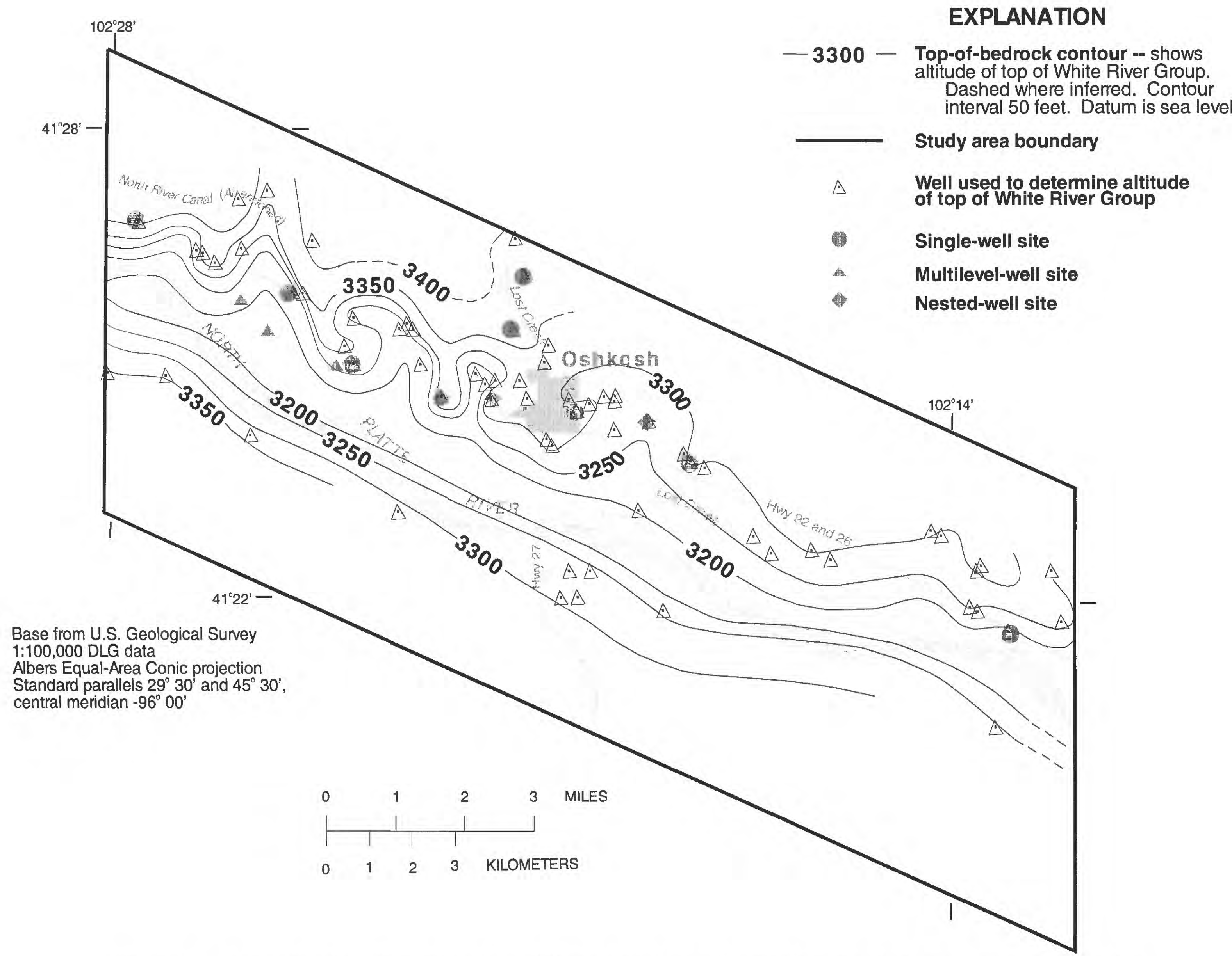


Figure 8. Generalized configuration of top of White River Group (bedrock) in the study area, western Nebraska.

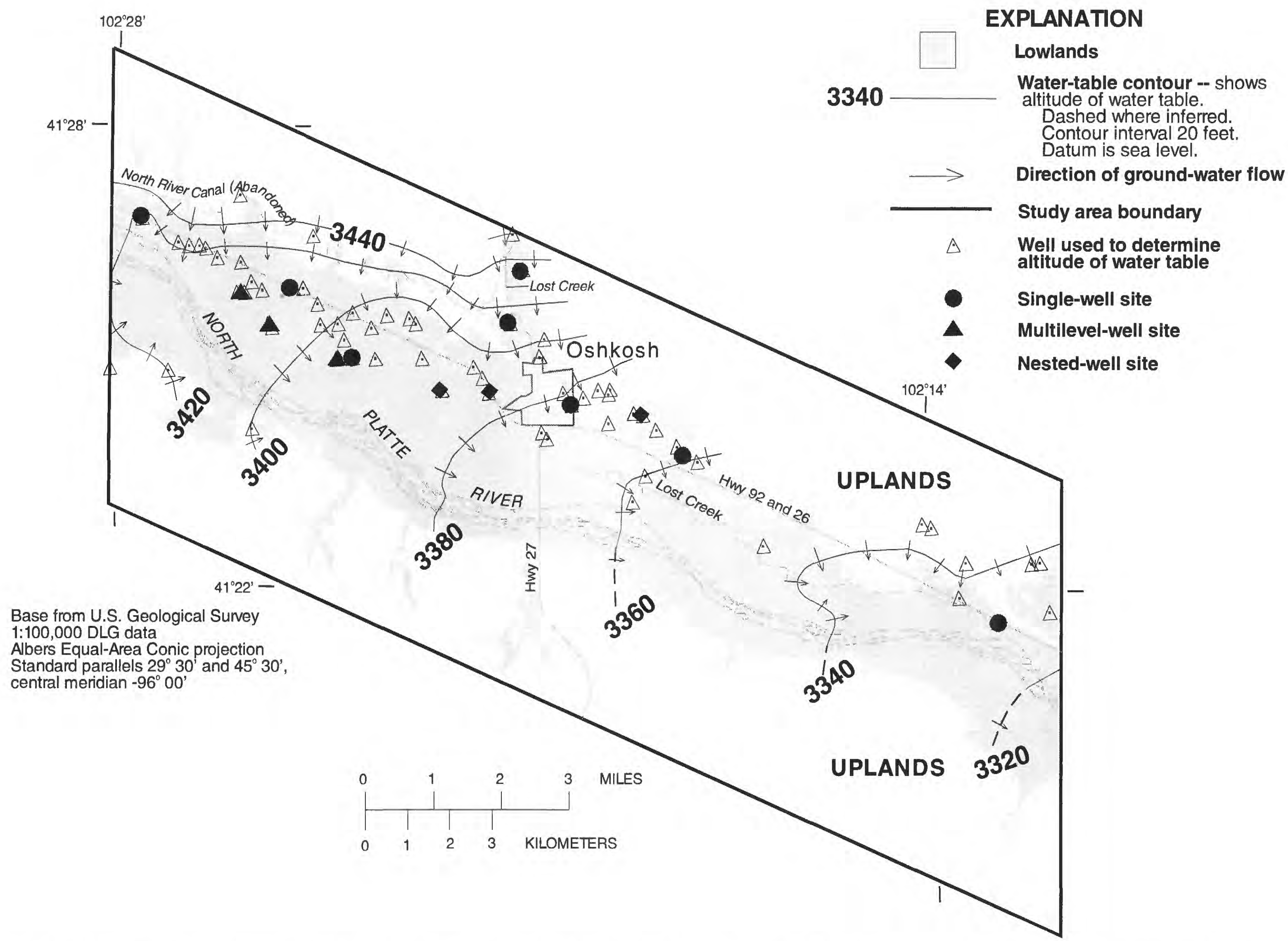


Figure 9. Altitude of water table and direction of ground-water flow in the alluvial aquifer in the study area, western Nebraska, spring 1993.

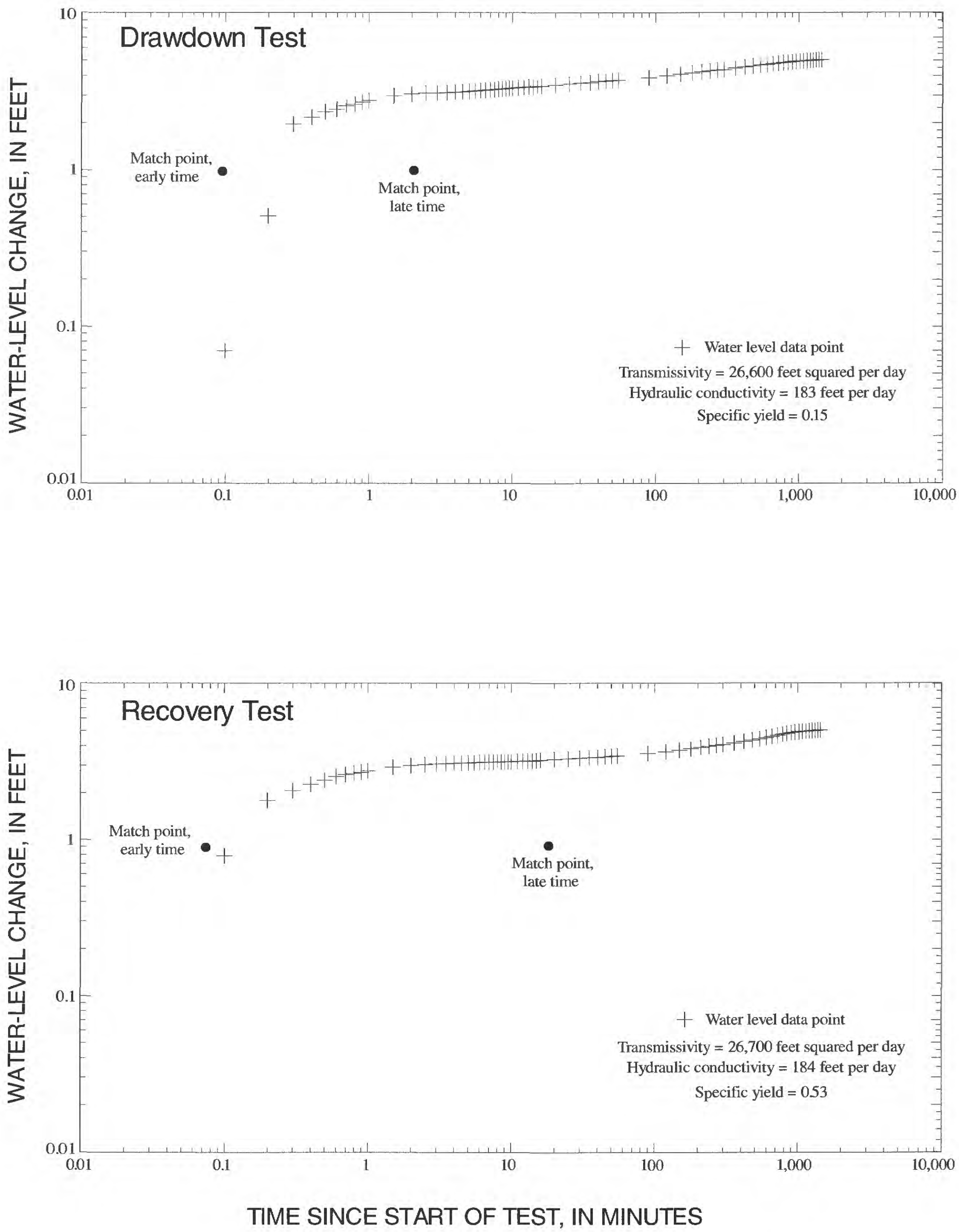


Figure 10. Water-level change as a function of time for monitor well NPGC03 during aquifer test from April 4-6, 1994, in the study area, western Nebraska.

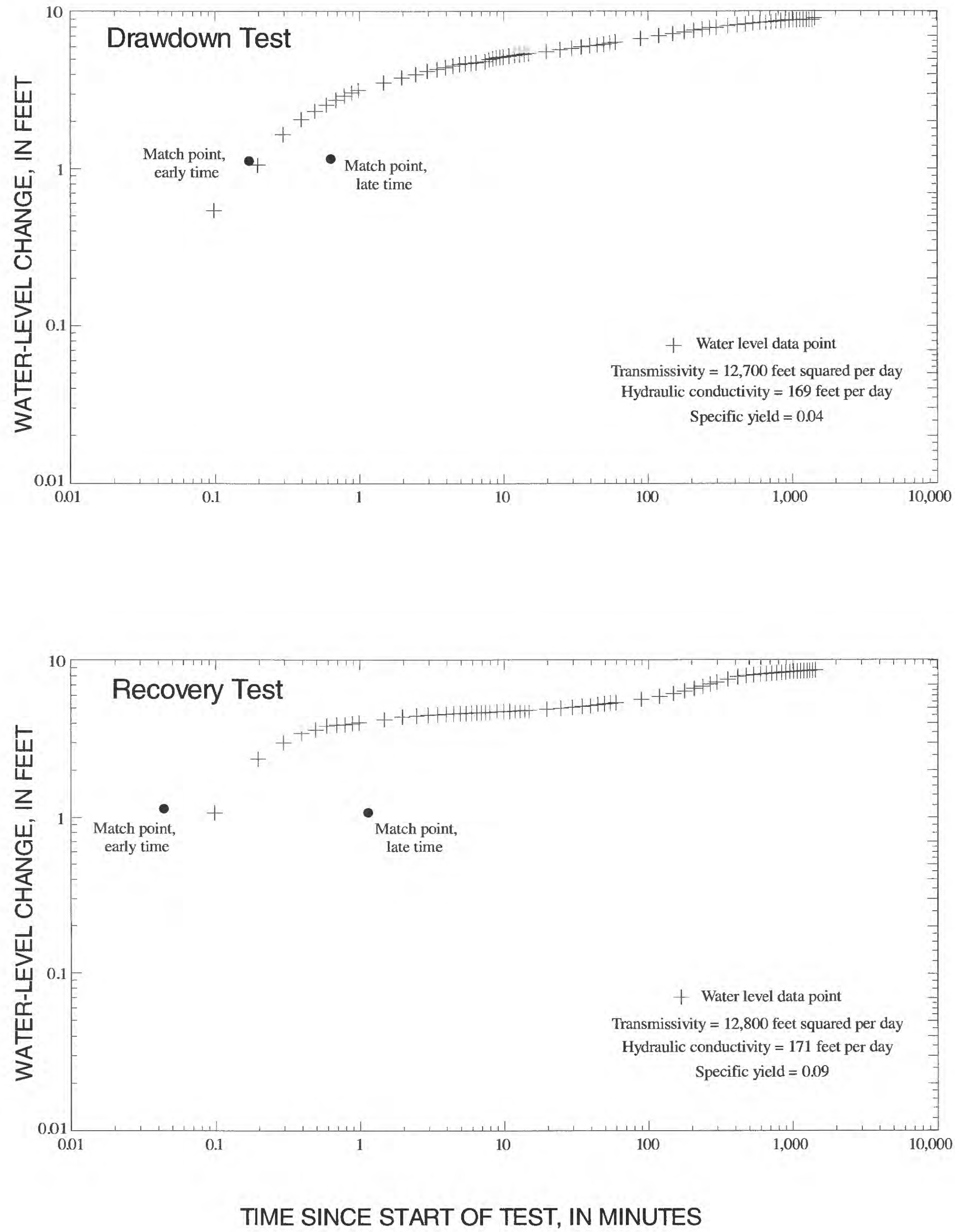


Figure 11. Water-level change as a function of time for monitor well NPGC08 during aquifer test from April 6-8, 1994, in the study area, western Nebraska.

Table 5. Constant-discharge aquifer test results for monitor wells NPGC03 and NPGC08, Garden County, western Nebraska, April 1994

[ft^3/d, cubic feet per day; ft^2/d, feet squared per day; ft/d, feet per day; --, dimensionless]

Aquifer characteristic	Units	NPGC03 Discharge test	NPGC03 Recovery test	NPGC08 Discharge test	NPGC08 Recovery test
Discharge	ft^3/d	318,600	0	193,300	0
Transmissivity	ft^2/d	26,600	26,700	12,700	12,800
Hydraulic conductivity	ft/d	183	184	169	171
Saturated thickness	ft	145	145	75	75
Specific yield	--	.15	.53	.04	.09

Therefore, using the calculated hydraulic conductivity from monitor well NPGC03, transmissivities in the alluvial aquifer at locations 200 ft and thicker than 200 ft could be larger than 36,000 ft^2/d.

The high hydraulic conductivity (169 and 183 ft/d) and transmissivity (12,700 and 26,600 ft^2/d) values, as determined from the two constant-discharge phases of the aquifer tests, suggest that the alluvial aquifer is transmissive enough to be susceptible to contamination from nonpoint sources. As seen in table 5, the recovery phase of the aquifer tests varied little from the discharge phase.

Vertical hydraulic conductivities were not measured directly. Estimates of the ratio of horizontal versus vertical hydraulic conductivities were made for input into Moench's (1993) algorithm to generate the type curves used in the analysis of the aquifer tests. Using these data, the ratio of horizontal to vertical hydraulic conductivities varied from 0.3 at NPGC03 to 0.1 at NPGC08. Thus, local vertical hydraulic conductivities in the alluvial aquifer may range from about 17 to 55 ft/d, dependant upon local conditions.

Specific yield is used as an indicator for the amount of water that a well can yield; the higher the specific yield, the greater the volume of water the aquifer can produce. Specific yield in unconfined aquifers typically range from 0.01 to 0.30 (Freeze and Cherry, 1979). Higher values of specific yield commonly are associated with medium to coarse sands and may be due, in part, to the fact that sands normally have a more uniform size distribution than gravels (Johnson, 1967). The lower specific yield value for the discharge phase of the aquifer test at NPGC03 (0.15, table 5) is substantially different than the higher specific yield value obtained for the recovery phase (0.53). Reasons for the difference in these two values could not be determined; therefore, the average of the two values was used. Likewise, the average specific yield for the discharge and recovery phases of the aquifer test at NPGC08 was used.

The average specific yield for the discharge and recovery tests were 0.34 at NPGC03 and 0.06 at NPGC08. Average specific yield for the discharge and recovery tests at both sites was 0.20. These values, like the hydraulic conductivity and the transmissivity values, probably are representative of the alluvial aquifer as a whole. In areas where sands and gravels predominate, like at NPGC03, specific yields in the alluvial aquifer can be over 0.30. However, specific yields in the alluvial aquifer are probably nearer the average of the two aquifer tests (0.20).

Ground-Water Flow

The predominant direction of ground-water flow in the alluvial aquifer in the North Platte River Valley, as shown on the water-table map of the alluvial aquifer (fig. 9), is northwest to southeast and generally parallel to the flow of the North Platte River. Exceptions to this direction can be found in areas of ephemeral streams such as Lost Creek, where the predominant flow direction is south (fig. 9).

Evaluation of water-table maps (Souders and Freethey, 1975; and fig. 9) and streamflow data was used to determine if the North Platte River was a gaining or losing river during the study period. These maps show that water generally flows from the alluvial aquifer into the North Platte River. In addition, streamflow data for water year 1993 (Boohar and others, 1994) indicate that the daily mean flow in the North Platte River generally increased from Lisco to Lewellen (locations in fig. 2). Therefore, during the study period, the North Platte River generally was a gaining river along the stretch that flows through the study area. However, it is likely that at times of high stage, water from the North Platte River may have recharged the aquifer.

An estimate of the average linear horizontal ground-water flow velocity in the alluvial aquifer was made using Darcy's law as described by Hall and others (1991, p. 172). Darcy's law, including effective porosity, is written as:

$$V = \frac{KI}{n},$$

where:

- V = average linear ground-water flow velocity, in ft/d;
- K = horizontal hydraulic conductivity, in ft/d;
- I = horizontal hydraulic gradient, in ft/ft; and
- n = effective porosity, as a decimal fraction.

An estimate of the horizontal ground-water flow velocity for the alluvial aquifer was made by assuming a hydraulic conductivity range of 169 to 183 ft/d, a hydraulic gradient of about 0.0012 ft/ft, and an effective porosity of 0.20. Using these values in the previous equation produced a linear velocity of about 1ft/d. The actual velocity at any location, however, depends on the orientation and distribution of the individual grains in the aquifer, and on the tortuosity of the ground-water flow around these grains. Therefore, the true ground-water flow velocity could differ from this estimate. No estimate of the vertical component of flow velocity was made.

GROUND-WATER QUALITY

Ground-water quality data are listed in the Supplemental Data section at the end of the report. All water-quality data, except the triazine immunoassay test results, are stored in the USGS National Water Information System (NWIS) data base.

Field Measurements

Specific conductance is the measure of the electrical conductivity of water. It is affected by the types and concentrations of dissolved solids present in the water. Specific conductance values ranged from 228 μS/cm (microsiemens per centimeter at 25 °C) to a maximum of 2,250 μS/cm (table 6) in samples collected during this study. The median specific conductance value was 1,270 μS/cm. Figure 12 shows how the field measurements in the ground water varied by month of sample.

Significant differences in selected field measurements in water samples, by well depth, were determined using rank-sum testing. Depth categories for the wells were shallower and deeper than the median well depth, 75 ft. Evaluation of these data indicate that water from wells shallower than 75 ft had a significantly (p=0.0000) higher median specific conductance value (1,500 μS/cm) than water from wells deeper than 75 ft (962 μS/cm).

This difference in median specific conductance value may be attributed to both the use of commercial fertilizers on fields and to a greater amount of feldspathic or other minerals present in the sediments that may contribute carbonates, chlorides, and sulfates to the ground water. Chemical compounds in the soil,

Table 6. Statistical summary of field measurements, Garden County, western Nebraska, 1993-94

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; %, percent; mm of Hg, millimeters of mercury]

Measurement	Number of observations	Minimum	Mean	Median	Maximum
Specific conductance, μS/cm	234	228	1,110	1,270	2,250
pH, standard units	242	6.9	7.5	7.5	8.0
Water temperature, °C	241	4.5	12.0	12.0	17.0
Dissolved oxygen, %	85	.1	3.9	4.1	8.9
Barometric pressure, mm of Hg	112	666	672	673	679

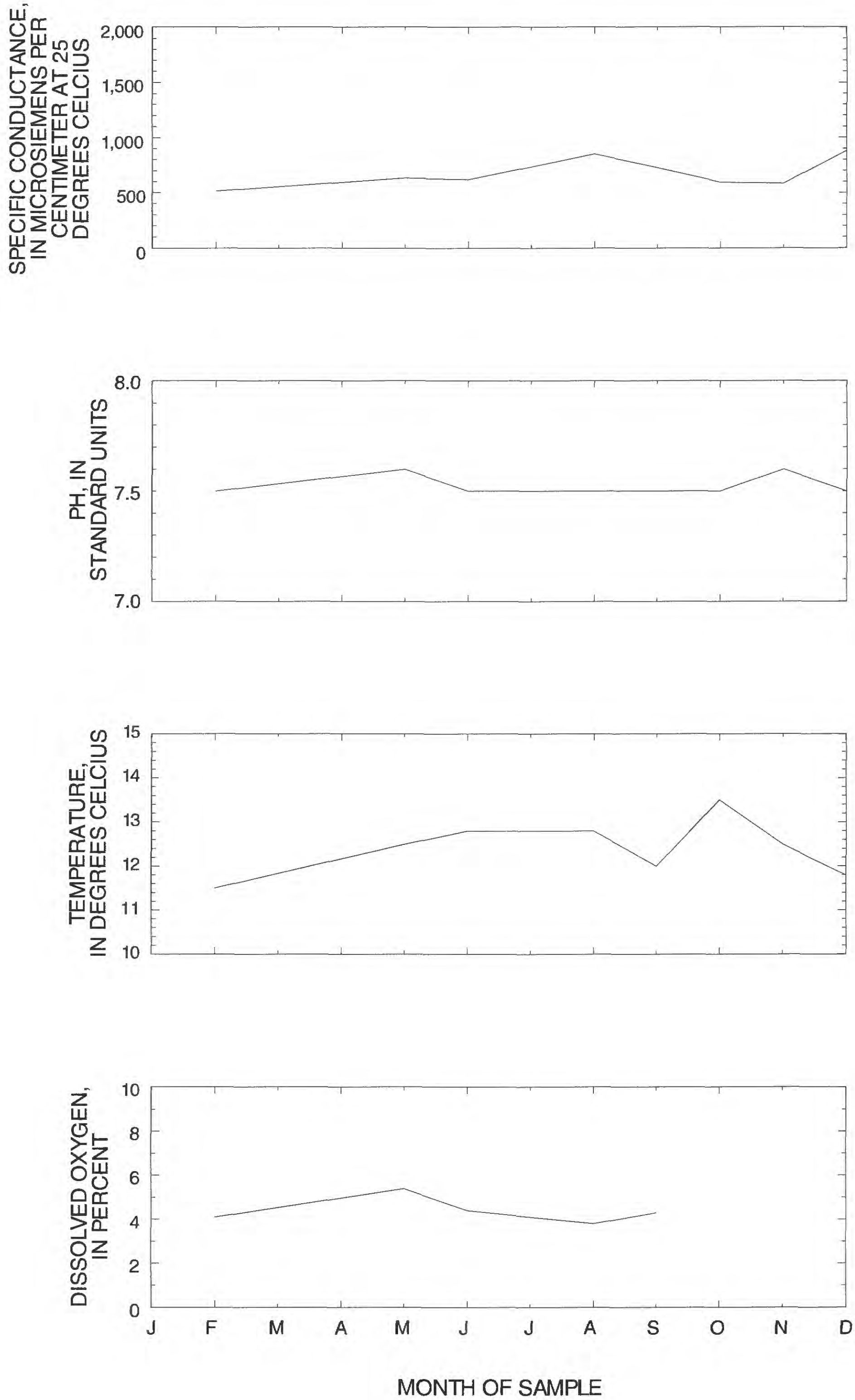


Figure 12. Median values of field measurements in ground-water samples, by month of sample, in the study area, western Nebraska, 1993-94 [missing values indicate no data].

such as nitrogen and phosphorus, which are present naturally or introduced by anthropogenic activities, can increase the amount of dissolved solids in the ground water if they are leached to the water table. Leaching of these chemical compounds could cause specific conductance values in the shallower part of the aquifer to be higher than in the deeper part.

Caution should be used when interpreting the significance of these results. Although evaluation of these data indicates that there is a significant difference in the specific conductance values from water samples collected from wells shallower or deeper than 75 ft, most of the deep wells—NPGC02, NPGC03, NPGC08, and NPGC11—are screened throughout most or all of the saturated thickness of the aquifer. Thus, water-quality data from these wells represent a composite sample over the entire depth of the monitor well.

Rank-sum testing also was performed on data collected at the three well-nest sites. At two of these sites—NPGC04 (p=0.5951) and NPGC09 (p=0.1777)—there were no significant differences in specific conductance values in water samples collected from the two depths. However, in monitor well NPGC07, there was a significant difference (p=0.0001) in specific conductance values in water samples from the two depths. Because the shallow and deep monitor-well depths at NPGC07 are equivalent to the shallow and deep monitor-well depths at NPGC04, at these three well-nest sites, specific conductance values did not appear to be a function of the difference in well depth.

Other field measurements included pH, water and air temperature, dissolved oxygen, and barometric pressure. Hem (1985) describes pH as a measurement of the hydrogen-ion concentration or activity that represents the negative base-10 log of the hydrogen activity in moles per liter. Values of pH in water samples ranged from 6.9 to 8.0 standard units with a median of 7.5 standard units, and did not vary significantly (p=0.89) in wells greater than versus less than 75 ft deep.

Water temperature, which can affect the density and the amount of dissolved gases in the water, ranged from 4.5 to 17.0 °C. Dissolved oxygen, which is affected by water temperature, ranged from 0.1 to 8.9 mg/L.

Major Ion Concentrations

Ground water in the study area generally varied between a calcium and sodium bicarbonate type (fig. 13). The concentrations of calcium present in the alluvial aquifer ranged from 38 to 170 mg/L (median of 92 mg/L) and concentrations of sodium ranged from 12 to 380 mg/L (median of 63 mg/L) (table 7). Sulfate concentrations ranged from 18 to 640 mg/L with a median of 110 mg/L. Sulfate concentrations in water samples collected at 3 of the 14 sites (NPGC08, OSHML1, and OSHML2) and in 8 of the 56 samples were above the Secondary Maximum Contaminant Level (SMCL) for drinking water of 250 mg/L (U.S. Environmental Protection Agency, 1996). Secondary drinking-water regulations were established to represent contaminant levels of constituents that can adversely affect the odor, taste, or appearance of drinking water.

Concentrations in 62 percent (35 of 56) of the samples analyzed for dissolved solids were above the USEPA's SMCL of 500 mg/L. Dissolved-solids concentrations ranged from 267 to 1,550 mg/L, with a median concentration of 614 mg/L.

High ratios of median concentrations of calcium versus sodium in water samples from monitor wells LCGC05 and LCGC06 suggest that water may be flowing into the alluvial aquifer through Lost Creek Valley (fig. 14). This same influx of water from Lost Creek also could be the source of the high ratios of calcium versus sodium found in water samples from NPGC11. High ratios of median concentrations of calcium versus sodium also were detected in water samples collected from monitor wells NPGC01 and NPGC11. Outcrops of the Ogallala Group can be found in many of the upper reaches of the Lost Creek Valley as well as near monitor well NPGC01. Calcareous paleosols described by Gardner and others (1992) also are common in these areas. Ground water likely passes through and dissolves some of the calcium ions in areas where caliches in the Ogallala Group lie near the surface.

High ratios of median concentrations of sodium versus calcium were detected in monitor well NPGC10, east of Oshkosh, and in monitor wells NPGC04D, NPGC04S, OSHML1, and OSHML2, west of Oshkosh. No definitive source of the high sodium concentrations was evident. Verstraeten and others (1995) report that the aquifer in the underlying confined Chadron Formation contains sodium-rich water with high specific conductance and high concentrations of dissolved solids. Ground water from

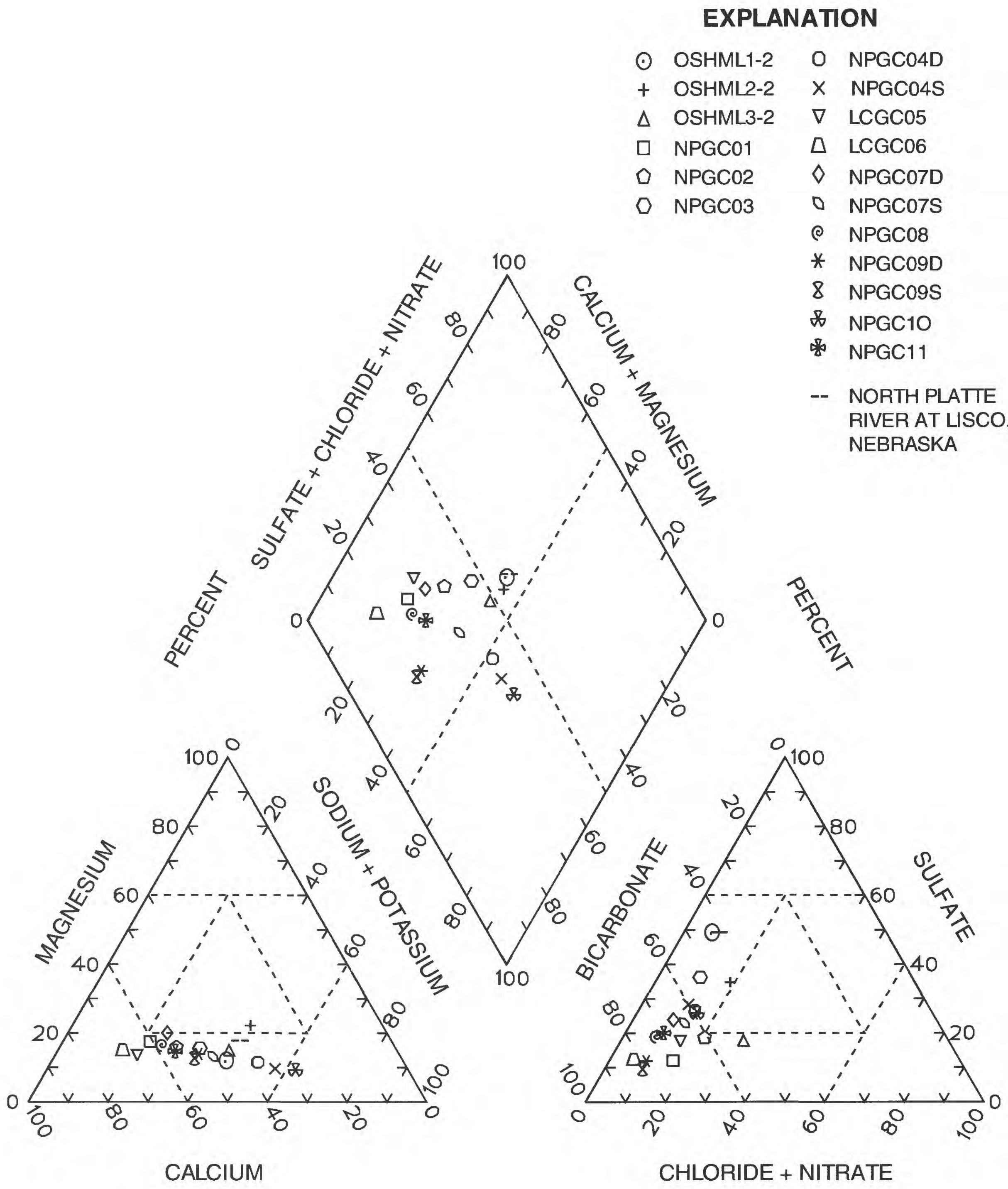


Figure 13. Ionic composition of ground water in the alluvial aquifer, by monitor-well site, and surface water in the North Platte River at Lisco, Garden County, western Nebraska, June 1993.

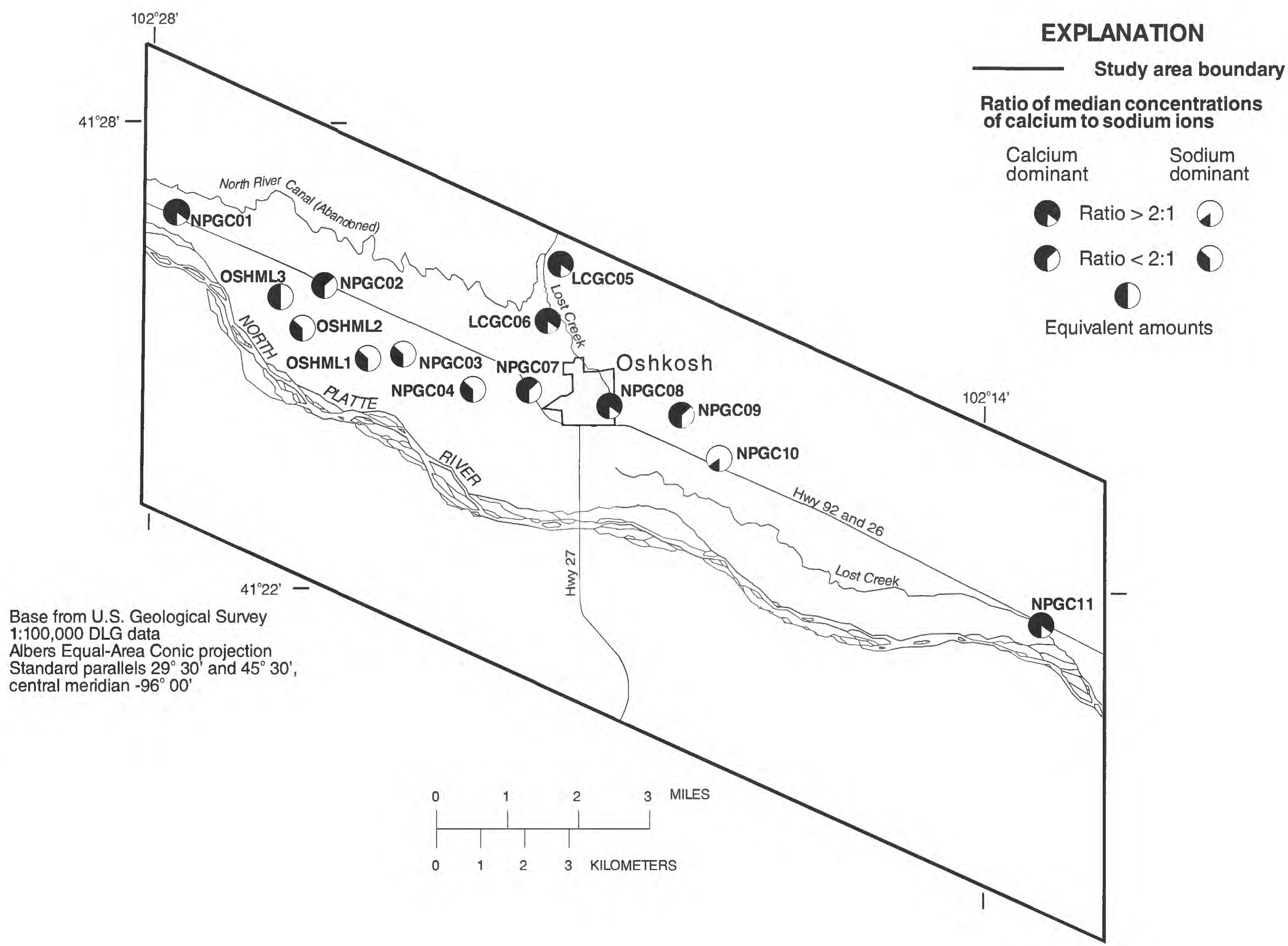


Figure 14. Ratio of median concentrations of calcium versus sodium per monitor-well site in the alluvial aquifer in the study area, western Nebraska, 1993-94.

Table 7. Statistical summary of major ion concentrations in the alluvial aquifer of the study area, western Nebraska, 1993-94
[mg/L, milligrams per liter; µg/L, micrograms per liter; USEPA, U.S. Environmental Protection Agency; MCL, Maximum Contaminant Level; SMCL, Secondary Maximum Contaminant Level; --, no MCL or SMCL; SAR, sodium adsorption ratio]

Major ion	Unit of measurement	Minimum	Median	Maximum	USEPA criteria	Number of samples meeting or exceeding MCL
Dissolved solids	mg/L	267	614	1,550	[1]500	35
Calcium	mg/L	38	92	170	--	--
Magnesium	mg/L	5.5	17	43	--	--
Sodium	mg/L	12	63	380	--	--
SAR	dimensionless	0.4	2	9	--	--
Potassium	mg/L	2	14	110	--	--
Sulfate	mg/L	18	110	640	[1]250	8
Chloride	mg/L	3.4	21	56	[1]250	0
Fluoride	mg/L	.3	0.5	1.5	[2]4	0
Silica	mg/L	44	57	72	--	
Iron[3]	µg/L	<3	<3	20	[1]300	0
Manganese[3]	µg/L	<1	<1	50	[1]50	1

[1]U. S. Environmental Protection Agency SMCL for drinking water.
[2]U. S. Environmental Protection Agency MCL for drinking water.
[3]Median derived by assigning censored data a value of one-half of reporting limit.

NPGC10 is not dissimilar to that found in the Chadron Formation.

The chemical composition of the North Platte River, especially the anionic composition, was dissimilar to that of most ground water (fig. 13). Because evaluation of 1993 stream discharge data suggests that the North Platte River generally was gaining through the study area, the river probably had little influence on the ground-water quality.

NITRATE CONCENTRATIONS

Water samples were analyzed for nitrate concentrations and the results were considered in terms of spatial and temporal variations. Temporal variations included: (1) changes in nitrate concentrations during the course of the study period (1993-94), and (2) changes in nitrate concentrations as indicated by analyses of water samples collected by the University of Nebraska-Lincoln in 1989 compared with samples collected in February and August 1994.

Study Period, 1993 to 1994

Nitrate concentrations varied areally and temporally throughout the study area. Nitrate concentrations in samples from all 14 monitor-well sites ranged from 1.5 to 56 mg/L as N, with median concentration per individual well ranging from 1.7 to 50 mg/L as N (table 8). In 130 of 262 samples, nitrate concentrations were greater than the MCL of 10 mg/L as N (U.S. Environmental Protection Agency, 1996) (table 11, Supplemental Data section). Nitrate concentrations in at least one sample from 7 of the 14 monitor-well sites were greater than the MCL (fig. 15). The minimum nitrate concentration in ground water from most monitor wells typically occurred in May 1993 and occasionally in August 1993 (figs. 16-20), whereas the maximum nitrate concentration typically occurred during August and September 1994. These temporal variations are likely attributed to several factors, such as: (1) the seasonal application of fertilizers containing nitrogen, (2) the frequency and amount of precipitation that fell during 1993, and (3) the amount of irrigation needed to supplement the lack of precipitation during the growing season (March through September) of 1994. March through May are the most active months for application of commercial fertilizers containing nitrogen. The amounts of fertilizer applied vary from one location to another with some fields having little, if any, applied.

Table 8. Statistical summary of nitrate concentrations in water samples from the North Platte River at Lisco, Nebraska and monitor wells in the study area, western Nebraska, 1993-94

Field identification	Depth below land surface (feet)	Number of samples	Concentrations			
			Minimum	Mean	Median	Maximum
North Platte River at Lisco, Nebraska[1]	--	10	<0.05	2.4	2.4	4.2
Single monitor wells						
NPGC01	33.7	9	7.2	8.2	8.5	8.7
NPGC02	163	8	15	18	18	23
NPGC03	145	8	5.3	12	7.5	34
LCGC05	70	9	2.1	6.2	5.3	11
LCGC06	38	9	1.5	1.8	1.7	2.3
NPGC08	87	9	2.0	2.5	2.5	3.4
NPGC10	58	8	26	27	29	31
NPGC11	130	9	7.6	8.7	8.8	9.2
Nested monitor wells						
NPGC04D	48	9	16	19	18	21
NPGC04S	28	9	12	15	14	18
NPGC07D	48	9	2.7	3.0	2.9	3.5
NPGC07S	28	9	4.6	6.0	5.7	7.8
NPGC09D	115	8	2.2	3.1	2.8	5.3
NPGC09S	65	9	2.1	2.7	2.8	3.1
Multilevel monitor wells						
OSHML1-1	10	9	1.6	2.0	1.9	2.8
OSHML1-2	15	4	2.2	2.6	2.6	2.8
OSHML1-3	20	4	2.5	2.6	2.6	2.8
OSHML1-4	25	4	2.5	2.7	2.7	2.8
OSHML1-5	30	9	1.9	2.9	3.1	3.4
OSHML1-6	40	4	2.9	3.2	3.3	3.4
OSHML1-7	50	4	2.6	2.9	3.0	3.1
OSHML1-8	60	9	2.4	2.8	2.9	3.2
OSHML2-1	10	9	16	29	30	35
OSHML2-2	15	4	29	33	32	37
OSHML2-3	20	4	28	32	30	37
OSHML2-4	25	4	26	30	30	33
OSHML2-5	30	9	22	27	26	36
OSHML2-6	40	4	18	20	20	22
OSHML2-7	50	4	17	20	20	22
OSHML2-8	60	9	13	15	16	17

Table 8. Statistical summary of nitrate concentrations in water samples from the North Platte River at Lisco, Nebraska and monitor wells in the study area, western Nebraska, 1993-94--Continued

Field identification	Depth below land surface (feet)	Number of samples	Concentrations			
			Minimum	Mean	Median	Maximum
Multilevel monitor wells--Continued						
OSHML3-1	10	7	41	47	50.	52
OSHML3-2	15	5	41	49	50	51
OSHML3-3	20	4	44	49	50	54
OSHML3-4	25	4	38	45	45	52
OSHML3-5	30	9	30	43	43	56
OSHML3-6	40	4	22	26	24	31
OSHML3-7	50	4	25	28	28	31
OSHML3-8	60	9	18	28	26	47

[1]Median derived by assigning censored data a value of one-half of reporting limit.

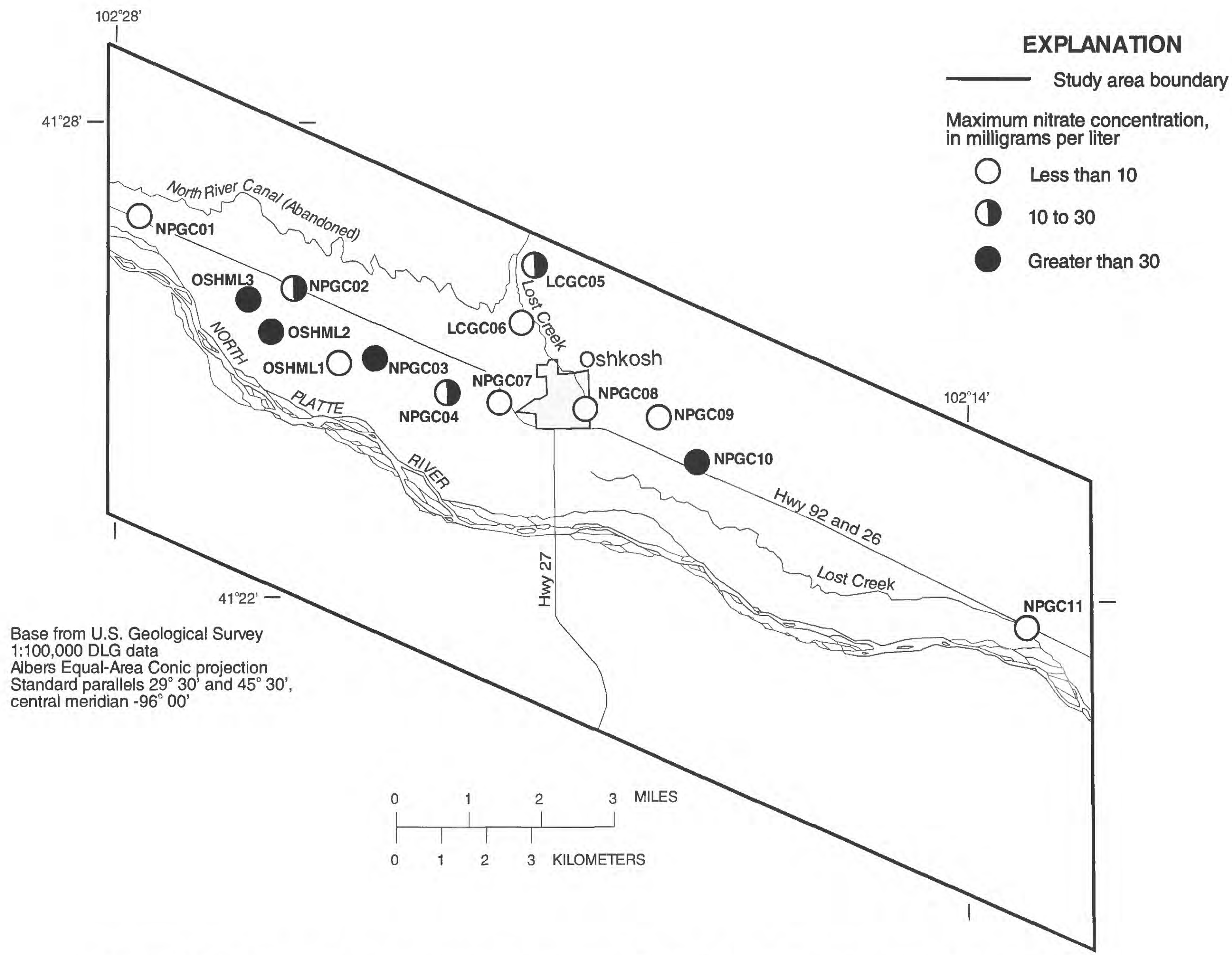


Figure 15. Maximum nitrate concentration per monitor-well site in the study area, western Nebraska, 1993-94.

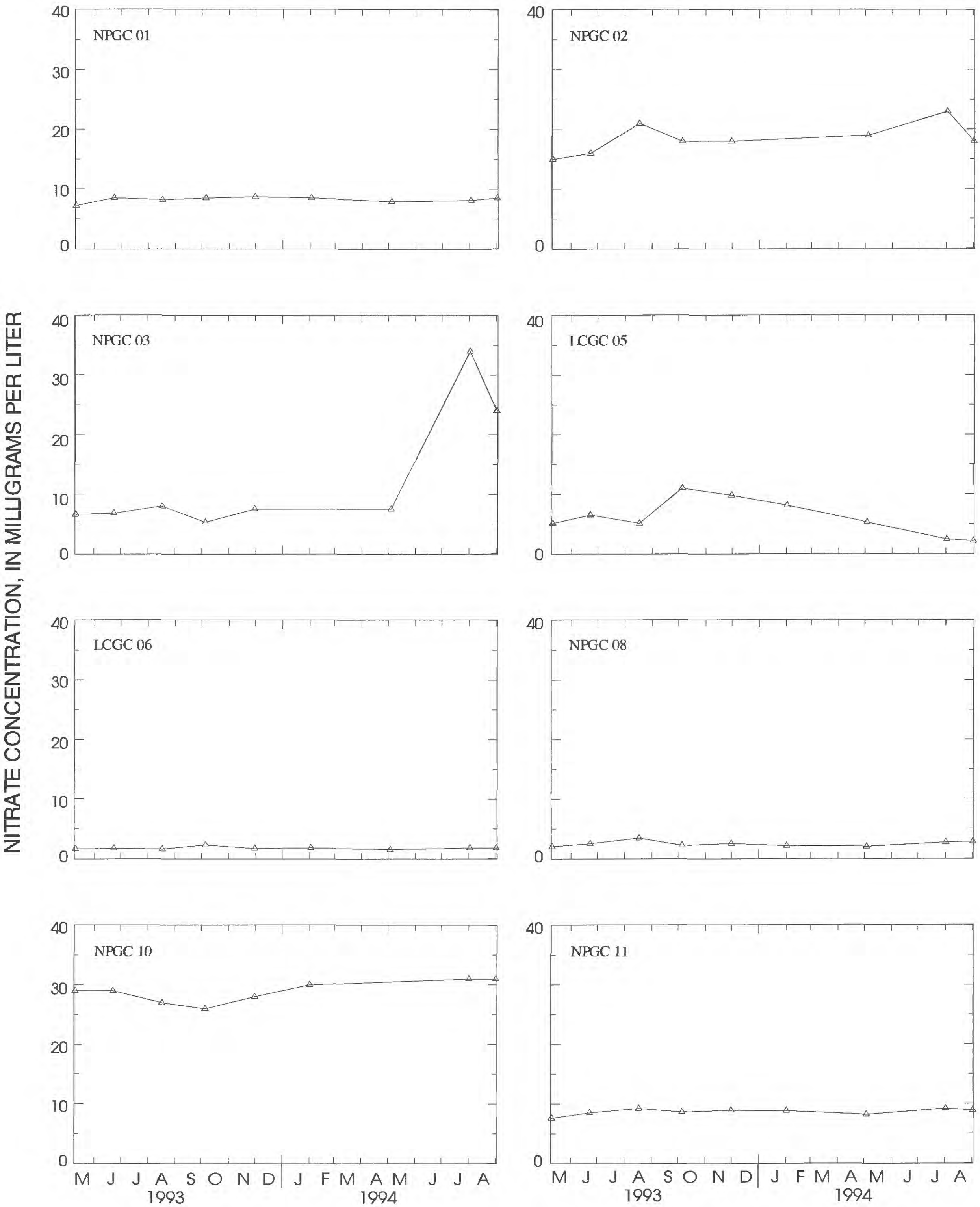


Figure 16. Nitrate concentration as a function of time for single monitor-well sites in the study area, western Nebraska, 1993-94.

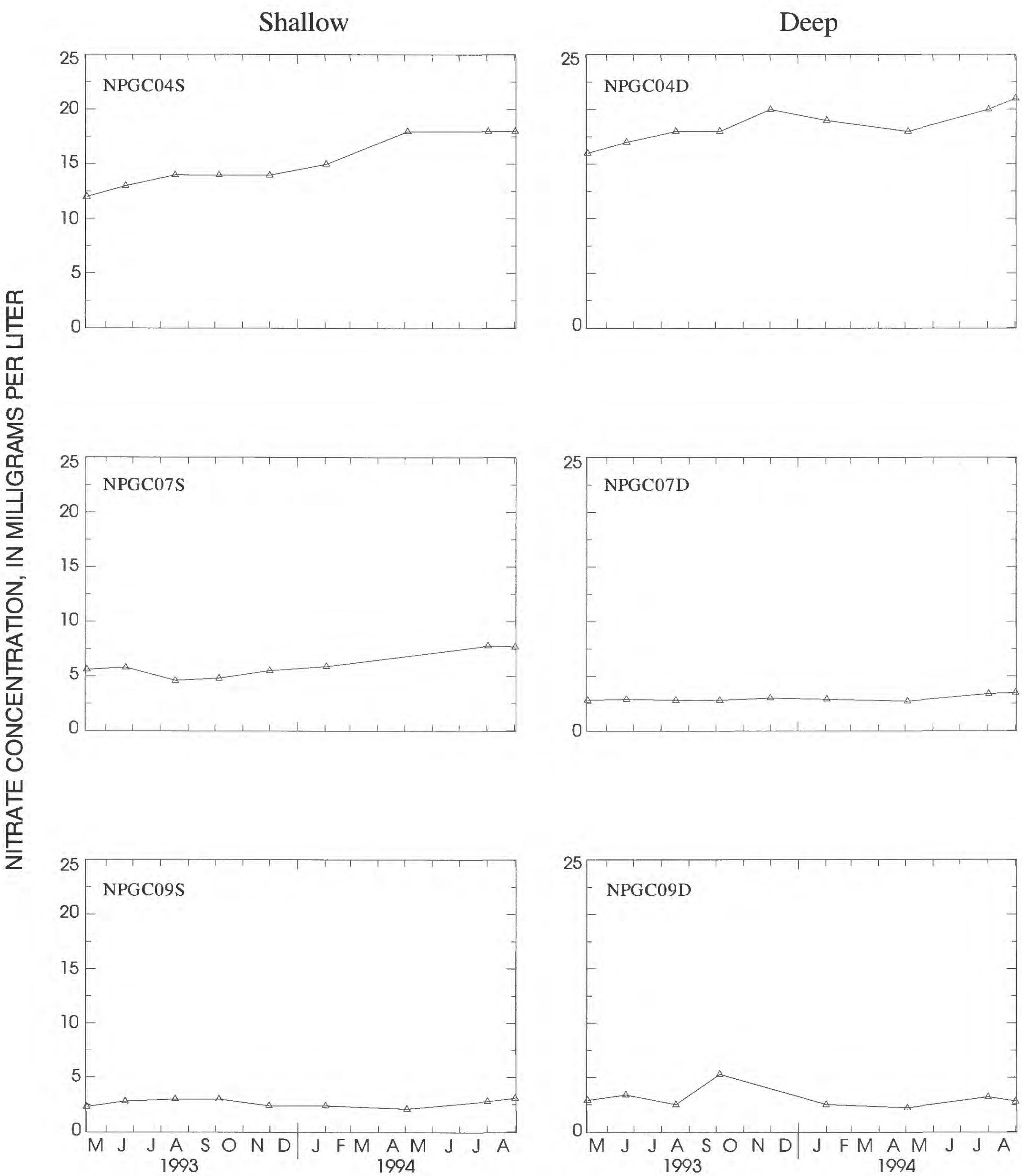


Figure 17. Nitrate concentration as a function of time for nested monitor-well sites in the study area, western Nebraska, 1993-94.

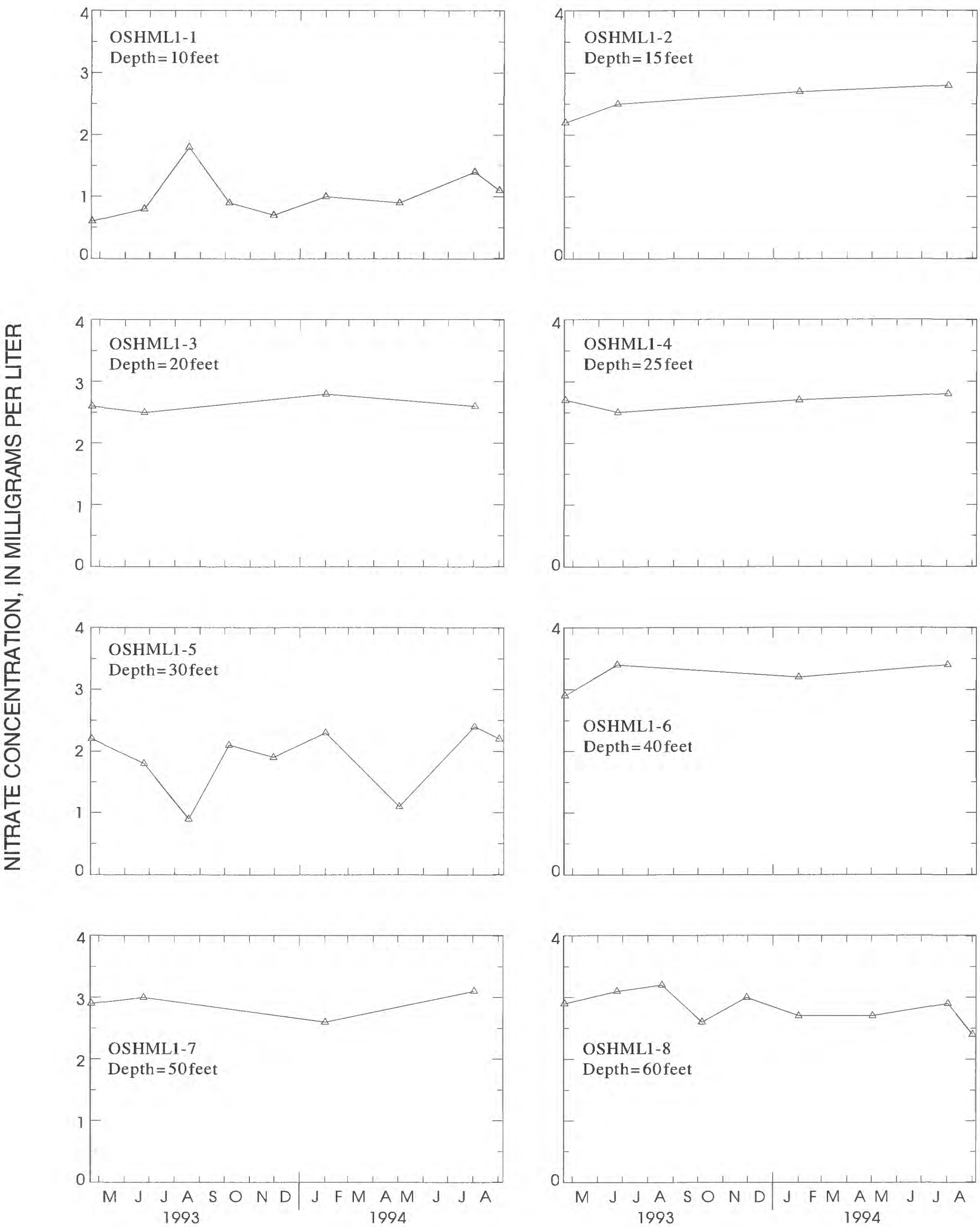


Figure 18. Nitrate concentration as a function of time in ground-water samples from multilevel monitor wells OSHML1-1 through OSHML1-8 in the study area, western Nebraska, 1993-94.

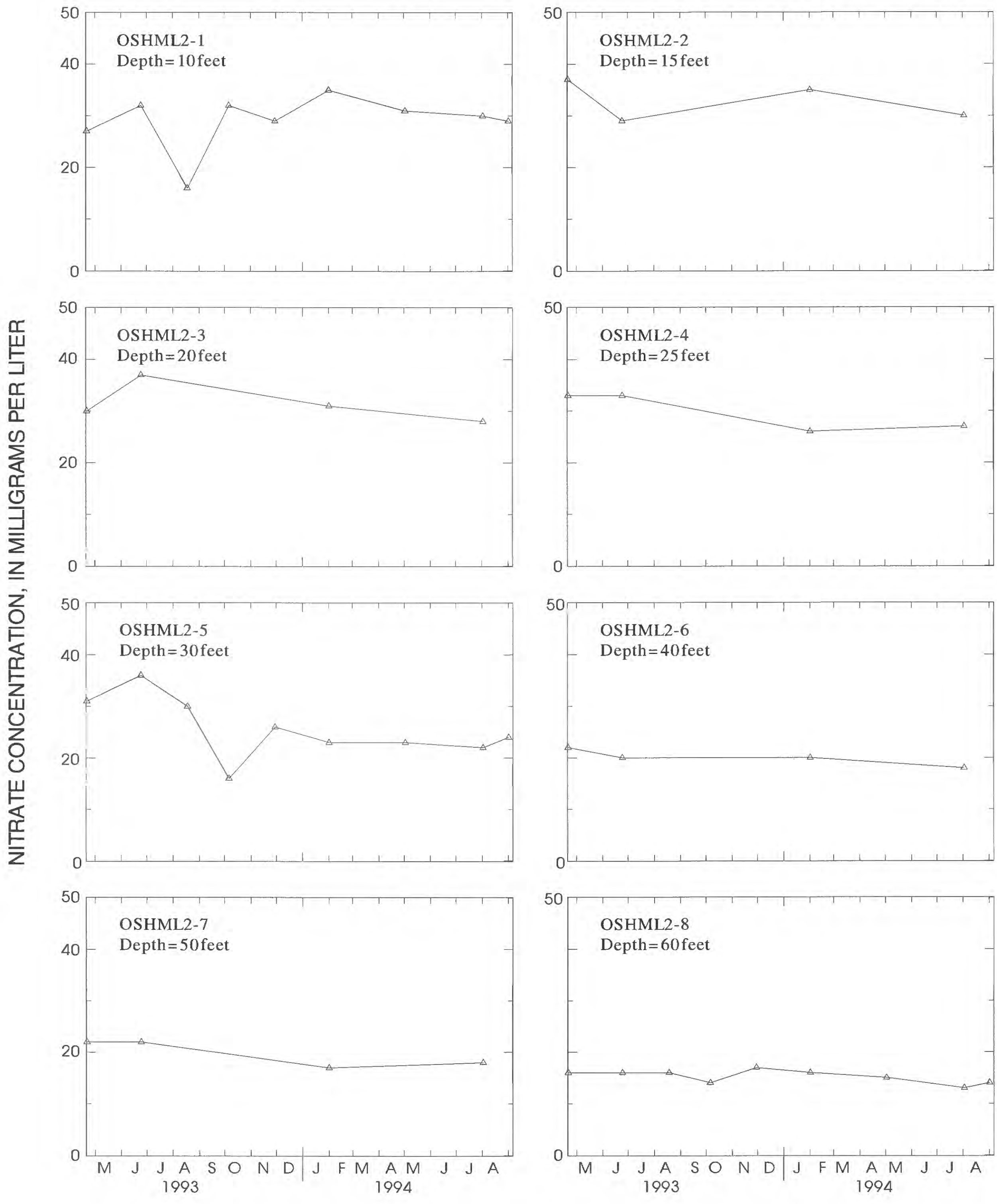


Figure 19. Nitrate concentration as a function of time in ground-water samples from multilevel monitor wells OSHML2-1 through OSHML2-8 in the study area, western Nebraska, 1993-94.

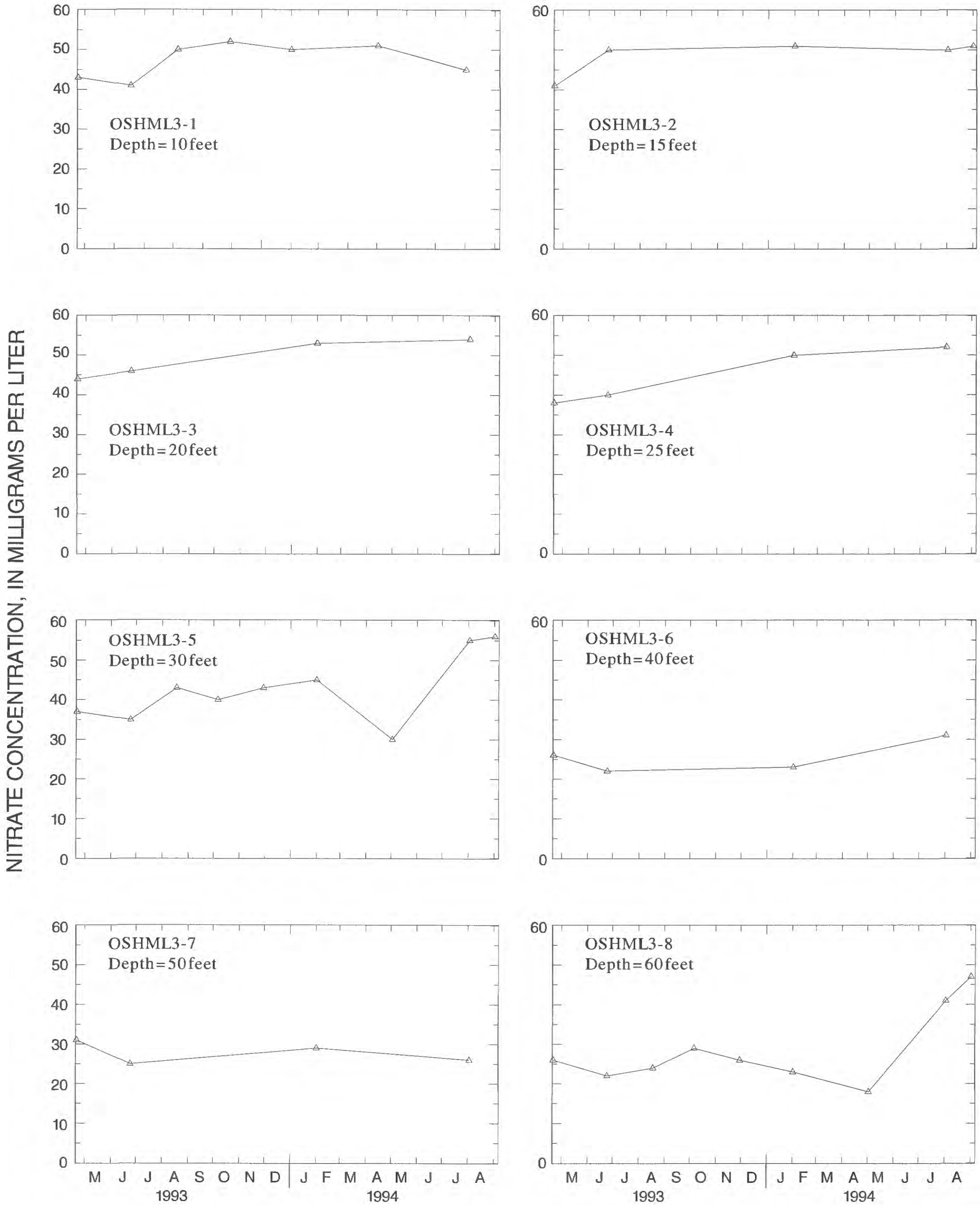


Figure 20. Nitrate concentration as a function of time in ground-water samples from multilevel monitor wells OSHML3-1 through OSHML3-8 in the study area, western Nebraska, 1993-94.

Rain frequently fell throughout the summer of 1993 (fig. 21) and not as much irrigation water was needed to supplement it as in drier years. Steele (1994) reported that the efficiency of water moving through the unsaturated zone is a direct function of the amount and the frequency of the water available. If the amount and frequency of precipitation is sufficient to maintain an appreciable amount of soil moisture, water can easily, and sometimes quickly, percolate through the unsaturated zone to the water table. This might explain some of the lowest nitrate concentrations detected in ground-water samples during the summer of 1993 (figs. 19 and 20). Rainfall was sufficient to maintain a high soil moisture content and enable the water to pass through the unsaturated zone, thereby diluting nitrate concentrations in the ground water. During the growing season of 1994, precipitation was less frequent (fig. 21) and irrigation was needed to supplement it. In the study area, ground water has been shown to contain nitrate concentrations exceeding 10 mg/L as N. Locally water containing these high concentrations of nitrate then is used for irrigation. If more water is applied than needed by the crop, the water already containing nitrate can pass through the unsaturated zone and leach yet more nitrogen, if available, from the soil. Thus, nitrate can become more concentrated in the ground water.

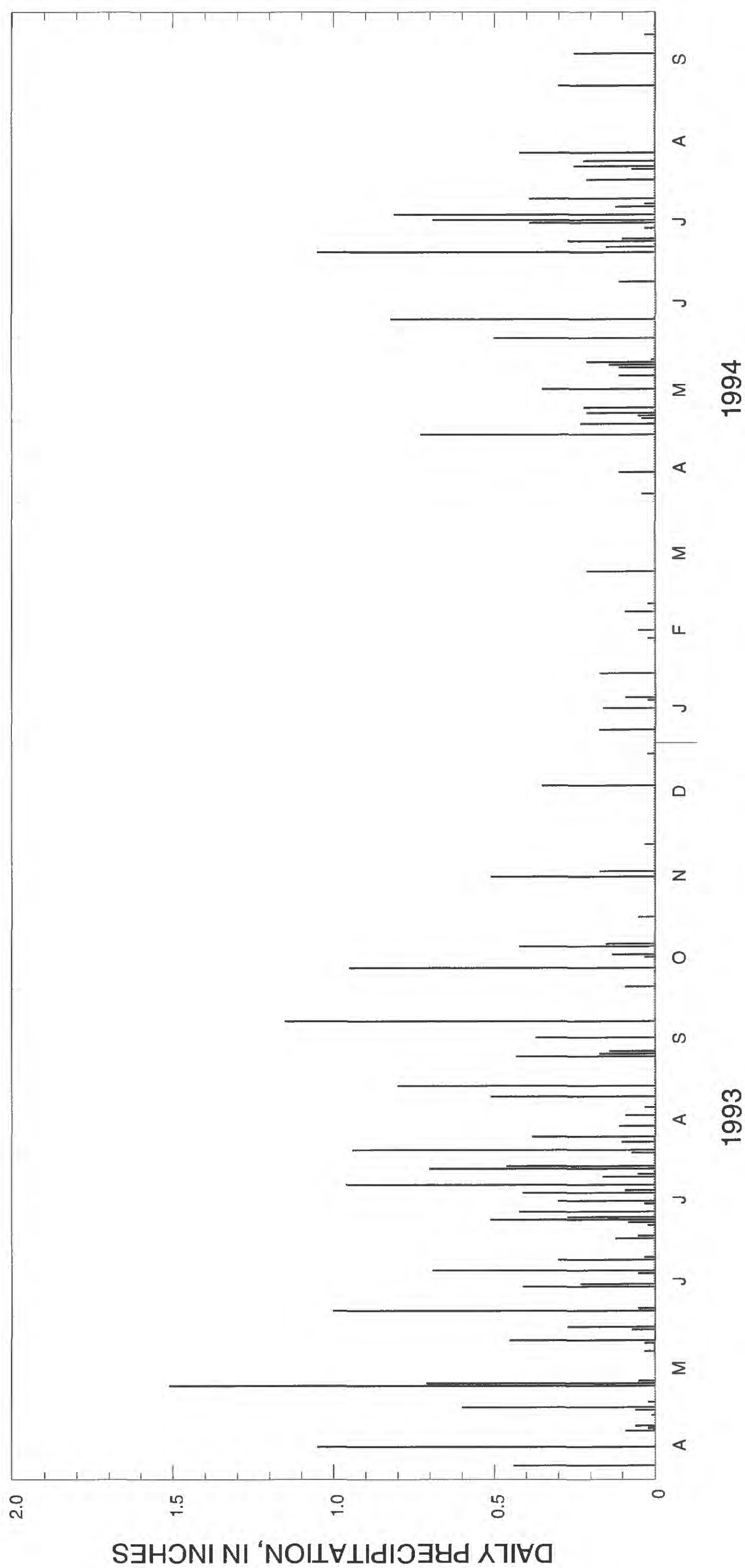
Concentrations of nitrate in water samples from wells located near the upgradient and downgradient ends of the study area generally were less than 10 mg/L as N. Except for one sample from monitor well LCGC05 in October 1993, nitrate concentrations in samples collected from NPGC01, LCGC05, and NPGC11 were less than the MCL (U.S. Environmental Protection Agency, 1996)(table 11). In addition, water samples collected from May 1993 to July 1994 from the North Platte River at Lisco, just upstream of the study area, were analyzed for nitrate to determine if nitrate concentrations in the North Platte River were significantly different from those in NPGC01, the monitor well the farthest upgradient and the closest to Lisco. Rank-sum testing shows that there is a significant ($p = 0.0003$) difference between nitrate concentrations in the North Platte River and water samples collected from monitor well NPGC01. Nitrate concentrations in the North Platte River ranged from less than 0.05 mg/L as N to 4.2 mg/L as N, with a median of 2.4 mg/L as N (table 8). These data indicate that nitrate in ground-water samples from NPGC01 probably were not derived from the North Platte River.

Monitor wells producing water samples with nitrate concentrations above the MCL (U.S. Environmental Protection Agency, 1996) of 10 mg/L as N prior to the start of the study or at the time of the first sampling, produced water with concentrations above that level throughout the study. Nitrate concentrations in samples from two monitor wells, LCGC05 and NPGC03, were below the MCL at the beginning of the study, but were above the MCL for one or more samplings during the study (fig. 16).

Monitor wells with nitrate concentrations in water samples above the MCL during any part of the study period were in or near areas of irrigated, row-crop agriculture. However, nitrate concentrations in or near areas of irrigated row-crop agriculture did not exceed, or rarely exceeded, 10 mg/L in water samples from some monitor wells—LCGC05, LCGC06, NPGC03, NPGC07D, NPGC07S, NPGC09D, NPGC09S, NPGC11, and OSHML1-1 through OSHML1-8.

Seasonal variation in nitrate concentrations in water samples from many of the monitor wells was observed. In most instances nitrate concentrations increased in samples collected in September and October. This increase could result from one or any combination of the following: (1) the time it takes for nitrate to leach through the soil during the irrigation season (late July through early September), (2) a decrease in the uptake of nitrogen by the crops, as they start to enter the dormant season (winter), associated with continued leaching of nitrogen through the unsaturated zone, or (3) the re-establishment of steady-state, natural or near natural, ground-water flow conditions following the irrigation season. The last consideration could be important if ground-water withdrawals during the irrigation season pull in ground water containing lower nitrate concentrations from upgradient areas, such as near NPGC01. Termination of active ground-water irrigation could cause the low-nitrate-containing ground water from upgradient areas to be replaced with higher-nitrate-containing ground water from adjacent areas. In any case, it appears that the highest concentrations of nitrate typically occurred after the irrigation season.

Nitrate concentrations in ground-water samples from the two monitor wells in Lost Creek Valley, LCGC05 (except for one sample on 10-5-93) and LCGC06, were below the MCL. These two monitor wells are north and upgradient of three wells at Oshkosh—NPGC07D, NPGC07S, and NPGC08. Nitrate concentrations in water samples from the sites in and



Source: National Oceanic and Atmospheric Administration, 1994, 1995

Figure 21. Daily precipitation for April 1993 to September 1994, at Oshkosh, Garden County, western Nebraska.

near Oshkosh have remained below the MCL of 10 mg/L as N (U.S. Environmental Protection Agency, 1996), whereas nitrate concentrations in samples from most of the monitor wells flanking Oshkosh to the east and west were greater than the MCL. It is likely, therefore, that the influx of ground water from Lost Creek Valley to the north of Oshkosh is diluting the nitrate concentrations in ground water in and near the town.

Nitrate concentrations at two of the three multilevel monitor wells generally decreased with depth (figs. 19-20). Nitrate concentrations in water samples collected from monitor wells OSHML2 and OSHML3 typically were higher (greater than or equal to 30 mg/L) within the top 30 ft of the alluvial aquifer than they were at greater depth. During the last two sample periods (August and September 1994), however, nitrate concentrations in water samples collected near the middle of the aquifer, monitor well OSHML3-5, were similar to, and exceeded, concentrations near the top of the aquifer (fig. 20) OSHML3-2.

Nitrate concentrations in water samples from two of the three nested monitor-well sites varied with well depth. Nitrate concentrations from monitor wells NPGC04S and NPGC04D (fig. 17) were greater in water samples from the deeper well than from the shallower well. The reverse was true for nitrate concentrations in samples from monitor wells NPGC07S and NPGC07D (fig. 17).

Historical Comparisons, 1989 to 1994

Comparisons were made between May 1989 and February and August 1994 (fig. 22) to determine if there were substantial changes prior to and following application of ground water by irrigation in 1994. February and August 1994 were the last two times that samples were collected from all eight discrete depths of the multilevel monitor wells.

Concentrations of nitrate in ground water at all three multilevel monitor wells varied from 1989 to 1994. At all eight discrete depths of monitor well OSHML1, nitrate concentrations in ground-water samples increased from May 1989 to February and August 1994. The maximum increase in concentrations of nitrate in ground-water samples from multilevel monitor wells from 1989 to 1994 was in water from monitor well OSHML2 (fig. 22). At this well, nitrate concentrations for the intervals of 40 to 60 ft increased 14 to 19 mg/L as N from May 1989 to February 1994. Decreases in nitrate concentrations for depths of 20 and 30 ft from May 1989 to February 1994 and slightly greater decreases in nitrate concentrations from May 1989 to August 1994 were observed in ground-water samples at monitor well OSHML2. Nitrate concentrations in the top half of the alluvial aquifer at this site have decreased from May 1989 to August 1994, with the greatest decrease being 6 mg/L as N. Nitrate concentrations in monitor well OSHML3 generally increased throughout the thickness of the alluvial aquifer from May 1989 to February and August 1994. The increase was most noticeable at the 60-foot interval in August 1994.

The changes in nitrate concentrations from 1989 to 1994 can be affected by many factors including: amount and intensity of precipitation, volume of ground water withdrawn for irrigation, total recharge and evapotranspiration, soil moisture, depth to water, and ground-water flow conditions. Therefore, the complexities of the system preclude definitive conclusions concerning the reasons for changes in nitrate concentrations.

Triazine- and Acetamide-Herbicide Concentrations

Ground-water samples were collected from the monitor wells to determine concentrations of eight triazine and acetamide herbicides and two atrazine metabolites. Of these ten constituents, atrazine and its metabolite, deethylatrazine, were the two most commonly detected herbicides in the water samples. No acetamide herbicides were detected during the study. Atrazine was detected in 10 of 34 samples (29 percent), and deethylatrazine was detected in 18 of 34 samples (53 percent) (table 12 in Supplemental Data section). The maximum concentrations of ametryn, atrazine, deethylatrazine, and deisopropylatrazine detected were 0.05, 2.9, 3.0, and 0.11 μg/L, respectively (table 12). Median concentrations were all less than the reporting limit of 0.05 μg/L. The atrazine metabolites, deethylatrazine and deisopropylatrazine, also can be produced by the degradation of propazine and simazine, respectively; however, atrazine metabolites are thought to represent atrazine degradation, based on the large number of atrazine detections (table 12).

Concentrations of atrazine were all less than the MCL of 3.0 μg/L (U.S. Environmental Protection Agency, 1996), although concentrations of atrazine in two samples, 2.9 and 2.6 μg/L, were near the MCL. Both of these samples were from monitor well OSHML2-2. The first, 2.9 μg/L, occurred on June 24,

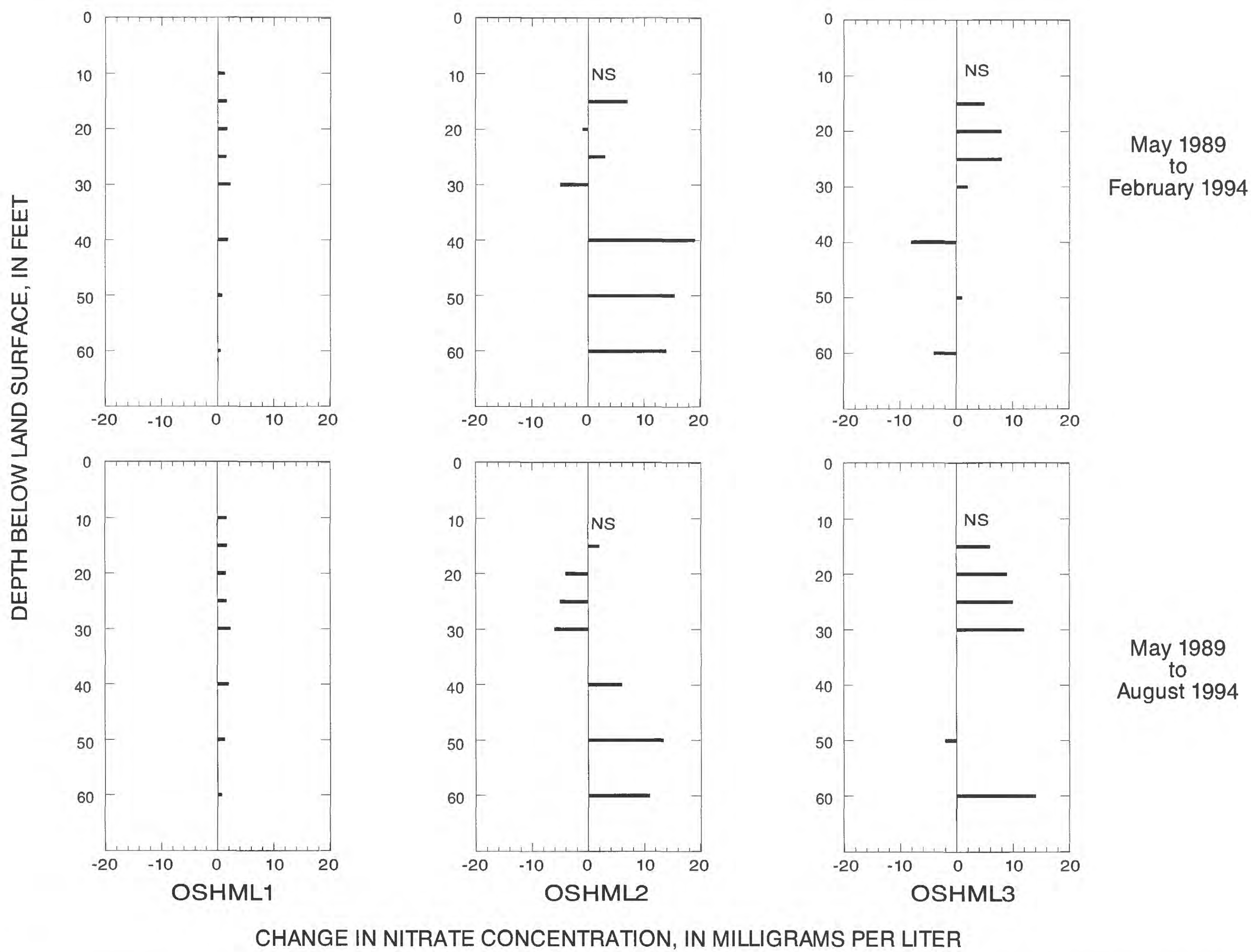


Figure 22. Change in nitrate concentrations in ground-water samples from multilevel monitor wells in the study area, western Nebraska, 1989 to 1994 [NS, not sampled in 1989].

1993, and the second, on August 2, 1994. Most atrazine concentrations in water samples from the other monitor wells were below 1 µg/L. Figure 23 shows the areal distribution of atrazine detections.

Deethylatrazine-to-atrazine ratio (DAR) was computed for the nine samples that contained measurable concentrations of deethylatrazine and atrazine. The DAR is the dimensionless ratio of deethylatrazine concentration to atrazine concentration and is a possible indicator of a point-source versus nonpoint-source contamination by atrazine (Adams and Thurman, 1991). DAR values greater than 0.7 indicate the possibility that atrazine is being slowly transported into the ground-water system and that deethylation of the atrazine by soil microorganisms has occurred (consistent with nonpoint-source contamination). DAR values of 0.2 to 0.3 may indicate rapid entry into the ground-water system (point-source contamination) without deethylation of the atrazine compound (E. Michael Thurman, U.S. Geological Survey, oral commun., 1996). DAR values between 0.3 and 0.7 generally can not be interpreted to reflect nonpoint-source or point-source contamination.

DAR values ranged from 0.45 at monitor well OSHML2-2 on June 6, 1993, to 8.22 at NPGC10 on August 1, 1994, with a median of 2.45. The 0.45 value at monitor well OSHML2-2 was the only sample with a ratio of less than 0.7. However, this site had atrazine concentrations greater than 2.0 µg/L and the DAR value for this site was higher than the 0.3 value that generally indicates contamination from a point source. This suggests the possibility that point-source contamination could have occurred and the atrazine compound has since been subject to deethylation (E. Michael Thurman, U.S. Geological Survey, oral commun., 1996). The DAR values at the other sites or times generally indicate nonpoint-source contamination or further deethylation of the atrazine previously present.

SUMMARY

In 1993, the U.S. Geological Survey and the North Platte Natural Resources District began a 3-year study to determine the geohydrology and water quality of the North Platte River alluvial aquifer near Oshkosh, Garden County, Nebraska. The objectives of the study were to describe the geohydrology of the alluvial aquifer near Oshkosh, to establish a well network for long-term monitoring of concentrations of agricultural chemicals including nitrate and herbicides, and to describe the water quality of the aquifer emphasizing agricultural chemicals.

Fourteen monitor wells were installed at 11 sites near Oshkosh. The geohydrologic properties of the aquifer were estimated from water-level measurements plus short-term constant-discharge aquifer tests near two monitor wells. Water samples were collected approximately bimonthly and analyzed for specific conductance, pH, water temperature, dissolved oxygen, and nutrients including dissolved nitrate. Samples were collected semiannually for analysis of major ions, and annually for triazine and acetamide herbicides.

The alluvial aquifer has locally high hydraulic conductivity and transmissivity values. Hydraulic conductivities and transmissivities calculated from two short-term constant-discharge aquifer tests ranged from 169 to 183 ft/d and 12,700 to 26,600 ft^2/d, respectively. For the alluvial aquifer, specific yields averaged 0.34 at NPGC03 and 0.06 at NPGC08 for a combined average of 0.20 and the overall ground-water gradient in the study area was 0.0012 ft/ft. Ground-water flow velocities were estimated to be about 1 ft/d. Ground-water flow direction in the North Platte River alluvial aquifer was northwest to southeast or generally parallel to the North Platte River. Ground-water flow in Lost Creek Valley is generally to the south until it mixes with flow in the North Platte River alluvial aquifer.

Specific conductance values ranged from 228 to 2,250 µS/cm, with a median value of 1,270 µS/cm. Wells shallower than 75 ft had significantly higher specific conductance values than wells deeper than 75 ft. The pH ranged from 6.9 to 8.0 standard units, with a median of 7.5 standard units. Water temperature ranged from 4.5 to 17.0 °C, and dissolved oxygen ranged from 0.1 to 8.9 mg/L.

Ground water in the study area varied between a calcium and sodium bicarbonate type depending on the location. Calcium was the predominant cation in wells in Lost Creek Valley and generally just downgradient from it, whereas sodium was the predominant cation in a few scattered wells. Water from wells with high specific conductance values and high concentrations of sodium were not dissimilar to the water found in the underlying confined Chadron Formation.

Elevated (greater than 10 mg/L as N) nitrate concentrations in ground-water samples collected by the North Platte Natural Resources District in 1988 continued to increase through 1994. Mary Exner-Spalding (University of Nebraska-Lincoln, written commun., 1991) attributed these elevated nitrate concentrations to the use of commercial fertilizers.

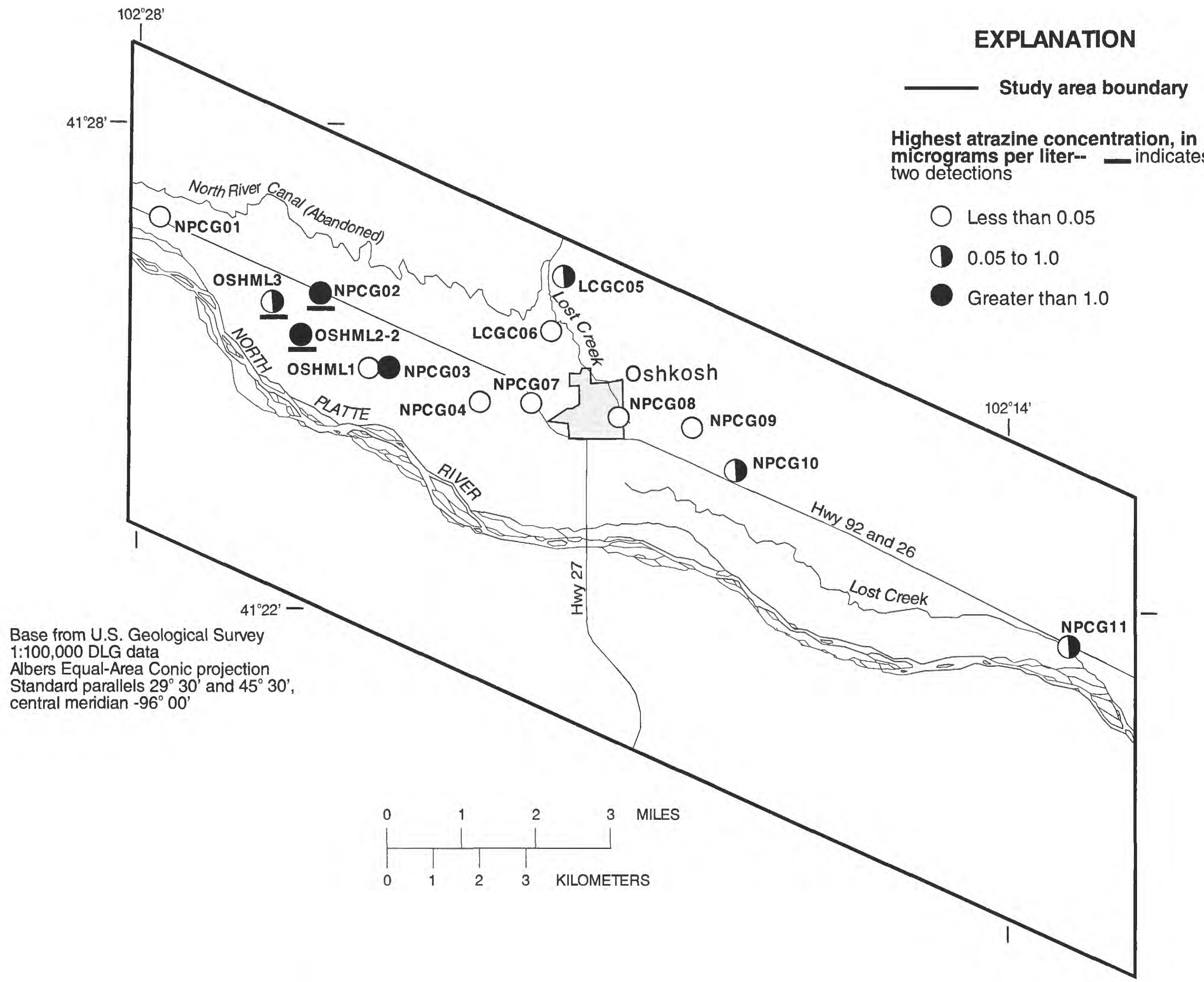


Figure 23. Areal distribution of atrazine detections in ground-water samples from the study area, western Nebraska, 1993-94.

Nitrate concentrations in the study area varied. Nitrate concentrations in water-quality samples collected from the 14 monitor-well sites ranged from 1.5 to 56 mg/L as N. The median nitrate concentration by well ranged from 1.7 to 50 mg/L as N. Nitrate concentrations in at least one sample from 7 of the 14 monitor-well sites were greater than the MCL of 10 mg/L as N.

Except for one sample from monitor well LCGC05, in October 1993, concentrations of nitrate in water samples from wells located near the upgradient and downgradient ends of the study area generally did not exceed the MCL of 10 mg/L. Furthermore, nitrate concentrations collected from the North Platte River at Lisco, just upstream of the study area, were less than 4.2 mg/L as N. Results of rank-sum tests indicate that there is a significant difference between nitrate concentrations in the North Platte River and water samples collected from NPGC01. This indicates that nitrate concentrations in the ground water probably were not derived from the North Platte River.

Monitor wells that produced water samples with nitrate concentrations higher than the MCL prior to the start of the study or at the time of the first sampling produced water with concentrations above that level throughout the study. In addition, monitor wells that produced samples with nitrate concentrations above 10 mg/L during any part of the study period were from wells in or near areas where agricultural row crops are present.

Ground water in Lost Creek Valley, north of Oshkosh, generally contained low concentrations of nitrates. As a result, ground water from Lost Creek Valley could be diluting nitrate concentrations near the town. Monitor wells flanking Oshkosh to the east and west continue to produce nitrate concentrations greater than the MCL.

Nitrate concentrations increased in most water-quality samples collected from the three multilevel sampling wells from May 1989 to February and August 1994. During this time, nitrate concentrations in samples from one well increased a maximum of 19 mg/L. Nitrate concentrations in samples at some intervals in the multilevel monitoring wells have declined from May 1989 to February and August 1994. Nitrate concentrations in samples from the monitor wells are probably affected by the amount and intensity of precipitation, the volume of water recharged to the aquifer, as well as the soil moisture, depth to water, and ground-water flow conditions. Thus, the complexities of the system preclude definitive conclusions concerning the reason(s) for changes in nitrate concentrations.

During the study, ground water samples were collected to analyze for eight triazine and acetamide herbicides and two atrazine metabolites. Atrazine was detected in 10 of 34 samples (29 percent), and its metabolite deethylatrazine was detected in 18 of 34 samples (53 percent). All samples produced concentrations of atrazine less than the MCL (3.0 µg/L); however, two samples, 2.9 µg/L and 2.6 µg/L, were just under the MCL.

SELECTED REFERENCES

Adams, C.D., and Thurman, E.M., 1991, Formation and transport of deethylatrazine in the soil and vadose zone: Journal of Environmental Quality, v. 20, p. 540-547.

Boohar, J.A., Hoy, C.G., and Steele, G.V., 1994, Water resources data—Nebraska, water year 1993: U.S. Geological Survey Water-Data Report NE-93-1, 403 p.

Boulton, N.S., 1963, Analysis of data from non-equilibrium pumping tests allowing for delayed yield from storage: London, Proceedings, Institute of Civil Engineers, v. 26, p. 469-482.

Darton, N.H., 1903, Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U.S. Geological Survey Professional Paper 17, 69 p., 43 pls.

Dawson, K.J., and Istok, J.D., 1991, Aquifer testing—design and analysis of pumping and slug tests: Chelsea, Mich., Lewis Publishers, 344 p.

Diffendal, R.F., Jr., 1982, Geometries and general features of some Cenozoic valleys and valley fills, western Nebraska [abs.], *in* Zechmann, Albert, eds., Proceedings of The Nebraska Academy of Sciences and Affiliated Societies, Ninety-Second Annual Meeting, Lincoln, Nebraska, April 16-17, 1982: Lincoln, Nebr., Nebraska Academy of Sciences, p. 47.

____ 1983, Megaclasts in channel fills in the Ogallala Group (Miocene), Banner, Kimball, and Morrill Counties, Nebraska [abs.], *in* Boyd, D.W., and Lillegraven, J.A. eds., Contributions to geology: Laramie, University of Wyoming, v. 22, no. 2, p. 109-115.

Diffendal, R.F., Jr., Swinehart, J.B., and Gottula, J.J., 1985, Characteristics, age relationships, and regional importance of some Cenozoic paleovalleys, southern Nebraska Panhandle, *in* Institute for Tertiary-Quaternary Studies, TER-QUA Symposium series: Lincoln, Nebr., Nebraska Academy of Sciences, v. 1, p. 21-32.

Domenico, P.A., and Schwartz, F.W., 1990, Physical and chemical hydrogeology: New York, Wiley and Sons, 824 p.

Dowdy, Shirley, and Wearden, Stanley, 1991, Statistics for research (2d ed.)—Wiley series in probability and mathematical statistics: New York, Wiley and Sons, 629 p.

Driscoll, F.G., 1986, Groundwater and wells (2d ed.): St. Paul, Minn., Johnson Division, 1089 p.

Dugan, J.T., 1984, Hydrologic characteristics of Nebraska soils: U.S. Geological Survey Water-Supply Paper 2222, 19 p., 12 pls.

Fenneman, N.M., 1946, Physical divisions of the United States: U.S. Geological Survey map, scale 1:7,000,000, 1 sheet.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, Inc., 604 p.

Friedman, L.C., and Fishman, M.J., 1982, Quality assurance practices for the chemical and biological analyses of water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, Chap. A6, 181 p.

Gardner, L.R., Diffendal, R.F., Jr., and Williams, D.F., 1992, Stable isotope composition of calcareous paleosols and ground-water cements from the Ogallala Group (Neogene), western Nebraska, *in* Boyd, D.W. and Lillegraven, J.A., eds., Contributions to geology: Laramie, University of Wyoming, v. 29, no. 2, p. 97-109.

Goodwin, R.G., and Diffendal, R.F., Jr., 1987, Paleohydrology of some Ogallala (Neogene) streams in the southern Panhandle of Nebraska: The Society of Economic Paleontologists and Mineralogists Special Publication no. 39, p. 149-157.

Gosselin, D.C., Sibray, S.S., and Ayers, Jerry, 1994, Geochemistry of K-rich alkaline lakes, western Sandhills, Nebraska, USA: Geochimica et Cosmochimica Acta, v. 58, no. 5, p. 1403-1418.

Hall, S.H., Luttrell, S.P., and Cronin, W.E., 1991, A method for estimating effective porosity and ground-water velocity: Ground Water, v. 29, no. 2, p. 172.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: Amsterdam, Elsevier Publications, 522 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Herrmann, Raymond, 1976, Shallow aquifers relative to surface water, lower North Platte River Valley, Wyoming: Water Resources Bulletin, v. 12, no. 2, p. 371-380.

Johnson, A.I., 1967, Specific yield—compilation of specific yields for various materials: U.S. Geological Survey Water-Supply Paper 1662-D, 74 p.

Jones, B.E., 1987, Quality control manual of the U.S. Geological Survey's National Water Quality Laboratory: U.S. Geological Survey Open-File Report 87-457, 17 p.

Kolpin, D.W, and Burkart, M.R., 1991, Work plan for regional reconnaissance for selected herbicides and nitrate in ground water of the mid-continental United States, 1991: U.S. Geological Survey Open-File Report 91-59, 18 p.

Kruseman, G.P., and de Ridder, N.A., 1990, Analysis and evaluation of pumping test data (2d ed.): Wageningen, The Netherlands, International Institute for Land Reclamation and Improvement Publication 47, 377 p.

LaBaugh, J.W., 1986, Limnological characteristics of selected lakes in the Nebraska Sandhills, U.S.A., and their relation to chemical characteristics of adjacent ground water: Journal of Hydrology, v. 86, p. 279-298.

Literathy, P., and Pinter, G.G., 1979, The influence of river quality on the quality of bank-filtered water, *in* The hydrology of areas of low precipitation, Canberra Symposium, December 1979, Proceedings: International Association of Hydrological Sciences, no. 128, p. 331-337.

Lohman, S.W., 1972, Ground-water hydraulics: U.S. Geological Survey Professional Paper 708, 70 p., 9 pls.

Mathey, S.B., ed., 1990, Ground-water site inventory system, vol. 2, chap. 4, *in* National water information system user's manual: U.S. Geological Survey Open-File Report 89-587, 288 p.

Missouri Basin State Association, 1982, Transmissivity and stream depletion factor maps–Platte and Kansas River Basins, Colorado, Kansas, Nebraska, Wyoming–Appendix II of Ground Water Depletions Technical Paper: Omaha, Nebr., Missouri Basin State Association, Missouri River Basin Hydrology Study, 16 pls.

Moench, A.F., 1993, Computation of type curves for flow to partially penetrating wells in water-table aquifers: Ground Water, v. 31, no. 6, p. 966-971.

____ 1994, Specific yield as determined by type-curve analysis of aquifer-test data: Ground Water, v. 32, no. 6, p. 949-957.

Morel-Seytoux, H.J., and Illangasekare, T.H., 1979, Field verification of the concept of reach transmissivity, *in* The hydrology of areas of low precipitation, Canberra Symposium, December 1979, Proceedings: International Association of Hydrological Sciences, no. 128, p. 355-359.

National Oceanic and Atmospheric Administration, 1994, Climatological data — annual summary, Nebraska, 1993: Asheville, N.C., U.S. Department of Commerce, v. 98, no. 13, 31 p.

____ 1995, Climatological data — annual summary, Nebraska, 1994: Asheville, N.C., U.S. Department of Commerce, v. 99, no. 13, 31 p.

National Research Council, 1978, Nitrates—An environmental assessment: Washington, D.C., National Academy of Sciences, 723 p.

Neuman, S.P., 1975, Analysis of pumping test data from anisotropic unconfined aquifers considering delayed gravity response: Water Resources Research, v. 11, no. 2, p. 329-342.

Olsson Associates, 1993, Groundwater management plan—North Platte Natural Resources District: Lincoln, Nebr., Olsson Associates, 271 p.

Richards, L.A. (ed.), 1954, Diagnosis and improvement of saline and alkali soils: U.S. Salinity Laboratory Staff, U.S. Department of Agriculture Handbook 60, 160 p.

Sophocleous, M.A., 1991, Stream-floodwave propagation through the Great Bend alluvial aquifer, Kansas—field measurements and numerical simulations: Journal of Hydrology, v. 124, p. 207-228.

Souders, V.L., and Freethey, G.W., 1975, Water-table configurations, fall 1971: Lincoln, Nebr., Conservation and Survey Division, University of Nebraska, scale 1:250,000, 1 sheet.

Stallman, R.W., 1965, Effects of water-table conditions on water-level changes near pumping wells: Water Resources Research, v. 1, no. 2, p. 295-312.

Steele, G.V., 1994, Groundwater-levels in response to precipitation events, central Nebraska, 1987-1992: Lincoln, Nebr., University of Nebraska, M.S. thesis, 183 p.

Stout, M.T., and Tanner, L.G., 1985, Geology of Blue Creek, Garden County, western Nebraska [abs], *in* Zechmann, Albert, ed., Proceedings of The Nebraska Academy of Sciences and Affiliated Societies, Ninety-Fifth Annual Meeting, Lincoln, Nebraska, April 12-13, 1985: Lincoln, Nebr., Nebraska Academy of Sciences, p. 55.

Swinehart, J.B., and Diffendal, R.F., Jr., 1987, Duer Ranch, Morrill County, Nebraska—Contrast between Cenozoic fluvial and eolian deposition: Geological Society of America Centennial Field Guide, North Central Section, p. 23-28.

____ 1997, Geologic map of the Scottsbluff 1° x 2° quadrangle, Nebraska and Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-12545, scale 1:250,000.

Swinehart, J.B., Souders, V.L., DeGraw, H.M, and Diffendal, R.F., Jr., 1985, Cenozoic paleogeography of western Nebraska, *in* Flores, R.M., and Kaplan, S.S., eds., Cenozoic paleogeography of west-central United States: Denver, Colo., Rocky Mountain Section—Society of Economic Paleontologists and Mineralogists, p. 213.

Terao, H., Yoshioka, R., and Kato, K., 1993, Groundwater pollution by nitrate originating from fertilizer in Kakamigahara Heights, central Japan, *in* Yasuo, Sakura, ed., Selected papers on environmental hydrogeology, from the 29th International Geological Congress (I.G.C.), Kyoto (Japan), August 24-September 3, 1992: Hannover, International Association of Hydrologists, Verlag Heinz Heise, v. 4, p. 51-62.

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.

Tychsen, P.C., 1954, A sedimentation study of the Brule Formation in northwest Nebraska: Lincoln, University of Nebraska, Ph.D. dissertation, 189 p., 25 pls.

U.S. Department of Agriculture, 1975, Land use map—Garden County, Nebraska: Soil Conservation Service, U.S. Department of Agriculture, scale 1:158,400.

U.S. Environmental Protection Agency, 1996, Drinking water regulations and health advisories: Office of Water, U.S. Environmental Protection Agency, 11 p.

Verstraeten, I.M., Sibray, S.S., Cannia, J.C., and Tanner, D.Q., 1995, Reconnaissance of ground-water quality in the North Platte Natural Resources District, western Nebraska, June-July 1991: U.S. Geological Survey Water-Resources Investigations Report 94-4057, 114 p.

Zlotnik, V.A., Burbach, M.E., Exner, M.E., and Spalding, R.F., 1995, Well sampling for agrichemicals in high capacity systems: Journal of Soil and Water Conservation, v. 50, no. 1, p. 95-101.

SUPPLEMENTAL DATA

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94

[USGS, U.S. Geological Survey; ft, foot; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm of Hg, millimeters of mercury; mg/L, milligrams per liter; --, no data]

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (μS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412648102274001	NPGC01	17N 45W13BCCD1	05-11-93	0940	34	614	7.5	--	13.5	676	6.1
412648102274001	NPGC01	17N 45W13BCCD1	06-23-93	1305	34	584	7.6	20.5	13.5	--	--
412648102274001	NPGC01	17N 45W13BCCD1	08-17-93	1530	34	591	7.6	31.0	14.5	670	6.3
412648102274001	NPGC01	17N 45W13BCCD1	10-05-93	1610	34	580	7.5	31.0	14.5	--	--
412648102274001	NPGC01	17N 45W13BCCD1	11-30-93	1345	34	584	7.7	--	12.5	--	7.8
412648102274001	NPGC01	17N 45W13BCCD1	02-02-94	1345	34	539	7.5	7.5	13.0	667	7.1
412648102274001	NPGC01	17N 45W13BCCD1	05-04-94	1200	34	604	7.6	--	13.5	673	7.3
412648102274001	NPGC01	17N 45W13BCCD1	08-02-94	1400	34	--	--	--	--	--	--
412648102274001	NPGC01	17N 45W13BCCD1	09-01-94	1735	34	584	7.5	17.5	13.0	674	6.5
412553102250701	NPGC02	17N 44W20BDDC1	05-11-93	0855	163	753	7.6	--	12.5	676	5.6
412553102250701	NPGC02	17N 44W20BDDC1	06-23-93	1225	163	758	7.5	--	13.0	666	7.0
412553102250701	NPGC02	17N 44W20BDDC1	08-17-93	1500	163	883	7.5	30.5	13.5	--	8.1
412553102250701	NPGC02	17N 44W20BDDC1	10-05-93	1545	163	802	7.4	31.5	14.0	--	--
412553102250701	NPGC02	17N 44W20BDDC1	11-30-93	1305	163	732	7.6	--	12.5	--	8.9
412553102250701	NPGC02	17N 44W20BDDC1	05-04-94	1245	163	791	7.3	--	13.0	673	8.3
412553102250701	NPGC02	17N 44W20BDDC1	08-02-94	1145	163	--	--	--	--	--	--
412553102250701	NPGC02	17N 44W20BDDC1	09-01-94	1610	163	680	7.6	17.5	13.0	673	7.0
412500102240301	NPGC03	17N 44W28CBAA1	05-11-93	0805	145	962	7.5	--	12.0	--	--
412500102240301	NPGC03	17N 44W28CBAA1	06-23-93	1140	145	953	7.5	22.0	13.0	666	.3
412500102240301	NPGC03	17N 44W28CBAA1	08-17-93	1425	145	1,030	7.6	30.0	13.5	--	.5
412500102240301	NPGC03	17N 44W28CBAA1	10-05-93	1510	145	933	7.5	31.0	13.5	--	--
412500102240301	NPGC03	17N 44W28CBAA1	11-30-93	1415	145	961	7.6	8.0	12.0	--	.6
412500102240301	NPGC03	17N 44W28CBAA1	05-04-94	1415	145	957	7.3	--	13.0	673	.4
412500102240301	NPGC03	17N 44W28CBAA1	08-02-94	1035	145	1,520	7.2	--	12.0	--	--
412500102240301	NPGC03	17N 44W28CBAA1	09-01-94	1505	145	1,200	7.5	19.0	12.5	674	2.5

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412435102223301	NPGC04D	17N 44W27DCCC1	05-10-93	1925	48	1,340	7.4	--	12.0	--	--
412435102223301	NPGC04D	17N 44W27DCCC1	06-23-93	0900	48	1,300	7.4	19.5	12.5	669	0.1
412435102223301	NPGC04D	17N 44W27DCCC1	08-17-93	1335	48	1,350	7.4	30.0	12.5	672	.4
412435102223301	NPGC04D	17N 44W27DCCC1	10-05-93	1435	48	1,360	7.3	32.5	13.0	--	--
412435102223301	NPGC04D	17N 44W27DCCC1	12-01-93	0827	48	1,220	7.4	2.0	11.5	672	--
412435102223301	NPGC04D	17N 44W27DCCC1	02-02-94	1110	48	1,240	7.3	2.0	11.5	670	.2
412435102223301	NPGC04D	17N 44W27DCCC1	05-04-94	0920	48	1,410	7.2	14.0	--	675	.5
412435102223301	NPGC04D	17N 44W27DCCC1	08-02-94	0945	48	1,470	7.1	--	12.0	--	--
412435102223301	NPGC04D	17N 44W27DCCC1	09-01-94	1410	48	1,340	7.5	16.5	12.0	673	.4
412435102223302	NPGC04S	17N 44W27DCCC2	05-10-93	1940	28	1,400	7.4	--	10.5	--	--
412435102223302	NPGC04S	17N 44W27DCCC2	06-23-93	0920	28	1,340	7.4	19.5	11.5	669	.1
412435102223302	NPGC04S	17N 44W27DCCC2	08-17-93	1350	28	1,380	7.5	30.0	12.5	672	.3
412435102223302	NPGC04S	17N 44W27DCCC2	10-05-93	1450	28	1,350	7.4	32.5	13.0	--	--
412435102223302	NPGC04S	17N 44W27DCCC2	12-01-93	0844	28	1,200	7.4	2.0	11.5	672	--
412435102223302	NPGC04S	17N 44W27DCCC2	02-02-94	1130	28	1,210	7.4	2.0	11.0	670	.1
412435102223302	NPGC04S	17N 44W27DCCC2	05-04-94	0940	28	1,430	7.3	14.5	10.5	675	1.8
412435102223302	NPGC04S	17N 44W27DCCC2	08-02-94	1000	28	1,490	7.1	--	11.0	--	--
412435102223302	NPGC04S	17N 44W27DCCC2	09-01-94	1425	28	1,360	7.6	17.0	12.0	674	.4
412605102211001	LCGC05	17N 44W23ACAA1	05-10-93	1710	70	352	7.9	--	13.5	679	--
412605102211001	LCGC05	17N 44W23ACAA1	06-22-93	1555	70	398	7.6	--	13.5	674	6.7
412605102211001	LCGC05	17N 44W23ACAA1	08-17-93	1050	70	347	7.8	26.0	13.5	671	6.4
412605102211001	LCGC05	17N 44W23ACAA1	10-05-93	1245	70	516	7.4	32.5	14.5	--	--
412605102211001	LCGC05	17N 44W23ACAA1	11-30-93	1135	70	503	7.5	--	12.5	--	7.0
412605102211001	LCGC05	17N 44W23ACAA1	02-01-94	1240	70	460	7.3	0.0	11.5	674	--
412605102211001	LCGC05	17N 44W23ACAA1	05-03-94	1355	70	356	7.8	18.0	12.5	668	6.4
412605102211001	LCGC05	17N 44W23ACAA1	08-02-94	0735	70	490	7.5	--	11.5	--	--
412605102211001	LCGC05	17N 44W23ACAA1	09-01-94	1145	70	477	7.4	14.5	12.0	673	1.9

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412526102212301	LCGC06	17N 44W26ABBB1	05-10-93	1750	38	422	7.6	--	12.0	--	--
412526102212301	LCGC06	17N 44W26ABBB1	06-23-93	1035	38	408	7.6	21.5	12.5	--	--
412526102212301	LCGC06	17N 44W26ABBB1	08-17-93	1130	38.	415	7.6	29.0	12.5	--	1.0
412526102212301	LCGC06	17N 44W26ABBB1	10-05-93	1320	38	412	7.5	32.5	13.0	--	--
412526102212301	LCGC06	17N 44W26ABBB1	11-30-93	1225	38	412	7.7	--	11.5	--	1.2
412526102212301	LCGC06	17N 44W26ABBB1	02-02-94	1305	38	371	7.4	4.5	11.0	669	1.0
412526102212301	LCGC06	17N 44W26ABBB1	05-03-94	1500	38	407	7.7	--	12.0	669	1.6
412526102212301	LCGC06	17N 44W26ABBB1	08-02-94	0820	38	435	7.2	--	12.0	--	--
412526102212301	LCGC06	17N 44W26ABBB1	09-01-94	1235	38	384	7.7	17.0	12.0	673	1.1
412434102214201	NPGC07D	17N 44W35BBAA1	05-10-93	1840	48	563	7.6	--	12.0	--	--
412434102214201	NPGC07D	17N 44W35BBAA1	06-23-93	0755	48	544	7.7	18.5	12.0	--	4.5
412434102214201	NPGC07D	17N 44W35BBAA1	08-17-93	1245	48	561	7.6	29.0	13.0	672	4.3
412434102214201	NPGC07D	17N 44W35BBAA1	10-05-93	1400	48	548	7.6	31.5	13.0	--	--
412434102214201	NPGC07D	17N 44W35BBAA1	12-01-93	0735	48	485	7.7	2.0	12.0	672	--
412434102214201	NPGC07D	17N 44W35BBAA1	02-02-94	1025	48	491	7.7	1.0	11.5	--	4.8
412434102214201	NPGC07D	17N 44W35BBAA1	05-03-94	1550	48	540	7.7	18.5	12.5	669	5.8
412434102214201	NPGC07D	17N 44W35BBAA1	08-02-94	0900	48	551	7.0	--	12.0	--	--
412434102214201	NPGC07D	17N 44W35BBAA1	09-01-94	1315	48	502	7.9	19.0	12.0	674	4.6
412434102214202	NPGC07S	17N 44W35BBAA2	05-10-93	1850	28	682	7.5	--	11.0	--	--
412434102214202	NPGC07S	17N 44W35BBAA2	06-23-93	0820	28	656	7.5	21.5	11.0	669	4.5
412434102214202	NPGC07S	17N 44W35BBAA2	08-17-93	1305	28	620	7.5	29.0	12.5	672	4.4
412434102214202	NPGC07S	17N 44W35BBAA2	10-05-93	1415	28	610	7.4	31.5	13.5	--	--
412434102214202	NPGC07S	17N 44W35BBAA2	12-01-93	0755	28	561	7.5	2.0	12.5	672	--
412434102214202	NPGC07S	17N 44W35BBAA2	02-02-94	1040	28	604	7.5	1.0	11.5	670	4.7
412434102214202	NPGC07S	17N 44W35BBAA2	05-03-94	1615	28	655	7.6	14.0	11.0	669	6.2
412434102214202	NPGC07S	17N 44W35BBAA2	08-02-94	0915	28	849	6.9	--	11.5	--	--
412434102214202	NPGC07S	17N 44W35BBAA2	09-01-94	1335	28	776	7.4	18.0	12.0	673	4.6

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412424102201801	NPGC08	17N 44W36BADD1	05-10-93	1610	87	342	7.8	--	12.5	677	--
412424102201801	NPGC08	17N 44W36BADD1	06-22-93	1640	87	483	7.5	21.0	12.5	--	2.8
412424102201801	NPGC08	17N 44W36BADD1	08-17-93	1205	87	876	7.3	29.0	13.0	671	2.3
412424102201801	NPGC08	17N 44W36BADD1	10-05-93	1215	87	380	7.6	27.0	13.0	--	--
412424102201801	NPGC08	17N 44W36BADD1	11-30-93	0925	87	424	7.6	--	12.0	--	3.7
412424102201801	NPGC08	17N 44W36BADD1	02-01-94	1020	87	340	7.8	-5.0	11.0	673	3.2
412424102201801	NPGC08	17N 44W36BADD1	05-03-94	1040	87	468	7.6	18.0	12.5	670	3.5
412424102201801	NPGC08	17N 44W36BADD1	08-01-94	1615	87	1,240	7.0	--	12.0	--	--
412424102201801	NPGC08	17N 44W36BADD1	09-01-94	1055	87	1,070	7.2	14.0	--	675	1.4
412416102182301	NPGC09D	17N 43W31BDAD1	05-10-93	1510	115	449	7.7	--	14.0	--	--
412416102182301	NPGC09D	17N 43W31BDAD1	06-22-93	1330	115	419	7.8	30.5	15.0	669	5.1
412416102182301	NPGC09D	17N 43W31BDAD1	08-17-93	0955	115	375	7.7	25.0	16.0	--	4.7
412416102182301	NPGC09D	17N 43W31BDAD1	10-05-93	1125	115	389	7.8	22.5	15.0	--	--
412416102182301	NPGC09D	17N 43W31BDAD1	02-01-94	1140	115	348	7.8	0.0	13.5	674	5.2
412416102182301	NPGC09D	17N 43W31BDAD1	05-03-94	1130	115	377	7.7	23.5	14.5	669	5.1
412416102182301	NPGC09D	17N 43W31BDAD1	08-01-94	1515	115	393	7.6	--	14.5	--	--
412416102182301	NPGC09D	17N 43W31BDAD1	09-01-94	1000	115	363	8.0	15.0	14.0	675	6.4
412416102182302	NPGC09S	17N 43W31BDAD2	05-10-93	1525	65	372	7.7	--	14.0	--	--
412416102182302	NPGC09S	17N 43W31BDAD2	06-22-93	1405	65	386	7.8	30.5	14.5	669	6.5
412416102182302	NPGC09S	17N 43W31BDAD2	08-17-93	1015	65	391	7.7	25.0	15.0	672	6.2
412416102182302	NPGC09S	17N 43W31BDAD2	10-05-93	1140	65	365	7.6	23.5	14.5	--	--
412416102182302	NPGC09S	17N 43W31BDAD2	11-30-93	1040	65	363	7.8	--	14.0	--	6.6
412416102182302	NPGC09S	17N 43W31BDAD2	02-01-94	1155	65	325	7.7	0	13.5	674	5.2
412416102182302	NPGC09S	17N 43W31BDAD2	05-03-94	1200	65	364	7.6	24.5	14.5	671	6.0
412416102182302	NPGC09S	17N 43W31BDAD2	08-01-94	1540	65	382	7.6	--	14.0	--	--
412416102182302	NPGC09S	17N 43W31BDAD2	09-01-94	1015	65	354	7.8	15.0	14.0	675	7.4
412345102182301	NPGC10	17N 43W32CCCA1	05-10-93	1420	58	1,740	7.3	20.0	12.5	--	--

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identi-fication	Well location	Date	Time	Depth (ft)	Specific conduct-ance (µS/cm)	pH (stan-dard units)	Air tem-per-ature (°C)	Water temper-ature (°C)	Baro-metric pres-sure (mm of Hg)	Dissolved oxygen (mg/L)
412345102182301	NPGC10	17N 43W32CCCA1	06-22-93	1100	58	1,740	7.4	26.5	12.5	--	4.0
412345102182301	NPGC10	17N 43W32CCCA1	08-17-93	0915	58	1,550	7.4	22.5	13.5	672	3.0
412345102182301	NPGC10	17N 43W32CCCA1	10-05-93	1045	58	1,400	7.2	18.0	13.0	--	--
412345102182301	NPGC10	17N 43W32CCCA1	11-30-93	1505	58	1,530	7.4	3.0	12.0	--	3.6
412345102182301	NPGC10	17N 43W32CCCA1	02-01-94	0940	58	1,460	7.5	0.0	11.5	673	3.3
412345102182301	NPGC10	17N 43W32CCCA1	05-03-94	0940	58	1,640	7.3	14.0	12.0	670	3.7
412345102182301	NPGC10	17N 43W32CCCA1	08-01-94	1425	58	1,580	7.2	--	12.5	--	--
412345102182301	NPGC10	17N 43W32CCCA1	09-01-94	0910	58	1,480	7.4	13.0	12.0	675	6.2
412137102130101	NPGC11	16N 43W14ACCB1	05-10-93	1225	130	911	7.5	21.0	14.0	679	--
412137102130101	NPGC11	16N 43W14ACCB1	06-22-93	0920	130	851	7.4	--	14.0	669	4.2
412137102130101	NPGC11	16N 43W14ACCB1	08-17-93	0820	130	857	7.4	21.5	16.5	--	3.3
412137102130101	NPGC11	16N 43W14ACCB1	10-05-93	0955	130	826	7.3	17.5	13.5	672	--
412137102130101	NPGC11	16N 43W14ACCB1	11-30-93	0750	130	820	7.4	2.0	13.0	671	5.5
412137102130101	NPGC11	16N 43W14ACCB1	02-01-94	0855	130	760	7.5	-3.0	12.5	675	4.1
412137102130101	NPGC11	16N 43W14ACCB1	05-03-94	0830	130	862	7.3	10.5	13.5	670	4.9
412137102130101	NPGC11	16N 43W14ACCB1	08-01-94	1320	130	918	7.2	--	13.5	--	--
412137102130101	NPGC11	16N 43W14ACCB1	09-01-94	0830	130	845	7.5	13.5	13.5	675	3.9
412500102241801	OSHML1-1	17N 44W29DAAA1	04-21-93	1400	10	1,960	7.5	--	9.5	--	--
412500102241801	OSHML1-1	17N 44W29DAAA1	06-24-93	1125	10	2,250	7.4	17.5	12.5	672	--
412500102241801	OSHML1-1	17N 44W29DAAA1	08-18-93	0810	10	2,280	7.5	22.0	14.0	--	--
412500102241801	OSHML1-1	17N 44W29DAAA1	10-06-93	0840	10	2,180	7.6	13.0	13.0	--	1.5
412500102241801	OSHML1-1	17N 44W29DAAA1	11-29-93	1435	10	2,040	7.5	--	9.5	--	--
412500102241801	OSHML1-1	17N 44W29DAAA1	02-01-94	1050	10	2,010	7.6	-5.0	4.5	673	--
412500102241801	OSHML1-1	17N 44W29DAAA1	05-02-94	1050	10	1,800	7.7	--	8.5	--	--
412500102241801	OSHML1-1	17N 44W29DAAA1	08-02-94	1111	10	--	7.4	--	12.5	--	--
412500102241801	OSHML1-1	17N 44W29DAAA1	09-01-94	1550	10	1,680	7.5	18.0	13.0	673	--
412500102241802	OSHML1-2	17N 44W29DAAA2	04-21-93	1400	15	1,770	7.3	--	10.5	--	--

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (μS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412500102241802	OSHML1-2	17N 44W29DAAA2	06-24-93	1120	15	1,720	7.4	17.0	13.0	672	--
412500102241802	OSHML1-2	17N 44W29DAAA2	02-01-94	1045	15	1,580	7.6	-5.0	7.5	673	--
412500102241802	OSHML1-2	17N 44W29DAAA2	08-02-94	1113	15	--	7.4	--	12.0	--	--
412500102241803	OSHML1-3	17N 44W29DAAA3	04-21-93	1400	20	1,470	7.3	--	10.5	--	--
412500102241803	OSHML1-3	17N 44W29DAAA3	06-24-93	1115	20	1,740	7.4	17.0	12.5	672	--
412500102241803	OSHML1-3	17N 44W29DAAA3	02-01-94	1040	20	1,570	7.6	-5.0	8.0	673	--
412500102241803	OSHML1-3	17N 44W29DAAA3	08-02-94	1109	20	--	7.3	--	12.0	--	--
412500102241804	OSHML1-4	17N 44W29DAAA4	04-21-93	1400	25	1,380	7.3	--	11.0	--	--
412500102241804	OSHML1-4	17N 44W29DAAA4	06-24-93	1110	25	1,740	7.4	17.0	13.0	672	--
412500102241804	OSHML1-4	17N 44W29DAAA4	02-01-94	1035	25	1,520	7.5	-5.0	8.5	673	--
412500102241804	OSHML1-4	17N 44W29DAAA4	08-02-94	1108	25	--	7.3	--	12.0	--	--
412500102241805	OSHML1-5	17N 44W29DAAA5	04-21-93	1400	30	1,300	7.3	--	11.0	--	--
412500102241805	OSHML1-5	17N 44W29DAAA5	06-24-93	1105	30	1,520	7.3	16.5	15.0	672	--
412500102241805	OSHML1-5	17N 44W29DAAA5	08-18-93	0810	30	1,580	7.4	22.0	13.0	--	--
412500102241805	OSHML1-5	17N 44W29DAAA5	10-06-93	0835	30	1,720	7.5	13.0	12.0	--	2.2
412500102241805	OSHML1-5	17N 44W29DAAA5	11-29-93	1425	30	1,350	7.3	--	9.5	--	--
412500102241805	OSHML1-5	17N 44W29DAAA5	02-01-94	1030	30	1,220	7.5	-5.0	8.5	673	--
412500102241805	OSHML1-5	17N 44W29DAAA5	05-02-94	1045	30	1,560	7.5	--	10.0	--	--
412500102241805	OSHML1-5	17N 44W29DAAA5	08-02-94	1107	30	--	7.3	--	12.5	--	--
412500102241805	OSHML1-5	17N 44W29DAAA5	09-01-94	1535	30	1,250	7.4	18.0	11.5	673	--
412500102241806	OSHML1-6	17N 44W29DAAA6	04-21-93	1400	40	1,180	7.3	--	11.5	--	--
412500102241806	OSHML1-6	17N 44W29DAAA6	06-24-93	1100	40	1,260	7.4	16.5	13.5	--	--
412500102241806	OSHML1-6	17N 44W29DAAA6	02-01-94	1025	40	1,280	7.5	-5.0	8.5	673	--
412500102241806	OSHML1-6	17N 44W29DAAA6	08-02-94	1106	40	--	7.2	--	12.5	--	--
412500102241807	OSHML1-7	17N 44W29DAAA7	04-21-93	1400	50	1,150	7.4	--	11.5	--	--
412500102241807	OSHML1-7	17N 44W29DAAA7	06-24-93	1055	50	1,150	7.4	16.5	13.5	674	--
412500102241807	OSHML1-7	17N 44W29DAAA7	02-01-94	1020	50	1,020	7.6	-5.0	9.0	673	--

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412500102241807	OSHML1-7	17N 44W29DAAA7	08-02-94	1104	50	--	7.2	--	13.5	--	--
412500102241808	OSHML1-8	17N 44W29DAAA8	04-21-93	1400	60	1,120	7.4	--	11.5	--	--
412500102241808	OSHML1-8	17N 44W29DAAA8	06-24-93	1050	60	1,150	7.2	16.5	15.0	674	--
412500102241808	OSHML1-8	17N 44W29DAAA8	08-18-93	0800	60	1,100	7.1	22.0	15.5	--	--
412500102241808	OSHML1-8	17N 44W29DAAA8	10-06-93	0830	60	1,140	7.7	13.0	12.0	--	2.1
412500102241808	OSHML1-8	17N 44W29DAAA8	11-29-93	1405	60	--	--	--	--	--	--
412500102241808	OSHML1-8	17N 44W29DAAA8	02-01-94	1015	60	1,030	7.4	-5.0	10.0	673	--
412500102241808	OSHML1-8	17N 44W29DAAA8	05-02-94	1040	60	1,100	7.4	--	10.5	--	--
412500102241808	OSHML1-8	17N 44W29DAAA8	08-02-94	1102	60	--	7.1	--	13.5	--	--
412500102241808	OSHML1-8	17N 44W29DAAA8	09-01-94	1530	60	949	7.6	18.0	12.0	673	--
412526102252701	OSHML2-1	17N 44W19DDDD1	04-21-93	0800	10	1,410	7.3	--	10.0	--	--
412526102252701	OSHML2-1	17N 44W19DDDD1	06-24-93	1025	10	1,570	7.4	15.5	12.0	674	--
412526102252701	OSHML2-1	17N 44W19DDDD1	08-18-93	0845	10	1,250	7.5	22.0	16.0	--	--
412526102252701	OSHML2-1	17N 44W19DDDD1	10-06-93	0945	10	1,410	7.5	17.0	15.5	--	3.5
412526102252701	OSHML2-1	17N 44W19DDDD1	11-29-93	1525	10	1,500	7.4	--	10.0	--	--
412526102252701	OSHML2-1	17N 44W19DDDD1	02-01-94	1000	10	1,600	7.6	0.0	6.5	673	--
412526102252701	OSHML2-1	17N 44W19DDDD1	05-02-94	1030	10	1,540	7.8	--	9.0	--	--
412526102252701	OSHML2-1	17N 44W19DDDD1	08-02-94	1228	10	--	--	--	--	--	--
412526102252701	OSHML2-1	17N 44W19DDDD1	09-01-94	1645	10	--	--	--	--	--	--
412526102252702	OSHML2-2	17N 44W19DDDD2	04-21-93	0800	15	1,570	7.4	--	9.5	--	--
412526102252702	OSHML2-2	17N 44W19DDDD2	06-24-93	1020	15	1,590	7.5	15.5	11.0	674	--
412526102252702	OSHML2-2	17N 44W19DDDD2	02-01-94	0955	15	1,520	7.6	0.0	10.0	673	--
412526102252702	OSHML2-2	17N 44W19DDDD2	08-02-94	1227	15	--	--	--	--	--	--
412526102252703	OSHML2-3	17N 44W19DDDD3	04-21-93	0800	20	1,560	7.3	--	10.0	--	--
412526102252703	OSHML2-3	17N 44W19DDDD3	06-24-93	1015	20	1,690	7.4	15.5	11.0	674	--
412526102252703	OSHML2-3	17N 44W19DDDD3	02-01-94	0950	20	1,520	7.6	0.0	9.0	673	--
412526102252703	OSHML2-3	17N 44W19DDDD3	08-02-94	1225	20	--	--	--	--	--	--

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412526102252704	OSHML2-4	17N 44W19DDDD4	04-21-93	0800	25	1,640	7.3	--	10.5	--	--
412526102252704	OSHML2-4	17N 44W19DDDD4	06-24-93	1010	25	1,660	7.4	15.5	11.5	--	--
412526102252704	OSHML2-4	17N 44W19DDDD4	02-01-94	0945	25	1,490	7.6	0.0	10.0	673	--
412526102252704	OSHML2-4	17N 44W19DDDD4	08-02-94	1223	25	--	--	--	--	--	--
412526102252705	OSHML2-5	17N 44W19DDDD5	04-21-93	0800	30	1,620	7.2	--	11.0	--	--
412526102252705	OSHML2-5	17N 44W19DDDD5	06-24-93	1005	30	1,700	7.3	15.0	17.0	674	--
412526102252705	OSHML2-5	17N 44W19DDDD5	08-18-93	0840	30	1,570	7.5	22.0	13.0	--	--
412526102252705	OSHML2-5	17N 44W19DDDD5	10-06-93	0935	30	1,550	7.6	17.0	12.5	--	3.1
412526102252705	OSHML2-5	17N 44W19DDDD5	11-29-93	1515	30	1,580	7.5	--	9.5	--	--
412526102252705	OSHML2-5	17N 44W19DDDD5	02-01-94	0940	30	1,470	7.5	.0	9.5	673	--
412526102252705	OSHML2-5	17N 44W19DDDD5	05-02-94	1000	30	1,490	7.7	--	9.5	--	--
412526102252705	OSHML2-5	17N 44W19DDDD5	08-02-94	1221	30	--	--	--	--	--	--
412526102252705	OSHML2-5	17N 44W19DDDD5	09-01-94	1635	30	1,360	7.5	17.5	12.0	674	--
412526102252706	OSHML2-6	17N 44W19DDDD6	04-21-93	0800	40	1,520	7.3	--	11.5	--	--
412526102252706	OSHML2-6	17N 44W19DDDD6	06-24-93	1000	40	1,470	7.3	15.0	12.0	--	--
412526102252706	OSHML2-6	17N 44W19DDDD6	02-01-94	0935	40	1,360	7.5	0.0	9.0	673	--
412526102252706	OSHML2-6	17N 44W19DDDD6	08-02-94	1219	40	--	--	--	--	--	--
412526102252707	OSHML2-7	17N 44W19DDDD7	04-21-93	0800	50	1,500	7.2	--	11.0	--	--
412526102252707	OSHML2-7	17N 44W19DDDD7	06-24-93	0955	50	1,500	7.2	15.0	12.0	674	--
412526102252707	OSHML2-7	17N 44W19DDDD7	02-01-94	0930	50	1,390	7.5	0.0	8.5	673	--
412526102252707	OSHML2-7	17N 44W19DDDD7	08-02-94	1217	50	--	--	--	--	--	--
412526102252708	OSHML2-8	17N 44W19DDDD8	04-21-93	0800	60	1,400	7.2	--	11.5	--	--
412526102252708	OSHML2-8	17N 44W19DDDD8	06-24-93	0950	60	1,400	7.1	15.0	13.0	674	--
412526102252708	OSHML2-8	17N 44W19DDDD8	08-18-93	0840	60	1,330	7.5	22.0	15.0	--	--
412526102252708	OSHML2-8	17N 44W19DDDD8	10-06-93	0930	60	1,340	7.4	16.0	13.5	--	2.0
412526102252708	OSHML2-8	17N 44W19DDDD8	11-29-93	1505	60	1,520	7.4	--	9.5	--	--
412526102252708	OSHML2-8	17N 44W19DDDD8	02-01-94	0925	60	1,360	7.4	0.0	9.5	673	--

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (μS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412526102252708	OSHML2-8	17N 44W19DDDD8	05-02-94	0955	60	1,360	7.5	--	10.0	--	--
412526102252708	OSHML2-8	17N 44W19DDDD8	08-02-94	1215	60	--	--	--	--	--	--
412526102252708	OSHML2-8	17N 44W19DDDD8	09-01-94	1625	60	1,170	7.0	17.5	12.0	674	--
412549102255401	OSHML3-1	17N 44W19DBBA1	06-24-93	0915	10	1,640	7.4	14.0	12.5	--	--
412549102255401	OSHML3-1	17N 44W19DBBA1	08-18-93	0910	10	1,570	7.4	25.0	15.0	--	--
412549102255401	OSHML3-1	17N 44W19DBBA1	10-06-93	1020	10	1,530	7.6	22.5	15.5	--	4.2
412549102255401	OSHML3-1	17N 44W19DBBA1	11-29-93	1600	10	1,440	7.5	--	10.0	--	--
412549102255401	OSHML3-1	17N 44W19DBBA1	02-01-94	0910	10	1,520	7.7	-3.0	8.0	675	--
412549102255401	OSHML3-1	17N 44W19DBBA1	05-02-94	0935	10	1,540	7.6	--	8.5	--	--
412549102255401	OSHML3-1	17N 44W19DBBA1	08-02-94	1302	10	--	--	--	--	--	--
412549102255402	OSHML3-2	17N 44W19DBBA2	04-21-93	1000	15	1,560	7.3	--	9.5	--	--
412549102255402	OSHML3-2	17N 44W19DBBA2	06-24-93	0905	15	1,620	7.4	14.0	12.0	--	--
412549102255402	OSHML3-2	17N 44W19DBBA2	02-01-94	0905	15	1,510	7.6	3.0	8.0	675	--
412549102255402	OSHML3-2	17N 44W19DBBA2	08-02-94	1304	15	--	--	--	--	--	--
412549102255402	OSHML3-2	17N 44W19DBBA2	09-01-94	1715	15	--	--	17.0	12.0	--	--
412549102255403	OSHML3-3	17N 44W19DBBA3	04-21-93	1000	20	1,590	7.2	--	10.0	--	--
412549102255403	OSHML3-3	17N 44W19DBBA3	06-24-93	0900	20	1,660	7.2	13.5	12.0	--	--
412549102255403	OSHML3-3	17N 44W19DBBA3	02-01-94	0900	20	1,570	7.6	-3.0	9.0	675	-
412549102255403	OSHML3-3	17N 44W19DBBA3	08-02-94	1300	20	--	--	--	--	--	--
412549102255404	OSHML3-4	17N 44W19DBBA4	04-21-93	1000	25	1,680	7.2	--	11.0	--	--
412549102255404	OSHML3-4	17N 44W19DBBA4	06-24-93	0855	25	1,700	7.2	13.0	12.5	--	--
412549102255404	OSHML3-4	17N 44W19DBBA4	02-01-94	0855	25	1,620	7.5	-3.0	9.5	675	--
412549102255404	OSHML3-4	17N 44W19DBBA4	08-02-94	1258	25	--	--	--	--	--	--
412549102255405	OSHML3-5	17N 44W19DBBA5	04-21-93	1000	30	1,630	7.1	--	11.0	--	--
412549102255405	OSHML3-5	17N 44W19DBBA5	06-24-93	0845	30	1,600	7.1	12.5	12.5	--	--
412549102255405	OSHML3-5	17N 44W19DBBA5	08-18-93	0905	30	1,660	7.2	25.0	14.0	--	--
412549102255405	OSHML3-5	17N 44W19DBBA5	10-06-93	1015	30	1,570	7.4	22.5	14.0	--	2.9

Table 9. Results of field measurements of ground-water samples, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Depth (ft)	Specific conductance (µS/cm)	pH (standard units)	Air temperature (°C)	Water temperature (°C)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)
412549102255405	OSHML3-5	17N 44W19DBBA5	11-29-93	1555	30	1,610	7.6	--	9.5	--	--
412549102255405	OSHML3-5	17N 44W19DBBA5	02-01-94	0850	30	1,550	7.5	-3.0	9.5	675	--
412549102255405	OSHML3-5	17N 44W19DBBA5	05-02-94	0930	30	1,370	7.4	--	10.0	--	--
412549102255405	OSHML3-5	17N 44W19DBBA5	08-02-94	1256	30	--	--	--	--	--	--
412549102255405	OSHML3-5	17N 44W19DBBA5	09-01-94	1705	30	1,480	7.4	17.0	12.0	674	--
412549102255406	OSHML3-6	17N 44W19DBBA6	04-21-93	1000	40	1,360	7.1	--	11.5	--	--
412549102255406	OSHML3-6	17N 44W19DBBA6	06-24-93	0840	40	1,280	7.1	12.5	13.0	--	--
412549102255406	OSHML3-6	17N 44W19DBBA6	02-01-94	0845	40	1,300	7.5	-3.0	9.5	675	--
412549102255406	OSHML3-6	17N 44W19DBBA6	08-02-94	1254	40	--	--	--	--	--	--
412549102255407	OSHML3-7	17N 44W19DBBA7	04-21-93	1000	50	1,500	7.1	--	11.5	--	--
412549102255407	OSHML3-7	17N 44W19DBBA7	06-24-93	0835	50	1,320	7.1	13.5	13.0	--	--
412549102255407	OSHML3-7	17N 44W19DBBA7	02-01-94	0840	50	1,320	7.5	-3.0	9.5	675	--
412549102255407	OSHML3-7	17N 44W19DBBA7	08-02-94	1252	50	--	--	--	--	--	--
412549102255408	OSHML3-8	17N 44W19DBBA8	04-21-93	1000	60	1,380	7.2	--	11.5	--	--
412549102255408	OSHML3-8	17N 44W19DBBA8	06-24-93	0830	60	1,300	7.1	13.5	13.0	--	--
412549102255408	OSHML3-8	17N 44W19DBBA8	08-18-93	0905	60	1,300	7.3	25.0	14.5	--	--
412549102255408	OSHML3-8	17N 44W19DBBA8	10-06-93	1005	60	1,330	7.5	22.5	14.0	--	2.3
412549102255408	OSHML3-8	17N 44W19DBBA8	11-29-93	1545	60	1,370	7.5	--	9.5	--	--
412549102255408	OSHML3-8	17N 44W19DBBA8	02-01-94	0835	60	1,220	7.3	-3.0	9.5	675	--
412549102255408	OSHML3-8	17N 44W19DBBA8	05-02-94	0925	60	1,230	7.3	--	10.5	--	--
412549102255408	OSHML3-8	17N 44W19DBBA8	08-02-94	1250	60	--	--	--	--	--	--
412549102255408	OSHML3-8	17N 44W19DBBA8	09-01-94	1655	60	1,390	7.3	17.0	12.5	674	--

Table 10. Table 10. Results of ground-water quality analyses for major ions, related data, and iron and manganese, Garden County, western Nebraska, 1993-94

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than indicated reporting level]

USGS site identification	Field identification	Date	Time	Dissolved solids (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Sodium adsorption ratio	Potassium (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Iron (µg/L)	Manganese (µg/L)
412648102274001	NPGC01	06-23-93	13:05	381	74	13	26	0.7	8	35	12	0.5	44	<3	<1
412648102274001	NPGC01	11-30-93	13:45	390	73	12	26	.7	10	32	12	.5	47	<3	<1
412648102274001	NPGC01	08-02-94	14:00	393	79	13	26	.7	10	32	14	.5	45	5	<1
412553102250701	NPGC02	06-23-93	12:25	520	86	15	45	1	13	70	16	.4	60	<3	<1
412553102250701	NPGC02	11-30-93	13:05	517	81	14	44	1	14	57	15	.4	63	<3	<1
412553102250701	NPGC02	08-02-94	11:45	563	92	15	54	1	16	63	19	.5	61	<3	<1
412500102240301	NPGC03	06-23-93	11:40	642	94	18	75	2	4	180	21	.3	54	13	2
412500102240301	NPGC03	11-30-93	14:15	674	97	17	78	2	14	180	21	.3	58	19	<1
412500102240301	NPGC03	08-02-94	10:35	1,050	81	36	140	3	110	150	34	1.2	72	<3	<1
412435102223301	NPGC04D	06-23-93	09:00	872	100	19	160	4	4	180	27	.4	56	<3	9
412435102223301	NPGC04D	12-01-93	08:27	946	110	20	160	4	14	200	30	.4	60	15	7
412435102223301	NPGC04D	08-02-94	09:45	942	120	21	150	3	16	210	30	.4	61	<3	9
412435102223302	NPGC04S	06-23-93	09:20	913	96	17	180	4	15	200	27	.5	56	3	16
412435102223302	NPGC04S	12-01-93	08:44	920	87	17	180	5	16	200	25	.6	61	<3	15
412435102223302	NPGC04S	08-02-94	10:00	990	100	18	190	5	15	210	29	.6	59	<3	23
412605102211001	LCGC05	06-22-93	15:55	277	48	6.0	12	.4	9	34	4.0	.4	54	9	1
412605102211001	LCGC05	11-30-93	11:35	365	63	7.7	24	.8	12	60	4.5	.4	54	11	<1
412605102211001	LCGC05	08-02-94	07:35	332	67	8.1	15	.5	10	71	3.5	.3	53	4	<1
412526102212301	LCGC06	06-23-93	10:35	281	57	7.6	14	.5	2	26	3.8	.5	55	<3	<1
412526102212301	LCGC06	11-30-93	12:25	289	55	7.5	14	0.5	9	24	3.4	0.5	58	<3	<1
412526102212301	LCGC06	08-02-94	08:20	290	57	7.7	15	.5	10	24	3.8	.5	56	<3	<1
412434102214201	NPGC07D	06-23-93	07:55	363	59	13	29	.9	3	65	12	.5	57	<3	<1
412434102214201	NPGC07D	12-01-93	07:35	383	62	13	28	.8	11	64	13	.5	62	6	<1
412434102214201	NPGC07D	08-02-94	09:00	367	56	11	34	1	10	54	12	.5	58	<3	<1
412434102214202	NPGC07S	06-23-93	08:20	435	59	10	55	2	4	76	16	1.0	57	3	<1
412434102214202	NPGC07S	12-01-93	07:55	401	59	10	52	2	14	32	16	.6	62	12	<1
412434102214202	NPGC07S	08-02-94	09:15	538	81	13	67	2	17	100	21	1.1	59	<3	<1

Table 10. Results of ground-water quality analyses for major ions, related data, and iron and manganese, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Date	Time	Dissolved solids (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Sodium adsorption ratio	Potassium (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Iron (µg/L)	Manganese (µg/L)
412424102201801	NPGC08	06-22-93	16:40	326	55	9.5	21	.7	11	47	7.2	.7	52	12	<1
412424102201801	NPGC08	11-30-93	09:25	304	55	8.9	18	.6	9	31	5.6	.6	57	9	<1
412424102201801	NPGC08	08-01-94	16:15	869	160	29	59	1	23	310	40	.8	55	<3	2
412416102182301	NPGC09D	06-22-93	13:30	304	43	7.2	30	1	9	25	5.2	.3	66	<3	<1
412416102182301	NPGC09D	08-01-94	15:15	283	39	5.8	31	1	8	21	5.4	.3	61	6	<1
412416102182302	NPGC09S	06-22-93	14:05	267	38	5.6	25	1	8	18	5.3	.4	59	6	<1
412416102182302	NPGC09S	11-30-93	10:40	268	38	5.5	25	1	9	19	4.3	.4	63	<3	<1
412416102182302	NPGC09S	08-01-94	15:40	271	39	5.6	26	1	8	18	5.0	.4	62	<3	<1
412345102182301	NPGC10	06-22-93	11:00	1,140	100	20	250	6	6	230	24	.7	54	4	<1
412345102182301	NPGC10	11-30-93	15:05	1,060	110	19	200	5	21	200	20	.6	58	3	<1
412345102182301	NPGC10	08-01-94	14:25	1,050	120	20	200	4	21	200	21	.6	57	<3	<1
412137102130101	NPGC11	06-22-93	09:20	570	100	16	52	1	15	88	8.7	.4	59	<3	<1
412137102130101	NPGC11	11-30-93	07:50	566	100	16	46	1	17	76	8.0	0.3	61	7	<1
412137102130101	NPGC11	08-01-94	13:20	586	120	17	42	1	16	100	10	.3	61	<3	<1
412500102241801	OSHML1-1	11-29-93	14:35	1,550	100	20	380	9	24	640	48	1.0	50	20	50
412500102241802	OSHML1-2	06-24-93	11:20	1,200	170	28	180	3	20	450	41	.5	50	<3	29
412500102241802	OSHML1-2	08-02-94	11:13	965	91	16	200	5	20	330	31	.7	50	<3	16
412500102241805	OSHML1-5	11-29-93	14:25	1,010	150	25	120	2	16	380	32	.5	53	<3	15
412500102241808	OSHML1-8	11-29-93	14:05	753	100	17	110	3	13	240	28	.5	55	<3	1
412526102252701	OSHML2-1	11-29-93	15:25	950	110	43	100	2	30	180	29	1.3	70	6	<1
412526102252702	OSHML2-2	06-24-93	10:20	1,000	99	40	150	3	5	270	32	1.4	54	<3	<1
412526102252702	OSHML2-2	08-02-94	12:27	1,030	93	41	140	3	63	220	31	1.5	61	<3	<1
412526102252705	OSHML2-5	11-29-93	15:15	1,030	110	31	130	3	54	290	29	1.5	51	8	<1
412526102252708	OSHML2-8	11-29-93	15:05	947	130	22	110	2	33	300	27	.6	52	<3	<1
412549102255401	OSHML3-1	11-29-93	16:00	1,050	110	28	150	3	48	120	47	1.0	60	4	<1
412549102255402	OSHML3-2	06-24-93	09:05	1,030	130	28	150	3	3	140	50	1.0	55	<3	<1
412549102255402	OSHML3-2	08-02-94	13:04	1,040	120	25	140	3	43	120	55	1.1	60	<3	<1
412549102255405	OSHML3-5	11-29-93	15:55	1,110	170	28	120	2	24	230	31	.6	57	13	<1
412549102255408	OSHML3-8	11-29-93	15:45	905	140	23	100	2	11	220	27	.5	57	<3	<1

Table 11. Results of ground-water quality analyses for nutrients, Garden County, western Nebraska, 1993-94

[All values are in milligrams per liter; USGS, U.S. Geological Survey; --, no analysis]

USGS site identification	Field identification	Well location	Date	Time	Nitrate plus nitrite	Phosphorus as PO_4
412648102274001	NPGC01	17N 45W13BCCD1	05-11-93	0940	7.2	0.09
412648102274001	NPGC01	17N 45W13BCCD1	06-23-93	1305	8.5	.09
412648102274001	NPGC01	17N 45W13BCCD1	08-17-93	1530	8.2	--
412648102274001	NPGC01	17N 45W13BCCD1	10-05-93	1610	8.5	--
412648102274001	NPGC01	17N 45W13BCCD1	11-30-93	1345	8.7	--
412648102274001	NPGC01	17N 45W13BCCD1	02-02-94	1345	8.5	--
412648102274001	NPGC01	17N 45W13BCCD1	05-04-94	1200	7.9	--
412648102274001	NPGC01	17N 45W13BCCD1	08-02-94	1400	8.1	.09
412648102274001	NPGC01	17N 45W13BCCD1	09-01-94	1735	8.5	--
412553102250701	NPGC02	17N 44W20BDDC1	05-11-93	0855	15	.18
412553102250701	NPGC02	17N 44W20BDDC1	06-23-93	1225	16	.06
412553102250701	NPGC02	17N 44W20BDDC1	08-17-93	1500	21	--
412553102250701	NPGC02	17N 44W20BDDC1	10-05-93	1545	18	--
412553102250701	NPGC02	17N 44W20BDDC1	11-30-93	1305	18	--
412553102250701	NPGC02	17N 44W20BDDC1	05-04-94	1245	19	--
412553102250701	NPGC02	17N 44W20BDDC1	08-02-94	1145	23	.09
412553102250701	NPGC02	17N 44W20BDDC1	09-01-94	1610	18	--
412500102240301	NPGC03	17N 44W28CBAA1	05-11-93	0805	6.6	.12
412500102240301	NPGC03	17N 44W28CBAA1	06-23-93	1140	6.8	.06
412500102240301	NPGC03	17N 44W28CBAA1	08-17-93	1425	8.0	--
412500102240301	NPGC03	17N 44W28CBAA1	10-05-93	1510	5.3	--
412500102240301	NPGC03	17N 44W28CBAA1	11-30-93	1415	7.5	--
412500102240301	NPGC03	17N 44W28CBAA1	05-04-94	1415	7.5	--
412500102240301	NPGC03	17N 44W28CBAA1	08-02-94	1035	34	.21
412500102240301	NPGC03	17N 44W28CBAA1	09-01-94	1505	24	--
412435102223301	NPGC04D	17N 44W27DCCC1	05-10-93	1925	16	.06
412435102223301	NPGC04D	17N 44W27DCCC1	06-23-93	0900	17	.09
412435102223301	NPGC04D	17N 44W27DCCC1	08-17-93	1335	18	--
412435102223301	NPGC04D	17N 44W27DCCC1	10-05-93	1435	18	--
412435102223301	NPGC04D	17N 44W27DCCC1	12-01-93	0827	20	--
412435102223301	NPGC04D	17N 44W27DCCC1	02-02-94	1110	19	--
412435102223301	NPGC04D	17N 44W27DCCC1	05-04-94	0920	18	--
412435102223301	NPGC04D	17N 44W27DCCC1	08-02-94	0945	20	.09
412435102223301	NPGC04D	17N 44W27DCCC1	09-01-94	1410	21	--
412435102223302	NPGC04S	17N 44W27DCCC2	05-10-93	1940	12	.12
412435102223302	NPGC04S	17N 44W27DCCC2	06-23-93	0920	13	.06

Table 11. Results of ground-water quality analyses for nutrients, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Nitrate plus nitrite	Phosphorus as PO_4
412435102223302	NPGC04S	17N 44W27DCCC2	08-17-93	1350	14	--
412435102223302	NPGC04S	17N 44W27DCCC2	10-05-93	1450	14	--
412435102223302	NPGC04S	17N 44W27DCCC2	12-01-93	0844	14	--
412435102223302	NPGC04S	17N 44W27DCCC2	02-02-94	1130	15	--
412435102223302	NPGC04S	17N 44W27DCCC2	05-04-94	0940	18	--
412435102223302	NPGC04S	17N 44W27DCCC2	08-02-94	1000	18	0.09
412435102223302	NPGC04S	17N 44W27DCCC2	09-01-94	1425	18	--
412605102211001	LCGC05	17N 44W23ACAA1	05-10-93	1710	5.1	.09
412605102211001	LCGC05	17N 44W23ACAA1	06-22-93	1555	6.5	.06
412605102211001	LCGC05	17N 44W23ACAA1	08-17-93	1050	5.1	--
412605102211001	LCGC05	17N 44W23ACAA1	10-05-93	1245	11	--
412605102211001	LCGC05	17N 44W23ACAA1	11-30-93	1135	9.8	--
412605102211001	LCGC05	17N 44W23ACAA1	02-01-94	1240	8.1	--
412605102211001	LCGC05	17N 44W23ACAA1	05-03-94	1355	5.3	--
412605102211001	LCGC05	17N 44W23ACAA1	08-02-94	0735	2.4	.09
412605102211001	LCGC05	17N 44W23ACAA1	09-01-94	1145	2.1	--
412526102212301	LCGC06	17N 44W26ABBB1	05-10-93	1750	1.6	.09
412526102212301	LCGC06	17N 44W26ABBB1	06-23-93	1035	1.7	.12
412526102212301	LCGC06	17N 44W26ABBB1	08-17-93	1130	1.6	--
412526102212301	LCGC06	17N 44W26ABBB1	10-05-93	1320	2.3	--
412526102212301	LCGC06	17N 44W26ABBB1	11-30-93	1225	1.7	--
412526102212301	LCGC06	17N 44W26ABBB1	02-02-94	1305	1.8	--
412526102212301	LCGC06	17N 44W26ABBB1	05-03-94	1500	1.5	--
412526102212301	LCGC06	17N 44W26ABBB1	08-02-94	0820	1.8	.09
412526102212301	LCGC06	17N 44W26ABBB1	09-01-94	1235	1.8	--
412434102214201	NPGC07D	17N 44W35BBAA1	05-10-93	1840	2.8	.06
412434102214201	NPGC07D	17N 44W35BBAA1	06-23-93	0755	2.9	.06
412434102214201	NPGC07D	17N 44W35BBAA1	08-17-93	1245	2.8	--
412434102214201	NPGC07D	17N 44W35BBAA1	10-05-93	1400	2.8	--
412434102214201	NPGC07D	17N 44W35BBAA1	12-01-93	0735	3.0	--
412434102214201	NPGC07D	17N 44W35BBAA1	02-02-94	1025	2.9	--
412434102214201	NPGC07D	17N 44W35BBAA1	05-03-94	1550	2.7	--
412434102214201	NPGC07D	17N 44W35BBAA1	08-02-94	0900	3.4	.09
412434102214201	NPGC07D	17N 44W35BBAA1	09-01-94	1315	3.5	--
412434102214202	NPGC07S	17N 44W35BBAA2	05-10-93	1850	5.6	.09
412434102214202	NPGC07S	17N 44W35BBAA2	06-23-93	0820	5.8	.09
412434102214202	NPGC07S	17N 44W35BBAA2	08-17-93	1305	4.6	--
412434102214202	NPGC07S	17N 44W35BBAA2	10-05-93	1415	4.8	--

Table 11. Results of ground-water quality analyses for nutrients, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Nitrate plus nitrite	Phosphorus as PO_4
412434102214202	NPGC07S	17N 44W35BBAA2	12-01-93	0755	5.5	--
412434102214202	NPGC07S	17N 44W35BBAA2	02-02-94	1040	5.9	--
412434102214202	NPGC07S	17N 44W35BBAA2	05-03-94	1615	5.5	--
412434102214202	NPGC07S	17N 44W35BBAA2	08-02-94	0915	7.8	0.09
412434102214202	NPGC07S	17N 44W35BBAA2	09-01-94	1335	7.7	--
412424102201801	NPGC08	17N 44W36BADD1	05-10-93	1610	2.0	.09
412424102201801	NPGC08	17N 44W36BADD1	06-22-93	1640	2.5	.12
412424102201801	NPGC08	17N 44W36BADD1	08-17-93	1205	3.4	--
412424102201801	NPGC08	17N 44W36BADD1	10-05-93	1215	2.2	--
412424102201801	NPGC08	17N 44W36BADD1	11-30-93	0925	2.5	--
412424102201801	NPGC08	17N 44W36BADD1	02-01-94	1020	2.1	--
412424102201801	NPGC08	17N 44W36BADD1	05-03-94	1040	2.0	--
412424102201801	NPGC08	17N 44W36BADD1	08-01-94	1615	2.7	.15
412424102201801	NPGC08	17N 44W36BADD1	09-01-94	1055	2.8	--
412416102182301	NPGC09D	17N 43W31BDAD1	05-10-93	1510	2.9	.09
412416102182301	NPGC09D	17N 43W31BDAD1	06-22-93	1330	3.4	.09
412416102182301	NPGC09D	17N 43W31BDAD1	08-17-93	0955	2.5	--
412416102182301	NPGC09D	17N 43W31BDAD1	10-05-93	1125	5.3	--
412416102182301	NPGC09D	17N 43W31BDAD1	02-01-94	1140	2.5	--
412416102182301	NPGC09D	17N 43W31BDAD1	05-03-94	1130	2.2	--
412416102182301	NPGC09D	17N 43W31BDAD1	08-01-94	1515	3.2	.06
412416102182301	NPGC09D	17N 43W31BDAD1	09-01-94	1000	2.8	--
412416102182302	NPGC09S	17N 43W31BDAD2	05-10-93	1525	2.3	.09
412416102182302	NPGC09S	17N 43W31BDAD2	06-22-93	1405	2.8	.09
412416102182302	NPGC09S	17N 43W31BDAD2	08-17-93	1015	3.0	--
412416102182302	NPGC09S	17N 43W31BDAD2	10-05-93	1140	3.0	--
412416102182302	NPGC09S	17N 43W31BDAD2	11-30-93	1040	2.4	--
412416102182302	NPGC09S	17N 43W31BDAD2	02-01-94	1155	2.4	--
412416102182302	NPGC09S	17N 43W31BDAD2	05-03-94	1200	2.1	--
412416102182302	NPGC09S	17N 43W31BDAD2	08-01-94	1540	2.8	.09
412416102182302	NPGC09S	17N 43W31BDAD2	09-01-94	1015	3.1	--
412345102182301	NPGC10	17N 43W32CCCA1	05-10-93	1420	29	.37
412345102182301	NPGC10	17N 43W32CCCA1	06-22-93	1100	29	.31
412345102182301	NPGC10	17N 43W32CCCA1	08-17-93	0915	27	--
412345102182301	NPGC10	17N 43W32CCCA1	10-05-93	1045	26	--
412345102182301	NPGC10	17N 43W32CCCA1	11-30-93	1505	28	--
412345102182301	NPGC10	17N 43W32CCCA1	02-01-94	0940	30	--
412345102182301	NPGC10	17N 43W32CCCA1	05-03-94	0940	--	--

Table 11. Results of ground-water quality analyses for nutrients, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Nitrate plus nitrite	Phosphorus as PO_4
412345102182301	NPGC10	17N 43W32CCCA1	08-01-94	1425	31	0.21
412345102182301	NPGC10	17N 43W32CCCA1	09-01-94	0910	31	--
412137102130101	NPGC11	16N 43W14ACCB1	05-10-93	1225	7.6	.15
412137102130101	NPGC11	16N 43W14ACCB1	06-22-93	0920	8.5	.15
412137102130101	NPGC11	16N 43W14ACCB1	08-17-93	0820	9.2	--
412137102130101	NPGC11	16N 43W14ACCB1	10-05-93	0955	8.6	--
412137102130101	NPGC11	16N 43W14ACCB1	11-30-93	0750	8.9	--
412137102130101	NPGC11	16N 43W14ACCB1	02-01-94	0855	8.8	--
412137102130101	NPGC11	16N 43W14ACCB1	05-03-94	0830	8.2	--
412137102130101	NPGC11	16N 43W14ACCB1	08-01-94	1320	9.2	.09
412137102130101	NPGC11	16N 43W14ACCB1	09-01-94	0830	8.9	--
412500102241801	OSHML1-1	17N 44W29DAAA1	04-21-93	1400	1.6	.21
412500102241801	OSHML1-1	17N 44W29DAAA1	06-24-93	1125	1.8	.28
412500102241801	OSHML1-1	17N 44W29DAAA1	08-18-93	0810	2.8	--
412500102241801	OSHML1-1	17N 44W29DAAA1	10-06-93	0840	1.9	--
412500102241801	OSHML1-1	17N 44W29DAAA1	11-29-93	1435	1.7	--
412500102241801	OSHML1-1	17N 44W29DAAA1	02-01-94	1050	2.0	--
412500102241801	OSHML1-1	17N 44W29DAAA1	05-02-94	1050	1.9	--
412500102241801	OSHML1-1	17N 44W29DAAA1	08-02-94	1111	2.4	.31
412500102241801	OSHML1-1	17N 44W29DAAA1	09-01-94	1550	2.1	--
412500102241802	OSHML1-2	17N 44W29DAAA2	04-21-93	1400	2.2	.15
412500102241802	OSHML1-2	17N 44W29DAAA2	06-24-93	1120	2.5	.09
412500102241802	OSHML1-2	17N 44W29DAAA2	02-01-94	1045	2.7	--
412500102241802	OSHML1-2	17N 44W29DAAA2	08-02-94	1113	2.8	.15
412500102241803	OSHML1-3	17N 44W29DAAA3	04-21-93	1400	2.6	.12
412500102241803	OSHML1-3	17N 44W29DAAA3	06-24-93	1115	2.5	.15
412500102241803	OSHML1-3	17N 44W29DAAA3	02-01-94	1040	2.8	--
412500102241803	OSHML1-3	17N 44W29DAAA3	08-02-94	1109	2.6	.12
412500102241804	OSHML1-4	17N 44W29DAAA4	04-21-93	1400	2.7	.12
412500102241804	OSHML1-4	17N 44W29DAAA4	06-24-93	1110	2.5	.09
412500102241804	OSHML1-4	17N 44W29DAAA4	02-01-94	1035	2.7	--
412500102241804	OSHML1-4	17N 44W29DAAA4	08-02-94	1108	2.8	.12
412500102241805	OSHML1-5	17N 44W29DAAA5	04-21-93	1400	3.2	.09
412500102241805	OSHML1-5	17N 44W29DAAA5	06-24-93	1105	2.8	.12
412500102241805	OSHML1-5	17N 44W29DAAA5	08-18-93	0810	1.9	--
412500102241805	OSHML1-5	17N 44W29DAAA5	10-06-93	0835	3.1	--
412500102241805	OSHML1-5	17N 44W29DAAA5	11-29-93	1425	2.9	--
412500102241805	OSHML1-5	17N 44W29DAAA5	02-01-94	1030	3.3	--

Table 11. Results of ground-water quality analyses for nutrients, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Nitrate plus nitrite	Phosphorus as PO_4
412500102241805	OSHML1-5	17N 44W29DAAA5	05-02-94	1045	2.1	--
412500102241805	OSHML1-5	17N 44W29DAAA5	08-02-94	1107	3.4	0.09
412500102241805	OSHML1-5	17N 44W29DAAA5	09-01-94	1535	3.2	--
412500102241806	OSHML1-6	17N 44W29DAAA6	04-21-93	1400	2.9	.09
412500102241806	OSHML1-6	17N 44W29DAAA6	06-24-93	1100	3.4	.09
412500102241806	OSHML1-6	17N 44W29DAAA6	02-01-94	1025	3.2	--
412500102241806	OSHML1-6	17N 44W29DAAA6	08-02-94	1106	3.4	.09
412500102241807	OSHML1-7	17N 44W29DAAA7	04-21-93	1400	2.9	.09
412500102241807	OSHML1-7	17N 44W29DAAA7	06-24-93	1055	3.0	.09
412500102241807	OSHML1-7	17N 44W29DAAA7	02-01-94	1020	2.6	--
412500102241807	OSHML1-7	17N 44W29DAAA7	08-02-94	1104	3.1	.09
412500102241808	OSHML1-8	17N 44W29DAAA8	04-21-93	1400	2.9	.09
412500102241808	OSHML1-8	17N 44W29DAAA8	06-24-93	1050	3.1	.09
412500102241808	OSHML1-8	17N 44W29DAAA8	08-18-93	0800	3.2	--
412500102241808	OSHML1-8	17N 44W29DAAA8	10-06-93	0830	2.6	--
412500102241808	OSHML1-8	17N 44W29DAAA8	11-29-93	1405	3.0	--
412500102241808	OSHML1-8	17N 44W29DAAA8	02-01-94	1015	2.7	--
412500102241808	OSHML1-8	17N 44W29DAAA8	05-02-94	1040	2.7	--
412500102241808	OSHML1-8	17N 44W29DAAA8	08-02-94	1102	2.9	.09
412500102241808	OSHML1-8	17N 44W29DAAA8	09-01-94	1530	2.4	--
412526102252701	OSHML2-1	17N 44W19DDDD1	04-21-93	0800	27	.15
412526102252701	OSHML2-1	17N 44W19DDDD1	06-24-93	1025	32	.15
412526102252701	OSHML2-1	17N 44W19DDDD1	08-18-93	0845	16	--
412526102252701	OSHML2-1	17N 44W19DDDD1	10-06-93	0945	32	--
412526102252701	OSHML2-1	17N 44W19DDDD1	11-29-93	1525	29	--
412526102252701	OSHML2-1	17N 44W19DDDD1	02-01-94	1000	35	--
412526102252701	OSHML2-1	17N 44W19DDDD1	05-02-94	1030	31	--
412526102252701	OSHML2-1	17N 44W19DDDD1	08-02-94	1228	30	.15
412526102252701	OSHML2-1	17N 44W19DDDD1	09-01-94	1645	29	--
412526102252702	OSHML2-2	17N 44W19DDDD2	04-21-93	0800	37	.12
412526102252702	OSHML2-2	17N 44W19DDDD2	06-24-93	1020	29	.15
412526102252702	OSHML2-2	17N 44W19DDDD2	02-01-94	0955	35	--
412526102252702	OSHML2-2	17N 44W19DDDD2	08-02-94	1227	30	.15
412526102252703	OSHML2-3	17N 44W19DDDD3	04-21-93	0800	30	.21
412526102252703	OSHML2-3	17N 44W19DDDD3	06-24-93	1015	37	.18
412526102252703	OSHML2-3	17N 44W19DDDD3	02-01-94	0950	31	--
412526102252703	OSHML2-3	17N 44W19DDDD3	08-02-94	1225	28	.21
412526102252704	OSHML2-4	17N 44W19DDDD4	04-21-93	0800	33	.21

Table 11. Results of ground-water quality analyses for nutrients, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Nitrate plus nitrite	Phosphorus as PO_4
412526102252704	OSHML2-4	17N 44W19DDDD4	06-24-93	1010	33	0.18
412526102252704	OSHML2-4	17N 44W19DDDD4	02-01-94	0945	26	--
412526102252704	OSHML2-4	17N 44W19DDDD4	08-02-94	1223	27	.21
412526102252705	OSHML2-5	17N 44W19DDDD5	04-21-93	0800	31	.21
412526102252705	OSHML2-5	17N 44W19DDDD5	06-24-93	1005	36	.18
412526102252705	OSHML2-5	17N 44W19DDDD5	08-18-93	0840	30	--
412526102252705	OSHML2-5	17N 44W19DDDD5	10-06-93	0935	28	--
412526102252705	OSHML2-5	17N 44W19DDDD5	11-29-93	1515	26	--
412526102252705	OSHML2-5	17N 44W19DDDD5	02-01-94	0940	23	--
412526102252705	OSHML2-5	17N 44W19DDDD5	05-02-94	1000	23	--
412526102252705	OSHML2-5	17N 44W19DDDD5	08-02-94	1221	22	.21
412526102252705	OSHML2-5	17N 44W19DDDD5	09-01-94	1635	24	--
412526102252706	OSHML2-6	17N 44W19DDDD6	04-21-93	0800	22	.21
412526102252706	OSHML2-6	17N 44W19DDDD6	06-24-93	1000	20	.25
412526102252706	OSHML2-6	17N 44W19DDDD6	02-01-94	0935	20	--
412526102252706	OSHML2-6	17N 44W19DDDD6	08-02-94	1219	18	.18
412526102252707	OSHML2-7	17N 44W19DDDD7	04-21-93	0800	22	.15
412526102252707	OSHML2-7	17N 44W19DDDD7	06-24-93	0955	22	.12
412526102252707	OSHML2-7	17N 44W19DDDD7	02-01-94	0930	17	--
412526102252707	OSHML2-7	17N 44W19DDDD7	08-02-94	1217	18	.18
412526102252708	OSHML2-8	17N 44W19DDDD8	04-21-93	0800	16	.09
412526102252708	OSHML2-8	17N 44W19DDDD8	06-24-93	0950	16	.06
412526102252708	OSHML2-8	17N 44W19DDDD8	08-18-93	0840	16	--
412526102252708	OSHML2-8	17N 44W19DDDD8	10-06-93	0930	16	--
412526102252708	OSHML2-8	17N 44W19DDDD8	11-29-93	1505	17	--
412526102252708	OSHML2-8	17N 44W19DDDD8	02-01-94	0925	16	--
412526102252708	OSHML2-8	17N 44W19DDDD8	05-02-94	0955	15	--
412526102252708	OSHML2-8	17N 44W19DDDD8	08-02-94	1215	13	.09
412526102252708	OSHML2-8	17N 44W19DDDD8	09-01-94	1625	14	--
412549102255401	OSHML3-1	17N 44W19DBBA1	06-24-93	0915	43	.18
412549102255401	OSHML3-1	17N 44W19DBBA1	08-18-93	0910	41	--
412549102255401	OSHML3-1	17N 44W19DBBA1	10-06-93	1020	50	--
412549102255401	OSHML3-1	17N 44W19DBBA1	11-29-93	1600	52	--
412549102255401	OSHML3-1	17N 44W19DBBA1	02-01-94	0910	50	--
412549102255401	OSHML3-1	17N 44W19DBBA1	05-02-94	0935	51	--
412549102255401	OSHML3-1	17N 44W19DBBA1	08-02-94	1302	45	.21
412549102255402	OSHML3-2	17N 44W19DBBA2	04-21-93	1000	41	.15
412549102255402	OSHML3-2	17N 44W19DBBA2	06-24-93	0905	50	.12

Table 11. Results of ground-water quality analyses for nutrients, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Nitrate plus nitrite	Phosphorus as PO_4
412549102255402	OSHML3-2	17N 44W19DBBA2	02-01-94	0905	51	--
412549102255402	OSHML3-2	17N 44W19DBBA2	08-02-94	1304	50	0.15
412549102255402	OSHML3-2	17N 44W19DBBA2	09-01-94	1715	51	--
412549102255403	OSHML3-3	17N 44W19DBBA3	04-21-93	1000	44	.15
412549102255403	OSHML3-3	17N 44W19DBBA3	06-24-93	0900	46	.12
412549102255403	OSHML3-3	17N 44W19DBBA3	02-01-94	0900	53	--
412549102255403	OSHML3-3	17N 44W19DBBA3	08-02-94	1300	54	.15
412549102255404	OSHML3-4	17N 44W19DBBA4	04-21-93	1000	38	.12
412549102255404	OSHML3-4	17N 44W19DBBA4	06-24-93	0855	40	.09
412549102255404	OSHML3-4	17N 44W19DBBA4	02-01-94	0855	50	--
412549102255404	OSHML3-4	17N 44W19DBBA4	08-02-94	1258	52	.12
412549102255405	OSHML3-5	17N 44W19DBBA5	04-21-93	1000	37	.12
412549102255405	OSHML3-5	17N 44W19DBBA5	06-24-93	0845	35	.09
412549102255405	OSHML3-5	17N 44W19DBBA5	08-18-93	0905	43	--
412549102255405	OSHML3-5	17N 44W19DBBA5	10-06-93	1015	40	--
412549102255405	OSHML3-5	17N 44W19DBBA5	11-29-93	1555	43	--
412549102255405	OSHML3-5	17N 44W19DBBA5	02-01-94	0850	45	--
412549102255405	OSHML3-5	17N 44W19DBBA5	05-02-94	0930	30	--
412549102255405	OSHML3-5	17N 44W19DBBA5	08-02-94	1256	55	.12
412549102255405	OSHML3-5	17N 44W19DBBA5	09-01-94	1705	56	--
412549102255406	OSHML3-6	17N 44W19DBBA6	04-21-93	1000	26	.09
412549102255406	OSHML3-6	17N 44W19DBBA6	06-24-93	0840	22	.06
412549102255406	OSHML3-6	17N 44W19DBBA6	02-01-94	0845	23	--
412549102255406	OSHML3-6	17N 44W19DBBA6	08-02-94	1254	31	.09
412549102255407	OSHML3-7	17N 44W19DBBA7	04-21-93	1000	31	.09
412549102255407	OSHML3-7	17N 44W19DBBA7	06-24-93	0835	25	.06
412549102255407	OSHML3-7	17N 44W19DBBA7	02-01-94	0840	29	--
412549102255407	OSHML3-7	17N 44W19DBBA7	08-02-94	1252	26	.09
412549102255408	OSHML3-8	17N 44W19DBBA8	04-21-93	1000	26	.06
412549102255408	OSHML3-8	17N 44W19DBBA8	06-24-93	0830	22	.03
412549102255408	OSHML3-8	17N 44W19DBBA8	08-18-93	0905	24	--
412549102255408	OSHML3-8	17N 44W19DBBA8	10-06-93	1005	29	--
412549102255408	OSHML3-8	17N 44W19DBBA8	11-29-93	1545	26	--
412549102255408	OSHML3-8	17N 44W19DBBA8	02-01-94	0835	23	--
412549102255408	OSHML3-8	17N 44W19DBBA8	05-02-94	0925	18	--
412549102255408	OSHML3-8	17N 44W19DBBA8	08-02-94	1250	41	.06
412549102255408	OSHML3-8	17N 44W19DBBA8	09-01-94	1655	47	--

Table 12. Results of ground-water quality analyses for triazine and acetamide herbicides, Garden County, western Nebraska, 1993-94

[All values are in micrograms per liter; USGS, U.S. Geological Survey; <, less than indicated reporting limit; table only shows immunoassay samples varified by gas chromatography/mass spectrometry analysis at the U.S. Geological Survey National Water Quality Laboratory—14 of the 17 samples collected in 1993 are shown]

USGS site identification	Field identification	Well location	Date	Time	Ametryn	Alachlor	Atrazine	Cyanazine	Deethylatrazine	Deisopropylatrazine	Metolachlor	Prometon	Prometryn	Propazine
412648102274001	NPGC01	17N 45W13BCCD1	06-23-93	1305	<0.05	<0.05	<0.05	<0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
412648102274001	NPGC01	17N 45W13BCCD1	08-02-94	1400	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412553102250701	NPGC02	17N 44W20BDDC1	06-23-93	1225	<.05	<.05	1.2	<.2	1.1	<.05	<.05	<.05	<.05	<.05
412553102250701	NPGC02	17N 44W20BDDC1	08-02-94	1145	<.05	<.05	.29	<.2	.71	<.05	<.05	<.05	<.05	<.05
412500102240301	NPGC03	17N 44W28CBAA1	06-23-93	1140	<.05	<.05	<.05	<.2	.1	<.05	<.05	<.05	<.05	<.05
412500102240301	NPGC03	17N 44W28CBAA1	08-02-94	1035	<.05	<.05	1.3	<.2	1.5	<.05	<.05	<.05	<.05	<.05
412435102223301	NPGC04D	17N 44W27DCCC1	06-23-93	0900	<.05	<.05	<.05	<.2	.08	<.05	<.05	<.05	<.05	<.05
412435102223301	NPGC04D	17N 44W27DCCC1	08-02-94	0945	.05	<.05	<.05	<.2	.11	<.05	<.05	<.05	<.05	<.05
412435102223302	NPGC04S	17N 44W27DCCC2	06-23-93	0920	<.05	<.05	<.05	<.2	.07	<.05	<.05	<.05	<.05	<.05
412435102223302	NPGC04S	17N 44W27DCCC2	08-02-94	1000	<.05	<.05	<.05	<.2	.07	<.05	<.05	<.05	<.05	<.05
412605102211001	LCGC05	17N 44W23ACAA1	06-22-93	1555	<.05	<.05	.1	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412605102211001	LCGC05	17N 44W23ACAA1	08-02-94	0735	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412526102212301	LCGC06	17N 44W26ABBB1	08-02-94	0820	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412434102214201	NPGC07D	17N 44W35BBAA1	06-23-93	0755	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412434102214201	NPGC07D	17N 44W35BBAA1	08-02-94	0900	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412434102214202	NPGC07S	17N 44W35BBAA2	08-02-94	0915	<.05	<.05	<.05	<.2	.06	<.05	<.05	<.05	<.05	<.05
412424102201801	NPGC08	17N 44W36BADD1	06-22-93	1640	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412424102201801	NPGC08	17N 44W36BADD1	08-01-94	1615	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412416102182301	NPGC09D	17N 43W31BDAD1	06-22-93	1330	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412416102182301	NPGC09D	17N 43W31BDAD1	08-01-94	1515	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412416102182302	NPGC09S	17N 43W31BDAD2	06-22-93	1405	<.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412416102182302	NPGC09S	17N 43W31BDAD2	08-01-94	1540	.05	<.05	<.05	<.2	<.05	<.05	<.05	<.05	<.05	<.05
412345102182301	NPGC10	17N 43W32CCCA1	08-01-94	1425	<0.05	<0.05	0.09	<0.2	0.74	<0.05	<0.05	<0.05	<0.05	<0.05
412137102130101	NPGC11	16N 43W14ACCB1	06-22-93	0920	<.05	<.05	.05	<.2	.15	<.05	<.05	<.05	<.05	<.05

Table 12. Results of ground-water quality analyses for triazine and acetamide herbicides, Garden County, western Nebraska, 1993-94--Continued

USGS site identification	Field identification	Well location	Date	Time	Ametryn	Alachlor	Atrazine	Cyanazine	Deethylatrazine	Deisopropylatrazine	Metolachlor	Prometon	Prometryn	Propazine
412137102130101	NPGC11	16N 43W14ACCB1	08-01-94	1320	<.05	<.05	<.05	<.2	.11	<.05	<.05	<.05	<.05	<.05
412500102241802	OSHML1-2	17N 44W29DAAA2	06-24-93	1120	<.05	<.05	<.05	<.2	.08	<.05	<.05	<.05	<.05	<.05
412500102241802	OSHML1-2	17N 44W29DAAA2	08-02-94	1113	<.05	<.05	<.05	<.2	.05	<.05	<.05	<.05	<.05	<.05
412526102252702	OSHML2-2	17N 44W19DDDD2	06-24-93	1020	<.05	<.05	2.9	<.2	1.3	.11	<.05	<.05	<.05	<.05
412526102252702	OSHML2-2	17N 44W19DDDD2	08-02-94	1227	<.05	<.05	2.6	<.2	3.0	.06	<.05	<.05	<.05	<.05
412549102255402	OSHML3-2	17N 44W19DBBA2	06-24-93	0905	<.05	<.05	.45	<.2	1.9	.06	<.05	<.05	<.05	<.05
412549102255402	OSHML3-2	17N 44W19DBBA2	08-02-94	1304	<.05	<.05	.48	<.2	1.9	<.05	<.05	<.05	<.05	<.05

Table 13. Lithologic log for monitor well NPGC01

Depth (feet)	Lithology
0-5	sand, fine to medium, mostly quartz
5-10	sand, fine to medium, some coarse, poorly sorted, very well rounded
10-15	sand, medium to coarse, mostly quartz, rounded to subrounded grains
15-23	sand, coarse to very coarse, subangular grains, 70 percent quartz
23-27	sand, fine to very coarse, some clay, slight fine gravel
27-30	sand, very coarse, 85 percent quartz, rounded grains, some clay
30-35	gravel, fine gravel to very coarse sand and gravel, 85 percent quartz, subangular
35-36	clay lenses
36-38	gravel, fine gravel to very coarse sand and gravel, 85 percent quartz
38	Brule Formation

Table 14. Lithologic log for monitor well NPGC02

Depth (feet)	Lithology
0-5	sand, very fine to fine, well sorted
5-8	sand, very fine to fine, some medium sand, slight clay amount
8-10	clay
10-15	sand, medium to coarse, some clay
15-25	sand, coarse to very coarse, well sorted, rounded grains, 90 percent quartz
25-30	same as above—some very coarse gravel, limonite grains
30-35	same as above—more very coarse gravel
35-40	sand, coarse to very coarse, bottom—20 percent feldspar - 80 percent quartz, very coarse sand to coarse sand and gravel, some pebbles
40-45	sand, medium with some fine, 90 percent quartz, well sorted, rounded grains, 80 percent medium sand
45-50	gravel, medium to coarse sand, 60 percent quartz, feldspar, well sorted
50-55	sand, very coarse, well sorted, 70 percent quartz, 30 percent feldspar
55-65	sand and gravel, coarse sand to fine gravel, some coarse gravel, subangular to subrounded grains
65-70	sand, very coarse and fine gravel, well sorted, 60 percent quartz, 35 percent feldspar
70-75	sand, coarse, very well sorted, some very coarse sand
75-80	same as above—some Brule Formation pebbles, more very coarse sand
80-90	sand, medium to coarse, very well sorted, 90 percent quartz, subrounded grains
90-95	same as above—some fine sand
95-100	sand, fine to medium, very well sorted, 85 percent quartz, 10 percent feldspar, 5 percent amphibole
100-105	sand, coarse to very coarse, well sorted, subrounded grains
105-110	sand, coarse to very coarse, with Brule Formation clasts
110-115	sand, medium to coarse
115-120	same as above—more very coarse sand, moderate sorting and Brule Formation clasts, very coarse sand near bottom
120-125	sand, medium to coarse, well sorted
125-130	same as above—some fine sand
130-135	sand, coarse to very coarse, well sorted, 85 percent quartz, subangular grains
135-145	same as above—more Brule Formation clasts
145-150	same as above—fine gravel to medium gravel, rounded to angular grains
150-155	gravel, coarse, 70 percent feldspar, Brule Formation clasts, subangular grains
155-160	same as above—some Brule Formation pebbles
160-165	very coarse sand to medium gravel, 75 percent feldspar, subangular grains
165-170	same as above—more coarse gravel
170-175	very coarse gravel to fine cobbles, subrounded grains, 60 percent quartz
175-180	same as above—Brule Formation at bottom

Table 15. Lithologic log for monitor well NPGC03

Depth (feet)	Lithology
0- 8	sand, very fine to fine, well sorted
8-10	gravel, medium, 65 percent feldspar, 20 percent mafic, 10 percent quartz, some coarse sand and very coarse sand, poorly sorted
10-20	sand, very coarse and fine gravel, mostly feldspar and mafic as above, intermixed, poorly sorted with small pebbles (feldspar and siltstone)
20-40	sand, fine to very coarse, 65 percent quartz, some fine gravel
40-45	gravel, fine to coarse with very coarse sand, poorly sorted, 60 percent feldspar, 30 percent quartz, small pebbles
45-55	same as above—with Brule Formation clasts
55-60	gravel, very coarse, siltstone clasts, 65 percent feldspar, 30 percent quartz,poorly sorted, rounded to subrounded
60-65	sand, medium to very coarse, some pebbles, moderate sorting
65-75	same as above—siltstone clasts
75-80	gravel, fine with coarse and very coarse sand, 70 percent quartz, moderately well sorted
80-85	sand, coarse to very coarse, coarse gravel at bottom, well sorted, rounded grains
85-90	gravel, very coarse to small pebbles, 60 percent feldspar, rounded grains
90-95	same as above—some coarse sand
95-100	same as above—more pebbles and siltstone
100-110	sand, very coarse to coarse gravel, some small pebbles, 60 percent quartz, moderate sorting, subrounded to rounded grains
110-120	same as above—Brule Formation clasts
120-125	gravel, medium to coarse with very coarse sand, rounded to angular grains, moderately well sorted
125-130	gravel, coarse to very coarse with small pebbles, rounded grains, moderately sorted
130-137	same as above—more very coarse sand, siltstone clasts
137-150	Brule Formation

Table 16. Lithologic log for monitor well NPGC04D

Depth (feet)	Lithology
0- 5	silty sand
5- 8	fine silty sand
8-9.5	clay, light brown
9.5-15	gravel and sand, medium sand to fine gravel, subrounded grains, some very coarse gravel
15-30	same as above—very coarse gravel, subangular grains
30-35	sand, coarse to very coarse, 60 percent quartz
35-40	sand, very coarse, 40 percent quartz, 50 percent feldspar, 10 percent mafic, some fine to medium gravel
40-45	sand, medium to very coarse with some coarse gravel and pebbles, well rounded sand, poorly sorted, subangular pebbles
45-48	same as above—clay clasts
48	Brule Formation

Table 17. Lithologic log for monitor well LCGC05

Depth (feet)	Lithology
0-11	sand, very fine, silty, dark
11-20	sand, medium to coarse, 10 percent very coarse, well sorted, obsidian clasts
20-25	sand, fine to medium, 80 percent quartz
25-30	same as above—some silt lenses
30-40	sand and gravel, coarse sand to medium gravel, moderately sorted
40-45	sand, fine to medium, 5 percent very coarse sand, some fine gravel
45-50	sand, fine to very coarse, 10 percent very coarse gravel, rounded
50-55	gravel, fine to medium with fine sand to very coarse sand, poorly sorted
55-60	sand, medium to coarse, angular, less than 5 percent pebbles
60-65	same as above—10 percent very coarse sand, rounded
65-70	gravel, fine with coarse and very coarse sand, 70 percent quartz
70-74	gravel, very coarse with small to medium pebbles and Brule Formation
74-80	Brule Formation

Table 18. Lithologic log for monitor well LCGC06

Depth (feet)	Lithology
0- 5	sand, very fine, silty
5-10	same as above—some fine sand, 10 percent
10-15	same as above—silty and clayey at about 15 feet, olive blue
15-20	sand, very fine, dark olive, medium to coarse sand at about 19 feet
20-25	sand, medium to coarse, well sorted
25-30	same as above—5 percent very coarse sand
30-33	same as above—10 percent very coarse sand, Brule Formation at about 33 feet
33-40	Brule Formation

Table 19. Lithologic log for monitor well NPGC07D

Depth (feet)	Lithology
0- 9	sand, very fine, silty, loamy, some clay
9-10	gravel, very coarse with very coarse sand
10-15	gravel, fine with clay
15-20	gravel, very coarse with very coarse sand, fine to very coarse gravel, poorly sorted, 60 percent feldspar, 30 percent mafic
20-25	gravel, fine with very coarse sand, some mafic, subangular, moderately sorted
25-45	same as above—some coarse gravel
45-48	sand and gravel, coarse sand to fine gravel, moderately sorted, rounded to subrounded grains
48-50	sand and gravel, very poorly sorted coarse sand to coarse gravel, Brule Formation clasts
50-55	Brule Formation

Table 20. Lithologic log for monitor well NPGC08

Depth (feet)	Lithology
0-15	sand, fine silty
15-20	gravel, medium to coarse, moderately sorted, some very coarse sand, some small pebbles (feldspar), 70 percent quartz
20-27	silt, light yellow brown
27-30	sand and gravel, coarse sand to coarse gravel, poorly sorted, coarse gravel—mafic
30-35	same as above—with small to medium pebbles, subangular
35-40	sand, coarse to very coarse, some gravel and small pebbles, 60 percent quartz, 30 percent feldspar
40-45	gravel, very coarse, 70 percent quartz, subrounded, some coarse sand and fine gravel
45-55	same as above—Brule Formation clasts and silt
55-60	same as above—some medium pebbles
60-70	sand, medium to very coarse with fine gravel and rounded small pebbles, moderately sorted
70-75	sand, medium to very coarse, well sorted, some small to medium pebbles
75-80	same as above—cemented light siltstone, some Brule Formation
80-85	sand, medium to coarse, 80-85 percent quartz, some cemented siltstone and very coarse sand and gravel, small pebbles, siltstone effervesces
85-86	same as above—more cemented siltstone
86-92	Brule Formation

Table 21. Lithologic log for monitor well NPGC09D

Depth (feet)	Lithology
0- 5	sand, very fine silty, dark brown, some clay
5-10	sand, very fine, firm, silty, less clay
10-15	sand, very fine, silty, darker brown, more clay
15-16	same as above—light brown silt
16-20	sand, very coarse, some very coarse gravel, subangular, moderately sorted, 20 percent mafic, 60 percent feldspar
20-25	sand, very coarse, some medium gravel and coarse sand, 50 percent feldspar
25-30	gravel, medium with some very coarse sand, 60 percent quartz, subangular, well sorted
30-35	gravel, very coarse to small pebbles, subangular, 20 percent mafic
35-40	sand, very coarse to very coarse gravel, small pebbles, rounded, poorly sorted
40-45	gravel, very coarse, 25 percent small pebbles, well sorted, subangular
45-50	sand, very coarse to very coarse gravel and small pebbles, rounded to subrounded, poorly sorted
50-55	gravel, fine to coarse, 60 percent feldspar, 25 percent mafic, rounded, clay stringers
55-60	same as above—more clay stringers and Brule Formation clasts, some small pebbles
60-75	gravel, fine to medium, well sorted, small pebbles, 70 percent feldspar
75-80	sand, very coarse to medium gravel, 50 percent quartz
80-95	sand, coarse to very coarse, well sorted, some very coarse gravel and small pebbles, less than 2 percent
95-100	sand, medium to coarse, 10 percent very coarse, some cemented, well sorted
100-105	same as above—some weathered Brule Formation and medium gravel
105-110	same as above—more gravel and Brule Formation, 50 percent gravel
110-115	sand, very coarse with fine to medium gravel, small pebbles
115-120	Brule Formation

Table 22. Lithologic log for monitor well NPGC10

Depth (feet)	Lithology
0- 5	sandy loam
5- 8	sand, fine
8-14	silt, sandy, some medium sand, less than 5 percent
14-15	very coarse sand and gravel, poorly sorted, some coarse sand, rounded to well rounded
15-20	same as above—moderately sorted, more coarse sand, 50 percent quartz, 30 percent feldspar
20-35	same as above—some clay stringers and small pebbles
35-40	sand, very coarse, well sorted, 50 percent quartz, subrounded
40-45	gravel, fine with very coarse sand, moderately sorted
45-50	same as above—more medium gravel
50-61	gravel, medium to coarse, small pebbles, 60 percent feldspar
61-65	Brule Formation

Table 23. Lithologic log for monitor well NPGC11

Depth (feet)	Lithology
0- 5	sand, very fine with some medium to coarse gravel
5-10	same as above—more clay
10-15	gravel and small to large pebbles, gravel, fine to medium, poorly sorted, subrounded
15-20	gravel, fine to very coarse with silt lenses, 65 percent feldspar, 15 percent mafic, 20 percent quartz
20-30	sand, fine to medium with fine gravel, less than 10 percent, well sorted, rounded, silt lenses
30-35	same as above—more fine to medium gravel
35-40	sand, fine to very coarse with medium gravel, rounded, approximately 40 percent small pebbles
40-50	same as above—some calcareous clasts, silt lenses, red-brown
50-55	gravel, coarse, some fine, small pebbles, angular, moderately well sorted, subrounded
55-60	same as above—more calcareous clasts
60-65	sand, fine to medium with some coarse sand
65-70	gravel, medium to coarse, well rounded and moderately sorted
70-75	same as above—with very coarse sand
75-80	coarse sand to very coarse gravel, poorly sorted, rounded to angular Brule Formation clasts
80-95	sand, coarse to very coarse with coarse gravel, some medium sand
95-100	same as above—small pebbles, angular, feldspar
100-105	sand, medium to coarse, 10 percent very coarse sand, small pebbles
105-110	gravel, medium to fine with some very coarse sand, well sorted
110-115	gravel, fine to medium with 30 percent very coarse sand
115-120	same as above —some very coarse gravel
120-125	same as above—more very coarse gravel, angular
125-130	gravel, very coarse, 40 percent very coarse sand and fine gravel, poorly sorted
130-145	same as above—Some Brule Formation clasts

☆ U.S. GOVERNMENT PRINTING OFFICE: 1998—673-083 / 20029 Region No. 8