Reconnaissance of Ground-Water Quality in the Papio-Missouri River Natural Resources District, Eastern Nebraska, July Through September 1992

By I.M. Verstraeten and M.J. Ellis

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

U.S. GEOLOGICAL SURVEY
GORDON P. EATON, Director

For additional information write to:

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

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
foot	0.3048	meter
gallon per minute	0.06308	liter per second
inch	25.4	millimeter
inch per hour	25.4	millimeter per hour
mile	1.609	kilometer
pound	453.6	gram
square mile	2.590	square kilometer
ton	0.9072	megagram

To be convert degree Fahrenheit (°F) to degree Celsius (°C) use the following equation:

$$°C = 5/9\ (°F - 32).$$

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.

Reconnaissance of Ground-Water Quality in the Papio-Missouri River Natural Resources District, Eastern Nebraska, July Through September 1992

By Ingrid M. Verstraeten *and* Michael J. Ellis

Abstract

A reconnaissance of ground-water quality was conducted in the Papio-Missouri River Natural Resources District of eastern Nebraska. Sixty-one irrigation, municipal, domestic, and industrial wells completed in the principal aquifers—the unconfined Elkhorn, Missouri, and Platte River Valley alluvial aquifers, the upland area alluvial aquifers, and the Dakota aquifer—were selected for water-quality sampling during July, August, and September 1992. Analyses of water samples from the wells included determination of dissolved nitrate as nitrogen and triazine and acetanilide herbicides. Water-quality analyses of a subset of 42 water samples included dissolved solids, major ions, metals, trace elements, and radionuclides.

Concentrations of dissolved nitrate as nitrogen in water samples from 2 of 13 wells completed in the upland area alluvial aquifers exceeded the U.S. Environmental Protection Agency Maximum Contaminant Level for drinking water of 10 milligrams per liter. Thirty-nine percent of the dissolved nitrate-as-nitrogen concentrations were less than the detection level of 0.05 milligram per liter. The largest median dissolved nitrate-as-nitrogen concentrations were in water from the upland area alluvial aquifers and the Dakota aquifer.

Water from all principal aquifers, except the Dakota aquifer, had detectable concentrations of herbicides. Herbicides detected included alachlor (1 detection), atrazine (13 detections), cyanazine (5 detections), deisopropylatrazine (6 detections), deethylatrazine (9 detections), metolachlor (6 detections), metribuzin (1 detection), prometon (6 detections), and simazine (2 detections). Herbicide concentrations did not exceed U.S. Environmental Protection Agency Maximum Contaminant Levels for drinking water. In areas where the hydraulic gradient favors loss of surface water to ground water, the detection of herbicides in water from wells along the banks of the Platte River indicates that the river could act as a line source of herbicides.

Water from the alluvial and bedrock aquifers generally was a calcium bicarbonate type and was hard. Two of nine water samples collected from the Dakota aquifer contained calcium sulfate type water. Results of analyses of 42 ground-water samples for major ions, metals, trace elements, and radionuclide constituents indicated that statistically at least one principal aquifer had significant differences in its water chemistry. In general, the water chemistry of the Dakota aquifer was similar to the water chemistry of the upland area alluvial aquifers in areas where there was a hydraulic connection. The water from the Dakota aquifer had large dissolved-solids, calcium, sulfate, chloride, iron, lithium, manganese, and strontium concentrations in areas where the aquifer is thought not to be in hydraulic connection with the Missouri River Valley and upland area alluvial aquifers.

Ground-water quality in the Papio-Missouri River Natural Resources District is generally suitable for most uses. However, the numerous occurrences of herbicides in water of the Elkhorn and Platte River Valley alluvial aquifers, especially near the Platte River, are of concern because U.S. Environmental Protection Agency Maximum Contaminant Levels could be exceeded. Concentrations in three of nine water samples collected from wells completed in the Dakota aquifer exceeded the U.S. Environmental Protection Agency Maximum Contaminant Levels or Secondary Maximum Contaminant Levels for gross alpha activity, radon-222 activity, dissolved solids, sulfate, or iron. Also of concern are the exceedances of the U.S Environmental Protection Agency proposed Maximum Contaminant Level for radon-222 activity.

INTRODUCTION

The State of Nebraska has been divided into 23 Natural Resources Districts (NRD's) to address the natural-resource issues of soil and water-resources management. As required by the 1984 Nebraska Ground Water Management and Protection Act (GWMPA), the Papio-Missouri River NRD submitted a ground-water management plan to the Nebraska Department of Environmental Quality in December 1989 (Papio-Missouri River Natural Resources District, 1989). Under 1991 Nebraska Law LB51, each NRD was required to amend the water-quality section of their ground-water management plan by July 1, 1993, to "...identify levels and sources of ground-water contamination and to recommend practices that would stabilize, reduce, or prevent to the extent possible additional spread and increases of ground-water contamination."

Information on quality of ground water in the Papio-Missouri River NRD was sparse and was limited to major-ion chemistry (U.S. Department of Energy, 1981; Engberg, 1984), dissolved nitrite-plus-nitrate-as-nitrogen data (Exner, 1980; Spalding, 1990), and agriculture-related chemicals and uranium data (Spalding, 1990). In 1991, the U.S. Geological Survey (USGS) entered into a cooperative agreement with the Papio-Missouri River NRD to conduct a ground-water-quality study for the purpose of developing detailed information on the water quality of the principal aquifers within the NRD.

Purpose and Scope

The purpose of this report is to describe the water quality of the principal aquifers in the study area (fig. 1). Wells representative of the geology and land use in the study area were selected for water-quality sampling. Constituent concentrations are compared with current (1993) U.S. Environmental Protection Agency (USEPA) drinking-water regulations. Variations in constituent concentration among aquifers are discussed. The report describes the spatial distributions of dissolved nitrite-plus-nitrate as nitrogen and triazine and other acetanilide herbicides and evaluates the effects of cropland application of nitrogen and herbicides on the ground-water quality within the study area. The report also summarizes the concentrations of dissolved major and trace constituents including radionuclide activity and concentration.

Acknowledgments

The authors gratefully thank well owners in the study area for granting permission to sample their wells and for their assistance in the field.

DESCRIPTION OF STUDY AREA

Location and Landforms

The Papio-Missouri River NRD encompasses about 979 square miles in the eastern part of Burt and Thurston Counties, southeastern part of Dodge County, and all of Dakota, Douglas, Sarpy, and Washington Counties in eastern Nebraska (fig. 1). Major cities in the study area are, in order of decreasing population, Omaha, Bellevue, Blair, South Sioux City, Dakota City, and Tekamah.

The study area is bounded on the east by the Missouri River and on the south and part of the west by the Platte River (fig. 1). The Elkhorn River is a major tributary of the Platte River, which in turn flows into the Missouri River south of Bellevue in southeastern Sarpy County. In addition, Papillion and Bell Creeks and many smaller streams drain the uplands.

The study area is part of the Dissected Till Plains Section of the Central Lowland physiographic

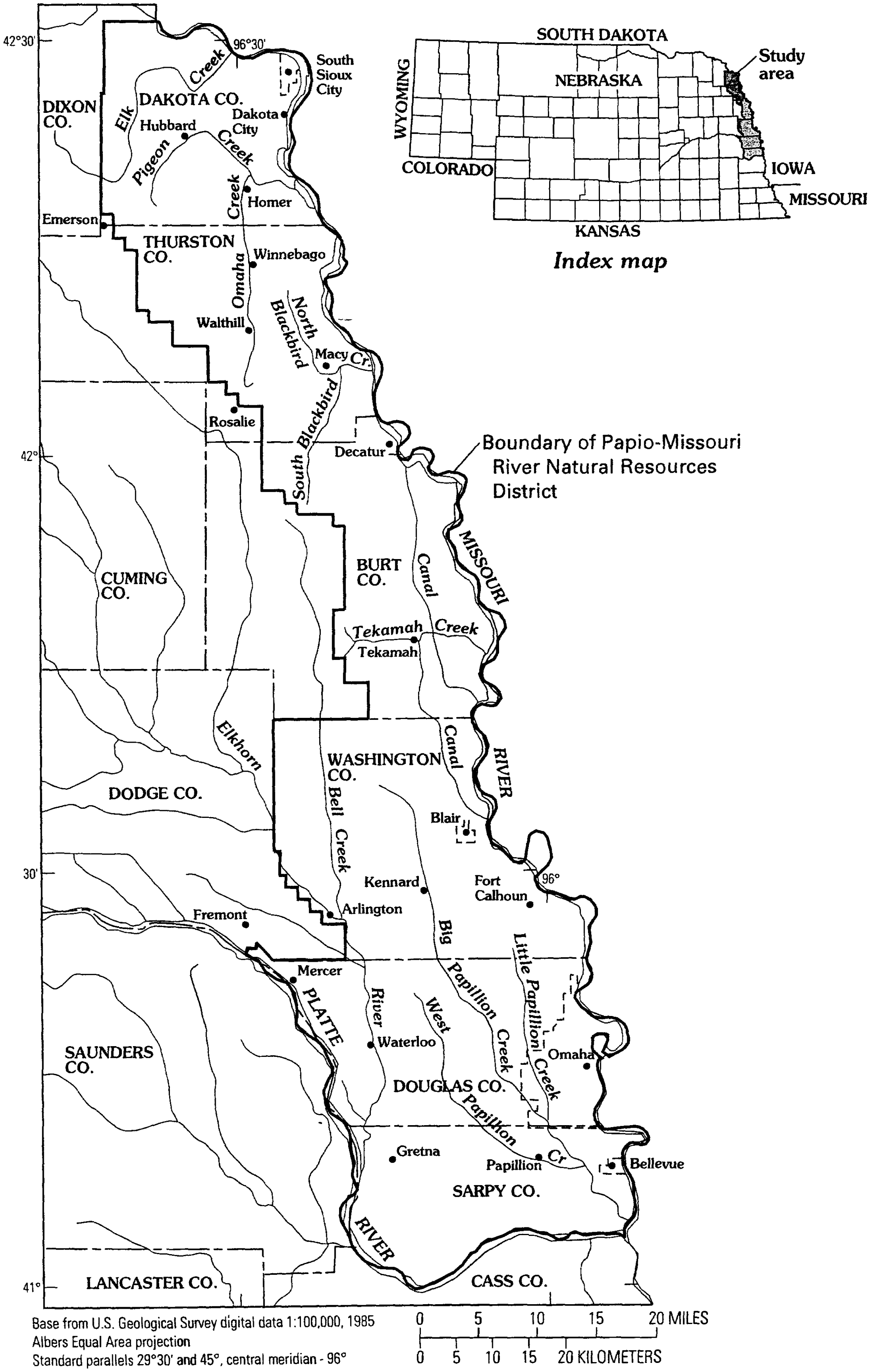


Figure 1. Location of the Papio-Missouri River Natural Resources District, eastern Nebraska.

province, which constitutes the central part of the loess-covered Central United States. The area is a glaciated region with submature to mature, dissected till plains and exposed pre-Illinoian glacial drift generally covered by loess (Fenneman, 1938; Fenneman and Johnson, 1946). The principal physiographic features include nearly flat valley lands along the major rivers separated by bluffs and escarpments with very steep and irregular slopes. On the uplands, a series of small ridges and valleys is present, reflecting the presence of former glaciers (Conservation and Survey Division, 1986). These glaciers created the southeast trending Papillion Creek and other smaller tributaries probably consequent to the pre-Illinoian drift (Fenneman, 1938; Wayne, 1985).

Climate

The climate in the Papio-Missouri River NRD is continental and temperate, with large seasonal variations in temperature and precipitation. From 1951 through 1980, mean annual precipitation was 28.79 inches at the Blair weather station, Washington County (National Oceanic and Atmospheric Administration, 1982). Mean monthly precipitation varied from 4.33 inches in June to 0.68 inch in January. Typically, most precipitation occurs between May and September. During the sampling period, July through September 1992, precipitation was frequent and totaled 12.82 inches at the Blair weather station (National Oceanic and Atmospheric Administration, 1992).

Soils

The major soil associations in the Papio-Missouri River NRD (fig. 2) are shown on a generalized soil map of Nebraska (Conservation and Survey Division, 1990), and their respective average permeability is discussed by Dugan (1984). More detailed information on the physical and chemical characteristics of each soil series is given in soil survey reports (Bartlett, 1975; Damoude, 1980; Greenawalt and McKenzie, 1964; Slama and others, 1972, 1976). Eight soil associations exist in the area.

The Albaton-Haynie-Sarpy Association occurs on the bottom land along the Missouri and Platte Rivers. This deep, nearly level association consists of poorly to well-drained clayey to silty soils and well- to excessively drained sandy soils formed in alluvium on the bottom lands. Permeability is generally less than 1 inch per hour, except in sandy soils close to the Missouri River where permeability is significantly larger. These soils generally have a large lime but a small organic matter content. They are formed in recent clayey alluvium and are not as affected by soil-forming processes as other soils in the Papio-Missouri River NRD. Therefore, the soil chemistry of this association mainly reflects the geochemistry of the geologic strata they are derived from—Carlile and Graneros Shale (Conservation and Survey Division, 1990).

The Shell-Muir-Hobbs and Gibbon-Gothenburg-Platte Associations occur on the bottom land, mainly along Bell Creek and east of the Elkhorn River, and occur with deep, nearly level, well-drained, silty soils formed in alluvium. These soil associations have permeability values generally ranging from 5 to 10 inches per hour (Conservation and Survey Division, 1990).

The Monona-Ida Association exists on the uplands in the Missouri and Platte River Basins. This is a deep to very deep association with strongly to steep-sloping, well- to excessively drained silty soil. Permeability values generally range between 1 and 2 inches per hour (Conservation and Survey Division, 1990).

The Nora-Moody-Judson and Marshall-Ponca Associations occur on the uplands, with very deep, nearly level to moderately steep soils. The Nora-Moody-Judson Association exists in Burt, Dakota, and Thurston Counties, and the Marshall-Ponca Association exists mainly in the western part of the study area. These soils consist of well-drained silty soils formed in loess and colluvium. Permeability values generally range between 1 and 2 inches per hour (Conservation and Survey Division, 1990).

The Nora-Crofton-Moody and Crofton-Alcester-Nora Associations exist on the uplands, mainly in Dakota County. These soils consist of very deep, gently sloping to very steep, well- to excessively drained silty soils formed in loess. Permeability values generally are as much as 2 inches per hour.

Soils with the greatest potential for leaching of contaminants to the ground water are the Shell-Muir-Hobbs and Gibbon-Gothenburg-Platte Associations, which generally have substantially larger permeability values and smaller organic-matter concentrations than soils on the bottom land along the Missouri River.

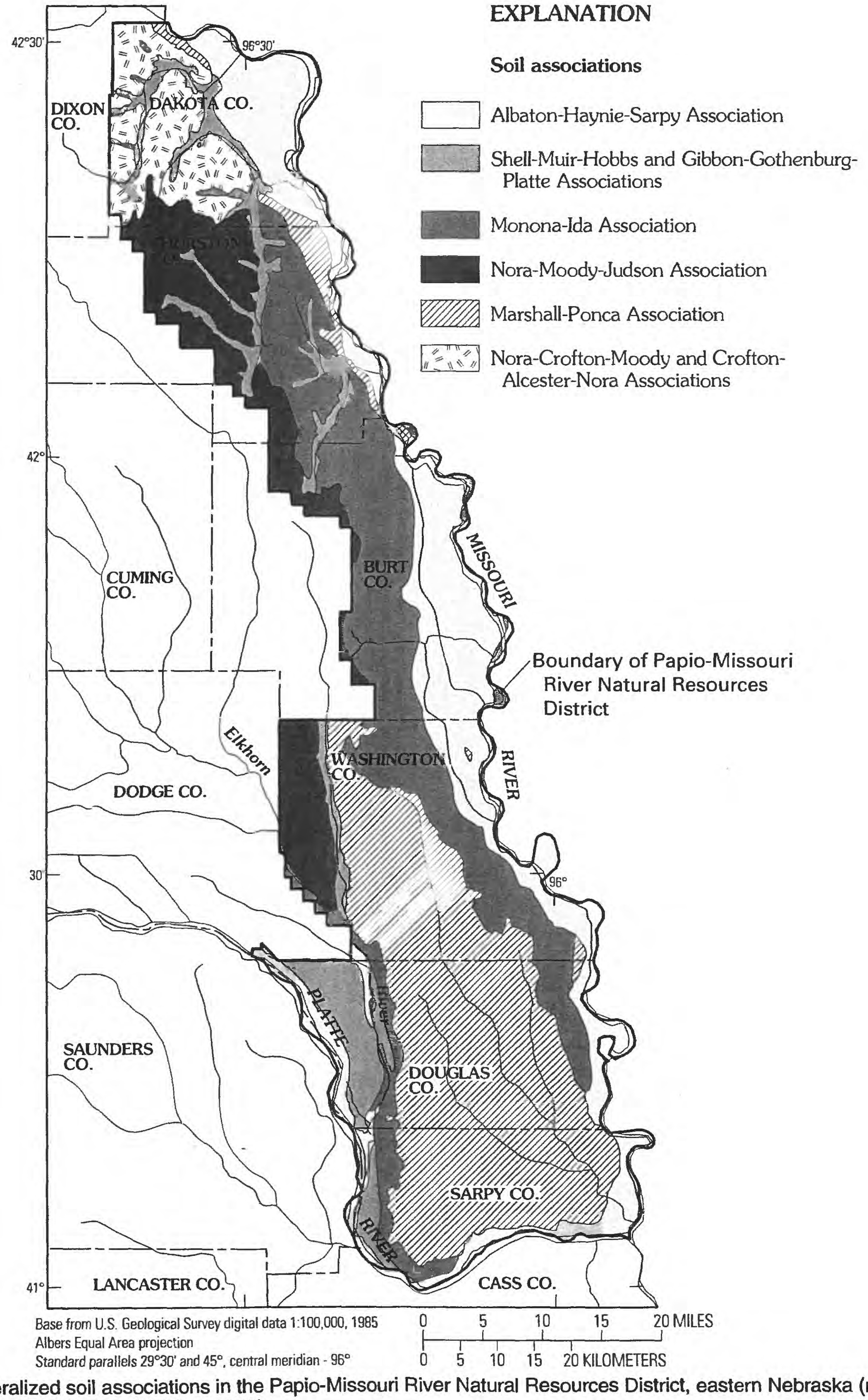


Figure 2. Generalized soil associations in the Papio-Missouri River Natural Resources District, eastern Nebraska (modified from Conservation and Survey Division, 1990).

Hydrogeology

This description of the hydrogeology of the Papio-Missouri River NRD is based on geologic and hydrologic information contained in published and unpublished reports that are available in the files of the Conservation and Survey Division (CSD), Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, and the USGS. The geologic units that comprise the unconsolidated surficial deposits and bedrock beneath the Papio-Missouri River NRD and corresponding aquifers, aquifer systems, and confining units are summarized in table 1.

Few geologic and hydrologic studies have been published that are specific to the Papio-Missouri River NRD, and most of these contain information about the geology or about a single aquifer in a limited part of the study area. The earliest such studies (Condra, 1908; Todd, 1908) include information on the geology and water resources of Dakota County. A variety of subsequent reports have been written, but for the purposes of this investigation, the most useful were geologic reports about the Omaha area by Miller (1964) and the Missouri River Valley alluvium and bedrock by Burchett (1965), logs of test holes drilled as part of a cooperative program between the CSD and the USGS (Burchett and Smith 1989a, 1989b, 1989c, 1991a, 1991b, 1992), and hydrogeologic reports on the Dakota Sandstone by O'Connor (1987) and the Paleozoic rocks in the Omaha area by Condra and others (1931, p. 52–70).

Most of the hydrogeologic information used in the preparation of this report was contained in reports that have a statewide or regional scope. These reports include geologic maps by Burchett and others (1975, 1988); hydrogeologic maps prepared jointly by the Nebraska Department of Environmental Quality and CSD (1980a, 1980b, 1980c, 1980d, 1980e, 1980f); descriptions of the Pleistocene deposits in Nebraska by Reed and Dreeszen (1965), Dreeszen (1970), and Wayne (1985); reports on the hydrogeology of the Dakota Sandstone by Ellis (1984, 1986) and Lawton and others (1984); and descriptions of the Paleozoic formations in Nebraska by Condra and Reed (1959), Carlson (1970), and Burchett (1983).

Hydrogeologic Units in Surficial Deposits

Quaternary deposits of alluvial, eolian, and glacial origin blanket the entire Papio-Missouri River NRD, except in small local areas where the bedrock crops out. The lithologic composition of the Quaternary deposits is variable both vertically and horizontally and ranges from relatively impermeable clay and silt to permeable sand-and-gravel deposits (figs. 3 and 4). In this study only the sand-and-gravel deposits are considered to be aquifers. Some domestic and stock wells in the study area probably are completed in silt deposits, but yields from these wells generally are very small and the deposits are not considered significant sources of water.

Because of potential variations in water yield and quality that can be the result of differences in lithology, sources of recharge, and land use, the Quaternary sand-and-gravel deposits were divided into the four areally restricted aquifers shown in figure 5. These aquifers are composed primarily of alluvial sand-and-gravel deposits along the Elkhorn, Missouri, and Platte River Valleys, and the scattered alluvial sand-and-gravel deposits that exist in the upland parts of the Papio-Missouri River NRD. Sufficient data are not available to accurately map the thickness of the Quaternary deposits throughout the study area.

Elkhorn River Valley Alluvial Aquifer

Most of the deposits in this aquifer consist of coarse-grained alluvial deposits beneath the flood plain and low terraces along the Elkhorn River Valley. In northwestern Sarpy and western Douglas Counties, however, the aquifer includes alluvial deposits under the bottom land between the Platte and Elkhorn Rivers. Most of these deposits are permeable sand and gravel, but clay and silt are intermixed and interbedded with the sand and gravel. Recharge to the aquifer is from infiltration of precipitation through the permeable soils, infiltration of runoff from upland areas, and infiltration from the adjacent Elkhorn and Platte Rivers when river stage is higher than ground-water levels.

Missouri River Valley Alluvial Aquifer

This aquifer consists of coarse-grained Quaternary deposits that exist beneath the flood plain and low terraces along the Missouri River. The coarse-grained deposits generally contain more sand than gravel and often are intermixed and interbedded with silt and clay. Many deposits in the Missouri River Valley were deposited by floods. The aquifer is recharged by infiltration of precipitation, infiltration of

Table 1. Summary of hydrogeologic units in the Papio-Missouri River Natural Resources District, eastern Nebraska

[NRD, Natural resources District; gal/min, gallon per minute]

Era	System	Geologic unit	Character and distribution	Hydrogeologic unit	Water-yielding properties
Cenozoic	Quaternary	Undifferentiated Holocene and Pleistocene deposits	Clay, silt, sand, and gravel. Includes eolian, glacial, and alluvial deposits everywhere, except in small areas where bedrock crops out. Deposits in river valleys usually are less than 100 feet thick. In upland parts of the NRD most deposits are between 50 and 250 feet thick. Maximum thickness, about 300 feet, is in the northern part of the NRD. Eolian deposits are loess, consisting of silt and clay-sized grains and are the surficial deposits in most upland parts of the NRD. Loess thickness usually ranges from 10 to 50 feet. Glacial deposits are clay tills that contain silt, sand, and gravel and occur under upland areas. Glacial deposits occur in the form of multiple till beds, and total thickness usually is 25 to 125 feet, but may be as much as 175 feet or be absent due to erosion. Alluvial deposits include clay, silt, sand, and gravel. Clay and silt deposits usually are intermixed or interbedded with sand and gravel deposits. Sand and gravel deposits are most common in river valleys.	Elkhorn River Valley alluvial aquifer	Unconfined aquifer with wells yielding 700 to 1,200 gal/min. Depth to water ranges from 5 to 15 feet, and saturated thickness ranges from 50 to 90 feet.
				Missouri River Valley alluvial aquifer	Aquifer usually unconfined, but locally may be partially confined. Most wells yield 600 to 1,200 gal/min. Depth to water ranges from 5 to 15 feet, and saturated thickness ranges from 70 to 100 feet.
				Platte River Valley alluvial aquifer	Unconfined aquifer with wells yielding 900 to 2,000 gal/min. Depth to water ranges from 5 to 15 feet, and saturated thickness ranges from 60 to 100 feet.
				Upland area alluvial aquifers	Confined or partially confined discontinuous beds of saturated sand and gravel. Well yields range from 10 to 300 gal/min. Depth to water ranges from 30 to 150 feet, and the saturated thickness of sand and gravel beds usually is less than 20 feet.

Table 1. Summary of hydrogeologic units in the Papio-Missouri River Natural Resources District, eastern Nebraska—Continued

Era	System	Geologic unit	Character and distribution	Hydrogeologic unit	Water-yielding properties
Mesozoic	Cretaceous	Undifferentiated Carlile Shale, Greenhorn Limestone, and Graneros Shale	Shale, marl, and limestone. Shale is calcareous. Limestone is thin-bedded, argillaceous, and interbedded with marl and shale beds. Present in parts of Dakota and Thurston Counties. Maximum thickness, about 125 feet, is in Dakota County.	Cretaceous confining unit	Forms a regional confining unit that, where present, separates the Dakota aquifer from aquifers in surficial deposits.
		Dakota Sandstone	Sandstone and claystone. Sandstone is very fine to coarse-grained, lenticular, friable, and locally is cemented with iron oxide. About 70 percent of the formation is sandstone. Claystone is massive and often silty. Maximum thickness, about 500 feet, is in Dakota and Thurston Counties where the formation is sandstone and is overlain by the Graneros Shale. In the rest of the NRD, the Dakota thins towards the south and east because of erosion. Erosional remnants less than 20 feet thick occur in Sarpy County.	Dakota aquifer	Confined or partially confined aquifer with wells yielding 10 to 600 gal/min depending on the thickness of saturated sandstone. Depth to water ranges from 15 to 100 feet, and the sandstone thickness from less than 1 to about 300 feet.

Table 1. Summary of hydrogeologic units in the Papio-Missouri River Natural Resources District, eastern Nebraska—Continued

Era	System	Geologic unit	Character and distribution	Hydrogeologic unit	Water-yielding properties
Paleozoic	Pennsylvanian	Undifferentiated limestone, shale, and sandstone beds	Limestone and shale. Limestone is thin-bedded to massive and usually dense. Shale is calcareous and fissile. Maximum thickness, about 400 feet, is in southeastern Washington County and northwestern Douglas County. These sediments are absent in Dakota and Thurston Counties and the northern part of Burt County.	Paleozoic confining unit	Forms a regional confining bed that, where present, separates the Lower Paleozoic aquifer system from the Dakota aquifer or from aquifers in Quaternary deposits. Wells completed in local fracture zones near the top of the unit may yield 5 to 50 gal/min.
	Mississippian-Cambrian, undifferentiated	Undifferentiated limestone, dolomite, sandstone, and shale beds	Predominantly massive dolomite bedding with some limestone beds in upper part, thin dolomitic shale in the middle, and sandstone beds in the lower part. Thickness increases from about 900 feet in Dakota County to 1,600 feet in Washington County and decreases from this thickness to the south and east.	Lower Paleozoic aquifer system	Confined aquifers. Available information indicates that well yields range from 200 to 1,300 gal/min, water levels range from 150 to 300 feet below land surface, and well depths range from 1,100 to 2,400 feet.
Precambrian	Undifferentiated	Undifferentiated	Undifferentiated igneous, metamorphic, and sedimentary rocks.	Precambrian confining unit	Regional base of Lower Paleozoic aquifer system.

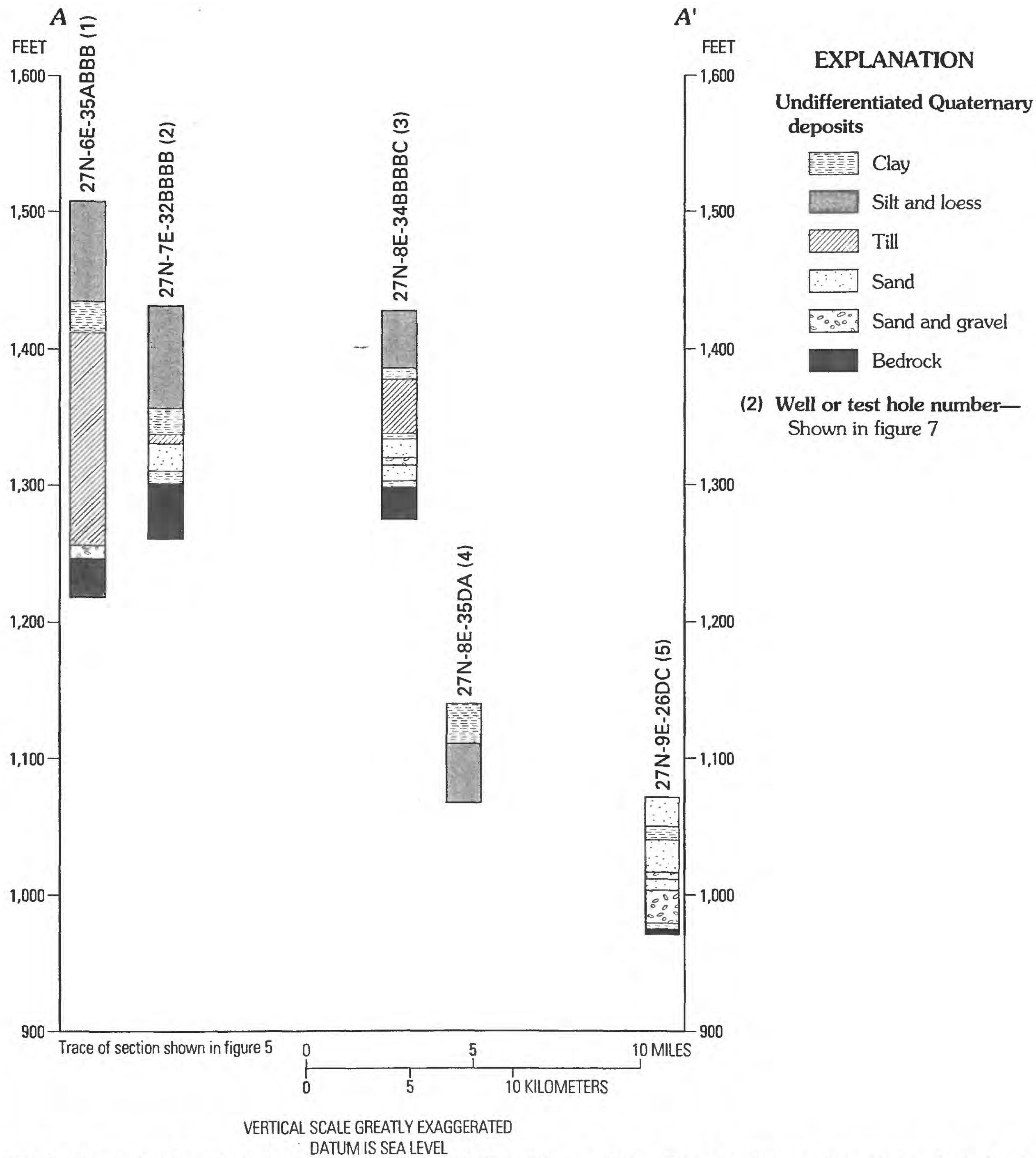


Figure 3. Generalized geologic section *A–A'* showing lithology of the undifferentiated Quaternary deposits in selected wells or test holes in the Papio-Missouri River Natural Resources District, eastern Nebraska.

runoff from the adjacent upland areas, and infiltration from the Missouri River when the river stage is higher than ground-water levels.

Platte River Valley Alluvial Aquifer

This aquifer is composed of coarse-grained alluvial deposits that exist beneath the flood plain and low terraces along the Platte River Valley from downstream of the mouth of the Elkhorn River to the mouth

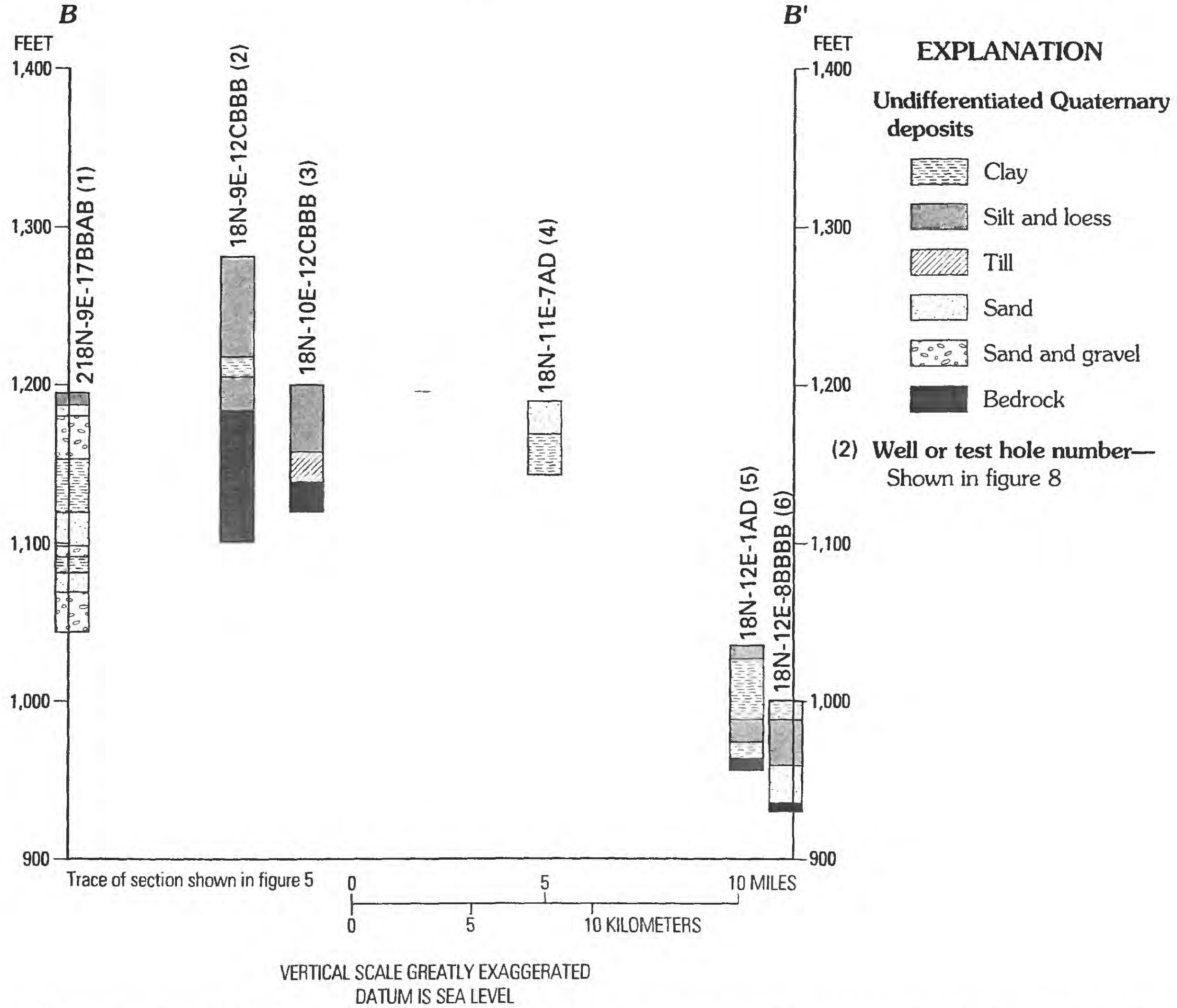


Figure 4. Generalized geologic section *B–B'* showing lithology of the undifferentiated Quaternary deposits in selected wells or test holes in the Papio-Missouri River Natural Resources District, eastern Nebraska.

of the Platte River. Most of the deposits are very permeable, coarse-grained sand and gravel. Clay and silt usually exist only in thin surficial deposits. Most recharge to the aquifer is by infiltration from the Platte River; the valley is very narrow and recharge from infiltration of runoff and precipitation has a limited area in which to occur.

Upland Area Alluvial Aquifers

These aquifers consist of the coarse-grained alluvial deposits that exist beneath the silt and clay beds that cover the upland parts of the Papio-Missouri River NRD. Available data indicate large variations in the thickness and in vertical and horizontal distribution of these isolated sand-and-gravel deposits (figs. 3 and 4). The available data, however, are not adequate to define and delineate the occurrence and distribution of these sand-and-gravel deposits, and in this study they are considered together as discontinuous aquifers. Almost all recharge to these aquifers is from the infiltration of precipitation.

Bedrock Hydrogeologic Units

The Papio-Missouri River NRD is underlain by bedrock formations ranging in age from Cretaceous through Precambrian; formations of Jurassic, Triassic, and Permian age are not present in the NRD. A bedrock geologic map of the Papio-Missouri-River NRD (fig. 6) shows that formations of Cretaceous and Pennsylvanian age directly underlie the unconsoli-

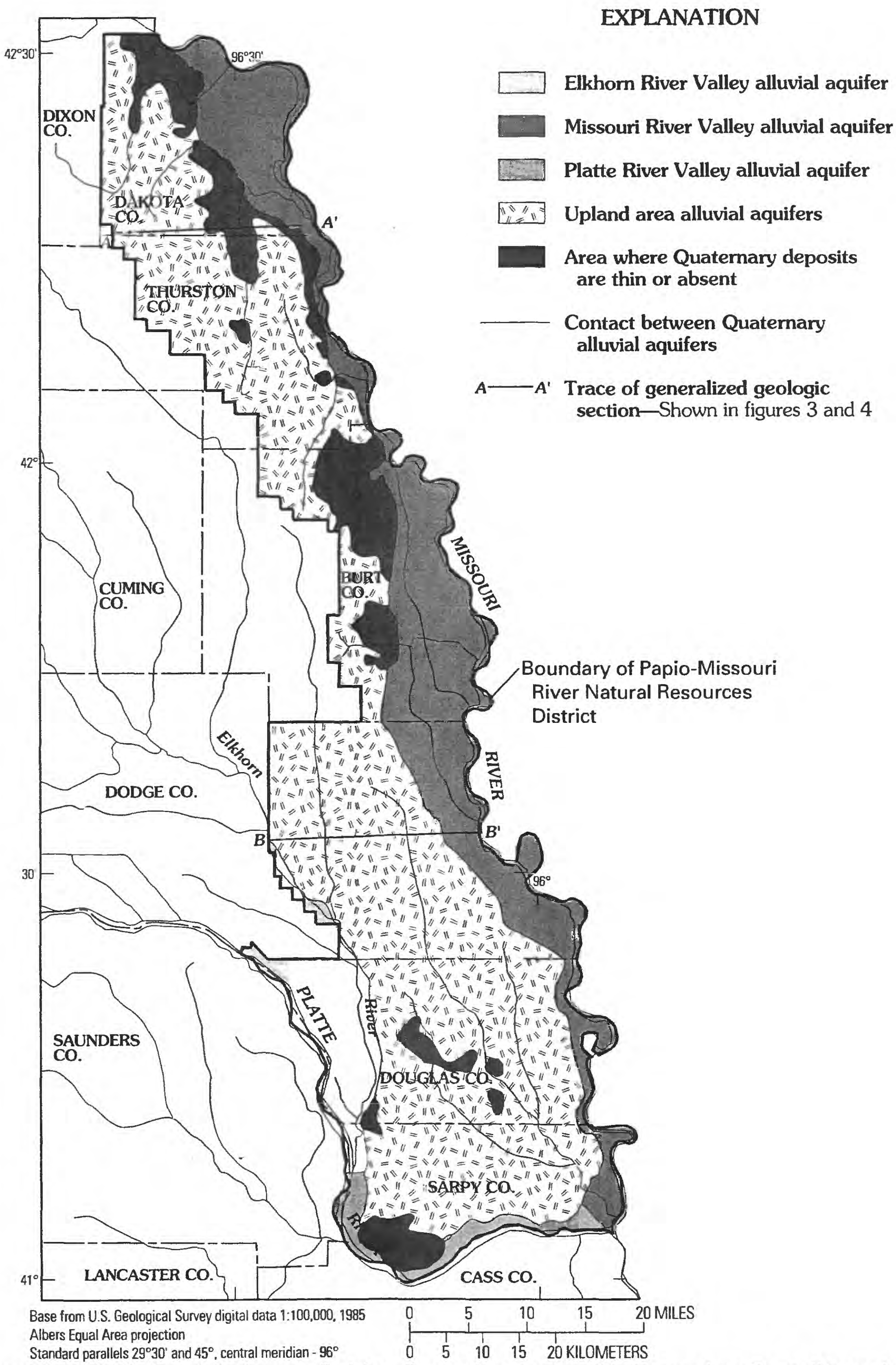


Figure 5. Generalized distribution of Quaternary alluvial aquifers and areas where Quaternary deposits are thin or absent in the Papio-Missouri River Natural Resources District, eastern Nebraska (area where the Quaternary deposits are thin or absent from Nebraska Department of Environmental Quality and Conservation and Survey Division, 1980c, 1980d).

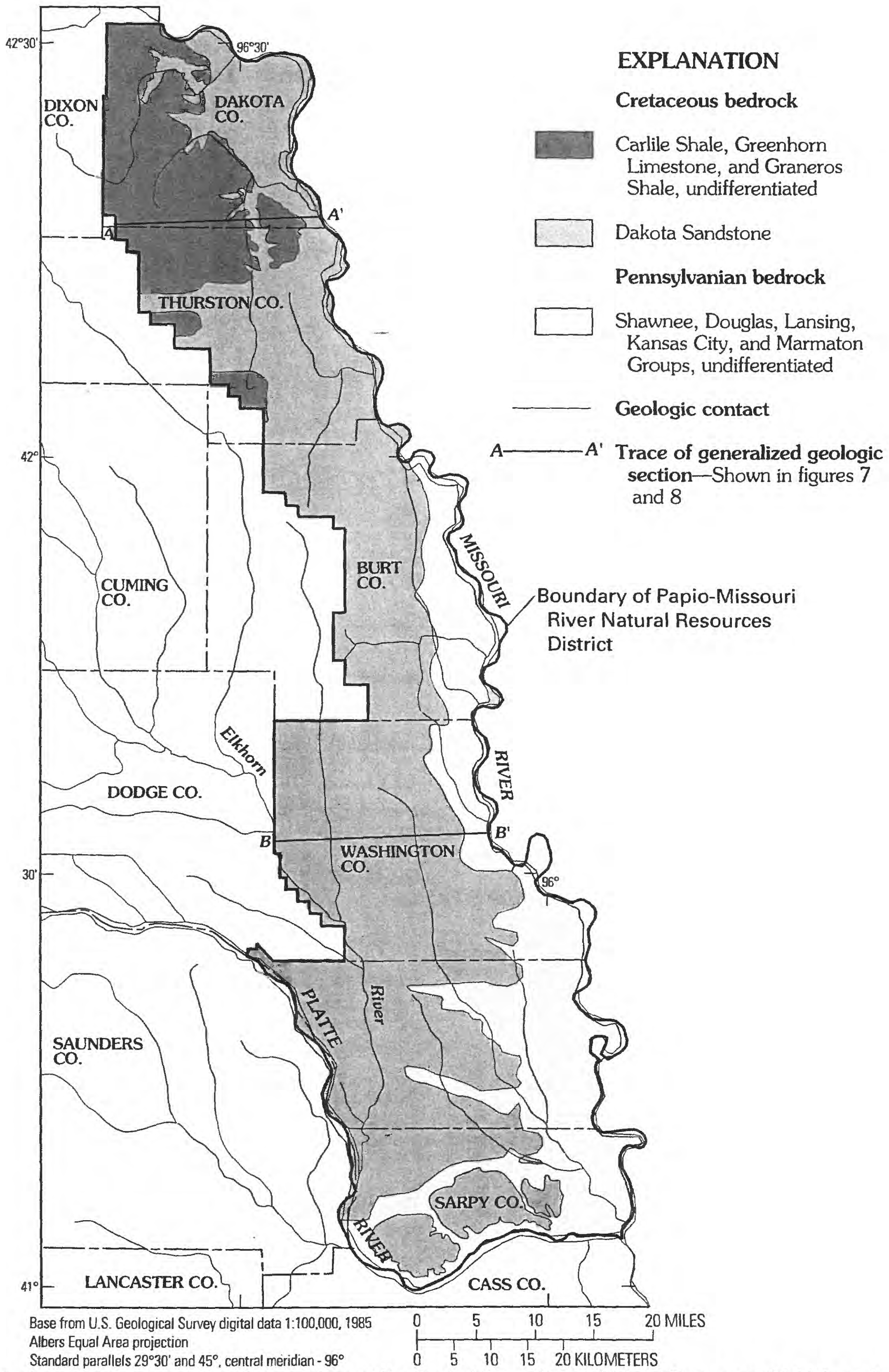
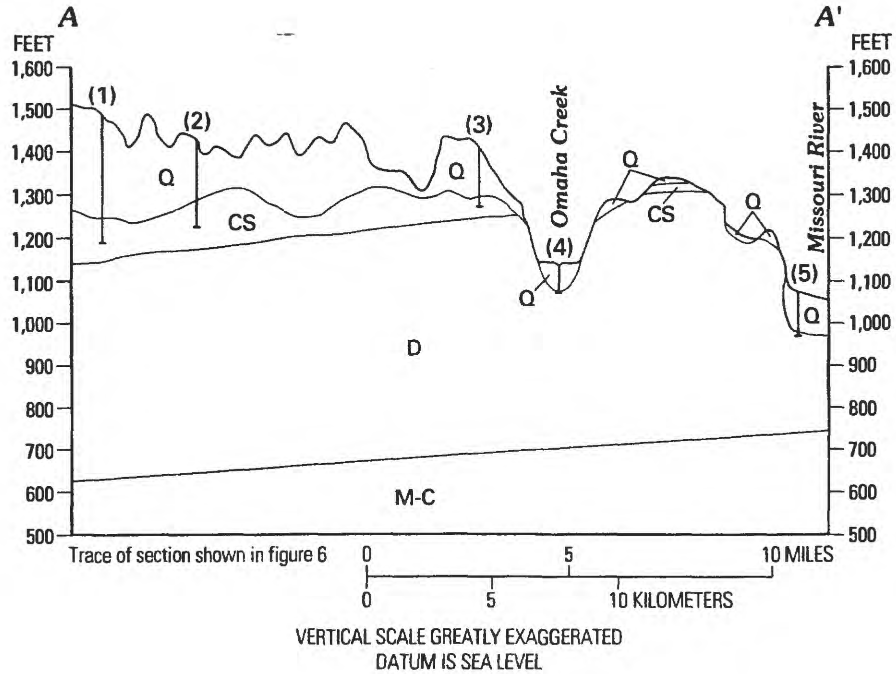


Figure 6. Generalized bedrock surface geology of the Papio-Missouri River Natural Resources District, eastern Nebraska (geology modified from Burchett and others, 1975, 1988).

dated surficial deposits. Two generalized geologic sections (figs. 7 and 8) show the vertical distribution and relations of the unconsolidated deposits and the bedrock of Cretaceous, Pennsylvanian, and Mississippian-Cambrian age. For the purposes of this investigation, the bedrock underlying the study area has been divided into five hydrogeologic units (table 1)—Cretaceous confining unit, the Dakota aquifer, the Paleozoic confining unit, the Lower Paleozoic aquifer system, and the Precambrian confining unit.

Cretaceous Confining Unit

The Cretaceous confining unit consists of shale and limestone formations that overlie the Dakota aquifer in some areas. These formations, in descending order, are the Carlile Shale, Greenhorn Limestone, and Graneros Shale. The confining unit exists only in parts of Dakota and Thurston Counties. The general distribution of these formations is shown in figure 6. Figure 7 illustrates the general stratigraphic relations of the confining unit with the underlying Dakota

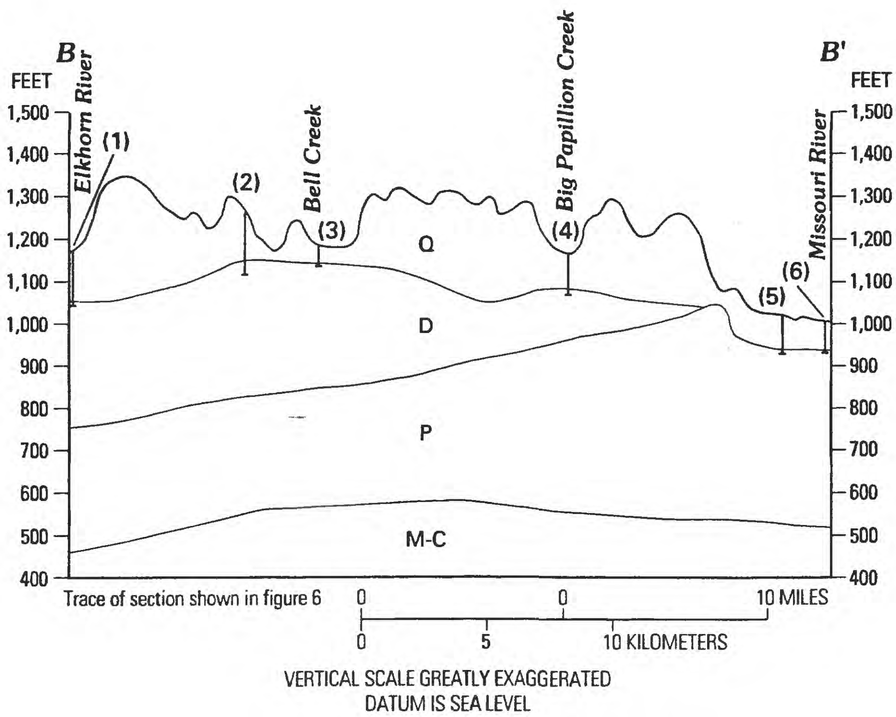


EXPLANATION

Era	System	Geologic unit	Description
Cenozoic	Quaternary	Q	Undifferentiated Holocene and Pleistocene deposits
Mesozoic	Cretaceous	CS	Undifferentiated Carlile Shale, Greenhorn Limestone, and Graneros Shale
		D	Dakota Sandstone
Paleozoic	Mississippian-Cambrian, undifferentiated	M-C	Undifferentiated limestone, dolomite, sandstone, and shale beds

(4) **Well or test hole**—Number is same as used for lithologic logs in figure 3

Figure 7. Generalized geologic section *A–A'* showing principal bedrock geologic units in selected wells or test holes in the Papio-Missouri River Natural Resources District, eastern Nebraska.



EXPLANATION

Era	System	Geologic unit	Description
Cenozoic	Quaternary	Q	Undifferentiated Holocene and Pleistocene deposits
Mesozoic	Cretaceous	D	Dakota Sandstone
Paleozoic	Pennsylvanian	P	Undifferentiated limestone, shale, and sandstone beds
	Mississippian-Cambrian, undifferentiated	M-C	Undifferentiated limestone, dolomite, sandstone, and shale beds

(4) **Well or test hole**—Number is same as used for lithologic logs in figure 4

Figure 8. Generalized geologic section *B–B'* showing principal bedrock geologic units in selected wells or test holes in the Papio-Missouri River Natural Resources District, eastern Nebraska.

Sandstone and the overlying unconsolidated Quaternary deposits.

Dakota Aquifer

The Dakota aquifer consists of the saturated sandstone in the Dakota Sandstone and commonly is used as a source of water for domestic, municipal, and irrigation supplies in those parts of the Papio-Missouri River NRD where the aquifer is present (fig. 6). Because the Dakota Sandstone is comprised of sand, silt, and clay of fluvial origin, large, abrupt horizontal and vertical lithologic variations are common. The Dakota aquifer directly underlies Quaternary deposits in most of the study area.

Paleozoic Confining Unit

Most rocks that compose the Paleozoic confining unit in the Papio-Missouri River NRD are of Pennsylvanian age. They are generally impermeable shale and dense limestone. None of the formations can be considered a significant source of water. However, some domestic and stock wells in the Papio-Missouri River NRD may be completed in water-yielding zones near the top of the confining unit where secondary porosity has developed. The secondary porosity generally is the result of fracturing and enlargement of the fractures by solution. The northern limit of the confining unit, which includes all Pennsylvanian rocks in the study area, is approximately parallel to and a few miles south of the Burt-Thurston County line. The general relation of the Paleozoic confining unit to overlying and underlying formations is shown in figure 8.

Lower Paleozoic Aquifer System

Available data indicate that saturated Lower Paleozoic carbonate rocks, sandstone, and shale underlie the entire study area at depths ranging from about 500 to 2,400 feet. In this report, these saturated deposits are considered to be the Lower Paleozoic aquifer system. The only significant use of the Lower Paleozoic aquifer system as a source of water within the Papio-Missouri River NRD existed in the Omaha area, where wells completed in the Lower Paleozoic aquifer system were a common source of water for industrial use from about 1870 to 1970. At the present time, however, most water for industrial use is from municipal supplies obtained from surface water and shallow aquifers in Quaternary alluvial deposits. Because of the variety of methods used to complete wells in the Lower Paleozoic aquifer system and the small amount of available data, it is not possible to make a detailed characterization of the water-bearing properties of any single aquifer or confining unit in the Lower Paleozoic aquifer system.

Precambrian Confining Unit

Because only a few wells in the northeastern part of Nebraska have been drilled into Precambrian rocks, sufficient data are not available to describe the hydrogeology of the Precambrian confining unit. Most of the Precambrian rocks are relatively dense, impermeable igneous and metamorphic rocks. This confining unit underlies all water-yielding formations found within the Papio-Missouri River NRD.

Land Use

Land use by type is summarized in table 2 and illustrated in figure 9. About 71 percent of the land in the Papio-Missouri River NRD is cropland. Only about 9 percent of this cropland is irrigated; less than 7 percent is used as pastureland. Burt and Washington Counties have the largest percentage of cropland (81 percent), whereas Dakota County has the largest percentage of pastureland (13 percent). Irrigation exists mainly along the Missouri River Valley in the east and along the Platte and Elkhorn River Valleys in the west (fig. 9).

The number of feedlots in Nebraska and specifically in the Papio-Missouri River NRD, has declined since 1980 (Nebraska Department of Agriculture, 1993). The largest number of hogs (67,000 head) and milk and beef cattle (36,000 head) in the NRD in 1993 were found in Washington County, which also had the largest number of farms (780) (Nebraska Department of Agriculture, 1993). Feedlots can affect the quality of the local ground water (Freeze and Cherry, 1979) through the addition of nitrogen and other constituents typical of feedlot operations.

Major crops in the study area are corn (52 percent) and soybeans (36 percent), with lesser amounts of hay (10 percent), sorghum (1 percent), and wheat (1 percent) (table 3). Minor crops not listed in table 3 include rye, potatoes, and winter wheat. Overall, Burt County has the most acres assigned to corn and soybean production (only 56 percent of Burt County is located within the Papio-Missouri River NRD). The main crop-production areas are found along the Missouri River, with smaller amounts on the upland areas to the west. Land in Douglas and Sarpy Counties is used the least for agricultural purposes. The smaller amount of agriculture in these counties is associated mainly with urbanization.

Before development, the study area consisted largely of prairie, with trees covering the steeper slopes (Fenneman, 1938). More recently, forest land occurs in areas along the Missouri River in Thurston County, in southeastern Washington County, in northeastern Sarpy County, and along bluffs and escarpments (fig. 9).

Table 4 presents fertilizer-use data in the Papio-Missouri River NRD. Total nitrogen purchases in 1990 were largest in Sarpy County and smallest in Douglas

Table 2. Summary of land-use acreage[1] in the Papio-Missouri River Natural Resources District, eastern Nebraska, 1983–84

[acreages from Mahendra Bansall, Nebraska Natural Resources Commission, written commun., 1993]

Land-use type	Burt County	Dakota County	Dodge County	Douglas County	Sarpy County	Thurston County	Washington County	Total
Nonirrigated cropland	109,645	111,701	496	97,328	101,032	121,973	194,262	736,437
Surface-irrigated cropland	18,566	768	44	7,720	4,608	0	6,208	37,914
Sprinkler-irrigated cropland	19,688	10,588	4	1,272	1,752	982	4,168	38,454
Nonirrigated pastureland	20,711	22,655	0	5,688	2,928	12,712	8,900	73,594
Rangeland	2,114	9,326	0	0	0	0	0	11,440
Forest land	3,120	5,740	456	13,888	16,432	21,881	18,338	79,855
Water	2,352	1,330	48	5,136	5,624	2,634	3,194	20,318
Other	7,176	8,354	52	87,704	26,344	3,850	16,736	150,216
Total irrigated cropland	38,254	11,356	48	8,992	6,360	982	10,376	76,368
Total cropland	147,899	123,057	544	106,320	107,392	122,955	204,638	812,805
Total pastureland	20,711	22,655	0	5,720	2,928	12,712	8,900	73,626
Total irrigated land	38,254	11,356	48	9,008	6,360	982	10,376	76,384
Total nonirrigated land	145,118	159,106	1,052	209,728	152,360	163,050	241,430	1,071,844
Total land	183,372	170,462	1,100	218,736	158,720	164,032	251,806	1,148,228

[1]Only 56 percent of Burt County and 61 percent of Thurston County are within the Papio-Missouri River Natural Resources District.

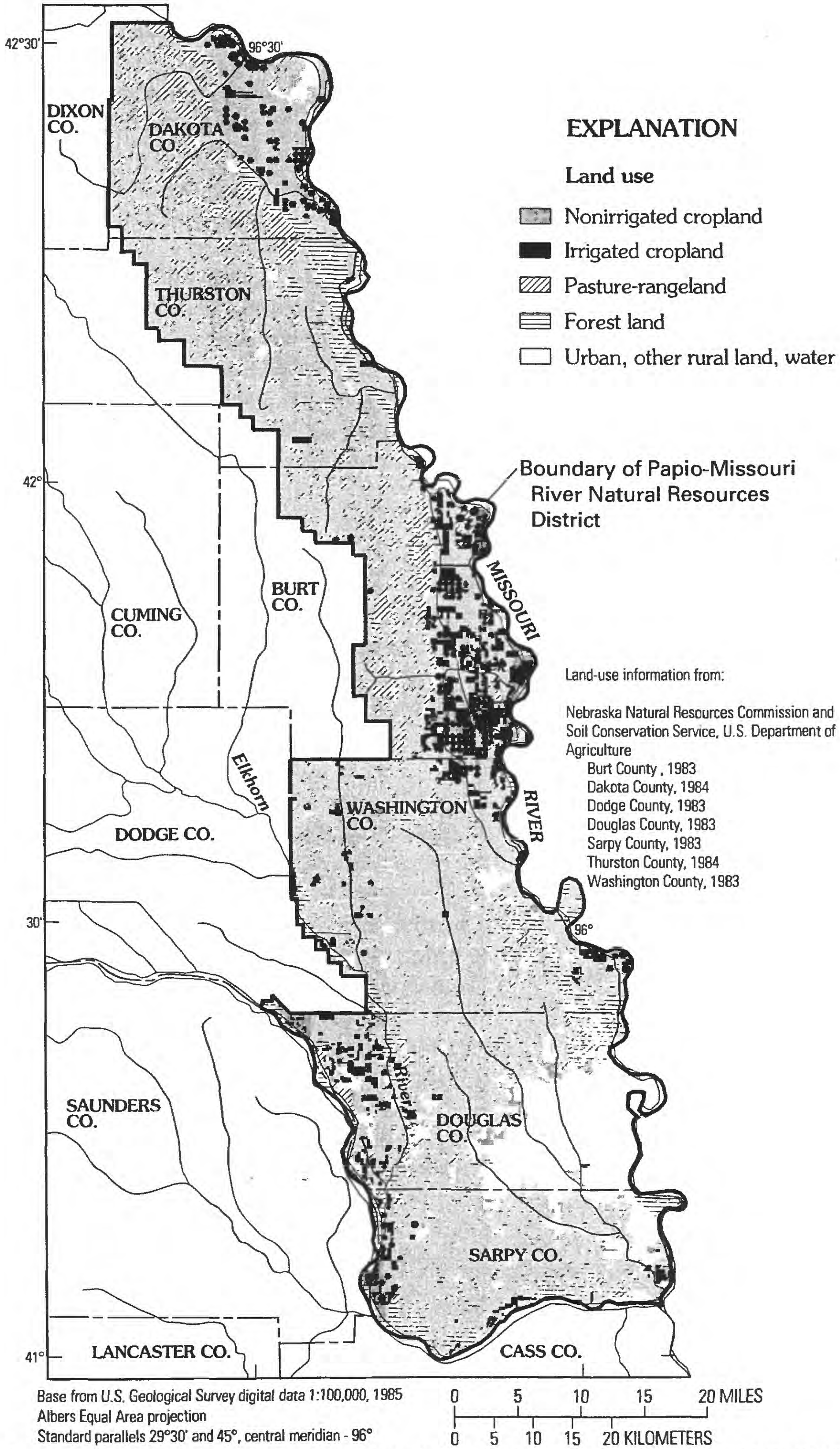


Figure 9. Land use in the Papio-Missouri River Natural Resources District, eastern Nebraska, 1983–84.

Table 3. Major crops planted, by county, eastern Nebraska, 1990[1]
[data, in thousands of acres, from Nebraska Department of Agriculture, 1992]

County	Corn	Hay[2]	Sorghum	Soybeans	Wheat	Total[3]
Burt	116.0	14.5	0.9	99.0	2.0	232.4
Dakota	54.0	11.0	.5	36.0	.2	101.7
Douglas	50.0	13.0	1.1	28.0	.8	92.9
Sarpy	46.0	12.0	1.1	34.0	1.1	94.2
Thurston	80.0	8.8	1.3	44.0	.1	134.2
Washington	91.0	22.0	2.2	68.0	2.1	185.3
Total	437.0	81.3	7.1	309.0	6.3	840.7

[1]Only 56 percent of Burt County and 61 percent of Thurston County are included in the Papio-Missouri River Natural Resources District. Data listed are for the entire counties.

[2]Hay includes alfalfa, tame hay, and wild hay.

[3]Total does not include acres planted in other crops.

County. Total phosphorus and lime purchases were largest in Dakota and Burt Counties and smallest in Douglas and Sarpy Counties. These fertilizer data are not necessarily a direct measure of fertilizer applied, but they provide an approximation of fertilizer use in the counties in the study area.

Table 5 lists the herbicides most frequently used on alfalfa, corn, soybeans, and pastureland in the study area, and table 6 lists the insecticides most frequently used on alfalfa, corn, and soybeans. Insecticides generally are not used on pastureland. Statistics on the quantity of herbicides and insecticides used in the Papio-Missouri River Natural Resources District are not available.

Water Use

The estimated ground- and surface-water use in the study area for 1990 is shown in table 7 (Zachary Hill, U.S. Geological Survey, written commun., 1993). The smallest amount of ground and surface water was used in Thurston County (3 percent of the total water use in the study area), and the largest amount of ground and surface water was used in Douglas County (51 percent of the total water use), the county with the largest population. Self-supplied irrigation used the most ground and surface water (27 percent of the total water use) followed by public-supply domestic uses (24 percent of the total water use). Public-supply water used for commercial and industrial purposes accounted for 21 percent of all water use. Smaller amounts of ground and surface water were used for self-supplied livestock, mining, domestic, and industrial purposes. Self-supplied surface water was used mainly for mining (63 percent of self-supplied surface water) and irrigation (34 percent of self-supplied surface water).

Most surface water was used in Douglas and Sarpy Counties. Surface-water use is regulated by the Nebraska Department of Water Resources. The surface-water supplies mainly are obtained, directly or indirectly, from the Missouri and Platte Rivers. The City of Omaha obtains most of its drinking water from the Missouri River. The City of Papillion and the Omaha Metropolitan Utilities District (MUD) obtain most of their drinking water from well fields along the Platte River. The City of Omaha also is constructing additional well fields near the Elkhorn and Platte Rivers.

Ground water was used mainly for irrigation and domestic purposes. Figure 10 shows the location of the 1,058 wells registered with the Nebraska Department of Water Resources, located within the Papio-Missouri River NRD as of 1992. The most intense ground-water use was in western Douglas and Sarpy Counties and in eastern Burt and Dakota Counties. Of the registered wells, about 83 percent were irrigation wells, 10 percent were municipal wells, 4 percent were industrial wells, and 4 percent were other wells (such as domestic wells). Most domestic wells are not registered.

PREVIOUS WATER-QUALITY INVESTIGATIONS

The general ground-water quality in Nebraska has been discussed by Engberg and Spalding (1979), Engberg (1984), the Conservation and Survey

Table 4. Fertilizer purchased, by county, eastern Nebraska, 1990[1]
[data, in tons purchased, from Nebraska Department of Agriculture, 1992]

County	Total nitrogen	Total phosphorus (P_2O_5)	Phosphate	Potash	Total potassium (K_2O)	Lime
Burt	5,670	2,026	893	965	705	77
Dakota	5,305	3,363	241	1,499	925	476
Douglas	1,790	303	70	2	108	0
Sarpy	7,597	598	109	104	81	0
Thurston	3,790	1,091	490	268	490	0
Total	24,152	7,381	1,803	2,838	2,309	553

[1]Only 56 percent of Burt County and 61 percent of Thurston County are included in the Papio-Missouri River Natural Resources District. Data listed are for the entire counties. Data for Washington County do not exist.

Table 5. Most frequently applied herbicides by major crop in the Papio-Missouri River Natural Resources District, eastern Nebraska
[information from James Peterson, John Wilson, Franklin Morse, Monty Stauffer, County Extension Agents of Burt, Dakota, Douglas, Sarpy, Thurston, and Washington Counties, oral commun., 1993; --, not used; X, used]

Herbicides (chemical compound)	Alfalfa	Corn	Soybeans	Pastureland
Alachlor	--	X	--	--
Acifluorfen, sodium salt	--	--	X	--
Atrazine	--	X	--	X
Benefin, benfluralin	X	--	--	--
Bentazon	--	--	X	--
Butylate	--	X	--	--
Clomazone	--	--	X	--
Cyanazine	--	X	--	--
2,4-D	--	X	--	X
Dicamba	--	--	--	X
EPTC	--	X	--	--
Fluazifop-butyl	--	--	X	--
Metolachlor	--	X	X	--
Metribuzin	X	--	X	--
Pendimethalin	--	--	X	--
Picloram	--	--	--	X
Pursuit[1]	--	--	X	--
Sethoxydim	X	--	X	--
Trifluralin	X	--	X	--

[1]The use of brand names is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

Division (1986), and Engberg and Druliner (1987). Statistical analyses of water quality of the major ground-water basins in Nebraska were discussed by Engberg (1973). Previous ground-water-quality investigations in the study area are restricted mainly to Douglas, Sarpy, and Washington Counties (Leonard and others, 1983; Ellis, 1984; O'Connor, 1987; Spalding, 1990). The USGS data base (WATSTORE) contains historical ground-water-quality data collected prior to this investigation. Dissolved solids for sam-

Table 6. Most frequently applied insecticides by major crop in the Papio-Missouri Natural Resources District, eastern Nebraska

[information from James Peterson, John Wilson, Franklin Morse, Monty Stauffer, County Extension Agents of Burt, Dakota, Sarpy, Thurston, and Washington Counties, respectively, oral commun., 1993; X, used; --, not used]

Insecticide (common name)	Alfafa	Corn	Soybeans
Carbaryl, Sevin	X	--	X
Carbofuran	X	X	--
Chlorpyrifos	X	X	X
Malathion	X	--	--
Parathion	X	X	--
Permethrin	X	X	X
Phorate	--	X	--
Terbufos	--	X	--

ples collected from 13 wells completed in Paleozoic rocks from 1945–71 and from drill-stem test recoveries of an oil-test well completed in 1953 also are included in this report.

Concentration maps of dissolved nitrate as nitrogen (NO_3-N) in ground water for the Fremont quadrangle (1x2 degree series) also have been published (Exner, 1980). These maps show that NO_3-N concentrations in ground water from the Papio-Missouri River NRD in 1980 generally were smaller than 7.6 mg/L (milligrams per liter). Occasionally concentrations exceeded this level.

A report on the water quality in the Platte River Basin evaluated the potential for ground-water pollution in the lower Platte Valley and provides information on ground-water quality with emphasis on NO_3-N, soluble herbicides, and distribution of uranium isotopes in surface water (Spalding, 1990). The report includes maps indicating the pollution potential for Sarpy, Washington, and part of Douglas Counties. Using DRASTIC, a computer program, the investigator concluded that the areas considered most vulnerable to contamination are located between the Elkhorn and Platte Rivers from southeast Dodge County (west of the study area) to the rivers' confluence in northwest Sarpy County. Another area of relatively large vulnerability for contamination was identified in the bottom land near the confluence of the Missouri and Platte Rivers. The study by Spalding (1990) showed that about 5 percent of all ground-water samples collected in the Papio-Missouri River NRD had NO_3-N concentrations greater than the USEPA Maximum Contaminant Level (MCL) of 10 mg/L (U.S. Environmental Protection Agency, 1991a), mainly in water from household wells. The areas that were thought to be vulnerable to contamination did not show large NO_3-N concentrations. Presence of atrazine and highly fractionated N-15 values indicated that denitrification in the saturated or unsaturated zone occurred in the Papio-Missouri River NRD (Spalding, 1990). Five samples had detectable amounts of atrazine [more than 0.05 µg/L (micrograms per liter)]. Atrazine in ground water was found to be induced from the Platte River in a large well field located along the banks of the Platte River west of the Papio-Missouri River NRD boundary near Gretna (Duncan and others, 1991; Davis, 1992). The concentration of atrazine in the ground water apparently was affected by time of year and amount of precipitation in the Platte River Basin.

The hydrogeology of the Dakota aquifer in Douglas, Sarpy, and Washington Counties was investigated by O'Connor (1987). He described the ground water within the Dakota aquifer as having generally small NO_3-N concentrations. Ground water was predominantly a calcium bicarbonate type, with a calcium sulfate type water in deeper wells located in Washington County. O'Connor (1987) concluded that concentrations of sodium, sulfate, and chloride ions in ground water appeared to increase toward the northwest and found that the water generally was saturated with respect to calcite. He found dissolved-solids concentrations generally less than 500 mg/L and suggested that recharge to the Dakota aquifer was predominantly from precipitation with some recharge from the underlying Lower Paleozoic aquifer system.

A regional investigation of the hydrogeology of the Dakota aquifer in eastern Nebraska also was done by Lawton and others (1984). As part of the USGS's Central Midwest Regional Aquifer System Analysis (RASA), ground-water quality data were assembled for the Dakota and deeper regional aquifer systems in the study area; Leonard and others (1983) and Ellis (1984) described water from the Dakota aquifer as a calcium bicarbonate type, with dissolved-solids concentrations generally less than 1,000 mg/L.

Water-quality data, such as specific conductance, major ions, and trace elements including uranium and thorium, were collected under the National Uranium Resource Evaluation (NURE) project (U.S. Department of Energy, 1981). The NURE study indicated that the largest uranium con-

Table 7. Estimated major water use for public and self supply in and around the Papio-Missouri River Natural Resources District, eastern Nebraska, 1990

[water-use data from Zachary Hill, U.S. Geological Survey, written commun., 1993; population data from U.S. Department of Commerce, 1991; water deliveries by type of use are reported in million gallons per day; GW, ground water; SW, surface water]

	Public-supply water use by county				Self-supply water use by county					
					Irrigation			Livestock		
County	Commer-cial	Domestic	Industrial	Total	GW	SW	Total	GW	SW	Total
Burt[1]	0.21	0.51	0.07	0.79	17.36	1.98	19.34	0.92	0.11	1.03
Dakota	.31	1.41	.16	1.88	5.09	.10	5.19	.31	.05	.36
Douglas	23.56	34.91	9.20	67.67	6.88	.09	6.97	.40	.07	.47
Sarpy	1.23	4.5	.74	6.47	3.95	.24	4.19	1.11	.10	1.21
Thurston[1]	.10	.34	.06	.50	2.98	.55	3.53	.68	.09	.77
Washington	.32	.95	.10	1.37	6.53	2.20	8.73	.87	.10	.97
Total	25.73	42.62	10.33	78.68	42.79	5.16	47.95	4.29	.52	4.81

	Self-supply water use by county—Continued													
	Mining			Domestic			Industrial			Total self supplied				
County	GW	SW	Total	GW	SW	Total	GW	SW	Total	GW	SW	Total	Total water use	Popu-lation
Burt[1]	0	0	0	0.26	0	0.26	0	0	0	18.54	2.09	20.63	21.42	2,650
Dakota	0	0	0	.23	0	.23	2.51	0	2.51	8.14	.15	8.29	10.17	2,340
Douglas	0	5.55	5.55	6.90	0	6.90	1.28	0	1.28	15.46	5.71	21.17	88.84	68,990
Sarpy	0	4.02	4.02	4.78	0	4.78	16.44	0	16.44	26.28	4.36	30.64	37.11	47,810
Thurston[1]	0	0	0	.38	0	.38	0	0	0	4.04	.64	4.68	5.18	3,780
Washington	0	.13	.13	.73	0	.73	.01	0	.01	8.14	2.43	10.57	11.94	6,980
Total[1]	0	9.70	9.70	13.28	0	13.28	20.24	0	20.24	80.60	15.38	95.98	174.66	132,550

[1]Water-use data for Burton and Thurston Counties reflect water use for the entire county, not just the Papio-Missouri Natural Resources District.

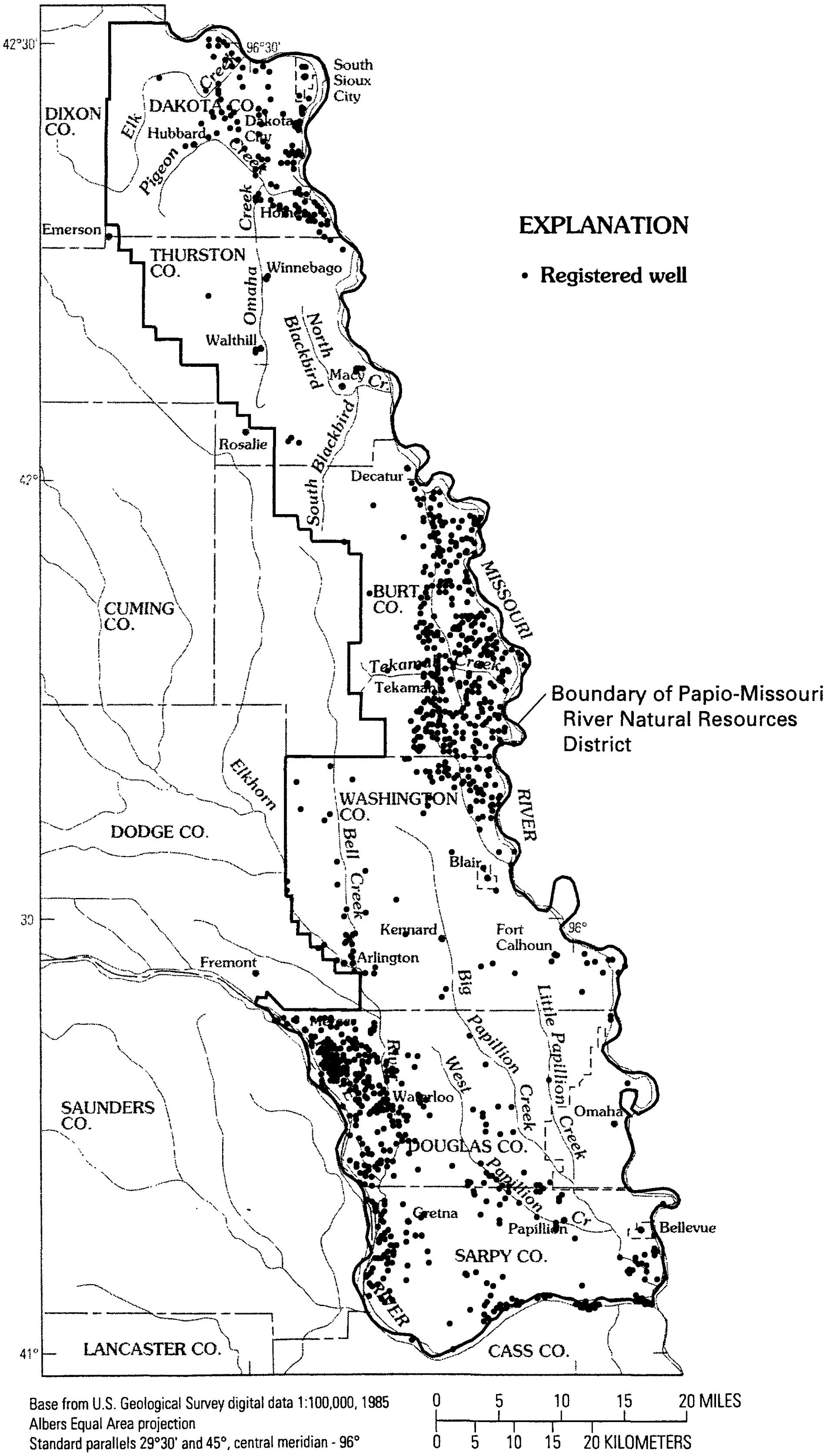


Figure 10. Location of wells registered with the Nebraska Department of Water Resources in the Papio-Missouri River Natural Resources District, eastern Nebraska, 1992.

centrations are associated with surficial Quaternary alluvial and glacial deposits.

Additional water-quality data such as nitrogen, herbicides, trace elements, and volatile organic compounds, have been collected from municipal water supplies by the Nebraska Department of Health (Scott Peterson, Nebraska Department of Health, written commun., 1992). Volatile organic compounds detected in municipal water supplies within the study area include bromodichloromethane, bromoform, carbon tetrachloride, chloroform, chloromethane, dibromochloromethane, 1,1-dichloroethane, and 1,2,4-trimethylbenzene.

Schuett (1964) and Barnes and Bentall (1968) described the water-mineral relations of Quaternary fill deposits in the Platte Valley. Schuett (1964) focused on carbonate and partial pressure of carbon dioxide $\left(P_{CO_2}\right)$-dissolved oxygen and ground-water sulfate-ion relations. He suggested that a hydraulic connection with the overlying Quaternary deposits exists and that the ground-water quality is a result of mixing of ground, surface, and rain water. In addition, Engberg (1973) discussed the presence of selenium in the ground water of Nebraska.

Pipes (1987) studied the hydrogeology of the aquifers in Paleozoic rocks in the southern part of the Papio-Missouri River NRD. Pipes suggested that the water quality of these aquifers in Douglas, Sarpy, and Washington Counties is suitable for most uses with the exception of water from the Mississippian rocks, and that water from these aquifers is generally a sodium sulfate and sometimes a sodium bicarbonate type.

SAMPLE COLLECTION AND LABORATORY PROCEDURES

This section presents an overview of well-selection procedures used in this investigation, standard USGS procedures for ground-water sampling and laboratory analyses, and generally describes standard and project-specific quality-assurance measures.

Well Selection

Sixty-one wells were selected for sampling to describe the ground-water quality of the principal aquifers in the study area (fig. 11). The wells were selected on the basis of their areal distribution, completion zones in the principal aquifers, and availability for sampling. Ground water from the following five aquifers was collected:

(1) Elkhorn River Valley alluvial aquifer,
(2) Missouri River Valley alluvial aquifer,
(3) Platte River Valley alluvial aquifer,
(4) upland area alluvial aquifers, and
(5) Dakota aquifer.

Because of the lack of information about wells completed in the upper and lower part of the Paleozoic confining unit and because the unit is not a significant source of ground water, no water samples were collected from the Paleozoic rocks for chemical analysis as part of this study.

It has been a common well-drilling practice to complete wells in both the surficial deposits and the Dakota aquifer when an adequate supply of water cannot be obtained from the surficial deposits alone. Therefore water samples were collected from wells screened only in a surficial aquifer or the Dakota aquifer.

A stratified (by aquifer) random approach was used to select 100 primary wells, 100 alternate wells, and a subset (42 wells) of the 100 primary wells completed in the primary aquifers for water-quality sampling. From each aquifer, an equal number of wells (20) was selected (when enough wells were present), and a subset of these was selected for more detailed water-quality analyses. From the available pool of registered wells, all wells completed in the Dakota aquifer were identified. The remaining wells were divided into four groups, completed in the four alluvial aquifers, on the basis of their location (fig. 5). Primary wells located in the same township and range were avoided, when possible, unless completed in different aquifers or if less than 20 wells were completed in the aquifer of interest at different township and range locations.

Because of wet-weather conditions that limited the number of active irrigation wells in the study area during the summer of 1992, numerous deviations in the sampling scheme were necessary. These changes included sampling a smaller number of wells and wells other than those previously selected. The number of wells sampled was reduced from 100, as originally planned, to 61. Forty-two of the 61 wells were selected for more detailed analyses using the well-selection approach just described. A listing of the number of wells sampled in each aquifer is given in table 8. Of the 61 wells from which water samples were collected, 25 were irrigation wells, 22 were

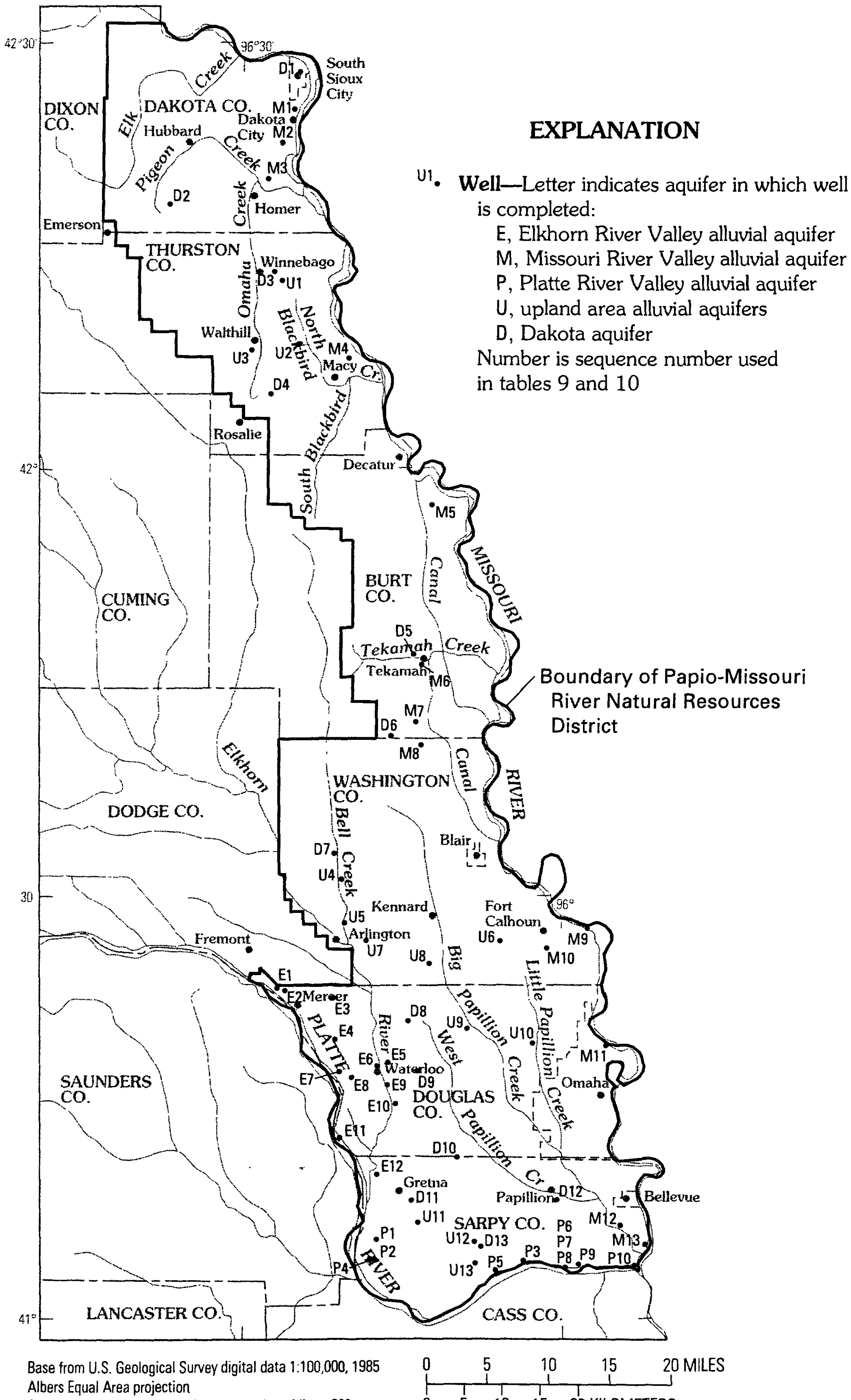


Figure 11. Locations of sampled wells in the Papio-Missouri Natural Resources District, eastern Nebraska, July through September 1992.

Table 8. Number of wells sampled, by aquifer

Aquifer	Dissolved nitrate as nitrogen, triazine herbicide enzyme-analyses, and field measurements[1]	Constituents	
		Major ions, metals, trace elements, and radionuclide analyses[2]	Quantitative triazine and acetanilide herbicide analyses[3]
Elkhorn River Valley alluvial aquifer	12	9	8
Missouri River Valley alluvial aquifer	13	10	2
Platte River Valley alluvial aquifer	10	8	7
Upland area alluvial aquifers	13	6	2
Dakota aquifer	13	9	1
Total	61	42	20

[1]Specific number of wells with well depth and dissolved-oxygen data are listed in tables 11 through 16.
[2]Specific number of wells with alkalinity, dissolved-solids, percent sodium, potassium, sulfate, chloride, fluoride, arsenic, boron, silver, radon-222, and uranium activity ratio data are listed in tables 11 through 16.
[3]Specific number of wells with cyanazine, deisopropylatrazine, deethylatrazine, prometon, prometryn, and simazine data are listed in tables 11 through 16.

municipal wells, 8 were domestic wells, and 6 were industrial wells (table 9 at end of the report).

Water-Quality Sampling

Water samples from the 61 wells were collected from July through September 1992 (fig. 11 and table 9). Onsite observations included well integrity, potential point sources of contamination, prevalent land use, and determination of land-surface altitudes at each sampling site. The altitudes (land-surface datum) for all well sites were determined from USGS 7.5-minute topographic maps (scale 1:24,000) with 5- or 10-foot contour intervals. Apparent potential point sources of contamination, such as septic tanks, feedlots, and other industrial activities, within a 1-mile radius of the sample location were noted on the field-data sheets to aid in the interpretation of anomalous water chemistry.

Water was collected from each well as close to the wellhead as possible. By using a flow-through chamber, specific conductance, pH, water temperature, and dissolved oxygen (when possible) were measured onsite at 5-minute intervals. A water sample was collected after the field measurements indicated that water-quality properties had stabilized (after pumping the well for more than 15 minutes). The properties were considered stable on the basis of three tolerances: specific conductance within 5 percent; pH within 0.1 standard units; and water temperature within 0.2 °C. These procedures ensured that water collected for analyses were representative of the aquifer surrounding the well screen.

A water sample from each of the wells was filtered through a 0.45-micrometer membrane filter immediately, preserved, and kept chilled at 4 °C for analyses of dissolved nitrate (NO_3) plus nitrite (NO_2). At each site, an additional water sample was collected in an amber-glass bottle and chilled for triazine herbicide analysis. Additional water samples were collected for detailed chemical analyses of the ground water. A water sample for radon-222 analysis was obtained using a syringe method. All water samples were filtered and preserved onsite as described in Pritt and Jones (1989). A list of chemical constituents is given in tables 9 and 10.

Laboratory Procedures

Analyses for dissolved NO_2 plus NO_3 as N, major ions, and trace elements were performed at the USGS National Water Quality Laboratory in Arvada, Colorado, in accordance with the standard methods described by Fishman and Friedman (1989). Dissolved-solids concentration in water was determined mathematically by totalling the concentrations of individual constituents of major ions and is referred to as dissolved solids. Analyses for alpha and beta radioactivity and radium-226 (Ra^{226}) were completed in accordance with USEPA methods 900.0 and 903.1.

The analyses for radon-222 (Rn^{222}) were done by scintillation (Whittaker and others, 1989). The concentrations of dissolved nitrite plus nitrate, considered to be mainly nitrate in ground water and reported as nitrogen (N), are referred to as such in the tables 9 through 17 included at the end of the report and are referred to as NO_3-N or nitrate in the remainder of this report. Analyses for uranium (U) concentrations and isotopic ratios of uranium-234 to uranium-238 (^{234}U:^{238}U) were performed at the USGS laboratory in Reston, Virginia, using an isotope-dilution method (Thatcher and others, 1977).

Concentrations of herbicides were determined using a two-tiered approach to decrease analytical cost. Total triazine herbicide content was estimated qualitatively using an enzyme-assay test and a differential photometer. If a water sample contained more than 0.10 μg/L triazine compounds according to the enzyme-assay test, the sample was sent to the USGS National Water Quality Laboratory for quantitative analysis of triazine and other acetanilide herbicides using solid-phase extraction and GC/MS (gas chromatography/mass spectrometry). Twenty water samples were analyzed for triazine and other acetanilide herbicides at the laboratory (table 9). The quantitative herbicide analyses included the compounds: alachlor, ametryn, atrazine, cyanazine, deisopropylatrazine and deethylatrazine (degradation products of atrazine), metolachlor, metribuzin, prometon, prometryn, propazine, and simazine.

Quality Control and Quality Assurance

The possibility of contamination of the water-quality samples, including bottles and preservatives, was evaluated through quality-control measures in the field and in the laboratory. The quality-assurance program at the laboratory includes participation in the USGS and USEPA interlaboratory evaluations and submission of blind, standard-reference water samples (Friedman and Fishman, 1982; Jones, 1987). In addition, cation-anion balances were calculated for each complete analysis to ensure internally consistent data. The cation-anion balances were within 10 percent for all samples.

More than 20 percent of all enzyme-assay tests were repeated on another aliquot of water sample as a measure of the test's reproducibility. The reproducibility was more than 90 percent. In addition, one blank was sent to the laboratory for analysis of triazine and other acetanilide herbicides to test for contamination during the sample collection and analysis process (table 9). Also, one blank and three duplicates were analyzed for all nonherbicide constituents. All blank-sample analytical results (table 9) were below the detection level for herbicides and below or near the detection level for all nonherbicide constituents. Duplicate samples showed a small percentage difference in results. In the laboratory, quality control and quality assurance for the GC/MS analyses included use of standard matrix spikes, blanks, and internal blanks.

DATA-ANALYSIS PROCEDURES

This section generally describes the statistical procedures used in this report. Statistical analyses of water-quality data are useful in identifying potential environmental water-quality problems. Statistical analysis could indicate variations, among and within the aquifers, in geology, mineralogy, hydrology, and the effect of point and nonpoint sources of contamination. The data were grouped for the Wilcoxon Rank-Sum test (Helsel and Hirsch, 1992) to illustrate water-quality patterns in terms of the aquifers, geographic regions, and land use. In addition to the statistical analyses, three maps are included in this report that illustrate the spatial distribution and regional variations of selected constituents.

The Shapiro-Wilk test (Helsel and Hirsch, 1992) rejected (alpha = 0.05) the hypothesis of normality for all water-quality variables of interest to this study except for barium and the ratio of uranium 234:238. Therefore, nonparametric statistical analyses, which generally are not sensitive to outlying values and require less stringent assumptions, were used for data analyses. Nonparametric hypothesis tests on ranks were used to determine whether differences in medians between aquifers could be explained by random variability alone. The tests involved the formulation of null and alternate hypotheses, where the null hypothesis was that the populations were identical.

The Spearman rank correlation (Helsel and Hirsch, 1992), a nonparametric correlation procedure that involves ranks of data rather than the actual data values, was used to identify the degree of association among water-quality constituents in all aquifers. By using an alpha level of 0.001, the significance level, Spearman correlation coefficients (*r*) larger than 0.53 and smaller than -0.53 for a sample size of 35 and larger than 0.41 and smaller than -0.41 for a sample size of 59 were considered significantly correlated.

The large-sample-approximation Kruskal-Wallis test (Helsel and Hirsch, 1992) was used to determine whether differences existed between the water-quality variables in this study. The probability that represents the attained significance level (*p* value) is presented in the first column of table 17 at the end of the report. If the *p* value is smaller than or equal to a selected alpha value, the null hypothesis is rejected; hence, the distribution of concentrations was not the same in all aquifers. An alpha level of 0.05 for data interpretation is used in this report, except when otherwise noted.

Multiple-comparison procedures are used to compare all possible combinations of group medians, ranking the medians in order and indicating which are similar to or different from others. They are used only after the null hypothesis of distributions of concentrations of the Kruskal-Wallis test has been rejected. Thus, to determine which aquifers had differences in water-quality concentrations and to ensure unbiased selection of groups of aquifers for further testing, the nonparametric Tukey's test (Helsel and Hirsch, 1992), a multiple-comparison procedure, was used (table 18 at the end of the report).

Because Tukey's test considers data from all aquifers and groups these data without recognition of actual differences in hydrogeological conditions, the Wilcoxon Rank-Sum test was performed on data collected from groups of aquifers on the basis of Tukey's test and known geohydrologic differences between the aquifers (last four columns in table 17).

Other analyses included in this report are statistical summaries and boxplots. The boxplots are used to summarize graphically the variability of the constituents by aquifer. Skewness of the nonparametric data observed in the boxplots illustrates the asymmetric distribution of the data around a mean or median. Outliers, values located outside the boxes and whiskers of the boxplots, can be significant indicators of water quality because they could reflect unusual hydrologic conditions. A simple substitution method was used to include censored data, also called "less than," in the statistical analyses. All values less than the detection level were considered to be zero for the statistical summaries and boxplot illustrations. A computerized geographic information system was used to aid in the interpretation of the data and to display the spatial distributions of the data.

GROUND-WATER QUALITY

This section addresses the water quality (including selected nutrients, herbicides, major ions, metals, trace elements, and radionuclide activity or concentration) of principal aquifers used in the study area. The discussion focuses on the areal and vertical differences in water quality and describes suitability of use for drinking water and irrigation. To a limited extent the discussion also relates chemistry of the water to the minerals and organic material present in the soil and unsaturated and saturated deposits.

All water-quality data are reported in tables 9 and 10 at the end of the report. A statistical summary of the data by aquifer, using all parameters except ametryn, prometryn, and propazine data (analytes not detected in the water samples), is given in tables 11 through 16 (at the end of the report). Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs) established by the USEPA also are included in tables 11 through 16. The water-quality data collected as part of this investigation are contained in the USGS's National Water Information System (NWIS) and WATSTORE data bases.

Nitrate and Selected Herbicides

Nitrate

Part of the purpose of the reconnaissance study was to evaluate the effects of cropland application of nitrogen and herbicides on the water quality within the Papio-Missouri River NRD. NO_3-N, an anion prone to leaching, commonly is used as an indicator of ground-water contamination in areas of intensive agriculture because nitrogen fertilizer commonly is applied on agricultural land to enhance crop production. In addition, nitrogen fertilizer is used in urban areas on lawns and golf courses. Natural sources of NO_3-N are soil, organic nitrogen, animal and human wastes, roots, and plant residues. NO_3-N concentrations in water are affected by the reducing-oxidizing conditions existing in the aquifer. Under reducing conditions, denitrification could occur. Occurrences of denitrifying conditions have been suggested by Gormly and Spalding (1979) and Tanner and Steele (1991) in ground water along the Missouri River and by Spalding (1990) in ground water along the Elkhorn and Platte Rivers and the bottom lands between the Platte and Elkhorn Rivers in Douglas County. Spalding (1990) suggested that the presence of a large percentage of clay and carbon content indicated that denitrification, at least partially, affects the fate of nitrogen in the unsaturated zone even in areas with a shallow aquifer system. The presence of small dissolved-oxygen concentrations (less than 2 mg/L) in ground water of the Elkhorn, Missouri, and Platte River Valley alluvial aquifers (see section on "pH and dissolved oxygen") indicates that the conditions in the aquifer are favorable for denitrification.

The NO_3-N concentrations in this study varied from less than the detection level (0.05 mg/L) to 30 mg/L, with a median of 0.07 mg/L (table 11). The areal distribution of NO_3-N concentrations is illustrated in figure 12. Boxplots of the NO_3-N concentration distributions and well-depth distributions by aquifer are shown in figure 13. The summary statistics of NO_3-N concentrations for each aquifer and respective well depths are given in tables 11 through 16.

In general, NO_3-N concentrations in water sampled during this study were small. However, larger NO_3-N concentrations sometimes are found in shallow domestic wells (Conservation and Survey Division, 1986). Thirty-nine percent of the NO_3-N concentrations were less than the detection level of 0.05 mg/L. The smallest median NO_3-N concentration was in the Missouri River Valley alluvial aquifer (median concentration, less than 0.05 mg/L; maximum concentration, 1.4 mg/L). The Elkhorn River Valley alluvial aquifer (median NO_3-N concentration, 0.12 mg/L; maximum concentration, 1.9 mg/L) and the Platte River Valley alluvial aquifer (median NO_3-N concentration, 0.14 mg/L; maximum concentration, 1.5 mg/L) also had relatively small NO_3-N concentrations. Larger NO_3-N concentrations were detected in the upland area alluvial aquifers (median concentration, 0.20 mg/L; maximum concentration, 30 mg/L) and in the Dakota aquifer (median concentration, 0.80 mg/L; maximum concentration, 6.4 mg/L), even though they had the largest median well depths, 144 feet and 238 feet, respectively (tables 15 and 16). Significant differences in NO_3-N concentrations among the principal aquifers of the study area do not exist as determined by the Kruskal-Wallis test.

Ground water containing small NO_3-N concentrations also exhibited small dissolved-oxygen concentrations (less than 2 mg/L). This indicates that denitrification conditions could exist in some parts of aquifers. Pollution-potential maps (Spalding, 1990) indicate a large potential for nonpoint-source contamination near the confluence of the Platte and Missouri Rivers, along the western edge of Douglas and Sarpy Counties, and in southwestern and northeastern Washington County and a moderate potential for contamination along Papillion Creek, Bell Creek, and the Missouri River. These pollution-potential maps do not account for reducing-oxidizing and other chemical conditions in saturated and unsaturated sediment profiles.

The water-quality results of this reconnaissance study indicate that areas where large contamination potentials have been identified do not coincide with areas having large or moderate NO_3-N concentrations in ground water, a finding similar to that of Spalding (1990). Wells with water containing NO_3-N greater than 5 mg/L were located in areas of irrigated cropland on or near the upland areas. These areas were identified as moderately to slightly susceptible to NO_3-N contamination because they are found in areas with soil-permeability values generally as large as 2 inches per hour.

A positive correlation exists between NO_3-N and uranium (r=0.57, N=35 samples). In contrast, a negative correlation exists between NO_3-N and sulfate (r=-0.66, N=35 samples). These correlations could be associated with sediment and water interactions, local reducing-oxidizing conditions, agricultural practices such as addition of fertilizers, or could be coincidental.

The USEPA MCL of 10 mg/L for NO_3-N (U.S. Environmental Protection Agency, 1991a) was exceeded in water obtained from wells U5 (17 mg/L) and U11 (30 mg/L), both irrigation wells completed in the upland area alluvial aquifers. Water from well U9, a domestic well, had a NO_3-N concentration of 9.90 mg/L. These three wells vary from a depth of 56 (well U9) to 198 feet (well U11). The relatively large NO_3-N concentration in water from well U11 could indicate leakage of nitrogen species into the well because of failing well construction or could reflect nonpoint- or point-source contamination in the area (table 9).

Selected Triazine and Acetanilide Herbicides

Enzyme-assay testing for triazine and acetanilide herbicides and degradation products (61 water samples) resulted in detections in water samples from 22 wells. Follow-up quantitative analyses for the herbicides and degradation products resulted in herbicide detections in water from 16 wells (6 irrigation,

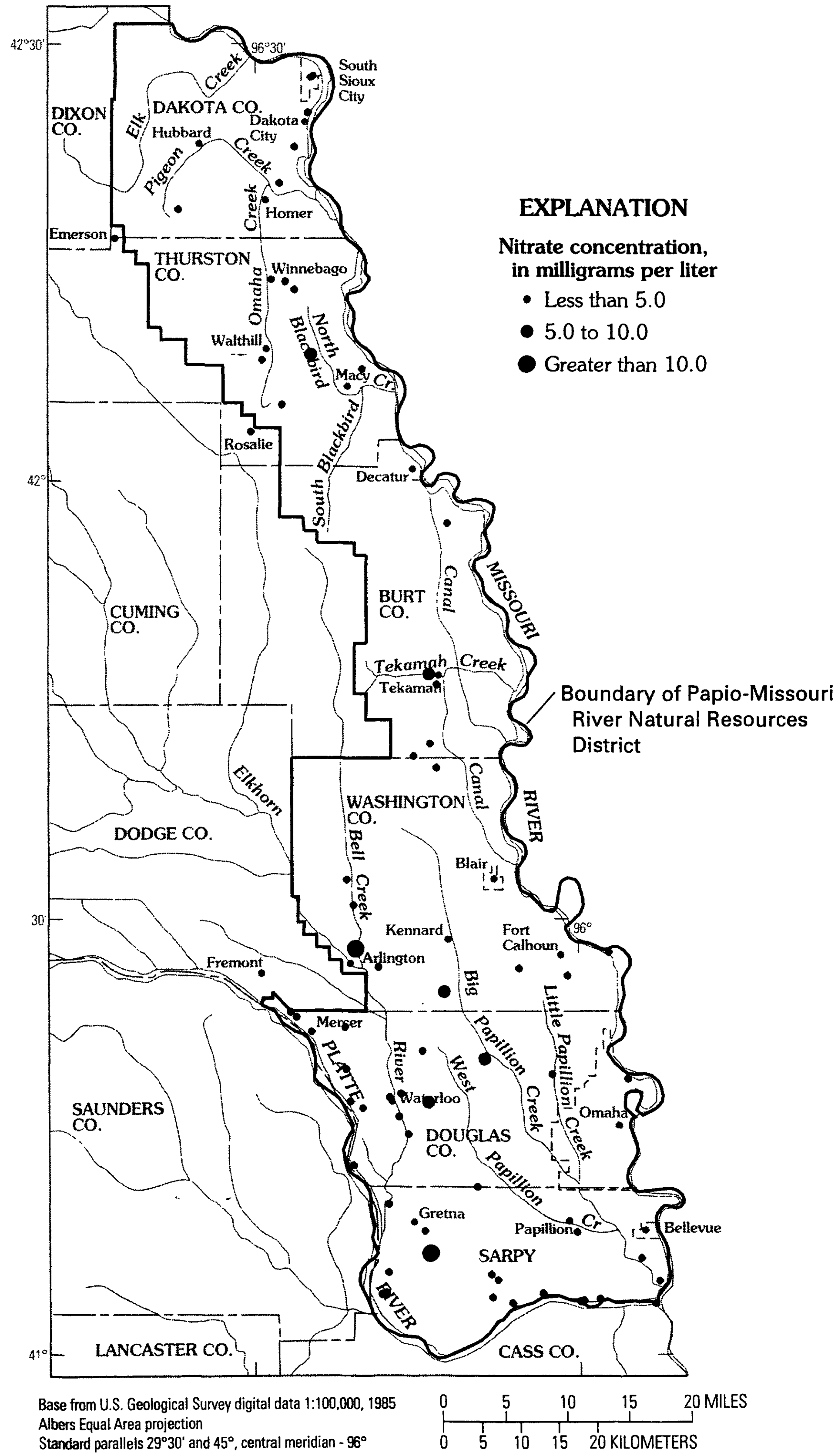


Figure 12. Dissolved-nitrate concentrations in ground water in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992.

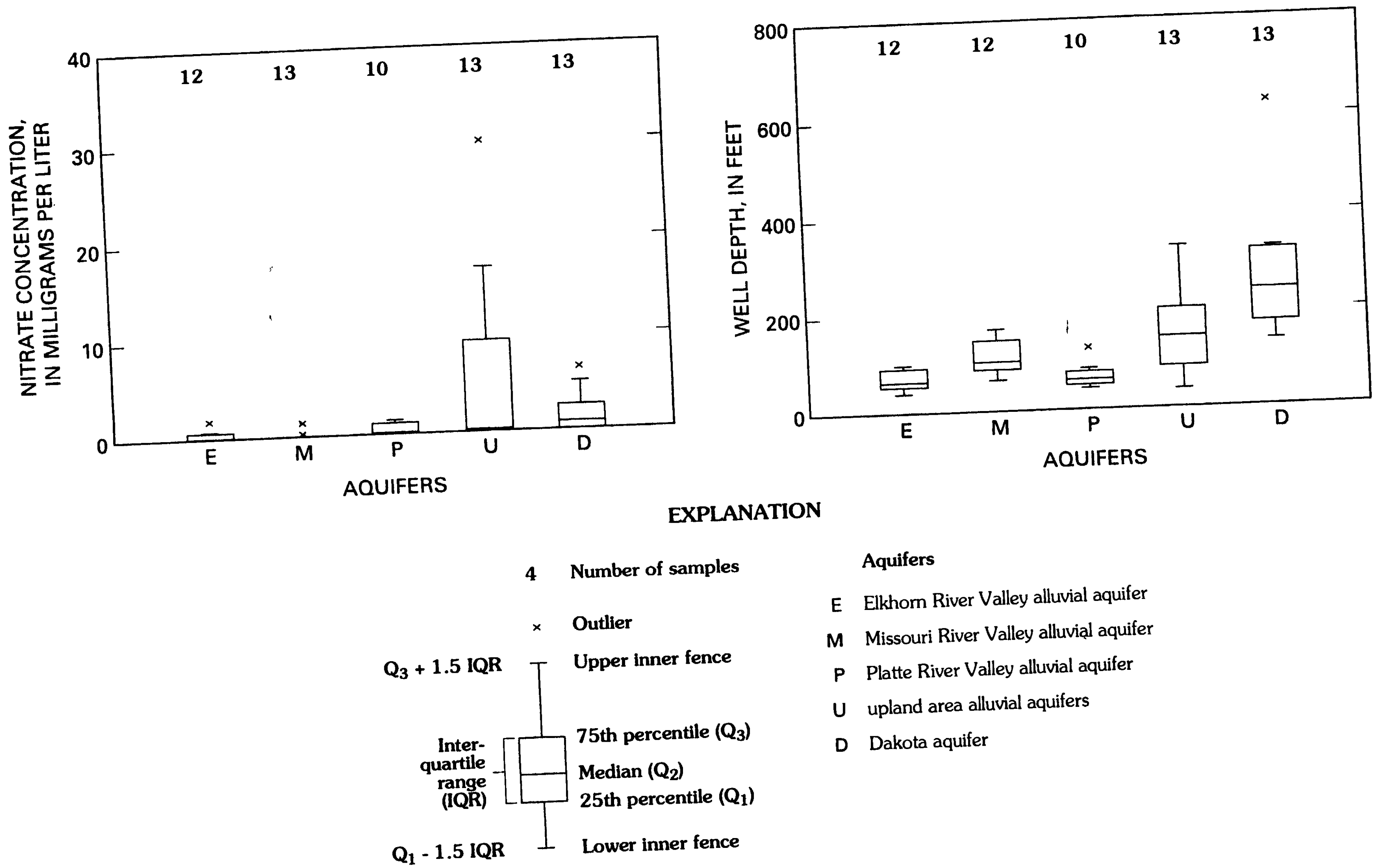


Figure 13. Distribution of dissolved-nitrate concentrations and well depth by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992.

9 municipal, and 1 industrial well) (fig. 14 and table 9). These were:

- One alachlor detection, with a concentration of 0.05 µg/L;
- Thirteen atrazine detections, with a maximum concentration of 1.8 µg/L;
- Five cyanazine detections, with a maximum concentration of 1.0 µg/L;
- Six deisopropylatrazine detections, with a maximum concentration of 0.29 µg/L;
- Nine deethylatrazine detections, with a maximum concentration of 0.26 µg/L;
- Six metolachlor detections, with a maximum concentration of 0.24 µg/L;
- One metribuzin detection, with a concentration of 0.07 µg/L;
- Six prometon detections, with a maximum concentration of 0.44 µg/L; and
- Two simazine detections, with a maximum concentration of 0.07 µg/L.

Summary statistics of all herbicides detected in at least one sample are listed in table 11. The minimum and median concentrations of all herbicides, except atrazine (median concentration is 0.14 µg/L), were less than the detection levels. All detections were less than the USEPA proposed MCLs of 2.0 µg/L for alachlor, 3.0 µg/L for atrazine, and 4.0 µg/L for simazine (U.S. Environmental Protection Agency, 1991a). The USEPA has not established MCLs for the remainder of the herbicides detected.

Herbicide detections were restricted to wells less than 100 feet deep, except well P10 with a depth of 126 feet, well M7 with a depth of 168 feet, and well U11 with a depth of 198 feet. Detections of herbicides appear to be restricted mainly to the Elkhorn and Platte River Valley alluvial aquifers, especially in wells near the river. In addition, prometon was detected in water from two wells (M6 and M7) completed in the Missouri River Valley alluvial aquifer and in water from one well (U11) completed in the upland area alluvial aquifers (table 9).

Herbicide concentrations detected in well water along the banks of the Platte River indicate that, at least locally, the Platte River could act as a line source of herbicides in areas where the hydraulic gradient favors loss of surface water to ground water in areas with extensive ground-water withdrawals near the well fields of the Omaha MUD and the City of Papillion. The areas where the Elkhorn and Platte River Valley alluvial aquifers are found are described as vulnerable to contamination by Spalding (1990). Information on actual herbicide inputs to the surface- and ground-water system would be important in helping to assess the potential for future herbicide contamination in these areas of the Papio-Missouri River NRD.

Detections of herbicides in water typically were not associated with occurrences of large NO_3-N concentrations in water from the same wells. This could be related to denitrification, which could have affected the NO_3-N concentrations in water samples from the Elkhorn and Platte River Valley alluvial aquifers but not the concentrations of the herbicides. Therefore, in this study area, the presence and concentration of herbicides—especially atrazine, its degradation products, metolachlor, and prometon—could be a better indication of the presence and extent of nonpoint-source contamination than concentrations of NO_3-N.

In water samples from wells having detections of atrazine and its degradation products, the concentrations of atrazine generally were the largest with intermediate deethylatrazine concentrations and small deisopropylatrazine concentrations. Both degradation products of atrazine are microbially mediated. The larger number of detections and the larger concentrations of deethylatrazine as compared to deisopropylatrazine are related to the relative stability of these degradation products under aqueous conditions.

Properties, Dissolved Solids, Major Ions, and Water Types

Specific Conductance and Dissolved Solids

Specific conductance of samples from all aquifers varied from 417 to 1,800 µS/cm (microsiemens per centimeter at 25 °C) (table 11), with a median of 710 µS/cm. Dissolved-solids concentration varied from 278 to 1,240 mg/L, with a median of 416 mg/L (table 11). Dissolved-solids concentration is a summation of concentrations of all constituents dissolved in water and is positively correlated with specific conductance (r=0.94) (fig. 15). Increased dissolved-solids concentration can arise from (1) mineral dissolution through increased leaching in irrigated areas, (2) dissolution of minerals in sediment and rocks that make up the aquifer, or (3) other unknown sources. Large specific conductance and dissolved-solids concentrations frequently were found in water from wells completed in the Missouri River

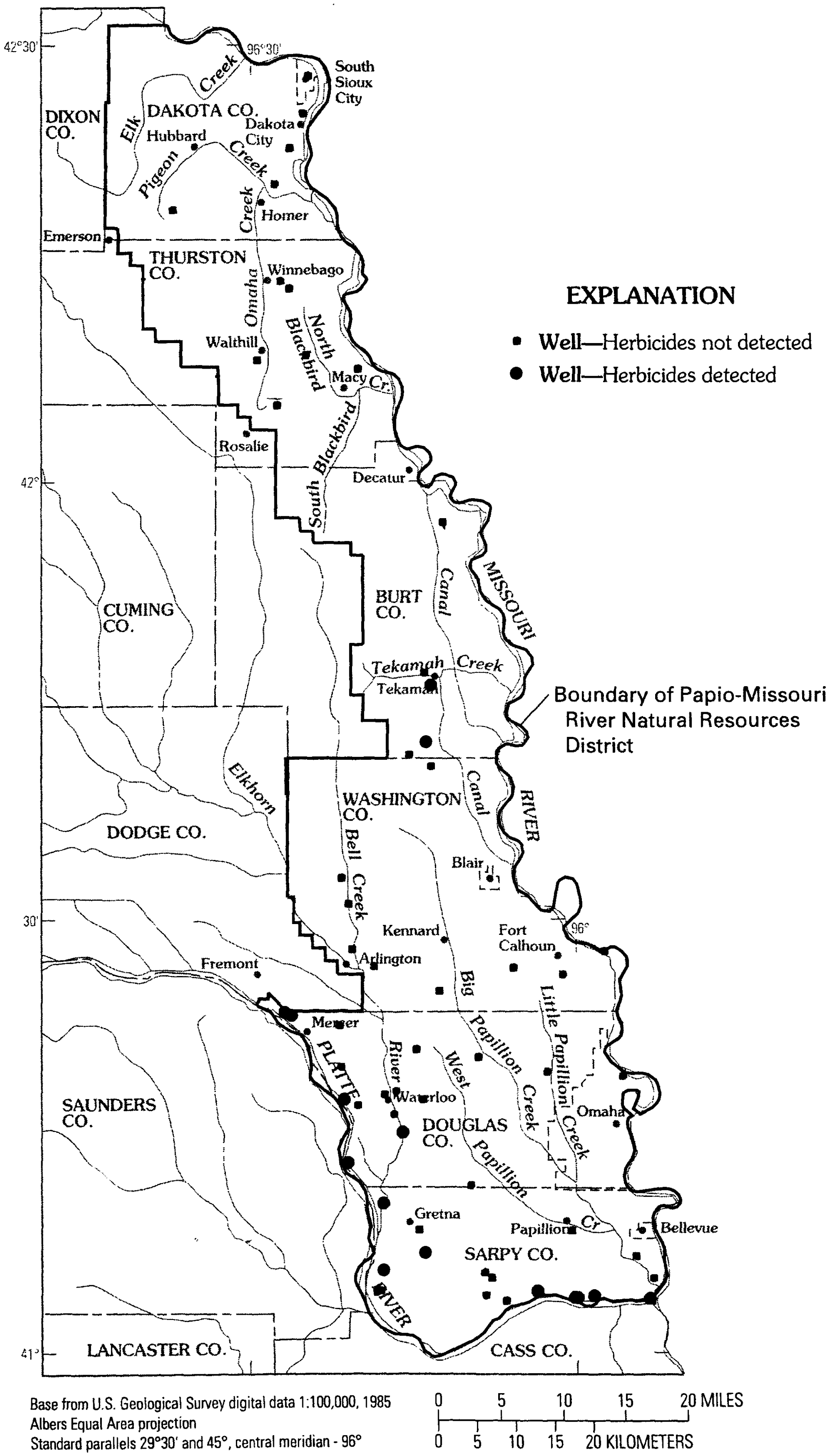


Figure 14. Location of sampled wells and wells with ground water containing detectable concentrations of alachlor, atrazine, cyanazine, deisopropylatrazine, deethylatrazine, metolachlor, metribuzin, prometon, or simazine, in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992.

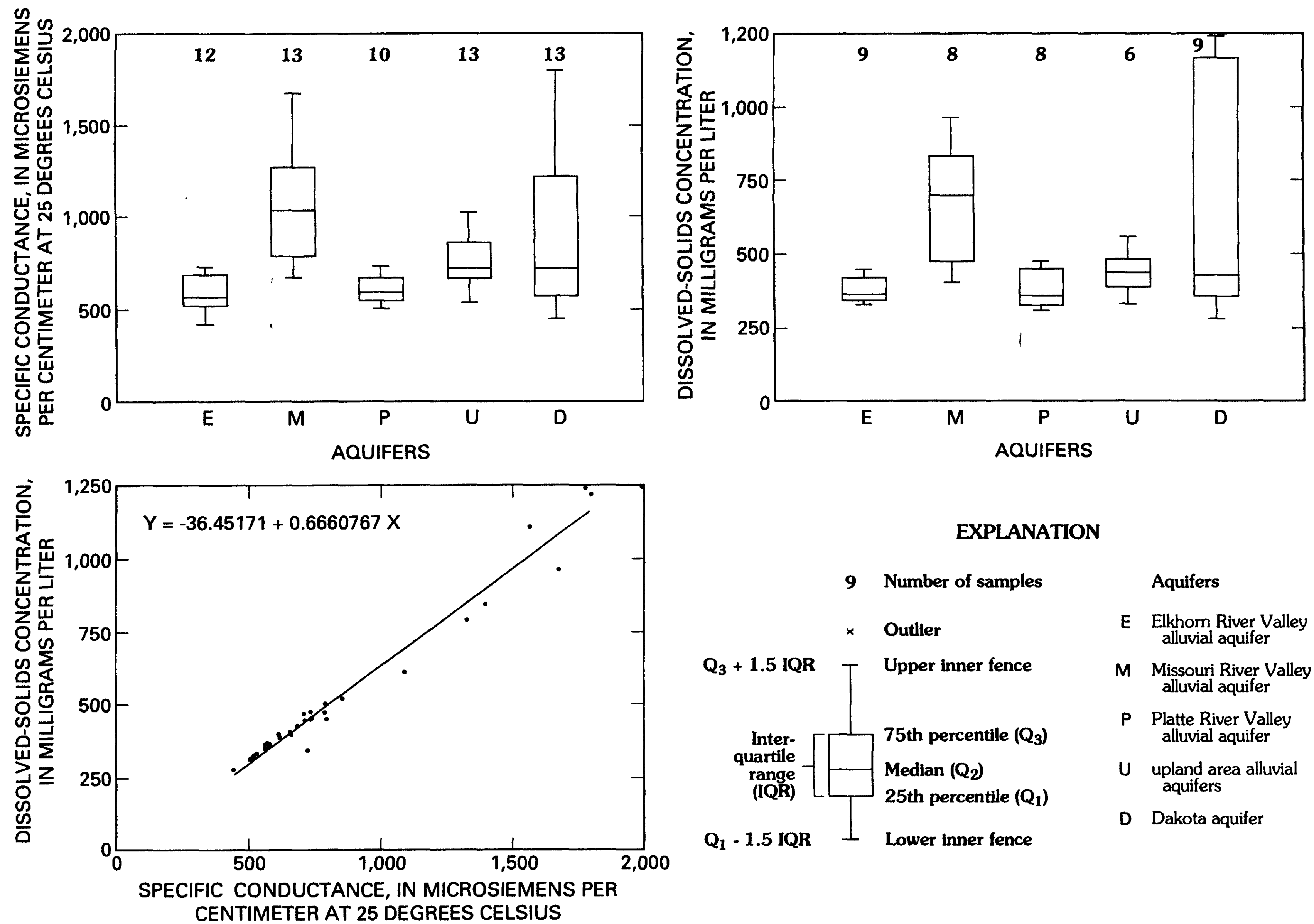


Figure 15. Distributions of specific conductance and dissolved-solids concentrations in ground-water samples by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and relation between dissolved-solids concentrations and specific conductance.

Valley alluvial aquifer and the Dakota aquifer (tables 13 and 16).

Specific conductance and dissolved-solids concentrations were positively correlated with alkalinity (r=0.63 and r=0.71), calcium (r=0.88 and r=0.83), magnesium (r=0.82 and r=0.79), and sulfate (r=0.54 and r=0.59) concentrations. Water from the Elkhorn and Platte River Valley alluvial aquifers (data combined) had significantly different median values of specific conductance (less than p=0.0001) and dissolved-solids concentration (p=0.0014) compared to water from the other principal aquifers (table 17). Water from the Missouri River Valley alluvial aquifer also had significant different median values of specific conductance (p=0.0001) and dissolved-solids concentrations (p=0.0029) compared to water in the other principal aquifers.

Water from a total of 10 wells completed in the Missouri River Valley alluvial aquifer (M1, M2, M9, M11, and M12), the upland area alluvial aquifers (U5), and the Dakota aquifer (D1, D2, D3, and D8), exceeded the SMCL of 500 mg/L for dissolved-solids concentration (U.S. Environmental Protection Agency, 1991d) (table 10). Water with dissolved-solids concentration greater than 1,000 mg/L (wells D1, D2, and D3) can adversely affect crops (Hem, 1985). These wells, located in Dakota and Thurston Counties, are completed in the Dakota aquifer in locations where this aquifer is thought to be hydraulically isolated from the Missouri River Valley or upland area alluvial aquifers based on well-log information. Also, water from these three wells had relatively larger calcium, chloride, iron, lithium, manganese, and strontium concentrations than water samples from the other principal aquifers.

pH and Dissolved Oxygen

pH in water from the principal aquifers varied from 6.3 to 7.9, with a median of 7.1 (table 11) (fig. 16). pH is an indication of the acidity of the water. Ground water with a pH from 6.5 to 7.8 is considered neutral (Hem, 1985). Water collected from municipal well P7 had an alkaline pH (pH = 7.9), and water collected from irrigation well E3 had an acidic pH (pH = 6.3) (table 9). One exceedance of the USEPA SMCL for pH of 6.5-8.5 (U.S. Environmental Protection Agency, 1991d) was detected in water from well E3.

Water from the Elkhorn and Platte River Valley alluvial aquifers had significantly different median field pH values (p=0.0067) than water from other aquifers (table 17). The smallest median pH was in water from the Dakota aquifer (pH=7.0) (table 16). A negative correlation of pH exists with calcium and magnesium (r=-0.58 and r=-0.54, respectively).

Dissolved-oxygen concentrations varied from 0.1 to 8.9 mg/L, with a median of 2.4 mg/L (table 11) (fig. 16). The smallest median dissolved-oxygen concentration was measured in water from the Missouri River Valley alluvial aquifer (0.2 mg/L) (table 13). The largest median dissolved-oxygen concentration was measured in water from the Dakota aquifer (4.0 mg/L) (table 16).

Dissolved oxygen was negatively correlated with sodium (r=-0.53, N=35 samples), sulfate (r=-0.73, N=35 samples), and positively with NO_3-N (r=0.51, N=39 samples). Thus, water with small dissolved-oxygen concentrations generally had small NO_3-N but large sulfate concentrations. Sulfate can form hydrogen sulfide gas under extreme reducing conditions. Apparently, extreme reducing conditions are not present in the aquifers studied.

Major Ions and Water Types

General Statistical Results

General statistical analyses, such as Spearman rank correlations, the Kruskal-Wallis test, and Tukey's multiple-comparison test, provide information about the relations among water-quality variables and about water-quality differences among the aquifers. Significant positive relations (N=35 samples) among the major ions were found for hardness, alkalinity, and magnesium with calcium (r=0.98, r=0.75, and r=0.86, respectively); alkalinity and hardness with magnesium (r=0.84 and r=0.93, respectively); sodium-adsorption ratio, potassium, sulfate, and chloride with sodium (r=0.94, r=0.58, r=0.74, and r=-0.54, respectively); sodium-adsorption ratio, sulfate, and chloride with potassium (r=0.60, r=0.60, r=0.66 respectively); hardness with alkalinity (r= 0.81); sulfate with chloride (r=0.56); and sodium-adsorption ratio with sulfate (r=0.58). Constituents with negative correlations were percent sodium with calcium (r= -0.56) and NO_3-N with sulfate (r= -0.66).

Significant positive and negative correlations among major ions result from interactions between solid and liquid phases in saturated and unsaturated media (Hem, 1985). The relation between the chemistry of liquid (water) and solid (geologic media)

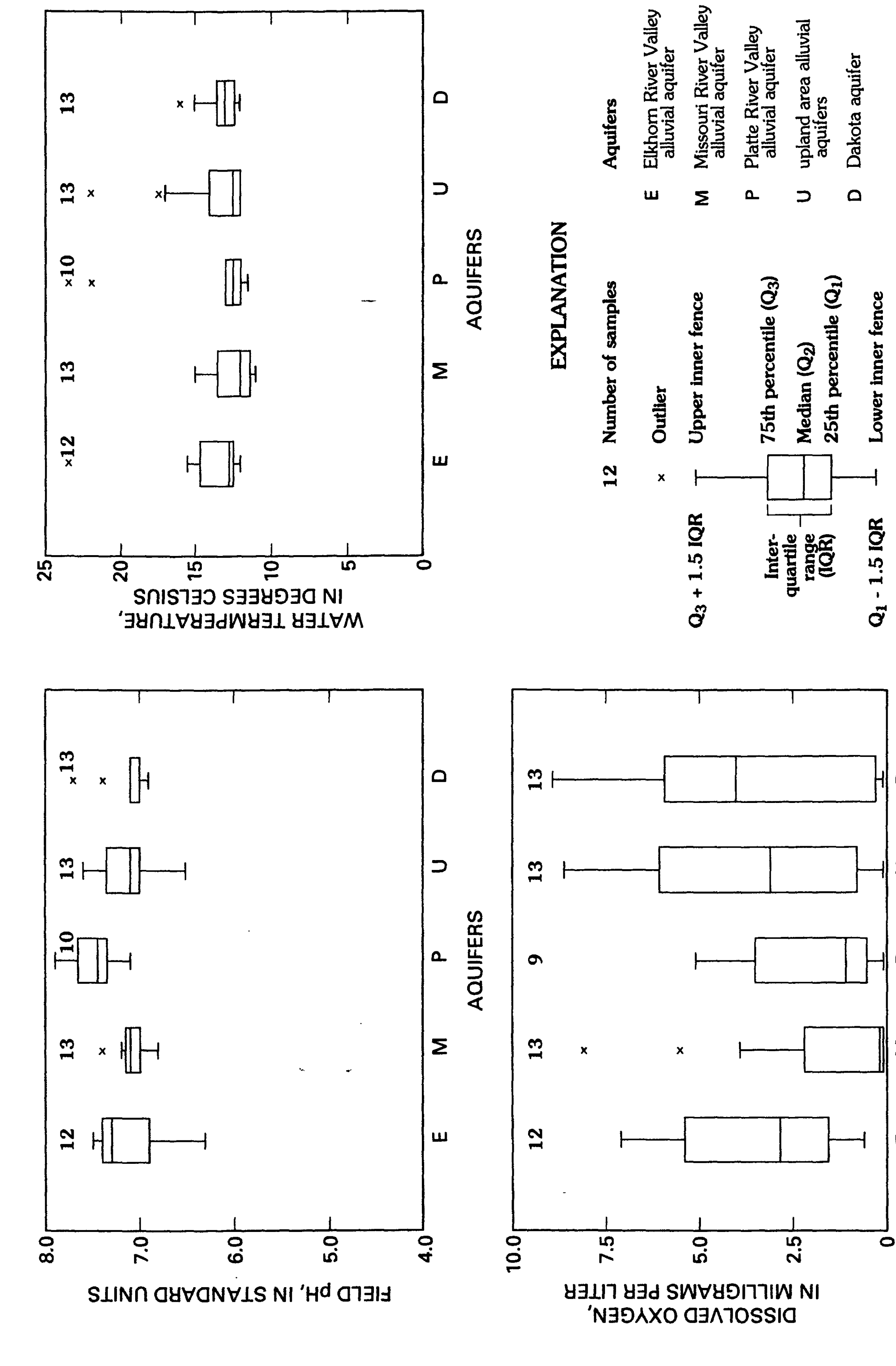


Figure 16. Distributions of field pH, water temperature, dissolved oxygen, hardness, alkalinity, calcium, magnesium, sodium, sodium-adsorption ratio, potassium, sulfate, chloride, fluoride, and silica by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992.

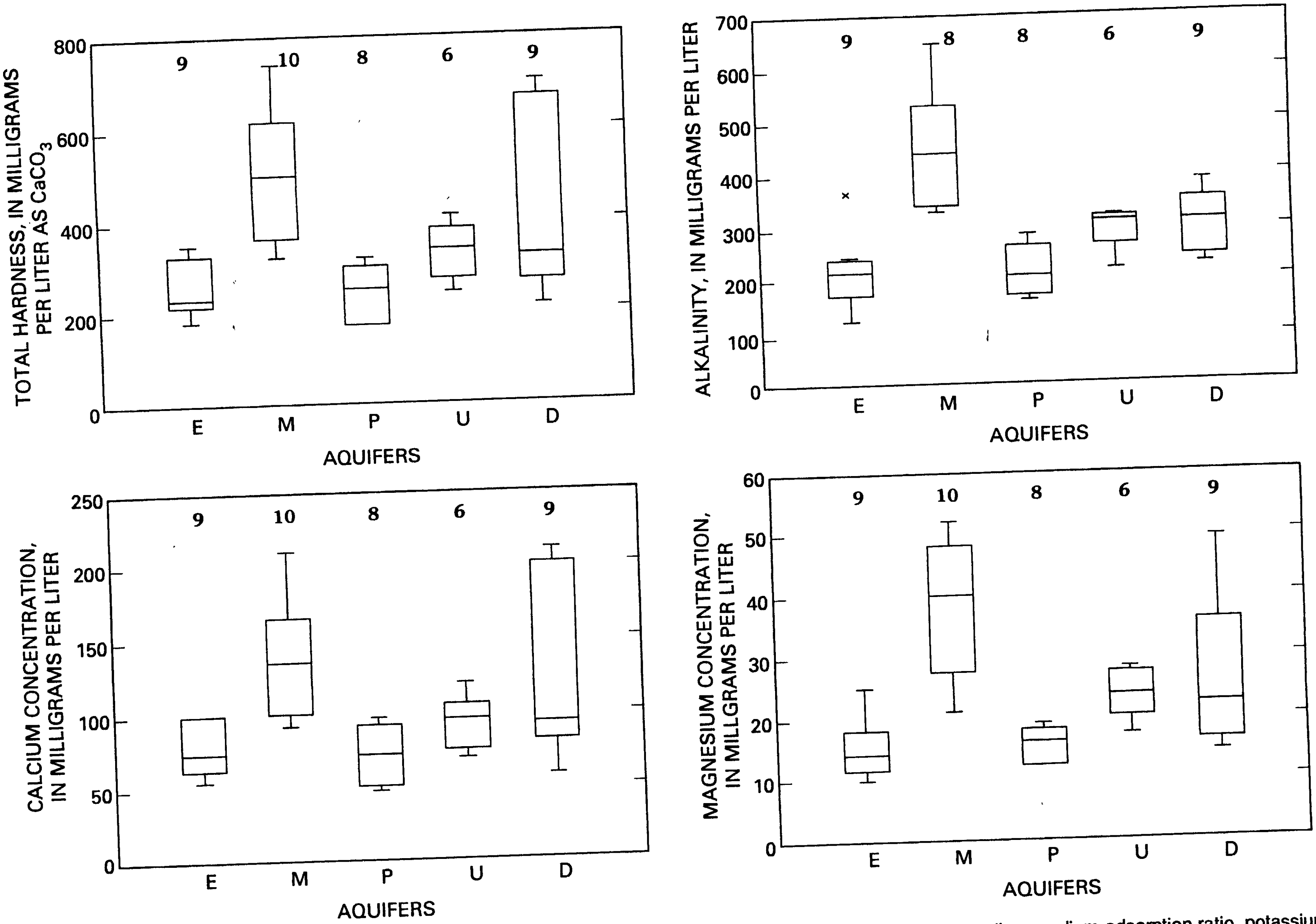


Figure 16. Distributions of field, pH, water temperature, dissolved oxygen, hardness, alkalinity, calcium, magnesium, sodium, sodium-adsorption ratio, potassium, sulfate, chloride, fluoride, and silica by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

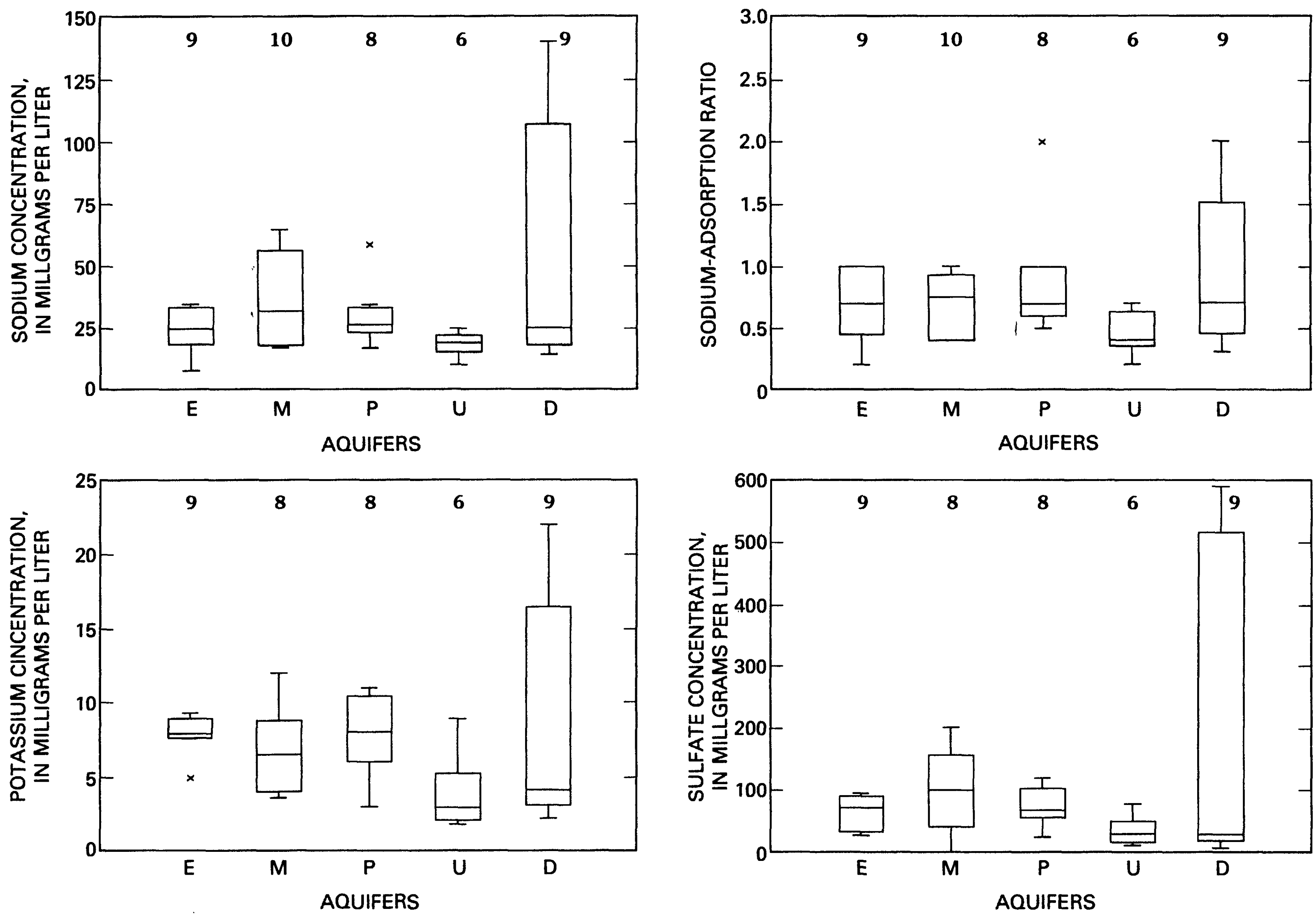


Figure 16. Distributions of field, pH, water temperature, dissolved oxygen, hardness, alkalinity, calcium, magnesium, sodium, sodium-adsorption ratio, potassium, sulfate, chloride, fluoride, and silica by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

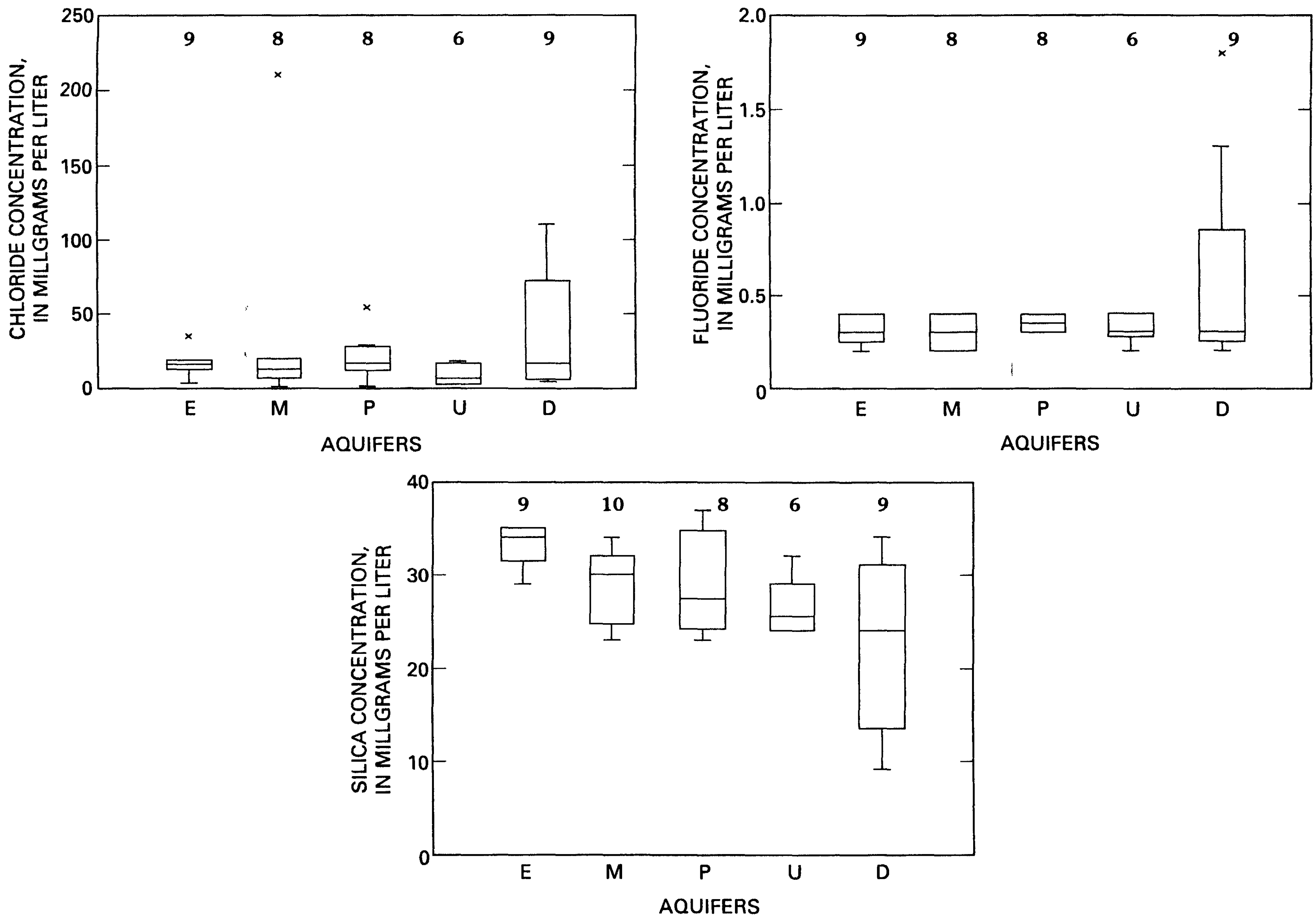


Figure 16. Distributions of field, pH, water temperature, dissolved oxygen, hardness, alkalinity, calcium, magnesium, sodium, sodium-adsorption ratio, potassium, sulfate, chloride, fluoride, and silica by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

phases depends upon the chemical and physical conditions present. For example, the negative correlation between NO_3-N and sulfate probably reflects the intensity of oxidizing or reducing conditions in the aquifers. Geochemical modeling, not within the scope of this study, would be useful to further address these relations.

The Kruskal-Wallis test indicates that at least one aquifer has different distributions of alkalinity (p=0.0001), dissolved solids (p=0.0093), calcium (p=0.0017), and magnesium (p=0.0001). Tukey's multiple-comparison test indicates that the upland area alluvial aquifers and the Dakota aquifer tend to have larger alkalinity than the other principal aquifers and that water from the Missouri River Valley and upland area alluvial aquifers and the Dakota aquifer tend to have larger dissolved-solids concentrations, calcium, and magnesium concentrations than the remaining principal aquifers. Grouping of the data and analyses with the Wilcoxon Rank-Sum test indicates that the Elkhorn and Platte (smallest medians) and the Missouri (largest median) River Valley alluvial aquifers have significantly different concentrations of dissolved solids, calcium, and magnesium.

Summary of Water Chemistry and Water Types by Aquifer

Water types are used in this report to designate differences in the ionic composition of water of the principal aquifers in this study. The chemistry of the water changes as it moves from recharge areas through the ground-water-flow system and interacts with sediment. Dissolved-solids concentrations tend to increase with the length of the flow paths and the age of the water. Dissolved-solids concentrations also tend to increase in irrigated areas because of the effects of irrigation return flow, especially concentrations of sulfate and chloride (Hem, 1985). The trilinear diagrams in figure 17 reflect the predominant cation(s) and anion(s) of the principal aquifers in the study area (Piper, 1944). In general, water from the principal aquifers in the study area was a calcium bicarbonate type and was hard [median hardness value, 320 mg/L as $CaCO_3$ (calcium carbonate)] (table 11).

The following sections describe the water quality by aquifer and include a summary of water chemistry, water types, and number of constituent concentrations that exceed MCLs and SMCLs. A summary of the constituents discussed in this section and number of constituent concentrations that exceed MCLs and SMCLs are given in tables 11 through 16. Boxplots that show the distributions of pH, water temperature, dissolved oxygen, hardness, alkalinity, calcium, magnesium, sodium, sodium-adsorption ratio, potassium, sulfate, chloride, fluoride, and silica are given in figure 16.

Elkhorn River Valley Alluvial Aquifer

Water in the Elkhorn River Valley alluvial aquifer was a calcium bicarbonate type (fig. 17A). Water collected from this aquifer had the largest median silica concentration (34 mg/L as SiO_2) but the smallest median hardness value (230 mg/L as $CaCO_3$). Water from both the Elkhorn and Platte River Valley alluvial aquifers had the largest median potassium concentrations (7.9 and 8.0 mg/L, respectively).

Water from the Elkhorn and Platte River Valley alluvial aquifers had similar calcium and magnesium chemistry as indicated by the boxplots in figure 16 and by multiple-comparison procedures (tables 17 and 18). In addition, water from the Elkhorn and Platte River Valley alluvial aquifers (data combined) had significantly different hardness (p=0.0001), alkalinity (less than p=0.0001), dissolved solids (p=0.0014), calcium (p=0.0003), magnesium (less than p=0.0001), and silica (p=0.005) than water from the other aquifers in this study (table 17). The smaller concentrations of calcium and magnesium in the Elkhorn and Platte River Valley alluvial aquifers can be related to the sand and gravel matrix of these aquifers. These aquifers have limited amounts of calcite cement, and water in these aquifers has a relatively small residence time as compared to the other principal aquifers.

Missouri River Valley Alluvial Aquifer

As discussed by Tanner and Steele (1991), the Missouri River Valley alluvial aquifer tends to have a different aqueous chemistry than other shallow aquifers in eastern Nebraska. The water from this aquifer generally was a calcium bicarbonate type and, locally, a calcium magnesium bicarbonate type (fig. 16B).

Water from the Missouri River Valley aquifer had the largest median hardness value (500 mg/L as $CaCO_3$), alkalinity value (438 mg/L as $CaCO_3$), and calcium (135 mg/L), magnesium (40 mg/L), sodium (32 mg/L), and sulfate (99 mg/L) concentrations. Water from wells M1, M2, M9, and M11 had sulfate concentrations greater than 100 mg/L (200, 140, 110, and 160 mg/L, respectively). One large chloride concentration in water from well M11 (210 mg/L) is

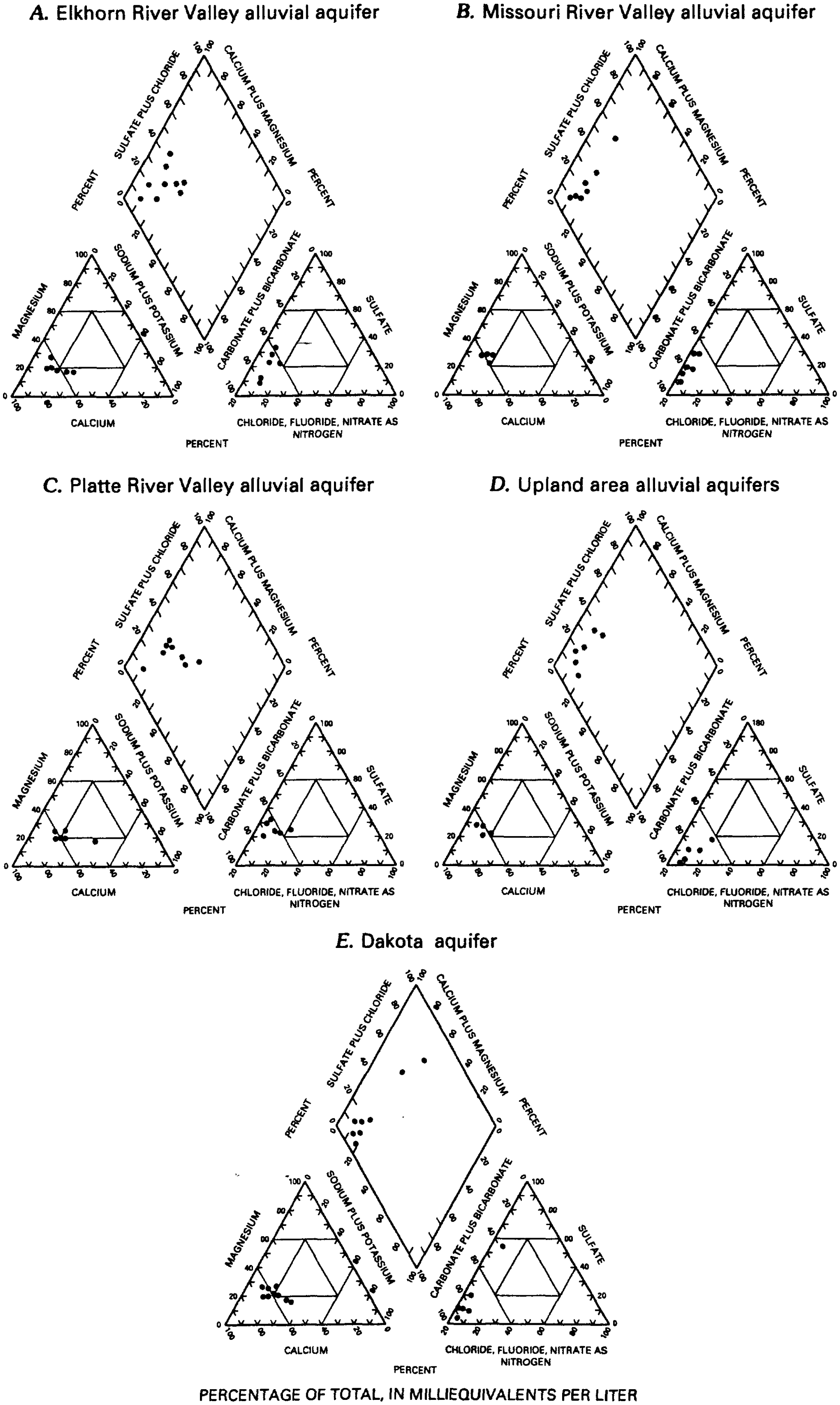


Figure 17. Ionic compositions of ground water by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska.

noteworthy. This well is an industrial well used for cooling. A salt and sand company is located 1,000 feet northwest of this well.

The large calcium and, to some extent, magnesium concentrations in water from the Missouri River Valley alluvial aquifer could be related to the abundance of lime in many soil profiles of the Albaton-Haynie-Sarpy Association along the Missouri River or in the aquifer materials. Significant differences exist in hardness values (p=0.0005), alkalinity values (p=0.0001), and dissolved-solids (p=0.0029), calcium (p=0.0009), and magnesium (p=0.0001) concentrations as compared to the chemistry of water from the other aquifers (table 17).

Platte River Valley Alluvial Aquifer

As mentioned previously, the Elkhorn and Platte River Valley alluvial aquifers exhibited similar calcium and magnesium water chemistry. Water from the Platte River Valley alluvial aquifer was a calcium bicarbonate type (fig. 17C). Water from this aquifer had the largest median pH (7.5) and fluoride (0.40 mg/L) concentration and the smallest median alkalinity value (204 mg/L as $CaCO_3$) and calcium (72mg/L) concentration. Alkalinity values and dissolved-solids, calcium, and magnesium concentrations in water from the Platte and Elkhorn River Valley alluvial aquifers differ significantly from the water of the other principal aquifers in the area (table 17).

Upland Area Alluvial Aquifers

Generally, the upland area alluvial aquifers have a major ion chemistry similar to the water collected from the Dakota aquifer, except where the Dakota aquifer is not in hydraulic connection with the upland area alluvial aquifers, such as in northern Dakota County. The water from these aquifers was generally a calcium bicarbonate type (fig. 17D). Water from the upland area alluvial aquifers had the smallest median sodium-adsorption ratio (0.4), and smallest median concentrations of sodium (19 mg/L), potassium (3.0 mg/L), and chloride (6.2 mg/L) as compared to the water from the other principal aquifers (tables 12-16). Statistically significant differences were not noted in the water quality from this aquifer as compared to the other principal aquifers.

Dakota Aquifer

The Dakota aquifer has a variable major ion chemistry. Although most samples collected from the Dakota aquifer contained a calcium bicarbonate type water, two samples (from wells D2 and D3) contained a calcium sulfate type water, and one sample (from well D1) exhibited an intermediate chemistry (fig. 17E). Three samples from the Dakota aquifer (from wells D1, D2, and D3) had sulfate concentrations of 470, 590, and 560 mg/L. These samples exceeded the USEPA SMCL for sulfate of 250 mg/L (table 10) (U.S. Environmental Protection Agency, 1991d).

Water from the Dakota aquifer had the largest median dissolved-oxygen concentration (4.0 mg/L) and water temperature (13.0 °C) and the smallest median sulfate (27 mg/L) and silica (24 mg/L) concentrations of all aquifers sampled. Statistically significant differences were not noted in the water quality from this aquifer as compared to the other principal aquifers, except for silica (p=0.0295).

Selected Metals and Trace Elements

Metals and trace elements in ground water can be attributed to both natural and human sources. Potential natural sources of metals and trace elements are sediment, precipitation, and surface water. Potential human sources are acid rain, fertilizers and pesticides, and industry-related activities. Trace elements were not detected in many water samples (table 10). Boxplots showing the distribution of arsenic, barium, boron, iron, lithium, manganese, selenium, strontium, and zinc concentrations are given in figure 18.

Arsenic concentrations varied from less than 1 to 14 µg/L in water from all aquifers, and iron concentrations varied from less than 3 to 17,000 µg/L, with a median concentration of 130 µg/L (table 11). The smallest arsenic concentrations were detected in water from the upland area alluvial and Dakota aquifers and varied from less than 1 to 2 µg/L. The smallest iron concentrations were detected in water from the upland area alluvial aquifers and varied from less than 3 to 66 µg/L. The largest median and maximum arsenic and iron concentrations (5 and 14 µg/L and 6,000 and 17,000 µg/L) were found in water from the Missouri River alluvial aquifer. The Platte River Valley alluvial aquifer also had a median arsenic concentration of 5 µg/L. Water from the Dakota aquifer tended to have small barium concentrations, and water from the

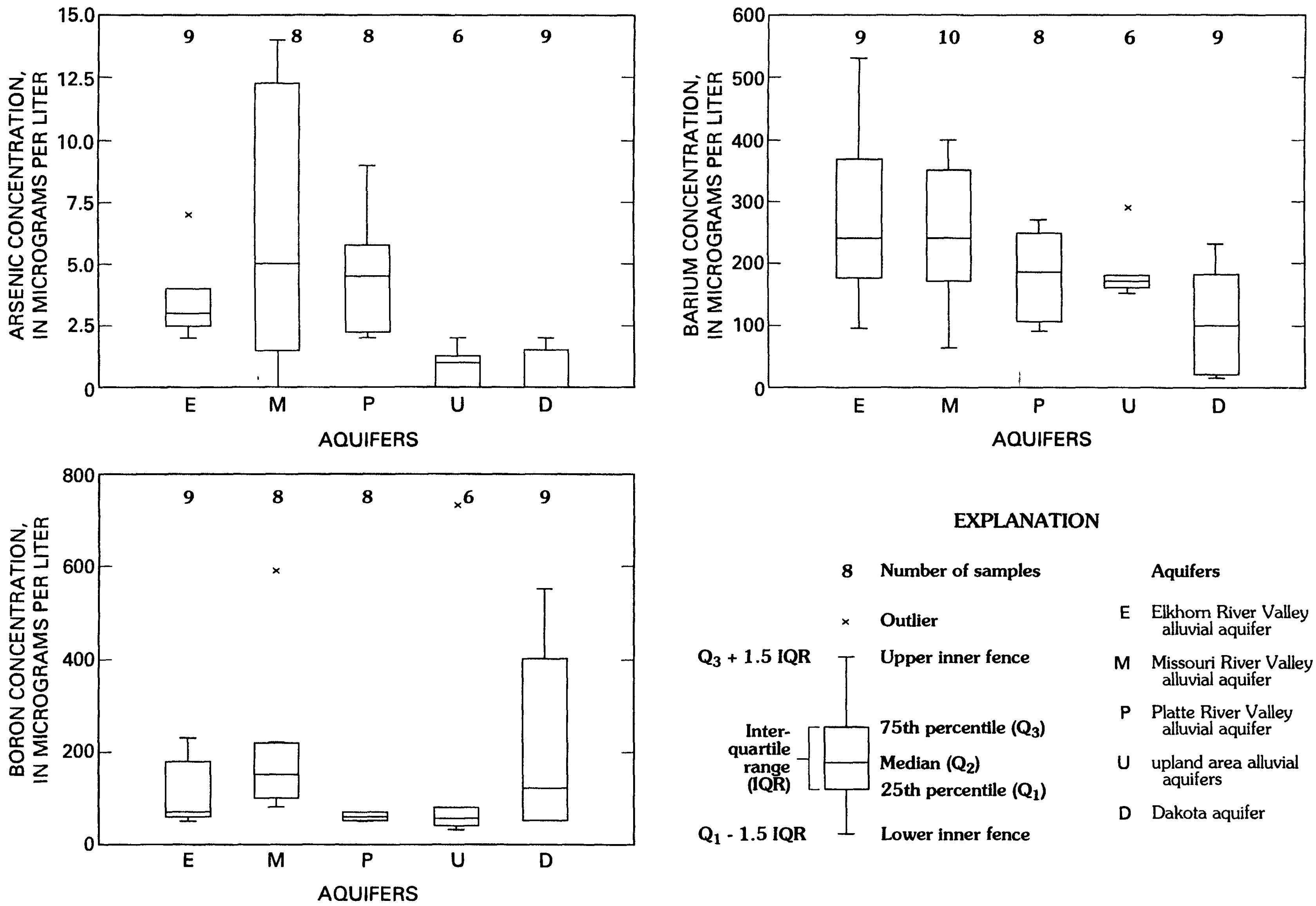


Figure 18. Distributions of selected metals and trace elements by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992.

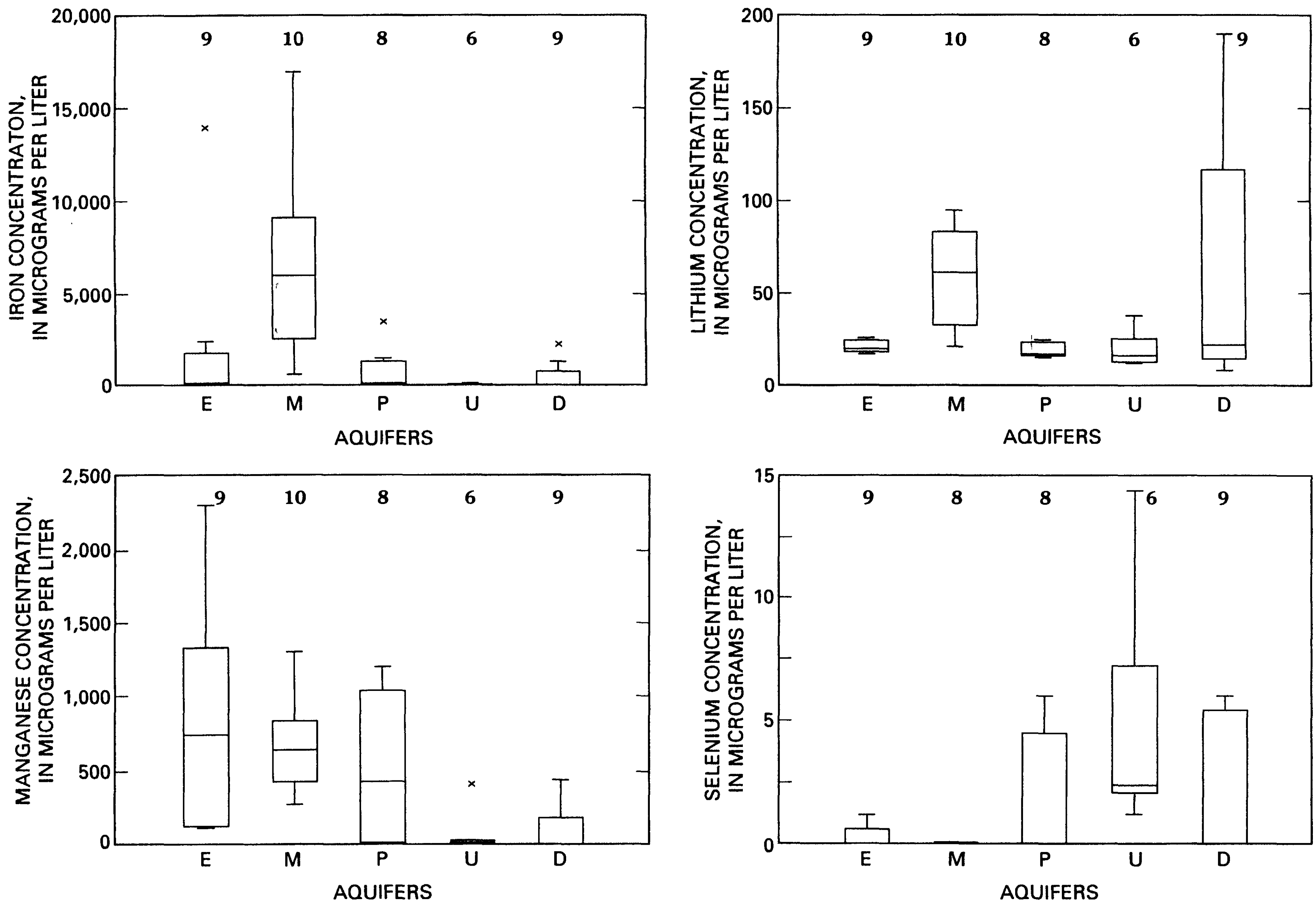


Figure 18. Distributions of selected metals and trace elements by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued.

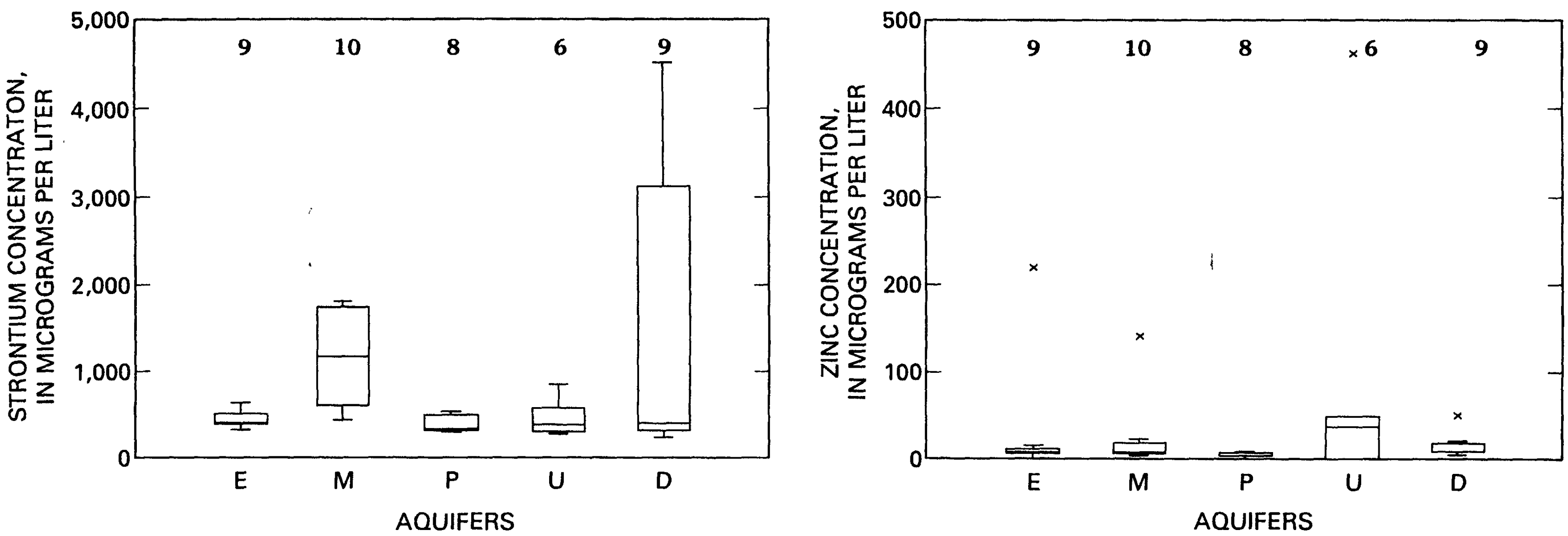


Figure 18. Distributions of selected metals and trace elements by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued.

upland area alluvial aquifers tended to have small arsenic, iron, and manganese, but large selenium concentrations (fig. 18). Water from the Missouri River Valley alluvial aquifer had the largest median concentrations of lithium (62 µg/L) and strontium (1,200 µg/L).

The USEPA MCLs for arsenic (50 µg/L), barium (2,000 µg/L), beryllium (4 µg/L), cadmium (5 µg/L), chromium (100 µg/L), nickel (100 µg/L), and selenium (50 µg/L) (U.S. Environmental Protection Agency, 1991a) were not exceeded. The USEPA SMCL of 300 µg/L for iron (U.S. Environmental Protection Agency, 1991d) was exceeded in 19 of 42 samples. Exceedances of the SMCL for iron were found in 4 of 9 samples collected from wells completed in the Elkhorn River Valley alluvial aquifer, in all 10 samples from wells completed in the Missouri River Valley alluvial aquifer, in 3 of 8 samples collected from wells completed in the Platte River Valley alluvial aquifer, in none of the 6 samples from the upland area alluvial aquifers, and in 2 of 9 samples collected from wells completed in the Dakota aquifer (tables 10, 12–16).

The USEPA SMCL of 50 µg/L for manganese was exceeded in 29 of 42 samples (U.S. Environmental Protection Agency, 1991d). Exceedances of this SMCL were found in all 9 samples collected from wells completed in the Elkhorn River Valley alluvial aquifer, all 10 samples from wells completed in the Missouri River Valley aquifer, 5 of 8 samples collected from wells completed in the Platte River Valley alluvial aquifer, 1 of 6 wells completed in the upland area alluvial aquifers, and 4 of 9 samples collected from wells completed in the Dakota aquifer (tables 10, 12–16).

Spearman rank correlation analyses indicate a positive correlation among concentrations of iron, lithium, manganese, selenium, and strontium. NO_3-N concentrations were correlated negatively with iron (r=0.72), lithium (r=-0.54), and manganese (r=-0.73) concentrations and positively correlated with selenium (r=0.81) concentrations. These relationships are to be expected as iron and manganese tend to be in solution under reducing conditions when dissolved-nitrate concentrations are small and selenium tends to be in solution under oxidizing conditions when dissolved-nitrate concentrations are large.

Nonparametric analysis of the metals and trace elements (alpha=0.05) by aquifer with the Kruskal-Wallis test showed that at least one aquifer had different distributions of arsenic (p=0.0007), barium (p=0.0372), iron (p=0.0002), lithium (p=0.0067), manganese (p=0.0007), selenium (p=0.0259), and strontium (p=0.0067) between aquifers. Differences in water quality by aquifer (table 17) also were found in water from:

The Elkhorn and Platte River Valley alluvial aquifers, which had significantly different arsenic (p=0.0090), manganese (p=0.0285), and strontium (p=0.0404) concentrations than the other aquifers;

The Missouri River Valley alluvial aquifer, which had significantly different concentrations of arsenic (p=0.0461), iron (less than p=0.0001), lithium (p=0.0007), manganese (p=0.0239), selenium (p=0.0425), and strontium (p=0.0007) than the other aquifers;

The upland area alluvial aquifers, which had significantly different concentrations of arsenic (p=0.0309), iron (p=0.0225), manganese (p=0.0153), and selenium (p=0.0076) than the other aquifers; and

The Dakota aquifer, which had significantly different concentrations of arsenic (p=0.0016), barium (p=0.0058), iron (p=0.0344), and manganese (p=0.0038) than the other aquifers.

Radionuclide Activity or Concentration

Radionuclides are chemical elements that undergo a spontaneous nuclear decay process. These changes produce alpha, beta, and gamma types of ionizing radiation. Variations in the distribution of radionuclides in ground water are related not only to the natural presence of radionuclides in sediment but also are affected by human factors. Human factors include coal, oil-and-gas, and nuclear-power combustion or production; mining; chemical fertilizer application (especially phosphates); and transport and disposal of radioactive materials. Fertilizer can be enriched with uranium and potassium salts (Meriwether and others, 1988). Radionuclide concentrations in water are determined by many factors, including the radionuclide concentration and distribution in the source rock; its chemical form; water chemistry such as pH, oxidation-reduction potential, and presence of complexing agents; microbial activity; half-life of the nuclide (which is the time required for one-half of the amount of nuclide to decay); and the presence of sorptive materials (Hem, 1985).

Radionuclide activity generally is expressed in pCi/L (picocuries per liter). One curie is defined as 3.7×10^{10} disintegrations per second. A picocurie is 10^{-12} curies. This study reports gross alpha (α) activity (alpha activity from all sources) as if it is thorium-230 (^{230}Th), gross beta (β) activity (beta activity from all sources) as if it is strontium-90 (^{90}Sr), radon-222 (^{222}Rn) activity, radium-226 (^{226}Ra) activity, total uranium concentration, and the ratio of uranium-238 (^{238}U) activity to uranium-234 (^{234}U) activity. Summary statistics for the radionuclide data are given in tables 11 through 16 and illustrated in figure 19. Selected significant (p less than 0.001) Spearman correlation coefficients are listed in the text.

Significant correlations (N=35 samples) existed for sodium, sodium-adsorption ratio, potassium, sulfate, and chloride with gross beta activity (r=0.60, r=0.64, r=0.60, r=0.61, and r=0.59, respectively), for uranium with gross alpha activity (r=0.72), for specific conductance with radium-226 (r=0.57), and for NO_3-N with total uranium (r=0.57). Further examination of these relations could be accomplished through geochemical modeling.

Gross Alpha and Beta Activities

The gross alpha activity in ground-water samples from all principal aquifers in the study area varied from 0.8 to 16 pCi/L as ^{230}Th, and gross beta activity varied from 3.2 to 30 pCi/L as ^{90}Sr (table 11). The Wilcoxon Rank-Sum test indicates that the gross alpha activity in water from the Missouri River Valley alluvial aquifer (p=0.0044) and from the Dakota aquifer (p=0.0480) differed significantly from that in the other principal aquifers and that gross beta activity in water from the Elkhorn and Platte River Valley alluvial aquifers (p=0.0129) and the upland area alluvial aquifers (p=0.0097) also differed significantly from that in the other principal aquifers (table 17).

Water from the Dakota aquifer had the largest median gross alpha activity (5.7 pCi/L as ^{230}Th) and the largest gross alpha activity (16 pCi/L as ^{230}Th). Water from the Missouri River Valley alluvial aquifer had the smallest median gross alpha activity (2.7 pCi/L as ^{230}Th). Water from the upland area alluvial aquifers had the smallest median gross beta activity (4.5 pCi/L as ^{90}Sr). Water from the Elkhorn and Platte River Valley alluvial aquifers had the largest median gross beta activities (9.9 and 9.4 pCi/L as ^{90}Sr, respectively). The largest gross beta activities were found in water from wells D2 and D3 completed in the Dakota aquifer (both with 30 pCi/L as ^{90}Sr).

Water from one well exceeded the USEPA MCL of 15 pCi/L for gross alpha activity (well D2 with 16 pCi/L as ^{230}Th) (U.S. Environmental Protection Agency, 1991a). These results might indicate that, in areas where the Dakota aquifer is not in hydraulic connection with the upland area alluvial aquifers, water from the Dakota aquifer locally could exceed the MCL for gross alpha activity.

Radon-222 Activity

Radon-222 is a naturally occurring, radioactive gas, which is a degradation product in the uranium-238 decay chain. Radon-222 has a half-life of 3.8 days (Hem, 1985). The mobility of radon-222 is affected by physical processes. It can be adsorbed by organic matter and is soluble in water and organic liquids, but it readily degases from water into the atmosphere because of its small partial pressure in air.

The activities of radon-222 measured in this study varied from 97 to 1,200 pCi/L as ^{222}Rn, with a median activity of 360 pCi/L as ^{222}Rn (table 11, fig. 20). Statistically, radon-222 activities of water from the aquifers did not differ (table 17).

Water from 26 of 40 wells (tables 12–16) completed in all aquifers exceeded the proposed USEPA MCL for radon-222 of 300 pCi/L as ^{222}Rn (U.S. Environmental Protection Agency, 1991e). These exceedances included:

Six of nine wells completed in the Elkhorn River Valley alluvial aquifer (wells E1, E6, E8, E9, E11, and E12);

Three of nine wells completed in the Missouri River Valley alluvial aquifer (wells M1, M2, and M10);

Six of eight wells completed in the Platte River Valley alluvial aquifer (wells P1, P3, P5, P6, P7, and P10);

All six wells completed in the upland area alluvial aquifers (wells U2, U5, U8, U9, U11, and U13); and

Five of eight wells completed in the Dakota aquifer (wells D6, D8, D9, D11, D12).

The largest radon-222 activities were found in water from wells U2 and U5 in the upland area alluvial aquifers (1,200 and 900 pCi/L as ^{222}Rn) (table 10).

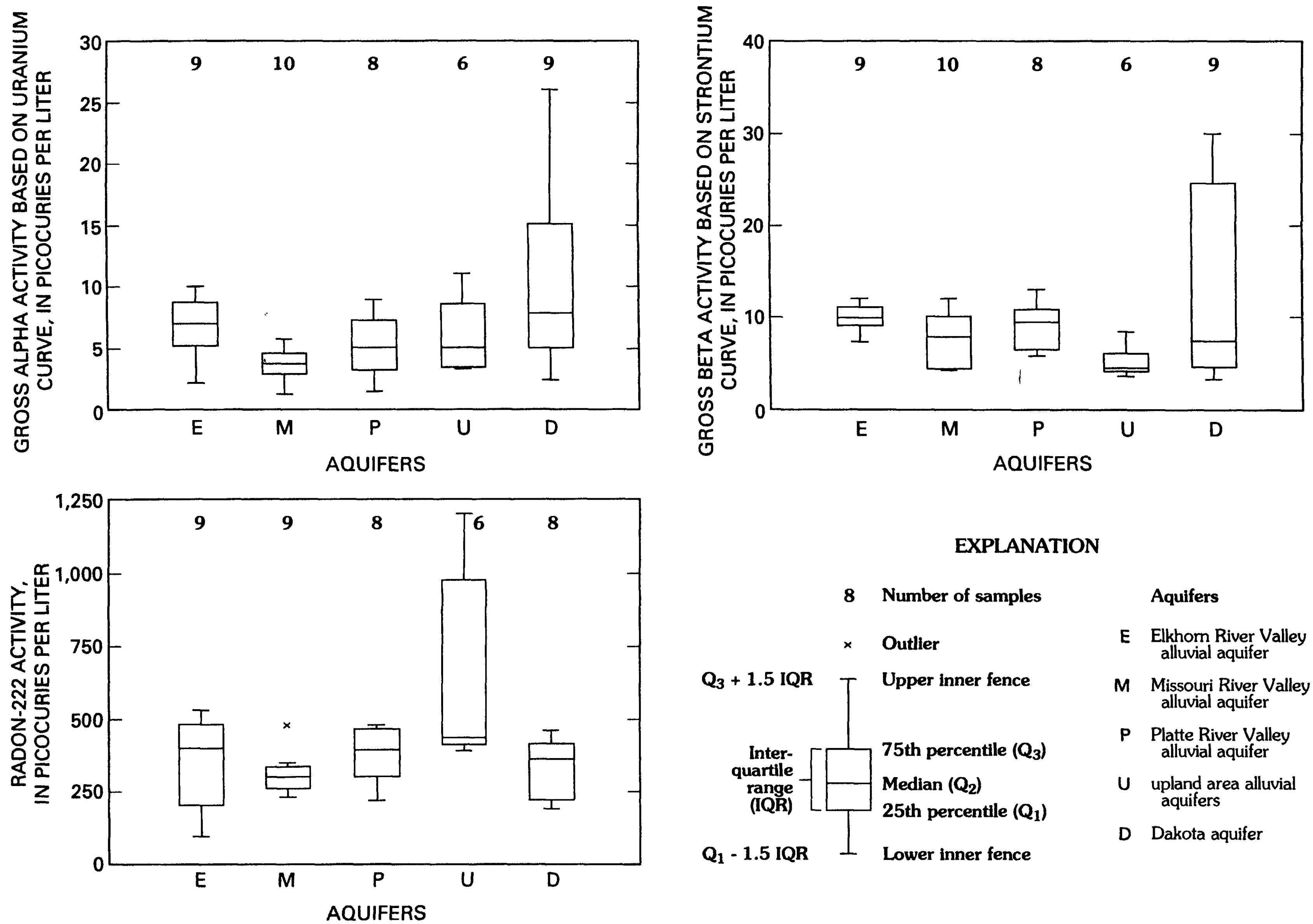


Figure 19. Distributions of radionuclide activity or concentration by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992.

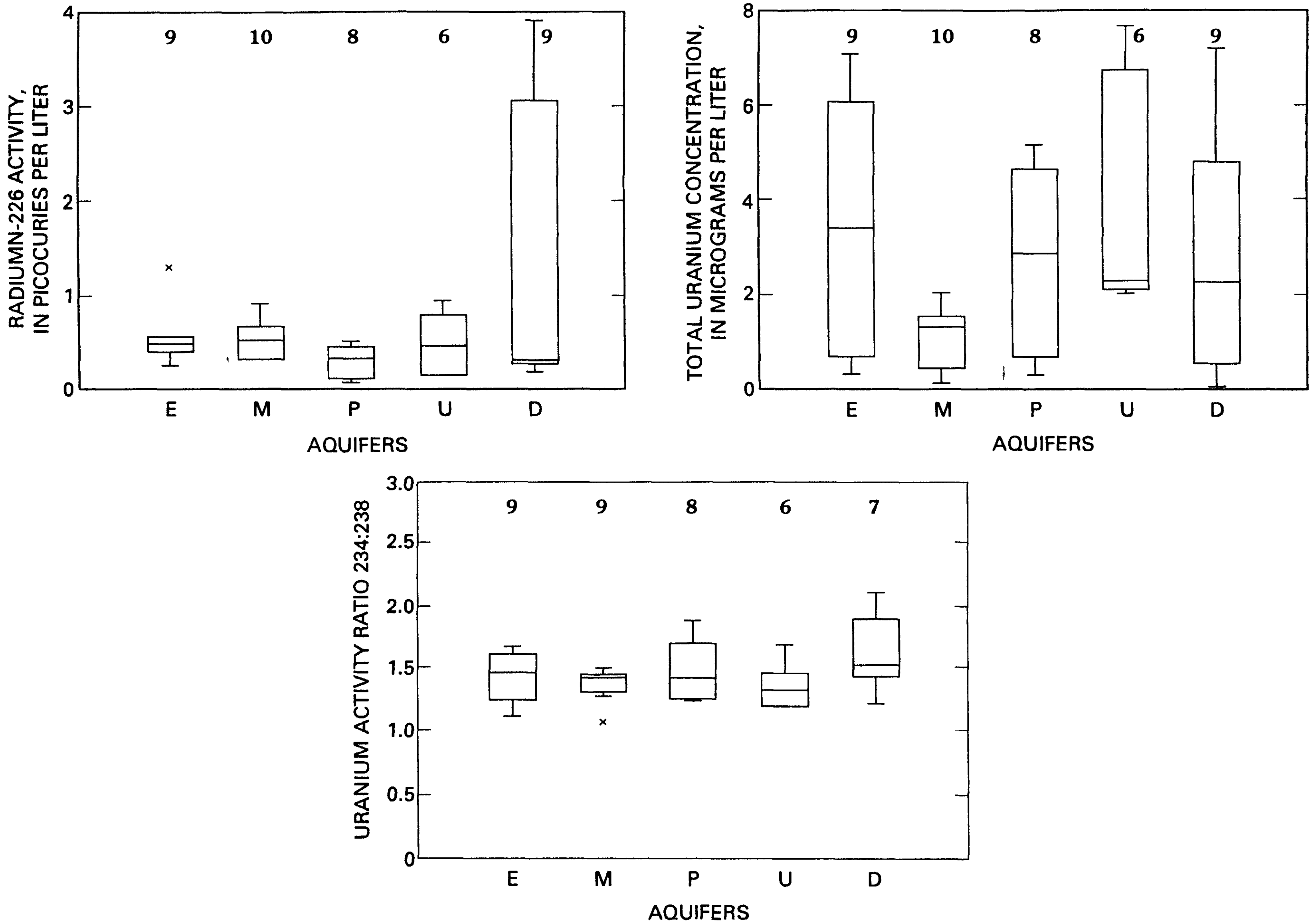


Figure 19. Distributions of radionuclide activity or concentration by aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued.

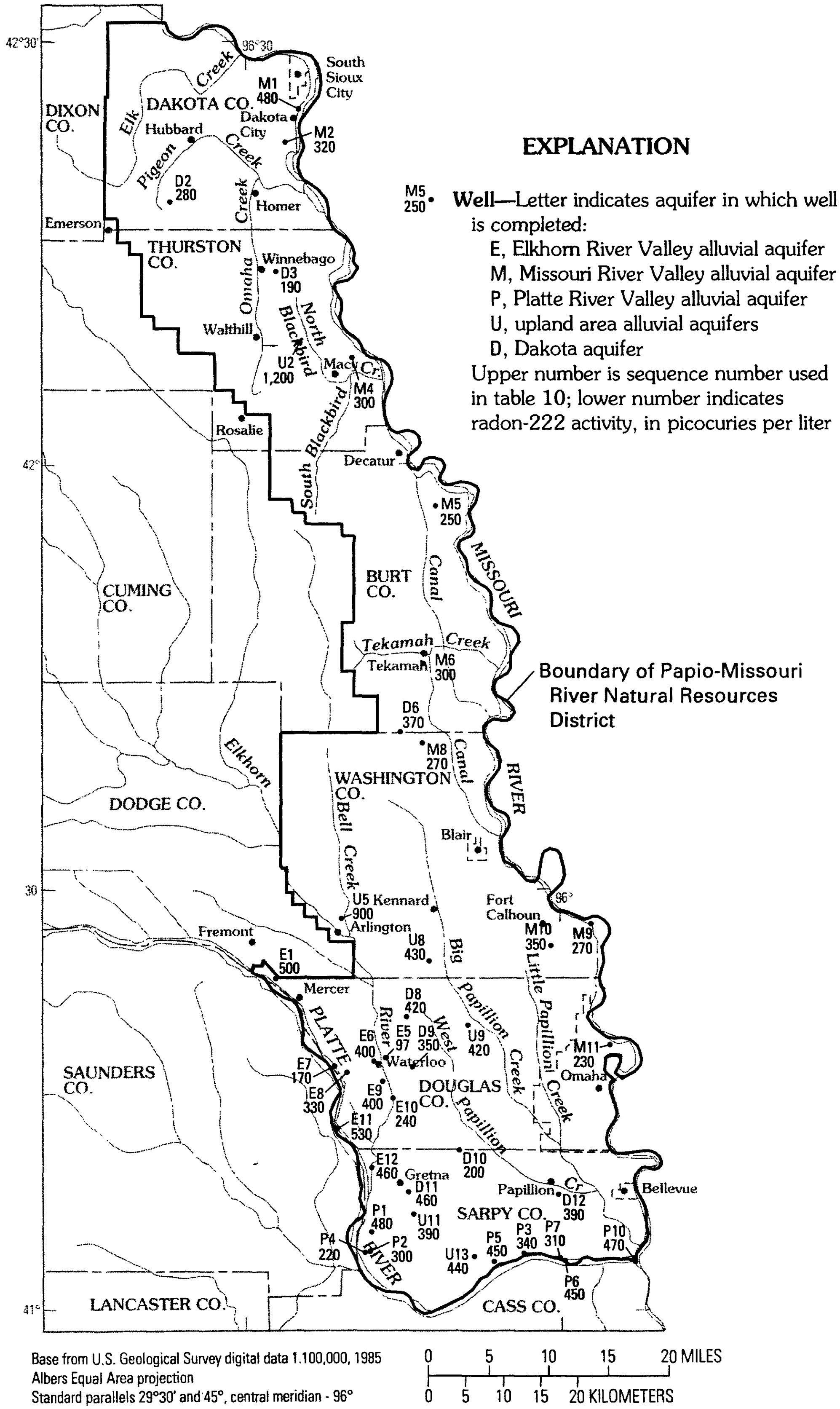


Figure 20. Radon-222 activities in water from sampled wells in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992.

Radium-226 Activity

Radium-226 and radium-228 are naturally occurring, radioactive isotopes. Radium-226 is of special concern because of its long half-life (1,600 years). Radium also tends to become concentrated in bones, in a manner similar to calcium. Radium tends to react similar to alkaline earth elements and can form strong complexes with carbonate and sulfate and weaker complexes with NO_3-N and chloride (Hem, 1985; Agency for Toxic Substances and Disease Registry, 1990).

The 42 water samples analyzed for radium-226 contained activities ranging from 0.07 to 3.9 pCi/L as ^{226}Ra, with a median activity of 0.46 pCi/L as ^{226}Ra (table 11). The USEPA proposed MCL of 5 pCi/L for radium-226 was not exceeded (U.S. Environmental Protection Agency, 1991a, 1991e). The largest activity of radium-226 was found in water from wells D1, D2, and D3 completed in the Dakota aquifer (2.2, 3.9, and 3.9 pCi/L as ^{226}Ra, respectively). Radium-226 activities in the aquifers were not significantly different from each other (table 17).

Total Uranium Concentration and Uranium Activity Ratio 234:238

In the Earth's crust, uranium exists in the forms of uranium-238, uranium-235, and uranium-234. Uranium-235 is not considered herein because of its relative lack of abundance in natural systems. In this report, uranium results are presented as total uranium (U-238 plus U-234) in micrograms per liter and the ratio of the activities of the two isotopes uranium-234 to uranium-238. The total uranium concentration in ground water varied from less than 0.1 to 7.7 μg/L as U, with a median of 2.0 μg/L as U (table 11). The uranium 234:238 activity ratios varied from 1.1 to 2.1.

The smallest median total uranium concentration by aquifer was found in water from the Missouri River Valley alluvial aquifer (1.3 μg/L). The small total uranium concentrations, especially in water from the Missouri River Valley alluvial aquifer, could be the result of reducing conditions in the geologic strata, which could cause precipitation of dissolved uranium, or a general lack of uranium in the geologic strata. Exceedances of the USEPA MCL of 20 μg/L for uranium (U.S. Environmental Protection Agency, 1991a) were not found. Statistical differences in uranium concentrations of the five aquifers were not noted.

SUMMARY AND CONCLUSIONS

The ground-water quality of the Papio-Missouri River NRD in eastern Nebraska was evaluated statistically on the basis of data collected from July through September 1992. Water samples were collected from 61 selected wells completed in the Elkhorn, Missouri, and Platte River Valley alluvial aquifers, the upland area alluvial aquifers, and the Dakota aquifer. Of these 61 wells, 25 were used for irrigation, 22 for municipal, 8 for domestic, and 6 for industrial purposes.

Thirty-nine percent of the NO_3-N concentrations were less than the detection level of 0.05 mg/L. Small NO_3-N concentrations, especially in the alluvial aquifers, could be caused by denitrifying conditions in the aquifers, especially in the Missouri River Valley alluvial aquifer. The largest median NO_3-N concentrations were in water from the upland area alluvial aquifers and the Dakota aquifer.

Herbicide detections were found in water samples from all principal aquifers except the Dakota aquifer, including alachlor (1 detection), atrazine (13 detections), cyanazine (5 detections), deisopropylatrazine (6 detections), deethylatrazine (9 detections), metolachlor (6 detections), metribuzin (1 detection), prometon (6 detections), and simazine (2 detections). These herbicide detections appear to be restricted mainly to water from wells completed in the Elkhorn and Platte River Valley alluvial aquifers. Herbicide concentrations in water from wells along the banks of the Platte River indicate that, at least locally, the Platte River acts as a line source of herbicides where the hydraulic gradient is from surface water to ground water. Consequently, the presence and concentrations of herbicides—especially atrazine, its degradation products (deisopropylatrazine and deethylatrazine), metolachlor, and prometon—could be a better indication of the presence and extent of nonpoint-source contamination in ground water in the Papio-Missouri River NRD than NO_3-N concentrations. Herbicide concentrations did not exceed U.S. Environmental Protection Agency MCL's for drinking water.

The results of analyses of 42 ground-water samples showed statistically that at least one aquifer had significant differences in the concentrations of major ions, metals, trace elements, and radionuclide constitu- ents among the principal aquifers. In general, the water in all principal aquifers was a calcium bicarbonate type, and the water was hard. Two samples from the Dakota aquifer indicated a calcium sulfate type water.

Water from the upland area alluvial aquifers had a major-ion chemistry similar to the water collected from the Dakota aquifer in areas where there is a hydraulic connection between the aquifers. In areas where the Dakota aquifer is thought not to be in hydraulic connection with the overlying Missouri River Valley alluvial aquifer or upland area alluvial aquifers, the Dakota aquifer had large dissolved-solids, calcium, sulfate, chloride, iron, lithium, manganese, and strontium concentrations.

The smallest median dissolved-oxygen concentration was found in water from the Missouri River Valley alluvial aquifer, which also was the aquifer with smallest median NO_3-N concentration (less than 0.05 mg/L as N) and the largest sulfate concentrations. Water with dissolved-solids concentrations greater than 1,000 mg/L was present in wells completed in the Dakota aquifer in Dakota and Thurston Counties where the Dakota aquifer probably is not in hydraulic connection with the Missouri River Valley alluvial aquifer or the upland area alluvial aquifers.

Water from the Elkhorn and Platte River Valley alluvial aquifers had similar calcium and magnesium concentrations. The large concentrations of calcium in water from the Missouri River Valley alluvial aquifer could be associated with the abundance of lime in many soil profiles of the Albaton-Haynie-Sarpy soil association along the Missouri River or in the aquifer materials.

Compared to the aqueous chemistry of water from the other aquifers, statistical analyses of metals and trace elements indicate that water from:

The Elkhorn and Platte River Valley alluvial aquifers had significantly different arsenic, manganese, and strontium concentrations;

The Missouri River Valley alluvial aquifer had significantly different arsenic, iron, lithium, manganese, selenium, and strontium concentrations;

The upland area alluvial aquifers had significantly different arsenic, iron, manganese, and selenium concentrations; and

The Dakota aquifer had significantly different arsenic, barium, iron, and manganese concentrations.

The largest radon-222 activities were found in water from wells completed in the upland area alluvial aquifers, whereas the largest radium-226 activities were found in water from three wells completed in the Dakota aquifer. In general, the small total uranium concentrations, especially in water from the Missouri River Valley alluvial aquifer, could be either the result of reducing conditions in the geologic strata that cause precipitation of dissolved uranium or a general lack of uranium in the geologic strata. In areas where the Dakota aquifer is thought to be not in hydraulic connection with the overlying Missouri River Valley or upland area alluvial aquifers, the Dakota aquifer locally might have large gross alpha activities.

Compared to the chemistry of water from the other principal aquifers, statistical analyses indicate different median gross alpha activities in water from the Missouri River Valley alluvial aquifer and the Dakota aquifer and different median gross beta activities in water from the Elkhorn and Platte River Valley alluvial aquifers and the upland area alluvial aquifers.

Ground-water samples collected during this study did not contain concentrations that exceed the USEPA MCLs for herbicides but exceeded the MCL of 10 mg/L for NO_3-N in two wells completed in the upland area alluvial aquifers. Other USEPA MCL and SMCL exceedances included:

(1) The dissolved-solids SMCL of 500 mg/L was exceeded in water from 10 of 40 wells completed in all aquifers—in 5 of 8 wells in the Missouri River Valley alluvial aquifer, 1 of 9 wells in the upland area alluvial aquifers, and 4 of 9 wells in the Dakota aquifer.

(2) The sulfate SMCL of 250 mg/L was exceeded in water from three wells completed in the Dakota aquifer.

(3) The iron SMCL of 300 µg/L was exceeded in water from 18 of 42 wells completed in all aquifers—in 3 of 9 wells in the Elkhorn, 10 of 10 wells in the Missouri, 3 of 8 wells in the Platte River Valley alluvial aquifers, and 2 of 9 wells in the Dakota aquifer.

(4) The manganese SMCL of 50 µg/L was exceeded in water from 28 of 42 wells completed in all aquifers—in 9 of 9 wells in the Elkhorn, 10 of 10 wells in the Missouri, and 5 of 8 wells in the Platte River Valley alluvial aquifers, 1 of 6 wells in the upland area alluvial aquifers, and 3 of 9 wells in the Dakota aquifer.

(5) The MCL for adjusted gross alpha activity of 15 pCi/L was exceeded in water from 1 of 9 wells completed in the Dakota aquifer.

(6) The proposed MCL for radon-222 activity of 300 pCi/L was exceeded in water from 26 of 40 wells completed in all aquifers—6 of 9 wells in the Elkhorn, 3 of 9 wells in the Missouri, and 6 of 8 wells in the Platte River Valley alluvial aquifers, 6 of 6 wells in the upland area alluvial aquifers, and 5 of 8 wells in the Dakota aquifer.

Thus, the water quality of the principal aquifers used in the Papio-Missouri River NRD is generally suitable for most uses. However, the numerous occurrences of herbicides in water of the Elkhorn and Platte River Valley alluvial aquifers, especially near the Platte River, are of concern because U.S. Environmental Protection Agency MCLs could be exceeded. Concentrations in three of nine water samples collected from wells completed in the Dakota aquifer exceeded the U.S. Environmental Protection Agency MCLs or SMCLs for gross alpha activity, radon-222 activity, dissolved solids, sulfate, or iron. Also of concern are the exceedances of the U.S. Environmental Protection Agency proposed MCL for radon-222 activity.

REFERENCES

Agency for Toxic Substances and Disease Registry, 1990, Toxicological profile for radium: U.S. Department of Health and Human Services, Public Health Service, TP-90-22, 131 p.

Barnes, Ivan, and Bentall, Ray, 1968, Water-mineral relations of Quaternary deposits in the lower Platte River drainage area in eastern Nebraska: U.S. Geological Survey Water-Supply Paper 1859-D, 39 p.

Bartlett, P.A., 1975, Soil survey of Douglas and Sarpy counties, Nebraska: U.S. Department of Agriculture Soil Conservation Service and University of Nebraska-Lincoln, Institute for Agriculture and Natural Resources, Conservation and Survey Division, 79 p.

Burchett, R.R., 1965, Correlation of formations drilled in test holes for Interstate 80 bridge between Omaha, Nebraska, and Council Bluffs, Iowa: Lincoln, Nebraska Geological Survey Paper 17, 30 p.

____1983, Surface to subsurface correlation of Pennsylvanian and lower Permian rocks across southern Nebraska: Lincoln, Nebraska Geological Survey Report of Investigations 8, 24 p.

____(compiler), 1986, Geologic bedrock map of Nebraska: University of Nebraska-Lincoln, Institute for Agriculture and Natural Resources, Conservation and Survey Division, 1 sheet, scale 1:1,000,000.

Burchett, R.R., Dreeszen V.H., Souders, V.L., and Prichard, G.E., 1988, Bedrock geologic map showing configuration of the bedrock surface in the Nebraska part of the Sioux City 1 x 2 quadrangle: U.S. Geological Survey Miscellaneous Investigation Series Map I-1979, 1 sheet, scale 1:250,000.

Burchett, R.R., Reed, E.C., Dreeszen, V.H., and Prichard, G.E., 1975, Bedrock geologic map showing thickness of overlying Quaternary deposits, Fremont quadrangle and part of Omaha quadrangle, Nebraska: U.S. Geological Survey Miscellaneous Investigations Series Map I-905, 1 sheet, scale 1:250,000.

Burchett, R.R., and Smith F.A., 1989a, Washington County test-hole logs: Lincoln, Nebraska Water Survey Test-Hole Report 89, 36 p.

____1989b, Sarpy County test-hole logs: Lincoln, Nebraska Water Survey Test-Hole Report 77, 70 p.

____1989c, Douglas County test-hole logs: Lincoln, Nebraska Water Survey Test-Hole Report 28, 48 p.

____1991a, Burt County test-hole logs: Lincoln, Nebraska Water Survey Test-Hole Report 11, 35 p.

____1991b, Dakota County test-hole logs: Lincoln, Nebraska Water Survey Test-Hole Report 22, 9 p.

____1992, Thurston County test-hole logs: Lincoln, Nebraska Water Survey Test-Hole Report 87, 37 p.

Carlson, M.P., 1970, Distribution and subdivision of Precambrian and lower and middle Paleozoic rocks in the subsurface of Nebraska: Lincoln, Nebraska Geological Survey Report of Investigations 3, 25 p.

Condra, G.E., 1908, Geology and water resources of a portion of the Missouri River valley in northeastern Nebraska: U.S. Geological Survey Water-Supply Paper 215, 59 p.

Condra, G.E., and Reed, E.C., 1959, The geological section of Nebraska, with current revisions by E.C. Reed: Lincoln, Nebraska Geological Survey Bulletin 14A, 86 p.

Condra, G.E., Schramm, E.F., and Lugn, A.L., 1931, Deep wells of Nebraska: Lincoln, Nebraska Geological Survey Bulletin 4, 288 p.

Conservation and Survey Division, 1986, Groundwater atlas of Nebraska: University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 32 p.

____1990, General soil map of Nebraska: University of Nebraska-Lincoln, 1 sheet, scale 1:1,000,000.

Damoude, D.W., 1980, Soil survey of Burt County, Nebraska: U.S. Department of Agriculture, Soil Conservation Service, in cooperation with the University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 165 p.

Davis, R.K., 1992, The water's edge—Hydrochemical interactions between the Platte River and the Lincoln municipal well field, Ashland, Nebraska: Lincoln, University of Nebraska, unpublished Ph.D. dissertation, 245 p.

Dreeszen, V.H., 1970, The stratigraphic framework of Pleistocene glacial and periglacial deposits in the Central Plains, *in* Dort, Wakefield, Jr., and Jones, J.K., eds., Pleistocene and recent environments of the central Great Plains: Lawrence, University of Kansas Press Special Publication 3, p. 9–22.

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

Duncan, Diana, Pederson, D.T., Shephard, T.R., and Carr, J.D., 1991, Atrazine used as a tracer of induced recharge: Ground Water Monitoring Review, Fall 1991, p. 144–150.

Ellis, M.J., 1984, Overview of the Dakota aquifer system in Nebraska, *in* Jorgensen, D.G. and Signor, D.C., eds., Geohydrology of the Dakota aquifer—Proceedings of the First C.V. Theis Conference on Geohydrology: Worthington, Ohio, National Water Well Association, p. 48–55.

____1986, Hydrogeologic data for the Dakota aquifer system in Nebraska: U.S. Geological Survey Open-File Report 86–526, 100 p.

Engberg, R.A., 1973, Selenium in Nebraska's groundwater and streams: University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, Nebraska Water Survey Paper 35, 42 p.

____1984, Appraisal of data for ground-water quality in Nebraska: U.S. Geological Survey Water-Supply Paper 2245, 54 p.

Engberg, R.A., and Druliner, A.D., 1987, Nebraska ground-water quality: U.S. Geological Survey Open-File Report 87–737, 9 p.

Engberg, R.A., and Spalding, R.F., 1979, Ground-water quality atlas of Nebraska: University of Nebraska-Lincoln, Institute for Agriculture and Natural Resources, Conservation and Survey Division Resource Atlas 3, 38 p.

Exner, M.E., 1980, Ground water nitrate-as-nitrogen concentrations, Fremont quadrangle: Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, 1 sheet, scale 1:250,000.

Fenneman, N.M., 1938, Physiography of eastern United States: New York, McGraw-Hill, Inc., p. 588–605.

Fenneman, N.M., and Johnson, D.W., 1946, The physical divisions of the United States: U.S. Department of Interior, Geological Survey, 1 plate.

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. Al, 545 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, Inc., p. 434–462.

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.

Gormly, J.R., and Spalding, R.F., 1979, Sources and concentrations of nitrate as nitrogen in ground water of the Central Platte Region, Nebraska: Ground Water, v. 17, no. 3, p. 291–300.

Greenawalt, R.D., and McKenzie, W.E., 1964, Soil survey of Washington County, Nebraska: U.S. Department of Agriculture, Soil Conservation Service, and University of Nebraska-Lincoln, Institute for Agriculture and Natural Resources, Conservation and Survey Division, 79 p.

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

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

Lawton, D.R., Goodenkauf, O.L., Hanson, B.V., and Smith F.A., 1984, Dakota aquifers in eastern Nebraska, aspects of water quality and use, *in* Jorgensen, D.G., and Signor, D.C., eds., Geohydrology of the Dakota aquifer—Proceedings of the First C.V. Theis Conference on Geohydrology: Worthington, Ohio, National Water Well Association, p. 221–228.

Leonard, R.B., Signor, D.C., Jorgensen, D.G., and Helgesen, J.O., 1983, Geohydrology and geochemistry of the Dakota aquifer, central United States: Water Resources Bulletin, American Water Resource Association, v. 19, no. 6, p. 903–911.

Meriwether, J.R., Beck, J.N., Keeley, D.F., Langley, M.P., Thompson, R.H., and Young, J.L., 1988, Radionuclides in Louisiana soils: Journal of Environmental Quality, v. 17, no. 4, p. 562–567.

Miller, R.R., 1964, Geology of the Omaha-Council Bluffs area, Nebraska-Iowa: U.S. Geological Survey Professional Paper 472, 70 p.

National Oceanic and Atmospheric Administration, 1982, Monthly normals of temperature, precipitation, and heating and cooling degree days, 1951–1980, Nebraska: Asheville, North Carolina, Environmental Data and Information Service, National Climatic Center, September 1982, 11 p.

____1992, Climatological data for Nebraska—Monthly precipitation departure from individual station normals (1951–1980): Asheville, North Carolina, Environmental Data and Information Service, National Climatic Center, July through September 1992, v. 97, nos. 7, 8, and 9.

Nebraska Department of Agriculture, 1992, 1990/1991 Nebraska agricultural statistics: Nebraska Agricultural Statistics Service, 154 p.

____1993, 1991/1992 Nebraska agricultural statistics: Lincoln, Nebraska Agricultural Statistics Service, 146 p.

Nebraska Department of Environmental Quality and Conservation and Survey Division, 1980a, Configuration of the base of the principal aquifer, 1979, Sioux City quadrangle: University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 1 sheet, scale 1:250,000.

____1980b, Configuration of the base of the principal aquifer, 1979, Fremont-Omaha quadrangle: University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 1 sheet, scale 1:250,000.

____1980c, Thickness of the principal aquifer, 1979, Sioux City quadrangle: University of Nebraska- Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 1 sheet, scale 1:250,000.

____1980d, Thickness of the principal aquifer, 1979, Fremont-Omaha quadrangle: University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 1 sheet, scale 1:250,000.

____1980e, Configuration of the water table, spring 1979, Sioux City quadrangle: University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 1 sheet, scale 1:250,000.

____1980f, Configuration of the water table, spring 1979, Fremont-Omaha quadrangle: University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 1 sheet, scale 1:250,000.

O'Connor, T.M., 1987, A preliminary study of the hydrogeology of the Dakota Sandstone in Douglas, Sarpy, and Washington Counties, eastern Nebraska: University of Nebraska-Lincoln, unpublished M.S. thesis, 147 p.

Papio-Missouri River Natural Resources District, 1989, Ground-water management plan: Omaha, Nebraska, December 1989, 78 p.

Piper, A.M., 1944, A graphic procedure in the geochemical interpretation of water analyses, American Geophysical Union Transactions. v. 25, p. 914–923.

Pipes, J.W., 1987, The hydrogeologic framework of the Paleozoic aquifers of the Papio Natural Resources District, Nebraska: University of Nebraska-Lincoln, unpublished M.S. thesis, 106 p.

Pritt, J.W., and Jones, B.E., eds., 1989, 1990 National Water Quality Laboratory services catalog: U.S. Geological Survey Open-File Report 89–386, 132 p.

Reed, E.C., and Dreeszen, V.H., 1965, Revision of the classification of the Pleistocene deposits of Nebraska: Lincoln, Nebraska Geological Survey Bulletin 23, 65 p.

Schuett, E.C., 1964, Petrography and water mineral relationships of two Quaternary fills in eastern Nebraska: University of Nebraska-Lincoln, unpublished M.S. thesis, 74 p.

Slama, N.L., Damoude, D.W., and Kerl, D.E., 1972, Soil survey of Thurston County, Nebraska: U.S. Department of Agriculture, Soil Conservation Service, and U.S. Department of Interior Bureau of Indian Affairs, in cooperation with the University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 64 p.

Slama, N.L., Kerl, D.E., and Damoude, D.W., 1976, Soil survey of Dakota County, Nebraska: U.S. Department of Agriculture, Soil Conservation Service, in cooperation with the University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources, Conservation and Survey Division, 91 p.

Spalding, R.F., 1990, Water quality in the lower Platte River Basin with emphasis on agrichemicals: Lincoln, Nebraska, Conservation and Survey Division of the University of Nebraska-Lincoln, Completion Report, 123 p.

Tanner, D.Q., and Steele, G.V., 1991, Ground-water quality in the Nemaha Natural Resources District, southeastern Nebraska, 1989: U.S. Geological Survey Water-Resources Investigations Report 90–4184, 52 p.

Thatcher, L.L, Janzen, V.J., and Edwards, K.N., 1977, Methods for determination of radioactive substances in water in fluvial sediments: U.S. Geological Survey Open-File Report 76–560, 243 p.

Todd, J.E., 1908, Description of the Elk Point quadrangle, South Dakota, Nebraska, Iowa: U.S. Geological Survey Geologic Atlas Folio 156, 8 p.

U.S. Department of Commerce, 1991, 1990 Census of population and housing, public law 94–171 data: Bureau of Census, Data User Services Division, compact disk.

U.S. Department of Energy, 1981, Hydrogeochemical and stream sediment reconnaissance basic data for Fremont Quadrangle, Nebraska and Iowa: Oak Ridge, Tenn., National Uranium Resource Evaluation Program, Oak Ridge Gaseous Diffusion Plant, 34 p.

U.S. Environmental Protection Agency, 1991a, Maximum contaminant levels (subpart B of part 141, National primary drinking water regulations): U.S. Code of Federal Regulations, Title 40, parts 100 to 149, revised as of July 1, 1991, p. 585–588.

____1991b, Maximum contaminant level goals (subpart F of part 141, National interim primary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, parts 100–149, revised as of July 1, 1991, p. 659–660.

____1991c, National revised primary drinking-water regulations, maximum contaminant levels (subpart G of part 141, National interim primary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, parts 100 to 149, revised as of July 1, 1991, p. 670–674.

____1991d, Secondary maximum contaminant levels (sec. 143.3 of part 143, National secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, parts 100 to 149, revised as of July 1, 1991, p. 758–759.

____1991e, National primary drinking water regulations—Radionuclides, Proposed rule: Federal Register, v. 56, no. 138, July 18, 1991, p. 33,050–33,127.

____1992, National primary drinking water regulations—Synthetic organic chemicals and inorganic chemicals, Final rule: Federal Register, v. 57, no. 138, July 17, 1992, p. 31,776–31,849.

Wayne, W.J., 1985, Drainage patterns and glaciations in eastern Nebraska: Nebraska Academy of Sciences Institute for Tertiary-Quaternary Research Symposium Series, v. 1, p. 111–117.

Whittaker, E.L., Akridge, J.D., and Giovino, J., 1989, Two test procedures for radon in drinking water: U.S. Environmental Protection Agency, EPA/600/2-87/082, March 1989.

Table 9. Summary of water-quality analyses for physical properties of water and concentrations of nitrogen species and herbicides in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992

[µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; --, not analyzed; <, less than, d, detected; n, not detected; dup, duplicate sample]

Well identification number[1] (fig. 11) County[2] Well depth, feet below land surface Well type[3] Date sampled, month/day/year	Unit of measurement	Reporting level	E1 055 91 M 7/23/92	E2 055 91 M 7/23/92	E3 055 39 I 7/21/92	E4 055 98 D 7/16/92	E5 055 52 I 8/17/92	E6 055 70 I 8/17/92	E7 055 58 I 7/22/92	E8 055 60 I 8/20/92	E9 055 87 I 8/17/92	E10 055 50 M 7/23/92	E11 055 65 M 7/16/92	E12 055 61 I 7/29/92	M1 043 162 N 7/15/92	M2 043 105 I 8/17/92	M3 043 153 I 7/21/92
Specific conductance, field	µS/cm	1.0	511	548	417	505	606	733	614	570	725	563	560	710	1,330	1,210	1,070
pH, field	standard units	.1	7.4	7.5	6.3	7.4	6.9	7.3	7.3	6.9	6.9	7.4	7.5	7.0	7.0	7.1	7.1
Water temperature, field	°C	.5	12.5	12.5	15.0	23.5	13.0	12.5	13.0	12.0	12.5	15.5	13.5	12.0	11.5	11.0	11.5
Oxygen, dissolved, field	mg/L	.1	2.4	2.5	7.1	3.5	6.6	1.3	6.0	2.9	2.8	3.0	.7	.6	.1	.1	.1
Nitrite plus nitrate as nitrogen	mg/L	.05	.68	.21	.06	1.90	.16	<.05	.07	.48	.06	<.05	.06	.77	<.05	.07	<.05
Triazine enzyme-assay result	µg/L	.01	d	d	n	d	d	n	d	n	n	d	d	d	n	n	n
Alachlor, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	<.05	--	--	--
Ametryn, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	<.05	--	--	--
Atrazine, dissolved	µg/L	.05	.32	.32	--	<.05	<.05	--	.06	--	--	.09	.27	<.05	--	--	--
Cyanazine, dissolved	µg/L	.20	<.20	<.20	--	<.20	<.20	--	<.20	--	--	<.20	<.20	<.20	--	--	--
Deisopropylatrazine, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	.12	--	--	--
Deethylatrazine, dissolved	µg/L	.05	.11	.10	--	<.05	<.05	--	<.05	--	--	<.05	.11	.05	--	--	--
Metolachlor, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	<.05	--	--	--
Metribuzin, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	<.05	--	--	--
Prometon, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	.44	--	--	--
Prometryn, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	<.05	--	--	--
Propazine, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	<.05	--	--	--
Simazine, dissolved	µg/L	.05	<.05	<.05	--	<.05	<.05	--	<.05	--	--	<.05	<.05	<.05	--	--	--

Table 9. Summary of water-quality analyses for physical properties of water and concentrations of nitrogen species and herbicides in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig. 11) County[2] Well depth, feet below land surface Well type[3] Date sampled, month/day/year	Unit of measurement	Reporting level	M4 173 93 I 7/20/92	M5 021 115 I 7/21/92	M6 021 95 I 8/17/92	M7 021 168 I 8/16/92	M8 177 63 M 7/15/92	M9 177 82 I 8/13/92	M10 177 – D 8/19/92	M11 055 80 N 7/16/92	M12 153 103 M 8/13/92	M13 153 97 N 7/15/92	P1 153 64 I 7/21/92	P2 153 43 I 8/19/92	P3 153 74 M 7/20/92	P4 153 52 I 8/20/92	P5 153 68 I 8/20/92
Specific conductance, field	µS/cm	1.0	875	900	790	756	671	1,400	786	1,680	1,090	1,030	579	706	575	736	561
pH, field	standard units	.1	7.1	7.0	7.1	6.8	7.2	7.1	7.2	6.9	7.0	7.4	7.4	7.4	7.5	7.1	7.2
Water temperature, field	°C	.5	11.0	11.0	12.0	13.5	13.0	12.0	12.5	14.0	13.5	15.0	12.5	12.5	12.0	11.5	12.0
Oxygen, dissolved, field	mg/L	.05	.2	.3	.2	5.5	3.9	.2	.1	.5	.2	8.1	.6	4.1	1.0	.1	5.1
Nitrite plus nitrate as nitrogen	mg/L	.10	.05	.06	.29	1.40	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	.21	<.05	1.50
Triazine enzyme-assay result	µg/L	.05	n	n	d	d	n	n	n	n	n	n	n	d	d	n	n
Alachlor, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	.05	--	--
Ametryn, dissolved	µg/L	.20	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	<.05	--	--
Atrazine, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	.16	--	.82	--	--
Cyanazine, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.20	--	--	--	--
Deisopropylatrazine, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--	--
Deethylatrazine, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--	--
Metolachlor, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	.17	--	--
Metribuzin, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	<.05	--	--
Prometon, dissolved	µg/L	.05	--	--	.10	.20	--	--	--	--	--	--	<.05	--	--	--	--
Prometryn, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--	--
Propazine, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--	--
Simazine, dissolved	µg/L	.05	--	--	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--	--

Table 9. Summary of water-quality analyses for physical properties of water and concentrations of nitrogen species and herbicides in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig. 11) County[2] Well depth, feet below land surface Well type[3] Date sampled, month/day/year	Unit of measurement	Reporting level	P6 153 52 M 7/14/92	P7 153 62 M 7/14/92	P8 153 46 M 7/14/92	P9 153 60 M 7/14/92	P10 153 126 N 7/15/92	U1 173 37 M 7/14/92	U2 173 100 D 7/20/92	U3 177 155 M 7/14/92	U4 177 131 I 8/19/92	U5 177 164 I 7/22/92	U6 177 330 D 7/20/92	U7 177 316 I 9/03/92	U8 177 144 I 8/13/92	U9 055 56 D 7/21/92	U10 055 141 I 7/16/92
Specific conductance, field	µS/cm	1.0	504	511	605	655	659	1,020	683	826	958	891	715	677	656	739	720
pH, field	standard units	.1	7.8	7.9	7.6	7.4	7.6	7.1	7.1	7.1	7.4	6.9	7.5	7.1	7.2	6.9	7.1
Water temperature, field	°C	.5	22.0	23.5	13.0	12.5	11.5	12.0	12.5	12.0	12.5	12.0	17.5	12.5	12.0	13.0	13.0
Oxygen, dissolved, field	mg/L	.1	.5	1.1	2.9	--	1.1	.1	2.3	8.6	3.1	2.4	1.2	4.1	5.8	3.3	.4
Nitrite plus nitrate as nitrogen	mg/L	.05	.72	1.10	1.30	.07	<.05	<.05	6.7	<.05	<.05	17	<.05	.20	8.80	9.90	<.05
Triazine enzyme-assay result	µg/L	.10	d	d	d	d	d	n	n	n	n	n	n	d	n	n	n
Alachlor, dissolved	µg/L	.05	<.05	<.05	<.05	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--
Ametryn, dissolved	µg/L	.05	<.05	<.05	<.05	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--
Atrazine, dissolved	µg/L	.05	1.8	1.8	.58	.47	.38	--	--	--	--	--	--	<.05	--	--	--
Cyanazine, dissolved	µg/L	.20	1.0	.60	.30	.20	.30	--	--	--	--	--	--	<.20	--	--	--
Deisopropylatrazine, dissolved	µg/L	.05	.19	.29	.09	.08	.05	--	--	--	--	--	--	<.05	--	--	--
Deethylatrazine, dissolved	µg/L	.05	.24	.26	.10	.12	.10	--	--	--	--	--	--	<.05	--	--	--
Metolachlor, dissolved	µg/L	.05	.24	.18	.09	.05	.07	--	--	--	--	--	--	<.05	--	--	--
Metribuzin, dissolved	µg/L	.05	<.05	.07	<.05	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--
Prometon, dissolved	µg/L	.05	.06	.05	<.05	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--
Prometryn, dissolved	µg/L	.05	<.05	<.05	<.05	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--
Propazine, dissolved	µg/L	.05	<.05	<.05	<.05	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--
Simazine, dissolved	µg/L	.05	.07	.07	<.05	<.05	<.05	--	--	--	--	--	--	<.05	--	--	--

Table 9. Summary of water-quality analyses for physical properties of water and concentrations of nitrogen species and herbicides in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig. 11)			U11	U12	U13	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
County[2]			153	153	153	043	043	173	173	021	021	177	055	055	153	153	153
Well depth, feet below land surface	Unit of	Reporti	198	206	66	270	625	325	300	172	133	172	325	238	235	315	134
Well type[3]	measure-	ng	I	M	N	M	D	M	D	M	I	D	M	M	M	M	N
Date sampled, month/day/year	ment	level	9/01/92	7/30/92	7/29/92	7/21/92	7/21/92	7/14/92	7/15/92	7/14/92	7/15/92	7/30/92	7/15/92	7/23/92	7/20/92	7/23/92	7/29/92
Specific conductance, field	µS/cm	1.0	795	623	532	1,570	1,780	1,800	719	787	659	741	861	684	519	620	445
pH, field	standard units	.1	6.5	7.6	7.3	7.0	7.1	7.1	7.0	7.0	7.1	7.7	7.1	6.9	7.4	7.0	7.0
Water temperature, field	°C	.5	12.5	17.0	22.0	12.0	15.0	12.0	13.5	12.5	13.5	13.5	16.0	12.0	13.0	13.0	13.0
Oxygen, dissolved, field	mg/L	.1	8.5	.2	6.3	.4	.4	.1	.1	4.0	3.0	.2	4.3	4.3	6.2	6.0	8.9
Nitrite plus nitrate as nitrogen	mg/L	.05	30	<.05	2.40	<.05	.09	<.05	<.05	6.40	2.80	.19	<.05	5.00	.80	1.80	.85
Triazine enzyme-assay result	µg/L	.10	d	n	n	n	n	n	n	n	d	n	n	n	n	n	n
Alachlor, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Ametryn, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Atrazine, dissolved	µg/L	.05	.11	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Cyanazine, dissolved	µg/L	.20	<.20	--	--	--	--	--	--	--	<.20	--	--	--	--	--	--
Deisopropylatrazine, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Deethylatrazine, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Metolachlor, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Metribuzin, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Prometon, dissolved	µg/L	.05	.14	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Prometryn, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Propazine, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--
Simazine, dissolved	µg/L	.05	<.05	--	--	--	--	--	--	--	<.05	--	--	--	--	--	--

Table 9. Summary of water-quality analyses for physical properties of water and concentrations of nitrogen species and herbicides in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig. 11) County[2] Well depth, feet below land surface Well type[3] Date sampled, month/day/year	Unit of measurement	Reporting level	D13 153 195 M 7/29/92	Blank – – – 7/22/92	M6 (dup) 021 95 I 8/17/92	M9 (dup) 177 82 I 8/13/92	D1 (dup) 043 270 M 7/21/92
Specific conductance, field	µS/cm	1.0	513	614	791	1,400	--
pH, field	standard units	.1	7.0	7.3	7.1	7.1	--
Water temperature, field	°C	.5	13.0	13.0	12.0	12.0	--
Oxygen, dissolved, field	mg/L	.1	5.8	6.0	.2	.1	--
Nitrite plus nitrate as nitrogen	mg/L	.05	2.30	<.05	.32	<.05	<0.05
Triazine enzyme-assay result	µg/L	.10	n	d	d	n	n
Alachlor, dissolved	µg/L	.05	--	<.05	<.05	--	--
Ametryn, dissolved	µg/L	.05	--	<.05	<.05	--	--
Atrazine, dissolved	µg/L	.05	--	<.05	<.05	--	--
Cyanazine, dissolved	µg/L	.20	--	<.20	<.20	--	--
Deisopropylatrazine, dissolved	µg/L	.05	--	<.05	<.05	--	--
Deethylatrazine, dissolved	µg/L	.05	--	<.05	<.05	--	--
Metolachlor, dissolved	µg/L	.05	--	<.05	<.05	--	--
Metribuzin, dissolved	µg/L	.05	--	<.05	<.05	--	--
Prometon, dissolved	µg/L	.05	--	<.05	.10	--	--
Prometryn, dissolved	µg/L	.05	--	<.05	<.05	--	--
Propazine, dissolved	µg/L	.05	--	<.05	<.05	--	--
Simazine, dissolved	µg/L	.05	--	<.05	<.05	--	--

[1]Well screened in:
- E—Elkhorn River Valley alluvial aquifer
- M—Missouri River Valley alluvial aquifer
- P—Platte River Valley alluvial aquifer
- U—upland area alluvial aquifers
- D—Dakota aquifer

[2]Counties:
- 021—Burt
- 043—Dakota
- 055—Douglas
- 153—Sarpy
- 173—Thurston
- 177—Washington

[3]Well type:
- D—domestic
- I—irrigation
- M—municipal
- N—industrial

Table 10. Summary of water-quality analyses for hardness, alkalinity, calculated dissolved solids, major ions, major metals, trace elements, and radionuclide activity or concentration in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992

[mg/L, milligrams per liter; °C, degrees Celsius; µg/L, micrograms per liter; pCi/L, picocuries per liter; --, not analyzed; <, less than]

Well identification number[1] (fig.11)			E1	E5	E6	E7	E8	E9	E10	E11
County[2]			055	055	055	055	055	055	055	055
Well depth, feet	Unit of	Report-	91	52	0	58	60	87	50	65
Well type[3]	measure-	ing	M	I	I	I	I	I	M	M
Date sampled, month/day/year	ment	level	7/23/92	8/17/92	8/17/92	7/22/92	8/20/92	8/17/92	7/23/92	7/16/92
Hardness, total	mg/L	1	180	260	320	230	230	330	230	200
Alkalinity, laboratory, dissolved	mg/L	1	165	232	232	208	212	120	242	174
Dissolved solids, calculated	mg/L	1	329	348	449	397	366	342	344	363
Calcium, dissolved	mg/L	.10	54	82	99	72	73	100	64	60
Magnesium, dissolved	mg/L	.10	9.8	14	17	13	12	19	17	11
Sodium, dissolved	mg/L	.10	33	7.6	25	34	27	20	23	35
Percent sodium, dissolved	percent	1	28	6	14	23	20	11	17	27
Sodium-adsorption ratio	--	--	1	.2	.6	1	.8	.5	.7	1
Potassium, dissolved	mg/L	.10	9.3	8.9	7.8	8.9	7.5	7.7	7.9	8.3
Sulfate, dissolved	mg/L	.10	74	26	88	90	70	71	34	95
Chloride, dissolved	mg/L	.10	11	19	35	17	15	14	19	16
Fluoride, dissolved	mg/L	.10	.40	.20	.30	.20	.30	.40	.40	.40
Silica, dissolved	mg/L	.10	35	33	34	35	29	35	31	32
Arsenic, dissolved	µg/L	1	7	4	3	3	3	2	<1	4
Barium, dissolved	µg/L	2	130	530	350	240	420	190	280	94
Beryllium, dissolved	µg/L	.5	.9	<.5	<.5	<.5	<.5	<.5	<.5	.7
Boron, dissolved	µg/L	10	70	50	160	70	230	60	60	80
Cadmium, dissolved	µg/L	1.0	1	3	<1	1	<1	<1	<1	<1
Chromium, dissolved	µg/L	5	<5	<5	<5	<5	<5	<5	<5	<5
Cobalt, dissolved	µg/L	3	<3	<3	<3	<3	<3	<3	<3	<3
Copper, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Iron, dissolved	µg/L	3	6	14,000	2,400	100	98	1,100	540	32
Lead, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Lithium, dissolved	µg/L	4	17	24	26	20	19	25	20	18
Manganese, dissolved	µg/L	1	110	2,300	740	1,100	1,300	540	1,400	110
Molybdenum, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Nickel, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium, dissolved	µg/L	1	1	<1	<1	<1	<1	<1	<1	<1
Silver, dissolved	µg/L	1.0	<1	3	2	<1	<1	<1	2	<1
Strontium, dissolved	µg/L	1	310	400	570	430	400	630	380	400
Vanadium, dissolved	µg/L	6	<6	<6	<6	<6	<6	<6	<6	<6
Zinc, dissolved	µg/L	3	7	220	6	7	<3	4	9	15
Gross alpha activity based on thorium-230 curve	pCi/L	.6	6.4	4.6	3.4	4.0	5.6	5.1	1.6	6.2
Gross beta activity based on strontium-90 curve	pCi/L	.6	12	9.6	9.7	9.9	11	10	8.5	11
Radon-222 activity, dissolved	pCi/L	80	500	97	400	170	330	400	240	530
Radium-226 activity, dissolved	pCi/L	0.02	0.49	0.50	0.56	0.42	0.46	0.57	0.40	0.26
Uranium, total	µg/L	.1	7.1	.3	.8	3.4	5.3	1.7	.6	6.7
Uranium activity ratio, uranium-234:238	234U:238U	--	1.64	1.11	1.34	1.57	1.51	1.67	1.15	1.46

Table 10. Summary of water-quality analyses for hardness, alkalinity, calculated dissolved solids, major ions, major metals, trace elements, and radionuclide activity or concentration in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig.11)			E12	M1	M2	M4	M5	M6	M8	M9
County[2]			055	043	043	173	021	021	177	177
Well depth, feet	Unit of		61	162	105	93	115	95	63	82
Well type[3]	measure-	Report-	I	N	I	I	I	I	M	I
Date sampled, month/day/year	ment	ing level	7/29/92	7/15/92	8/17/92	7/20/92	7/21/92	8/17/92	7/15/92	8/13/92
Hardness, total	mg/L	1	350	600	560	420	450	370	320	660
Alkalinity, laboratory, dissolved	mg/L	1	367	443	546	--	--	338	327	647
Dissolved solids, calculated	mg/L	1	441	791	782	--	--	497	403	845
Calcium, dissolved	mg/L	.10	100	160	160	120	110	100	91	180
Magnesium, dissolved	mg/L	.10	25	47	39	30	42	29	23	51
Sodium, dissolved	mg/L	.10	17	57	48	18	18	27	17	56
Percent sodium, dissolved	percent	1	9	17	15	--	--	14	10	15
Sodium-adsorption ratio	--	--	.4	1	.9	.4	.4	.6	.4	.9
Potassium, dissolved	mg/L	.10	5	8.9	12	--	--	4.1	4	6.8
Sulfate, dissolved	mg/L	.10	31	200	140	--	--	88	36	110
Chloride, dissolved	mg/L	.10	3.2	20	14	--	--	17	8.8	11
Fluoride, dissolved	mg/L	.10	.30	.30	.40	--	--	.40	.40	.20
Silica, dissolved	mg/L	.10	35	24	32	25	30	26	23	30
Arsenic, dissolved	µg/L	1	3	6	13	--	--	1	14	4
Barium, dissolved	µg/L	2	190	73	63	380	170	220	230	350
Beryllium, dissolved	µg/L	.5	<.5	.6	<.5	<.5	<.5	<.5	.7	<.5
Boron, dissolved	µg/L	10	590	210	220	--	--	90	80	140
Cadmium, dissolved	µg/L	1.0	<1	<1	<1	1	<1	<1	<1	<1
Chromium, dissolved	µg/L	5	<5	<5	<5	<5	<5	<5	<5	<5
Cobalt, dissolved	µg/L	3	<3	10	<3	6	6	<3	6	<3
Copper, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Iron, dissolved	µg/L	3	10	5,700	6,100	6,100	5,900	580	1,500	9,000
Lead, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Lithium, dissolved	µg/L	4	19	80	95	42	56	37	21	69
Manganese, dissolved	µg/L	1	130	610	420	670	270	430	830	800
Molybdenum, dissolved	µg/L	10	<10	10	<10	<10	<10	<10	<10	<10
Nickel, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium, dissolved	µg/L	1	1	<1	<1	--	--	<1	<1	<1
Silver, dissolved	µg/L	1.0	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.0
Strontium, dissolved	µg/L	1	390	1,700	1,800	770	900	600	590	1,800
Vanadium, dissolved	µg/L	6	<6	<6	<6	<6	<6	<6	<6	<6
Zinc, dissolved	µg/L	3	9	7	5	6	6	5	22	3
Gross alpha activity based on thorium-230 curve	pCi/L	.6	6.2	3.3	5.7	4.3	2.1	3.5	2.5	2.2
Gross beta activity based on strontium-90 curve	pCi/L	.6	7.3	10	12	9.2	4.2	4.5	4.2	7.9
Radon-222 activity, dissolved	pCi/L	80	460	480	320	300	250	300	270	270
Radium-226 activity, dissolved	pCi/L	.02	1.3	.91	.42	.56	.71	.32	.33	.52
Uranium, total	µg/L	.1	5.4	1.4	2.0	1.3	1.4	2.0	1.4	.9
Uranium activity ratio, uranium-234:238	234U:238U	--	1.43	1.35	1.5	1.38	1.27	1.42	1.42	1.07

Table 10. Summary of water-quality analyses for hardness, alkalinity, calculated dissolved solids, major ions, major metals, trace elements, and radionuclide activity or concentration in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig.11)			M10	M11	M12	P1	P2	P3	P4	P5
County[2]			177	055	153	153	153	153	153	153
Well depth, feet	Unit of	Report-	--	80	103	84	43	74	52	68
Well type[3]	measure-	ing	D	N	M	I	I	M	I	I
Date sampled, month/day/year	ment	level	8/19/92	7/16/92	8/13/92	7/21/92	8/19/92	7/20/92	8/20/92	8/20/92
Hardness, total	mg/L	1	340	740	550	260	310	240	320	270
Alkalinity, laboratory, dissolved	mg/L	1	433	346	479	202	263	205	255	284
Dissolved solids, calculated	mg/L	1	467	965	610	353	465	362	477	348
Calcium, dissolved	mg/L	.10	100	210	150	79	96	66	97	77
Magnesium, dissolved	mg/L	.10	21	52	41	14	18	19	18	18
Sodium, dissolved	mg/L	.10	37	65	25	23	25	25	28	17
Percent sodium, dissolved	percent	1	19	16	9	16	14	18	16	12
Sodium-adsorption ratio	--	--	0.9	1	.5	.6	.6	.7	.7	.5
Potassium, dissolved	mg/L	.10	3.6	8.3	6.2	5.8	7.6	6.7	8.4	3.0
Sulfate, dissolved	mg/L	.10	.8	160	55	59	110	75	120	24
Chloride, dissolved	mg/L	.10	5.9	210	.8	12	12	21	13	1.1
Fluoride, dissolved	mg/L	.10	.20	.20	.30	.30	.30	.30	.40	.30
Silica, dissolved	mg/L	.10	34	32	32	37	35	23	34	30
Arsenic, dissolved	µg/L	1	<1	10	3	4	6	3	2	2
Barium, dissolved	µg/L	2	250	340	400	160	250	150	270	240
Beryllium, dissolved	µg/L	.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
Boron, dissolved	µg/L	10	220	160	130	50	50	60	60	60
Cadmium, dissolved	µg/L	1.0	<1	3	2	2.0	<1	<1	<1	<1
Chromium, dissolved	µg/L	5	<5	<5	<5	<5	<5	<5	<5	<5
Cobalt, dissolved	µg/L	3	<3	8	<3	<3	<3	<3	<3	<3
Copper, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Iron, dissolved	µg/L	3	2,900	17,000	9,400	690	1,500	11	3,500	6
Lead, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Lithium, dissolved	µg/L	4	21	93	67	17	25	15	25	17
Manganese, dissolved	µg/L	1	430	1,300	1,100	310	550	1,100	1,200	11
Molybdenum, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Nickel, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium, dissolved	µg/L	1	<1	<1	<1	<1	<1	<1	<1	5
Silver, dissolved	µg/L	1.0	<1.0	<1.0	3.0	<1	<1	<1	1	<1
Strontium, dissolved	µg/L	1	420	1,600	1,400	380	520	320	530	290
Vanadium, dissolved	µg/L	6	<6	<6	<6	<6	<6	<6	<6	<6
Zinc, dissolved	µg/L	3	140	5	17	7	8	6	<3	7
Gross alpha activity based on thorium-230 curve	pCi/L	.6	.8	2.8	1.4	1.0	2.4	5.0	3.0	4.5
Gross beta activity based on strontium-90 curve	pCi/L	.6	4.6	10	7.8	6.2	9.1	7.7	9.7	5.8
Radon-222 activity, dissolved	pCi/L	80	350	230	--	480	300	340	220	450
Radium-226 activity, dissolved	pCi/L	.02	.32	.53	.65	.52	.44	.20	.46	.24
Uranium, total	µg/L	.1	.1	.5	.4	.7	.7	3.7	.3	4.9
Uranium activity ratio, uranium-234:238	234U:238U	--	--	1.47	1.42	1.24	1.43	1.4	1.29	1.23

Table 10. Summary of water-quality analyses for hardness, alkalinity, calculated dissolved solids, major ions, major metals, trace elements, and radionuclide activity or concentration in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig.11)			P6	P7	P10	U2	U5	U8	U9	U11
County[2]			153	153	153	173	177	177	55	153
Well depth, feet	Unit of	Report-	52	62	126	100	164	144	56	198
Well type[3]	measure-	ing	M	M	N	D	I	I	D	I
Date sampled, month/day/year	ment	level	7/14/92	7/14/92	7/15/92	7/20/92	7/22/92	8/13/92	7/21/92	9/01/92
Hardness, total	mg/L	1	170	170	180	370	410	320	350	280
Alkalinity, laboratory, dissolved	mg/L	1	157	163	179	319	302	314	312	213
Dissolved solids, calculated	mg/L	1	308	318	399	427	557	406	454	444
Calcium, dissolved	mg/L	.10	50	47	52	100	120	94	96	76
Magnesium, dissolved	mg/L	.10	12	12	12	28	27	21	26	21
Sodium, dissolved	mg/L	.10	29	35	59	10	20	18	17	25
Percent sodium, dissolved	percent	1	25	30	40	6	9	11	10	16
Sodium-adsorption ratio	--	--	1	1	2	.2	.4	.4	.4	.7
Potassium, dissolved	mg/L	.10	11	11	8.6	2.4	8.9	2.2	1.8	4
Sulfate, dissolved	mg/L	.10	60	55	79	39	77	17	39	18
Chloride, dissolved	mg/L	.10	24	29	54	1.9	18	1.9	16	6.3
Fluoride, dissolved	mg/L	.10	.40	.40	.40	.40	.40	.20	.30	.30
Silica, dissolved	mg/L	.10	24	25	25	24	28	24	26	32
Arsenic, dissolved	µg/L	1	5	5	9	1	<1	1	1	2
Barium, dissolved	µg/L	2	91	90	210	160	180	150	290	180
Beryllium, dissolved	µg/L	.5	.8	.8	.8	<.5	<.5	<.5	<.5	<.5
Boron, dissolved	µg/L	10	70	70	70	50	80	40	30	60
Cadmium, dissolved	µg/L	1.0	<1	<1	<1	<1	<1	<1	<1	<1
Chromium, dissolved	µg/L	5	<5	<5	<5	<5	<5	<5	<5	<5
Cobalt, dissolved	µg/L	3	<3	<3	<3	<3	<3	<3	<3	3
Copper, dissolved	µg/L	10	<10	10	<10	<10	<10	<10	<10	<10
Iron, dissolved	µg/L	3	<3	<3	180	<3	66	16	4	8
Lead, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Lithium, dissolved	µg/L	4	16	17	19	21	38	18	13	14
Manganese, dissolved	µg/L	1	11	2	850	1	410	10	27	<1
Molybdenum, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Nickel, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium, dissolved	µg/L	1	3	4	<1	12	1	2	4	2
Silver, dissolved	µg/L	1.0	<1	<1	<1	<1.0	<1.0	2.0	<1.0	<1.0
Strontium, dissolved	µg/L	1	320	310	340	460	840	380	360	300
Vanadium, dissolved	µg/L	6	<6	9	<6	<6	<6	<6	<6	<6
Zinc, dissolved	µg/L	3	4	6	3	38	32	<3	47	<3
Gross alpha activity based on thorium-230 curve	pCi/L	.6	2.1	6.8	4.9	8.7	2.8	2.3	5.5	2.6
Gross beta activity based on strontium-90 curve	pCi/L	.6	13	10	11	5.3	8.4	3.6	4.5	4.5
Radon-222 activity, dissolved	pCi/L	80	450	310	470	1,200	900	430	420	390
Radium-226 activity, dissolved	pCi/L	.02	.09	.07	.45	.66	.73	.14	.15	.94
Uranium, total	µg/L	.1	5.2	2.6	3.1	6.4	2.2	2.1	7.7	2.3
Uranium activity ratio, uranium-234:238	234U:238U	--	1.71	1.88	1.65	1.2	1.19	1.69	1.28	1.37

Table 10. Summary of water-quality analyses for hardness, alkalinity, calculated dissolved solids, major ions, major metals, trace elements, and radionuclide activity or concentration in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig.11)	Unit of measurement	Reporting level	U13	D1	D2	D3	D6	D8	D9	D10
County[2]			153	043	043	173	021	055	055	153
Well depth, feet			66	270	625	325	133	325	238	235
Well type[3]			N	M	D	M	I	M	M	
Date sampled, month/day/year			7/29/92	7/21/92	7/21/92	7/14/92	7/15/92	7/15/92	7/23/92	7/20/92
Hardness, total	mg/L	1	240	700	650	680	320	380	310	250
Alkalinity, laboratory, dissolved	mg/L	1	277	382	221	230	334	361	317	272
Dissolved solids, calculated	mg/L	1	329	1,110	1,240	1,220	402	518	426	324
Calcium, dissolved	mg/L	.10	68	200	200	210	91	110	92	76
Magnesium, dissolved	mg/L	.10	17	49	35	36	22	26	20	14
Sodium, dissolved	mg/L	.10	21	84	140	130	14	39	20	16
Percent sodium, dissolved	percent	1	16	20	31	29	9	18	12	12
Sodium-adsorption ratio	--	--	.6	1	2	2	.3	.9	.5	.4
Potassium, dissolved	mg/L	.10	3.5	12	22	21	2.4	3.8	6.4	4.1
Sulfate, dissolved	mg/L	.10	9.6	470	590	560	26	80	24	11
Chloride, dissolved	mg/L	.10	6	43	100	110	8.5	16	16	52
Fluoride, dissolved	mg/L	.10	.30	.40	1.8	1.3	.30	.30	.30	.30
Silica, dissolved	mg/L	.10	25	16	9.1	11	24	25	34	30
Arsenic, dissolved	µg/L	1	<1	<1	1	1	<1	<1	2	2
Barium, dissolved	µg/L	2	160	20	14	21	230	58	210	170
Beryllium, dissolved	µg/L	.5	<.5	<.5	<.5	.6	.8	.7	<.5	<.5
Boron, dissolved	µg/L	10	730	210	490	370	60	120	50	50
Cadmium, dissolved	µg/L	1.0	<1	<1	<1	<1	<1	<1	<1	2
Chromium, dissolved	µg/L	5	<5	<5	<5	<5	<5	<5	<5	<5
Cobalt, dissolved	µg/L	3	<3	<3	<3	6	<3	<3	<3	<3
Copper, dissolved	µg/L	10	210	<10	<10	<10	<10	10	<10	20
Iron, dissolved	µg/L	3	<3	1,300	160	2,200	4	5	<3	5
Lead, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Lithium, dissolved	µg/L	4	12	73	190	160	22	33	14	15
Manganese, dissolved	µg/L	1	6	440	77	170	2	200	<1	4
Molybdenum, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Nickel, dissolved	µg/L	10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium, dissolved	µg/L	1	2	<1	<1	<1	4	<1	5	2
Silver, dissolved	µg/L	1.0	2	<1	<1	<1	<1	<1	<1	<1
Strontium, dissolved	µg/L	1	260	2,100	4,500	4,100	380	610	340	260
Vanadium, dissolved	µg/L	6	<6	<6	<6	<6	<6	<6	<6	<6
Zinc, dissolved	µg/L	3	460	3	19	8	7	12	6	15
Gross alpha activity based on thorium-230 curve	pCi/L	.6	4.4	11	16	13	4.0	6.4	5.7	3.1
Gross beta activity based on strontium-90 curve	pCi/L	.6	4.3	19	30	30	4.1	5.1	9.2	5.7
Radon-222 activity, dissolved	pCi/L	80	440	--	280	190	370	420	350	200
Radium-226 activity, dissolved	pCi/L	.02	.26	2.2	3.9	3.9	.28	.31	.27	.28
Uranium, total	µg/L	.1	2	1.0	.1	<.1	4.0	4.8	7.2	2.2
Uranium activity ratio, uranium-234:238	234U:238U	--	1.38	2.12	--	--	1.6	1.9	1.22	1.49

Table 10. Summary of water-quality analyses for hardness, alkalinity, calculated dissolved solids, major ions, major metals, trace elements, and radionuclide activity or concentration in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig.11)			**D11**	**D12**
County[2]			**153**	**153**
Well depth, feet			**315**	**134**
Well type[3]	**Unit of**	**Reporting**	**M**	**N**
Date sampled, month/day/year	**measurement**	**level**	**7/23/92**	**7/29/92**
Hardness, total	mg/L	1	280	210
Alkalinity, laboratory, dissolved	mg/L	1	306	245
Dissolved solids, calculated	mg/L	1	386	278
Calcium, dissolved	mg/L	.10	84	56
Magnesium, dissolved	mg/L	.10	16	16
Sodium, dissolved	mg/L	.10	25	20
Percent sodium, dissolved	percent	1	16	17
Sodium-adsorption ratio	--	--	.7	.6
Potassium, dissolved	mg/L	.10	4.1	2.2
Sulfate, dissolved	mg/L	.10	27	4.6
Chloride, dissolved	mg/L	.10	5.6	3.7
Fluoride, dissolved	mg/L	.10	.20	.20
Silica, dissolved	mg/L	.10	32	24
Arsenic, dissolved	µg/L	1	<1	<1
Barium, dissolved	µg/L	2	99	150
Beryllium, dissolved	µg/L	.5	<.5	<.5
Boron, dissolved	µg/L	10	50	550
Cadmium, dissolved	µg/L	1.0	<1	<1
Chromium, dissolved	µg/L	5	<5	7
Cobalt, dissolved	µg/L	3	<3	<3
Copper, dissolved	µg/L	10	<10	40
Iron, dissolved	µg/L	3	3	<3
Lead, dissolved	µg/L	10	<10	<10
Lithium, dissolved	µg/L	4	17	8
Manganese, dissolved	µg/L	1	<1	<1
Molybdenum, dissolved	µg/L	10	<10	<10
Nickel, dissolved	µg/L	10	<10	<10
Selenium, dissolved	µg/L	1	5	<1
Silver, dissolved	µg/L	1.0	1	<1
Strontium, dissolved	µg/L	1	370	220
Vanadium, dissolved	µg/L	6	<6	<6
Zinc, dissolved	µg/L	3	7	48
Gross alpha activity based on thorium-230 curve	pCi/L	.6	4.9	1.6
Gross beta activity based on strontium-90 curve	pCi/L	.6	7.4	3.2

Table 10. Summary of water-quality analyses for hardness, alkalinity, calculated dissolved solids, major ions, major metals, trace elements, and radionuclide activity or concentration in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992—Continued

Well identification number[1] (fig.11)			D11	D12
County[2]			153	153
Well depth, feet			315	134
Well type[3]	Unit of	Reporting	M	N
Date sampled, month/day/year	measurement	level	7/23/92	7/29/92
Radon-222, dissolved	pCi/L	80	460	390
Radium-226, dissolved	pCi/L	.02	.49	.18
Uranium, total	µg/L	.1	4.8	1.6
Uranium activity ratio, uranium-234:238	234U:238U	--	1.44	1.53

[1]Well screened in:
- E—Elkhorn River Valley alluvial aquifer
- M—Missouri River Valley alluvial aquifer
- P—Platte River Valley alluvial aquifer
- U—upland area alluvial aquifers
- D—Dakota aquifer

[2]Counties:
- 021—Burt
- 043—Dakota
- 055—Douglas
- 153—Sarpy
- 173—Thurston
- 177—Washington

Well type:
- D—domestic
- I—irrigation
- M—municipal
- N—industrial

Table 11. Statistical summary of water-quality analyses from the Papio-Missouri River Natural District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency drinking-water regulations

[µS/cm, microsiemens per centimeter at 25 degrees Celsius (°C), °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; TT, treatment technique; F, final; P, proposed; R, under review; **, copper action level (1,300 µg/L), lead action level (15 µg/L) (U.S. Environmental Protection Agency, 1991a); ***, the Maximum Contaminant Level (MCL) for total beta particle and photon activity is 4 millirems per roentgen (U.S. Environmental Protection Agency, 1991); --, not applicable]

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Well depth	feet	1.0	60	37	99	625	100	--	--	--	--
Specific conductance, field	µS/cm	1.0	61	417	710	1,800	318	--	--	--	--
pH, field	standard units	.1	61	6.3	7.1	7.9	.29	--	--	F 6.5–8.5	0
Water temperature, field	°C	.5	61	11	12.5	23.5	3.0	--	--	--	--
Oxygen, dissolved, field	mg/L	.1	60	.1	2.4	8.9	2.6	--	--	--	--
Nitrite plus nitrate as nitrogen	mg/L	.05	61	<.05	.07	30	4.70	10	F 10	--	2
Hardness, total	mg/L as $CaCO_3$	1	42	170	320	740	160	--	--	--	--
Alkalinity, laboratory, dissolved	mg/L as $CaCO_3$	1	40	120	275	647	110	--	--	--	--
Dissolved solids, calculated	mg/L	1	40	278	416	1,240	249	--	--	F 500	10
Calcium, dissolved	mg/L	.10	42	47	95	210	45	--	--	--	--
Magnesium, dissolved	mg/L	.10	42	9.8	21	52	12	--	--	--	--
Sodium, dissolved	mg/L	.10	42	7.6	25	140	16	--	--	--	--
Percent sodium, dissolved	percent	1	40	6	16	40	7	--	--	--	--
Sodium-adsorption ratio	--	--	42	.2	.7	2	.4	--	--	--	--
Potassium, dissolved	mg/L	.10	40	1.8	7.2	22	4.4	--	--	--	--
Sulfate, dissolved	mg/L	.10	40	.80	65	590	140	--	--	F 250	3
Chloride, dissolved	mg/L	.10	40	.8	14.5	210	38	--	--	F250	0
Fluoride, dissolved	mg/L	.10	40	.20	.30	1.8	.30	--	--	R 2.0	0
Silica, dissolved	mg/L	.10	42	9.1	30	37	6.3	--	--	--	--
Arsenic, dissolved	µg/L	1	40	<1	2	14	3	--	F 50	--	0

Table 11. Statistical summary of water-quality analyses from the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Barium, dissolved	µg/L	2	42	14	190	530	120	2,000	F 2,000	--	0
Beryllium, dissolved	µg/L	.5	42	<.5	<.5	.9	.3	4	F 4	--	0
Boron, dissolved	µg/L	10	40	30	70	730	170	--	--	--	--
Cadmium, dissolved	µg/L	1.0	42	<1.0	<1.0	3.0	.8	5	F 5	--	0
Chromium, dissolved	µg/L	5	42	<5	<5	7	1	100	F 100	--	0
Cobalt, dissolved	µg/L	3	42	<3	<3	10	3	--	--	--	--
Copper, dissolved	µg/L	10	42	<10	<10	210	33	1,300	F TT**	F 1,000	0
Iron, dissolved	µg/L	3	42	<3	130	17,000	3,900	--	--	F 300	19
Lead, dissolved	µg/L	10	42	<10	<10	<10	--	0	F TT**	--	--
Lithium, dissolved	µg/L	4	42	8	21	190	39	--	--	--	--
Manganese, dissolved	µg/L	1	42	<1	360	2,300	530	200	R	F 50	29
Molybdenum, dissolved	µg/L	10	42	<10	<10	10	2	--	--	--	--
Nickel, dissolved	µg/L	10	42	<10	<10	<10	--	100	F 100	--	0
Selenium, dissolved	µg/L	1	40	<1	<1	12	2	50	F 50	--	0
Silver, dissolved	µg/L	1.0	42	<1.0	<1.0	3.0	.9	--		F 100	0
Strontium, dissolved	µg/L	10	42	220	410	4,500	930	--	--	--	--
Vanadium, dissolved	µg/L	6	42	<6	<6	9	1	--	--	--	--
Zinc, dissolved	µg/L	3	42	<3	7	460	79	--	--	F 5,000	0
Gross alpha activity based on thorium-230 curve	pCi/L	.6	42	0.8	4	16	3.1	0	F 15	--	1
Gross beta activity based on strontium-90 curve	pCi/L	.6	42	3.2	8.5	30	5.7	0	F ***	--	--

Table 11. Statistical summary of water-quality analyses from the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Radon-222 activity, dissolved	pCi/L	80	40	97	360	1,200	188	0	P 300	--	26
Radium-226 activity, dissolved	pCi/L	.02	42	.07	.46	3.9	.82	0	P 5	-	0
Uranium, total	µg/L	.1	42	<.1	2.0	7.7	2.3	0	F 20	--	0
Uranium activity ratio, uranium-234:238	$^{234}U:^{238}U$	--	39	1.1	1.4	2.1	.20	--	--	--	--
Alachlor	µg/L	.05	20	<.05	<.05	.05	<.05	0	F2.0	--	0
Atrazine	µg/L	.05	20	<.05	.14	1.8	.54	3	F3.0	--	0
Cyanazine	µg/L	.20	19	<.20	<.20	1.0	.27	--	--	--	--
Deisopropylatrazine	µg/L	.05	19	<.05	<.05	.29	.08	--	--	--	--
Deethylatrazine	µg/L	.05	19	<.05	<.05	.26	.08	--	--	--	--
Metolachlor	µg/L	.05	20	<0.05	<0.05	.24	.07	--	--	--	--
Metribuzin	µg/L	.05	20	<.05	<.05	.24	0.02	--	--	--	--
Prometon	µg/L	.05	19	<.05	<.05	.44	0.11	--	--	--	--
Simazine	µg/L	.05	19	<.05	<.05	.07	.02	4	F 4.0	--	0

[1]MCLG, Maximum Contaminant Level Goal, a nonenforceable concentration of a drinking-water contaminant that is protective of adverse health effects and allows an adequate margin of safety (U.S. Environmental Protection Agency, 1991b, 1991e, 1992).

MCL, Maximum Contaminant Level, maximum permissible level of a contaminant in water that is delivered to any user of a public-water system (U.S. Environmental Protection Agency, 1991a, 1991c, 1991e, 1992).

SMCL, Secondary Maximum Contaminant Level, a nonenforceable concentration of a drinking-water contaminant that can adversely affect the odor or appearance of water (U.S. Environmental Protection Agency, 1991d).

Table 12. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Elkhorn River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations

[µS/cm, microsiemens per centimeter at 25 degrees Celsius (°C), °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; TT, treatment technique; F, final; P, proposed; R, under review; **, copper action level (1,300 µg/L), lead action level (15 µg/L) (U.S. Environmental Protection Agency, 1991a); ***, the Maximum Contaminant Level (MCL) for total beta particle and photon activity is 4 millirems per roentgen (U.S. Environmental Protection Agency, 1991); --, not applicable]

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Concentrations			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Well depth	feet	1.0	12	39	63	98	19	--	--	--	--
Specific conductance, field	µS/cm	1.0	12	417	567	733	96	--	--	--	--
pH, field	standard units	.1	12	6.3	7.3	7.5	.40	--	--	F 6.5-8.5	0
Water temperature, field	°C	.5	12	12.0	12.8	23.5	3.2	--	--	--	--
Oxygen, dissolved, field	mg/L	.1	12	.6	2.9	7.1	2.2	--	--	--	--
Nitrite plus nitrate as nitrogen	mg/L	.05	12	<.05	.12	1.9	.55	10	F 10	--	0
Hardness, total	mg/L as $CaCO_3$	1	9	180	230	350	61	--	--	--	--
Alkalinity, laboratory, dissolved	mg/L as $CaCO_3$	1	9	120	212	367	69	--	--	--	--
Dissolved solids, calculated	mg/L	1	9	329	363	449	44	--	--	F 500	0
Calcium, dissolved	mg/L	.10	9	54	73	100	18	--	--	--	--
Magnesium, dissolved	mg/L	.10	9	9.8	14	25	4.8	--	--	--	--
Sodium, dissolved	mg/L	.10	9	7.6	25	35	9.0	--	--	--	--
Percent sodium, dissolved	percent	1	9	6	17	28	8	--	--	--	--
Sodium-adsorption ratio	--	--	9	.2	.7	1	.3	--	--	--	--
Potassium, dissolved	mg/L	.10	9	5.0	7.9	9.3	1.3	--	--	--	--
Sulfate, dissolved	mg/L	.10	9	26	71	95	27	--	--	F 250	0
Chloride, dissolved	mg/L	.10	9	3.2	16	35	8.4	--	--	F 250	0
Fluoride, dissolved	mg/L	.10	9	.20	.30	.40	.1	--	--	R 2	0
Silica, dissolved	mg/L	.10	9	29	34	35	2.2	--	--	--	--
Arsenic, dissolved	µg/L	1	9	<1	3	7	2	--	F 50	--	0
Barium, dissolved	µg/L	2	9	94	240	530	140	2,000	F 2,000	--	0
Beryllium, dissolved	µg/L	.5	9	<.5	<.5	.9	.4	4	F 4	--	0
Boron, dissolved	µg/L	10	9	50	70	590	170	--	--	--	--
Cadmium, dissolved	µg/L	1.0	9	<1.0	<1.0	3.0	1.0	5	F 5	--	0
Chromium, dissolved	µg/L	5	9	<5	<5	<5	--	100	F 100	--	0

Table 12. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Elkhorn River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Concentrations			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Cobalt, dissolved	µg/L	3	9	<3	<3	<3	--	--	--	--	--
Copper, dissolved	µg/L	10	9	<10	<10	<10	--	1,300	F TT**	F 1,000	0
Iron, dissolved	µg/L	3	9	6	100	14,000	4,500	--	--	F 300	4
Lead, dissolved	µg/L	10	9	<10	<10	<10	--	0	F TT**	--	--
Lithium, dissolved	µg/L	4	9	17	20	26	3	--	--	--	--
Manganese, dissolved	µg/L	1	9	110	740	2,300	740	200	R	F 50	9
Molybdenum, dissolved	µg/L	10	9	<10	<10	<10	--	--	--	--	--
Nickel, dissolved	µg/L	10	9	<10	<10	<10	--	100	F 100	--	0
Selenium, dissolved	µg/L	1	9	<1	<1	1	.4	50	F 50	--	0
Silver, dissolved	µg/L	1.0	9	<1.0	<1.0	3.0	1.2	--	--	F 100	0
Strontium, dissolved	µg/L	10	9	310	400	630	100	--	--	--	--
Vanadium, dissolved	µg/L	6	9	<6	<6	<6	--	--	--	--	--
Zinc, dissolved	µg/L	3	9	<3	7	220	71	--	--	F 5,000	0
Gross alpha activity based on thorium-230 curve	pCi/L	.6	9	1.6	5.1	6.4	1.6	0	F 15	--	0
Gross beta activity based on strontium-90 curve	pCi/L	.6	9	7.3	9.9	12	1.4	0	F ***	--	--
Radon-222, dissolved	pCi/L	80	9	97	400	530	150	0	P 300	--	6
Radium-226, dissolved	pCi/L	.02	9	.26	.49	1.3	.30	0	P 5	--	0
Uranium, total	µg/L	.1	9	.3	3.4	7.1	2.7	0	F20	--	0
Uranium activity ratio, uranium-234:238	^{234}U:^{238}U	--	9	1.1	1.5	1.7	.2	--	--	--	--
Alachlor	µg/L	.05	8	<.05	<.05	<.05	--	0	F 2	--	0
Atrazine	µg/L	.05	8	<.05	.08	.32	.15	3	F 3	--	0
Cyanazine	µg/L	.20	8	<.20	<.20	<.20	--	--	--	--	--
Deisopropylatrazine	µg/L	.05	8	<.05	<.05	.12	.04	--	--	-	--
Deethylatrazine	µg/L	.05	8	<.05	<.05	.11	.05	--	--	-	--
Metolachlor	µg/L	.05	8	<.05	<.05	<.05	--	--	--	--	--

Table 12. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Elkhorn River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Concentrations			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Metribuzin	µg/L	0.05	8	<0.05	<0.05	<0.05	--	--	--	--	--
Prometon	µg/L	.05	8	<.05	<.05	.44	0.16	--	--	--	--
Simazine	µg/L	.05	8	<.05	<.05	<.05	--	4	F 4	--	0

[1]MCLG, Maximum Contaminant Level Goal, a nonenforceable concentration of a drinking-water contaminant that is protective of adverse health effects and allows an adequate margin of safety (U.S. Environmental Protection Agency, 1991b, 1991e, 1992).

MCL, Maximum Contaminant Level, maximum permissible level of a contaminant in water that is delivered to any user of a public-water system (U.S. Environmental Protection Agency, 1991a, 1991c, 1991e, 1992).

SMCL, Secondary Maximum Contaminant Level, a nonenforceable concentration of a drinking-water contaminant that can adversely affect the odor or appearance of water (U.S. Environmental Protection Agency, 1991d).

Table 13. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Missouri River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations

[µS/cm, microsiemens per centimeter at 25 degrees Celsius (°C), °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; TT, treatment technique; F, final; P, proposed; R, under review; **, copper action level (1,300 µg/L), lead action level (15 µg/L) (U.S. Environmental Protection Agency, 1991a); ***, the Maximum Contaminant Level (MCL) for total beta particle and photon activity is 4 millirems per roentgen (U.S. Environmental Protection Agency, 1991); --, not applicable]

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values: Minimum	Values: Median	Values: Maximum	Standard deviation	USEPA drinking-water regulation[1]: MCLG	USEPA drinking-water regulation[1]: MCL	USEPA drinking-water regulation[1]: SMCL	Number of samples exceeding USEPA drinking-water regulations
Well depth	feet	1.0	12	63	100	168	34	--	--	--	--
Specific conductance, field	µS/cm	1.0	13	671	1,030	1,680	295	--	--	--	--
pH, field	standard units	.1	13	6.8	7.1	7.4	.1	--	--	F6.5–8.5	0
Water temperature, field	°C	.5	13	11.0	12.0	15.0	1.3	--	--	--	--
Oxygen, dissolved, field	mg/L	.1	13	.1	.2	8.1	2.6	--	--	--	--
Nitrite plus nitrate as nitrogen	mg/L	.05	13	<.05	<.05	1.4	.40	10	F 10	--	0
Hardness, total	mg/L as $CaCO_3$	1	10	320	500	740	140	--	--	--	--
Alkalinity, laboratory, dissolved	mg/L as $CaCO_3$	1	8	327	438	647	112	--	--	--	--
Dissolved solids, calculated	mg/L	1	8	403	696	965	204	--	--	F 500	5
Calcium, dissolved	mg/L	.10	10	91	135	210	40	--	--	--	--
Magnesium, dissolved	mg/L	.10	10	21	40	52	11	--	--	--	--
Sodium, dissolved	mg/L	.10	10	17	32	65	18	--	--	--	--
Percent sodium, dissolved	percent	1	8	9	15	19	3	--	--	--	--
Sodium-adsorption ratio	--	--	10	.4	.8	1	.3	--	--	--	--
Potassium, dissolved	mg/L	.10	8	3.6	6.5	12	2.9	--	--	--	--
Sulfate, dissolved	mg/L	.10	8	.80	99	200	67	--	--	F 250	0
Chloride, dissolved	mg/L	.10	8	.80	12.5	210	70.6	--	--	F 250	0
Fluoride, dissolved	mg/L	.10	8	.20	.30	.40	.10	--	--	R 2	0
Silica, dissolved	mg/L	.10	10	23	30	34	3.9	--	--	--	--
Arsenic, dissolved	µg/L	1	8	<1	5	14	5	--	F 50	--	0
Barium, dissolved	µg/L	2	10	63	240	400	121	2,000	F 2,000	--	0
Beryllium, dissolved	µg/L	.5	10	<.5	<.5	.7	.3	4	F 4	--	0
Boron, dissolved	µg/L	10	8	80	150	220	60	--	--	--	--
Cadmium, dissolved	µg/L	1.0	10	<1	<1	3	1	5	F 5	--	0
Chromium, dissolved	µg/L	5	10	<5	<5	<5	--	100	F 100	--	0

Table 13. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Missouri River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values: Minimum	Values: Median	Values: Maximum	Standard deviation	USEPA drinking-water regulation[1]: MCLG	USEPA drinking-water regulation[1]: MCL	USEPA drinking-water regulation[1]: SMCL	Number of samples exceeding USEPA drinking-water regulations
Cobalt, dissolved	µg/L	3	10	<3	3	10	4	--	--	--	--
Copper, dissolved	µg/L	10	10	<10	<10	<10	--	1,300	F TT**	F 1,000	0
Iron, dissolved	µg/L	3	10	580	6,000	17,000	4,700	--	--	F 300	10
Lead, dissolved	µg/L	10	10	<10	<10	<10	--	0	F TT**	--	--
Lithium, dissolved	µg/L	4	10	21	62	95	27	--	--		--
Manganese, dissolved	µg/L	1	10	270	640	1,300	330	200	R	F 50	10
Molybdenum, dissolved	µg/L	10	10	<10	<10	10	3	--	--	--	--
Nickel, dissolved	µg/L	10	10	<10	<10	<10	--	100	F 100	--	0
Selenium, dissolved	µg/L	1	8	<1	<1	<1	--	50	F 50	--	0
Silver, dissolved	µg/L	1.0	10	<1.0	<1.0	3.0	1.0	--	--	F 100	0
Strontium, dissolved	µg/L	10	10	420	1,200	1,800	550	--	--	--	--
Vanadium, dissolved	µg/L	6	10	<6	<6	<6	--	--	--	--	--
Zinc, dissolved	µg/L	3	10	3	6	140	42	--	--	F 5,000	0
Gross alpha activity based on thorium-230 curve	pCi/L	.6	10	0.8	2.7	4.3	--	0	F 15	--	0
Gross beta activity based on strontium-90 curve	pCi/L	.6	10	4.2	7.9	12	2.9	0	F ***	--	--
Radon-222, dissolved	pCi/L	80	9	230	300	480	70	0	P 300	--	3
Radium-226, dissolved	pCi/L	.02	10	.32	.53	.91	.19	0	P 5	--	0
Uranium, total	µg/L	.1	10	.1	1.3	2.0	.6	0	F 20	--	0
Uranium activity ratio, uranium-234:238	$^{234}U:^{238}U$	--	9	1.1	1.4	1.5	.1	0	--	--	--
Alachlor	µg/L	.05	2	<.05	--	<.05	--	0	F 2	--	0
Atrazine	µg/L	.05	2	<.05	--	<.05	--	3	F 3	--	0
Cyanazine	µg/L	.20	2	<.20	--	<.20	--	--	--	--	--
Deisopropylatrazine	µg/L	.05	2	<.05	--	<.05	--	--	--	--	--
Deethylatrazine	µg/L	.05	2	<.05	--	<.05	--	--	--	--	--

Table 13. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Missouri River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Metolachlor	μg/L	0.05	2	<0.05	--	<0.05	--	--	--	--	--
Metribuzin	μg/L	.05	2	<.05	--	<.05	--	--	--	--	--
Prometon	μg/L	.05	2	.10	--	.21	--	--	--	--	--
Simazine	μg/L	.05	2	<.05	--	<.05	--	4	F 4	--	0

[1]MCLG, Maximum Contaminant Level Goal, a nonenforceable concentration of a drinking-water contaminant that is protective of adverse health effects and allows an adequate margin of safety (U.S. Environmental Protection Agency, 1991b, 1991e, 1992).

MCL, Maximum Contaminant Level, maximum permissible level of a contaminant in water that is delivered to any user of a public-water system (U.S. Environmental Protection Agency, 1991a, 1991c, 1991e, 1992).

SMCL, Secondary Maximum Contaminant Level, a nonenforceable concentration of a drinking-water contaminant that can adversely affect the odor or appearance of water (U.S. Environmental Protection Agency, 1991d).

Table 14. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Platte River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations

[µS/cm, microsiemens per centimeter at 25 degrees Celsius (°C), °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; TT, treatment technique; F, final; P, proposed; R, under review; **, copper action level (1,300 µg/L), lead action level (15 µg/L) (U.S. Environmental Protection Agency, 1991a); ***, the Maximum Contaminant Level (MCL) for total beta particle and photon activity is 4 millirems per roentgen (U.S. Environmental Protection Agency, 1991); --, not applicable]

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Well depth	feet	1.0	10	43	61	126	24	--	--	--	--
Specific conductance, field	µS/cm	1.0	10	504	592	736	78	--	--	--	--
pH, field	standard units	.1	10	7.1	7.5	7.9	.2	--	--	F 6.5–8.5	0
Water temperature, field	°C	.5	10	11.5	12.5	23.5	4.5	--	--	--	--
Oxygen, dissolved, field	mg/L	.1	9	.1	1.1	5.1	1.8	--	--	--	--
Nitrite plus nitrate as nitrogen	mg/L	.05	10	<.05	.14	1.5	.61	10	F 10	--	0
Hardness, total	mg/L as $CaCO_3$	1	8	170	250	320	61	--	--	--	--
Alkalinity, laboratory, dissolved	mg/L as $CaCO_3$	1	8	157	204	284	48	--	--	--	--
Dissolved solids, calculated	mg/L	1	8	308	358	477	63	--	--	F 500	0
Calcium, dissolved	mg/L	.10	8	47	72	97	20	--	--	--	--
Magnesium, dissolved	mg/L	.10	8	12	16	19	3.2	--	--	--	--
Sodium, dissolved	mg/L	.10	8	17	27	59	13	--	--	--	--
Percent sodium, dissolved	percent	1	8	12	17	40	10	--	--	--	--
Sodium-adsorption ratio	--	--	8	.5	.7	2	.5	--	--	--	--
Potassium, dissolved	mg/L	.10	8	3.0	8.0	11	2.7	--	--	--	--
Sulfate, dissolved	mg/L	.10	8	24	68	120	40	--	--	F 250	0
Chloride, dissolved	mg/L	.10	8	1.1	17	54	16	--	--	F 250	0
Fluoride, dissolved	mg/L	.10	8	.30	.40	.40	.1	--	--	R 2	0
Silica, dissolved	mg/L	.10	8	23	28	37	5.6	--	--	--	--
Arsenic, dissolved	µg/L	1	8	2	5	9	2	--	F 50	--	0

Table 14. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Platte River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values: Minimum	Values: Median	Values: Maximum	Standard deviation	USEPA drinking-water regulation[1]: MCLG	USEPA drinking-water regulation[1]: MCL	USEPA drinking-water regulation[1]: SMCL	Number of samples exceeding USEPA drinking-water regulations
Barium, dissolved	µg/L	2	8	90	190	270	70	2,000	F 2,000	--	0
Beryllium, dissolved	µg/L	.5	8	<.5	<.5	.8	.4	4	F 4	--	0
Boron, dissolved	µg/L	10	8	50	60	70	8	--	--	--	--
Cadmium, dissolved	µg/L	1.0	8	<1.0	<1.0	2.0	.7	5	F 5	--	0
Chromium, dissolved	µg/L	5	8	<5	<5	<5	--	100	F 100	--	0
Cobalt, dissolved	µg/L	3	8	<3	<3	<3	--	--	--	--	--
Copper, dissolved	µg/L	10	8	<10	<10	10	3.5	1,300	F TT**	F 1,000	0
Iron, dissolved	µg/L	3	8	<3	96	3,500	1,200	--	--	F 300	3
Lead, dissolved	µg/L	10	8	<10	<10	<10	--	0	F TT**	--	--
Lithium, dissolved	µg/L	4	8	15	17	25	4	--	--	--	--
Manganese, dissolved	µg/L	1	8	2	430	1,200	500	200	R	F 50	5
Molybdenum, dissolved	µg/L	10	8	<10	<10	<10	--	--	--	--	--
Nickel, dissolved	µg/L	10	8	<10	<10	<10	--	100	F 100	--	0
Selenium, dissolved	µg/L	1	8	<1	<1	5	2	50	F 50	--	0
Silver, dissolved	µg/L	1.0	8	<1.0	<1.0	1.0	.4	--	--	F 100	0
Strontium, dissolved	µg/L	10	8	290	330	530	95	--	--	--	--
Vanadium, dissolved	µg/L	6	8	<6	<6	9	3	--	--	--	--
Zinc, dissolved	µg/L	3	8	<3	6	8	3	--	--	F 5,000	0
Gross alpha activity based on thorium-230 curve	pCi/L	.6	8	1.0	3.8	6.8	1.9	0	F 15	--	0
Gross beta activity based on strontium-90 curve	pCi/L	.6	8	5.8	9.4	13	2.4	0	F ***	--	--
Radon-222, dissolved	pCi/L	80	8	220	400	480	100	0	P 300	--	6
Radium-226, dissolved	pCi/L	.02	8	.07	.34	.52	.18	0	P 5	--	0
Uranium, total	µg/L	.1	8	.3	2.9	5.2	1.9	0	F 20	--	0
Uranium ratio activity, uranium-234:238	$^{234}U:^{238}U$	--	8	1.2	1.4	1.9	.2	--	--	--	--
Alachlor	µg/L	.05	7	<.05	<.05	<.05	.02	0	F 2	--	0

Table 14. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Platte River Valley alluvial aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
				Minimum	Median	Maximum		MCLG	MCL	SMCL	
Atrazine	μg/L	0.05	7	0.16	0.58	1.8	0.67	3	F 3	--	0
Cyanazine	μg/L	.20	6	<.20	.30	1.0	.35	--	--	--	--
Deisopropylatrazine	μg/L	.05	6	<.05	.09	.29	.11	--	--	--	--
Deethylatrazine	μg/L	.05	6	<.05	.11	.26	.10	--	--	--	--
Metolachlor	μg/L	.05	7	<.05	.09	.24	.09	--	--	--	--
Metribuzin	μg/L	.05	7	<.05	<.05	.07	.03	--	--	--	--
Prometon	μg/L	.05	6	<.05	<.05	.06	.03	--	--	--	--
Simazine	μg/L	.05	6	<.05	<.05	.07	.04	4	F 4	--	0

[1]MCLG, Maximum Contaminant Level Goal, a nonenforceable concentration of a drinking-water contaminant that is protective of adverse health effects and allows an adequate margin of safety (U.S. Environmental Protection Agency, 1991b, 1991e, 1992).

MCL, Maximum Contaminant Level, maximum permissible level of a contaminant in water that is delivered to any user of a public-water system (U.S. Environmental Protection Agency, 1991a, 1991c, 1991e, 1992).

SMCL, Secondary Maximum Contaminant Level, a nonenforceable concentration of a drinking-water contaminant that can adversely affect the odor or appearance of water (U.S. Environmental Protection Agency, 1991d).

Table 15. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the upland area alluvial aquifers in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations

[µS/cm, microsiemens per centimeter at 25 degrees Celsius (°C), °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; TT, treatment technique; F, final; P, proposed; R, under review; **, copper action level (1,300 µg/L), lead action level (15 µg/L) (U.S. Environmental Protection Agency, 1991a); ***, the Maximum Contaminant Level (MCL) for total beta particle and photon activity is 4 millirems per roentgen (U.S. Environmental Protection Agency, 1991); --, not applicable]

Constituent	Unit of measurement	Reporting level	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
			Minimum	Median	Maximum		MCLG[1]	MCL[2]	SMCL	
Well depth	feet	1.0	37	144	330	89	--	--	--	--
Specific conductance, field	µ S/cm	1.0	532	720	1,020	138	--	--	--	--
pH, field	standard units	.1	6.5	7.1	7.6	.3	--	--	F 6.5–8.5	0
Water temperature, field	°C	.5	12.0	12.5	22.0	3.1	--	--	--	--
Oxygen, dissolved, field	mg/L	.1	.1	3.1	8.6	3.0	--	--	--	--
Nitrite plus nitrate as nitrogen	mg/L	.05	<.05	.20	30	9.0	10	F 10	--	2
Hardness, total	mg/L as $CaCO_3$	1	240	340	410	62	--	--	--	--
Alkalinity, laboratory, dissolved	mg/L as $CaCO_3$	1	210	310	320	40	--	--	--	--
Dissolved solids, calculated	mg/L	1	329	436	557	74	--	--	F 500	1
Calcium, dissolved	mg/L	.10	68	95	120	18	--	--	--	--
Magnesium, dissolved	mg/L	.10	17	24	28	4.3	--	--	--	--
Sodium, dissolved	mg/L	.10	10	19	25	5.0	--	--	--	--
Percent sodium, dissolved	percent	1	6	11	16	4	--	--	--	--
Sodium-adsorption ratio	--	--	.2	.4	.7	.2	--	--	--	--
Potassium, dissolved	mg/L	.10	1.8	3.0	8.9	2.6	--	--	--	--
Sulfate, dissolved	mg/L	.10	9.6	29	77	25	--	--	F 250	0
Chloride, dissolved	mg/L	.10	1.9	6.2	18	7.0	--	--	F 250	0
Fluoride, dissolved	mg/L	.10	.20	.30	.40	.1	--	--	R 2	0
Silica, dissolved	mg/L	.10	24	26	32	3.1	--	--	--	--
Arsenic, dissolved	µ g/L	1	<1	1	2	.8	--	F 50	--	0
Barium, dissolved	µ g/L	2	150	170	290	52	2,000	F 2,000	--	0
Beryllium, dissolved	µ g/L	.5	<.5	<.5	<.5	--	4	F 4	--	0
Boron, dissolved	µ g/L	10	30	55	730	280	--	--	--	--
Cadmium, dissolved	µ g/L	1.0	<1.0	<1.0	<1.0	--	5	F 5	--	0
Chromium, dissolved	µ g/L	5	<5	<5	<5	--	100	F 100	--	0

Table 15. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the upland area alluvial aquifers in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
			Minimum	Median	Maximum		MCLG[1]	MCL[2]	SMCL	
Cobalt, dissolved	μ g/L	3	<3	<3	<3	--	--	--	--	--
Copper, dissolved	μ g/L	10	<10	<10	210	86	1,300	F TT**	F 1,000	0
Iron, dissolved	μ g/L	3	<3	6	66	25	--	--	F 300	0
Lead, dissolved	μ g/L	10	<10	<10	<10	--	0	F TT**	--	--
Lithium, dissolved	μ g/L	4	12	16	38	10	--	--	--	--
Manganese, dissolved	μ g/L	1	<1	8	410	160	200	R	F 50	1
Molybdenum, dissolved	μ g/L	10	<10	<10	<10	--	--	--	--	--
Nickel, dissolved	μ g/L	10	<10	<10	<10	--	100	F 100	--	0
Selenium, dissolved	μ g/L	1	1	2	12	4	50	F 50	--	0
Silver, dissolved	μ g/L	1.0	<1.0	<1.0	2.0	1	--	--	F 100	0
Strontium, dissolved	μ g/L	10	260	370	840	210	--	--	--	--
Vanadium, dissolved	μ g/L	6	<6	<6	<6	--	--	--	--	--
Zinc, dissolved	μ g/L	3	<3	35	460	180	--	--	F 5,000	0
Gross alpha activity based on thorium-230 curve	pCi/L	.6	2.3	3.6	8.7	2.4	0	F 15	--	0
Gross beta activity based on strontium-90 curve	pCi/L	.6	3.6	4.5	8.4	1.7	0	F ***	--	--
Radon-222, dissolved	pCi/L	80	390	440	1,200	340	0	P 300	--	6
Radium-226, dissolved	pCi/L	.02	.14	.46	.94	.34	0	P 5	--	0
Uranium, total	μ g/L	.1	2.0	2.3	7.7	2.5	0	F 20	--	0
Uranium ratio activity, uranium-234:238	^{234}U:^{238}U	--	1.2	1.3	1.7	.20	--	--	--	--
Alachlor	μ g/L	.05	<.05	--	<.05	--	0	F 2	--	0
Atrazine	μ g/L	.05	<.05	--	.11	--	3	F 3	--	0
Cyanazine	μ g/L	.20	<.20	--	<.20	--	--	--	--	--
Deisopropylatrazine	μ g/L	.05	<.05	--	<.05	--	--	--	--	--
Deethylatrazine	μ g/L	.05	<.05	--	<.05	--	--	--	--	--
Metolachlor	μ g/L	.05	<.05	--	<.05	--	--	--	--	--

Table 15. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the upland area alluvial aquifers in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Values			Standard deviation	USEPA drinking-water regulation[1]			Number of samples exceeding USEPA drinking-water regulations
			Minimum	Median	Maximum		MCLG[1]	MCL[2]	SMCL	
Metribuzin	μg/L	0.05	<0.05	--	<0.05	--	--	--	--	--
Prometon	μg/L	.05	<.05	--	.14	--	--	--	--	--
Simazine	μg/L	.05	<.05	--	<.05	--	4	F 4	--	0

[1]MCLG, Maximum Contaminant Level Goal, a nonenforceable concentration of a drinking-water contaminant that is protective of adverse health effects and allows an adequate margin of safety (U.S. Environmental Protection Agency, 1991b, 1991e, 1992).

MCL, Maximum Contaminant Level, maximum permissible level of a contaminant in water that is delivered to any user of a public-water system (U.S. Environmental Protection Agency, 1991a, 1991c, 1991e, 1992).

SMCL, Secondary Maximum Contaminant Level, a nonenforceable concentration of a drinking-water contaminant that can adversely affect the odor or appearance of water (U.S. Environmental Protection Agency, 1991d).

Table 16. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Dakota aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations

[µS/cm, microsiemens per centimeter at 25 degrees Celsius (°C), °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; TT, treatment technique; F, final; P, proposed; R, under review; **, copper action level (1,300 µg/L), lead action level (15 µg/L) (U.S. Environmental Protection Agency, 1991a); ***, the Maximum Contaminant Level (MCL) for total beta particle and photon activity is 4 millirems per roentgen (U.S. Environmental Protection Agency, 1991); --, not applicable]

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values: Minimum	Values: Median	Values: Maximum	Standard deviation	USEPA drinking-water regulation[1]: MCLG	USEPA drinking-water regulation[1]: MCL	USEPA drinking-water regulation[1]: SMCL	Number of samples exceeding USEPA drinking-water regulations
Well depth	feet	1.0	13	133	238	625	129	--	--	--	--
Specific conductance, field	µS/cm	1.0	13	445	719	1,800	482	--	--	--	--
pH, field	standard units	.1	13	6.9	7.0	7.7	.2	--	--	F 6.5–8.5	0
Water temperature, field	°C	.5	13	12	13	16	1.2	--	--	--	--
Oxygen, dissolved, field	mg/L	.1	13	.1	4	8.9	2.9	--	--	--	--
Nitrite plus nitrate as nitrogen	mg/L	.05	13	<.05	.80	6.4	2.1	10	F 10	--	0
Hardness, total	mg/L as $CaCO_3$	1	9	210	320	700	200	--	--	--	--
Alkalinity, laboratory, dissolved	mg/L as $CaCO_3$	1	9	221	306	382	58	--	--	--	--
Dissolved solids, calculated	mg/L	1	9	278	426	1,240	407	--	--	F 500	4
Calcium, dissolved	mg/L	.10	9	56	92	210	61	--	--	--	--
Magnesium, dissolved	mg/L	.10	9	14	22	49	12	--	--	--	--
Sodium, dissolved	mg/L	.10	9	14	25	140	51	--	--	--	--
Percent sodium, dissolved	percent	1	9	9	17	31	8	--	--	--	--
Sodium-adsorption ratio	--	--	9	.3	.7	2	.6	--	--	--	--
Potassium, dissolved	mg/L	.10	9	2.2	4.1	22	7.8	--	--	--	--
Sulfate, dissolved	mg/L	.10	9	4.6	27	590	260	--	--	F 250	3
Chloride, dissolved	mg/L	.10	9	3.7	16	110	42	--	--	F 250	0
Fluoride, dissolved	mg/L	.10	9	.20	.30	1.8	.57	--	--	R 2	0
Silica, dissolved	mg/L	.10	9	9.1	24	34	9.0	--	--	--	--
Arsenic, dissolved	µg/L	1	9	<1	<1	2	1	--	F 50	--	0
Barium, dissolved	µg/L	2	9	14	99	230	85	2,000	F 2,000	--	0
Beryllium, dissolved	µg/L	.5	9	<.5	<.5	.8	.4	4	F 4	--	0
Boron, dissolved	µg/L	10	9	50	120	550	200	--	--	--	--
Cadmium, dissolved	µg/L	1.0	9	<1	<1	2	1	5	F 5	--	0
Chromium, dissolved	µg/L	5	9	<5	<5	7	2	100	F 100	--	0

Table 16. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Dakota aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values: Minimum	Values: Median	Values: Maximum	Standard deviation	USEPA drinking-water regulation[1]: MCLG	USEPA drinking-water regulation[1]: MCL	USEPA drinking-water regulation[1]: SMCL	Number of samples exceeding USEPA drinking-water regulations
Cobalt, dissolved	µg/L	3	9	<3	<3	6	2	--	--	--	--
Copper, dissolved	µg/L	10	9	<10	<10	40	14	1,300	F TT**	F 1,000	0
Iron, dissolved	µg/L	3	9	<3	5	2,200	790	--	--	F 300	2
Lead, dissolved	µg/L	10	9	<10	<10	<10	--	0	F TT**	--	--
Lithium, dissolved	µg/L	4	9	8	22	190	69	--	--	--	--
Manganese, dissolved	µg/L	1	9	<1	4	440	150	200	R	F 50	4
Molybdenum, dissolved	µg/L	10	9	<10	<10	<10	--	--	--	--	--
Nickel, dissolved	µg/L	10	9	<10	<10	<10	--	100	F 100	--	0
Selenium, dissolved	µg/L	1	9	<1	<1	5	2.3	50	F 50	--	0
Silver, dissolved	µg/L	1.0	9	<1.0	<1.0	1.0	.33	--	--	F 100	0
Strontium, dissolved	µg/L	10	9	220	380	4,500	1,700	--	--	--	--
Vanadium, dissolved	µg/L	6	9	<6	<6	<6	--	--	--	--	--
Zinc, dissolved	µg/L	3	9	3	8	48	14	--	--	F 5,000	0
Gross alpha activity based on thorium-230 curve	pCi/L	.6	9	1.6	5.7	16	4.5	0	F 15	--	1
Gross beta activity based on strontium-90 curve	pCi/L	.6	9	3.2	7.4	30	10.9	0	F ***	--	--
Radon-222, dissolved	pCi/L	80	8	190	360	460	100	0	P 300	--	5
Radium-226, dissolved	pCi/L	.02	9	.18	.31	3.9	1.6	0	P 5	--	0
Uranium, total	µg/L	.1	9	<.1	2.2	7.2	2.5	0	P 20	--	0
Uranium ratio activity, uranium-234:238	$^{234}U:^{238}U$	--	7	1.2	1.5	2.1	.3	--	--	--	--
Alachlor[2]	µg/L	.05	1	--	<.05	--	--	0	F 2	--	0
Atrazine[2]	µg/L	.05	1	--	<.05	--	--	3	F 3	--	0
Cyanazine[2]	µg/L	.20	1	--	<.20	--	--	--	--	--	--
Deisopropylatrazine[2]	µg/L	.05	1	--	<.05	--	--	--	--	--	--
Deethylatrazine[2]	µg/L	.05	1	--	<.05	--	--	--	--	--	--
Metolachlor[2]	µg/L	.05	1	--	<.05	--	--	--	--	--	--

Table 16. Statistical summary of water-quality analyses, except ametryn, prometryn, and propazine herbicides, of samples from the Dakota aquifer in the Papio-Missouri River Natural Resources District, eastern Nebraska, July through September 1992, and U.S. Environmental Protection Agency (USEPA) drinking-water regulations—Continued

Constituent	Unit of measurement	Reporting level	Number of samples analyzed	Values: Minimum	Values: Median	Values: Maximum	Standard deviation	USEPA drinking-water regulation[1]: MCLG	USEPA drinking-water regulation[1]: MCL	USEPA drinking-water regulation[1]: SMCL	Number of samples exceeding USEPA drinking-water regulations
Metribuzin[2]	µg/L	0.05	1	--	<0.05	--	--	--	--	--	--
Prometon[2]	µg/L	.05	1	--	<.05	--	--	--	--	--	--
Simazine[2]	µg/L	.05	1	--	<.05	--	--	4	F 4	--	0

[1]MCLG, Maximum Contaminant Level Goal, a nonenforceable concentration of a drinking-water contaminant that is protective of adverse health effects and allows an adequate margin of safety (U.S. Environmental Protection Agency, 1991b, 1991e, 1992).

MCL, Maximum Contaminant Level, maximum permissible level of a contaminant in water that is delivered to any user of a public-water system (U.S. Environmental Protection Agency, 1991a, 1991c, 1991e, 1992).

SMCL, Secondary Maximum Contaminant Level, a nonenforceable concentration of a drinking-water contaminant that can adversely affect the odor or appearance of water (U.S. Environmental Protection Agency, 1991d).

[2]Concentrations of triazine herbicides are shown for one sample; therefore, no minimum, maximum, or median exists, and the actual concentration is listed under median.

Table 17. Results of Kruskal-Wallis and Wilcoxon Rank-Sum tests to determine differences in water chemistry or other characteristics among the aquifers in the Papio-Missouri River Natural Resources District, eastern Nebraska

[____, indicates significant differences at an alpha level of 0.05 if the Kruskal-Wallis one-way analysis of variance among all aquifers was significantly different; E, Elkhorn River Valley alluvial aquifer; P, Platte River Valley alluvial aquifer; M, Missouri River Valley alluvial aquifer; U, upland area alluvial aquifers; D, Dakota aquifer]

Water-quality constituent,[1] property, or physical characteristic	*p*-values of differences				
	Kruskal-Wallis test	E and P versus other aquifers	M versus other aquifers	U versus other aquifers	D versus other aquifers
Well depth	≤0.0001	≤0.0001	0.7055	0.5801	≤0.0001
Specific conductance, field	≤.0001	≤.0001	.0001	.4078	.6407
pH, field	.0061	.0067	.1367	.8464	.1344
Water temperature, field	.3393	.7468	.0860	.8671	.2415
Oxygen, dissolved, field	.0573	.4711	.0064	.2508	.4565
Nitrite plus nitrate as nitrogen	.1813	.9521	.0211	.3240	.2111
Hardness, total	.0005	.0001	.0005	.7463	.3343
Alkalinity, lab, dissolved	.0001	≤.0001	.0001	.6769	.3907
Dissolved solids, calculated	.0093	.0014	.0029	.8055	.4662
Calcium, dissolved	.0017	.0003	.0009	.9284	.3343
Magnesium, dissolved	.0001	≤.0001	.0001	.4612	.5001
Sodium, dissolved	.2216	.8376	.2556	.0325	.5603
Sodium-adsorption ratio	.2090	.2650	.9765	.0247	.5398
Potassium, dissolved	.0981	.0429	1.0000	.0124	.7956
Sulfate, dissolved	.2853	.5472	.2048	.0447	.8332
Chloride, dissolved	.5042	.0364	.7480	.0994	.7831
Fluoride, dissolved	.8705	.4436	.4368	.8202	.9742
Silica, dissolved	.0126	.0050	.8710	.2356	.0295
Arsenic, dissolved	.0007	.0090	.0461	.0309	.0016
Barium, dissolved	.0372	.2385	.1246	.7737	.0058
Beryllium, dissolved	.7410	.4574	.6901	.2809	.6567
Boron, dissolved	.0602	.2287	.0235	.1501	.6271
Cadmium, dissolved	.7855	.7102	.4785	.3883	.6567
Chromium, dissolved	.9925	.8276	.8826	.9141	.6130
Cobalt, dissolved	.2626	.1913	.0248	.5176	.8301
Copper, dissolved	.7282	.5556	.4603	.7737	.2202
Iron, dissolved	.0002	.8577	≤.0001	.0225	.0344
Lithium, dissolved	.0067	.0837	.0007	.0668	.9146
Manganese, dissolved	.0007	.0285	.0239	.0153	.0038
Molybdenum, dissolved	.9942	.8276	.6366	.9141	.8903
Selenium, dissolved	.0259	.3739	.0425	.0076	.4761
Silver, dissolved	.6877	.6724	.9765	.6662	.3993
Strontium, dissolved	.0067	.0404	.0007	.1835	.9511
Vanadium, dissolved	.9900	.7487	.8826	.9141	.8903
Zinc, dissolved	.3678	.2285	.6578	.2972	.3118

Table 17. Results of Kruskal-Wallis and Wilcoxon Rank-Sum tests to determine differences in water chemistry or other characteristics among the aquifers in the Papio-Missouri River Natural Resources District, eastern Nebraska—Continued

Water-quality constituent,[1] property, or physical characteristic	*p*-values of differences				
	Kruskal-Wallis test	E and P versus other aquifers	M versus other aquifers	U versus other aquifers	D versus other aquifers
Gross alpha activity based on thorium-230 curve	0.0242	0.4122	0.0044	1.0000	0.0480
Gross beta activity based on strontium-90 curve	.0382	.0129	.4785	.0097	0.9756
Radon-222 activity, dissolved	.0949	.6517	.0775	.0189	.4171
Radium-226 activity, dissolved	.2756	.1869	.2317	.8433	.8782
Uranium, total	.1103	.3630	.0142	.1058	.9389
Uranium ratio activity, uranium-234:238	.2207	.6302	.2787	.1554	.0570

[1] All concentrations of nickel and lead were less than the detection level.

Table 18. Statistically significant results (alpha = 0.05) of the Tukey's test to test for differences in median concentrations or values of water-quality constituents or other characteristics among the aquifers in the Papio-Missouri Natural Resources District, eastern Nebraska

[Group medians with boxes shaded along the same row are not significantly different and illustrate the pattern of concentration levels of the data; E, Elkhorn River Valley alluvial aquifer; M, Missouri River Valley alluvial aquifer; P, Platte River Valley alluvial aquifer; U, upland area alluvial aquifer; D, Dakota aquifer]

Water-quality constituent, property, or physical characteristic[1]	Aquifers				
	E	M	P	U	D
Well depth	■		■		
		■		■	
Specific conductance, field	■		■		
			■		■
				■	■
		■		■	
pH, field	■	■		■	■
	■		■		
Hardness, total	■		■	■	
	■			■	■
		■		■	■
Alkalinity, laboratory, dissolved	■		■	■	
				■	■
Dissolved solids, calculated	■		■	■	■
		■		■	■
Calcium, dissolved	■		■		
	■			■	■
		■		■	■
Magnesium, dissolved			■		
				■	■
		■		■	■
Silica, dissolved		■	■	■	■
	■	■	■		
Arsenic, dissolved				■	■
	■	■			
	■	■	■		
Barium, dissolved			■	■	■
		■	■	■	
	■	■	■	■	
Boron, dissolved	■		■	■	■
	■	■		■	■

Table 18. Statistically significant results (alpha = 0.05) of the Tukey's multiple-comparison procedure to test for differences in median concentrations of water-quality constituents among the aquifers in the Papio-Missouri Natural Resources District—Continued

Water-quality constituent, property, or physical characteristic[1]	Aquifers				
	E	M	P	U	D
Cobalt, dissolved	■		■	■	■
Iron, dissolved	■		■	■	■
Lithium, dissolved	■		■	■	■
	■	■			■
Manganese, dissolved			■	■	■
		■	■		
	■	■	■		
Selenium, dissolved	■	■	■		■
			■	■	■
Strontium, dissolved	■		■	■	■
	■	■			■
Gross alpha activity based on thorium-230 curve		■	■	■	
			■	■	■
	■		■	■	■
Gross beta activity based on strontium-90 curve		■	■	■	■
	■	■	■		■

[1]Significant differences were not noted for water temperature, dissolved oxygen, nitrite plus nitrate as nitrogen, sodium, percent sodium, sodium-adsorption ratio, potassium, sulfate, chloride, fluoride, beryllium, cadmium, chromium, copper, lead, molybdenum, nickel, silver, vanadium, zinc, radon-222, radium-226, and total uranium.

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