WATER-QUALITY ASSESSMENT OF THE RIO GRANDE VALLEY, COLORADO, NEW MEXICO, AND TEXAS -- GROUND-WATER QUALITY IN THE RIO GRANDE FLOOD PLAIN, COCHITI LAKE, NEW MEXICO, TO EL PASO, TEXAS, 1995

By Laura M. Bexfield and Scott K. Anderholm

U.S. GEOLOGICAL SURVEY

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BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information write to:

District Chief
U.S. Geological Survey
Water Resources Division
4501 Indian School Road NE, Suite 200
Albuquerque, NM 87110-3929

Copies of this report can be purchased from:

U.S. Geological Survey
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<http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html>

FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	4,047	square meter
square mile	2.590	square kilometer
gallon	3.785	liter
cubic foot per second	0.02832	cubic meter per second
gallon per minute	0.06309	liter per second

Temperatures in degrees Celsius (°C) and degrees Fahrenheit (°F) can be converted by the equations:

$$^{\circ}F = 9/5\ (^{\circ}C) + 32$$

$$^{\circ}C = 5/9\ (^{\circ}F - 32)$$

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

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By Laura M. Bexfield and Scott K. Anderholm

ABSTRACT

From March to May of 1995, water samples were collected from 30 wells located in the flood plain of the Rio Grande between Cochiti Lake, New Mexico, and El Paso, Texas. These samples were analyzed for a broad host of constituents, including field parameters, major constituents, nutrients, dissolved organic carbon, trace elements, radiochemicals, pesticides, and volatile organic compounds. The main purpose of this study was to observe the quality of ground water in this part of the Rio Grande Valley study unit of the U.S. Geological Survey National Water-Quality Assessment program. The sampling effort was limited to the basin-fill aquifer beneath the above-defined reach of the Rio Grande flood plain because of the relative homogeneity of the hydrogeology, the large amount of ground-water use for public supply, and the potential for land-use activities to affect the quality of ground water. Most of the wells sampled for the study are used for domestic purposes, including drinking water. Depths to the tops of the sampling intervals in the 30 wells ranged from 10 to 345 feet below land surface, and the median was 161.5 feet; the sampling intervals in most of the wells spanned about 10 feet or less. Quality-control data were collected at three of the wells.

A significant amount of variation was found in the chemical composition of ground water sampled throughout the study area, but the water generally was found to be of suitable chemical quality for use as drinking water, according to current enforceable standards established by the U.S. Environmental Protection Agency (EPA). Nutrients generally were measured at concentrations near or below their method reporting limits. The most dominant nutrient species was nitrite plus nitrate, at a maximum concentration of 1.9 milligrams per liter (as N). Only eight of the trace elements analyzed for had median concentrations greater than their respective minimum reporting levels. Water from one well exceeded the lifetime health advisory established by the EPA for molybdenum; water from a different well exceeded the proposed EPA maximum contaminant level for uranium. Gross alpha and gross beta particle activities generally appeared to strongly correlate with quantities of uranium and potassium, respectively, detected in ground water. However, water from one well exceeded the EPA maximum contaminant level for gross alpha particle activity and may exceed the EPA maximum contaminant level for beta particle and photon activity, although current data on gross beta particle activities are not conclusive on this point. Radon concentrations did not appear to directly correlate with uranium concentrations. The herbicide prometon was the only synthetic organic compound detected in ground water in the study area, and was detected in only one well, at a concentration of 0.038 microgram per liter. This well is shallow and is not used for drinking water. With the exception of the one detection of prometon, no strong evidence was found of effects on ground-water quality from human activities. Therefore, most of the water sampled probably recharged at the margins of the alluvial basins or recharged through the flood plain before human development began.

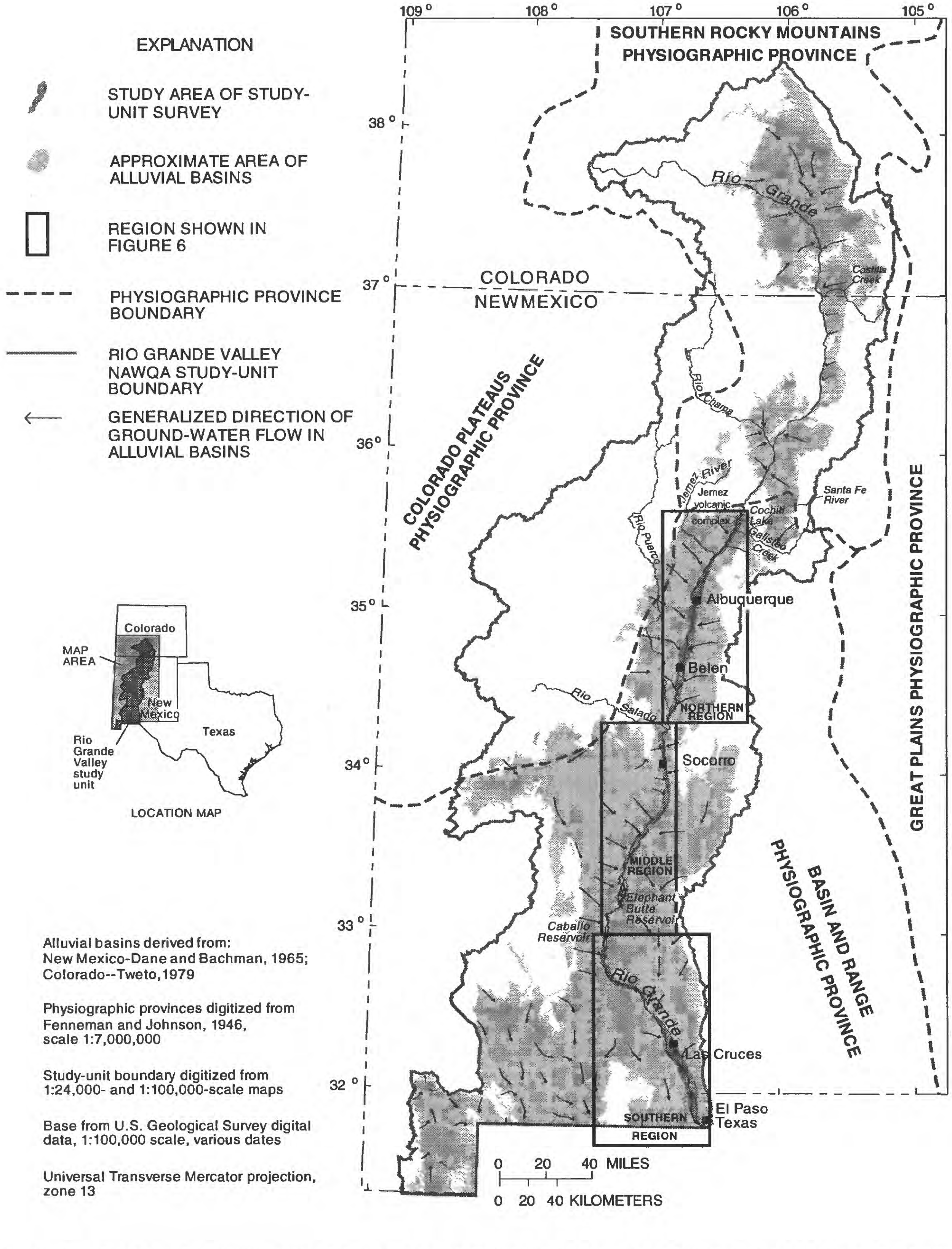
With respect to major constituents, the concentrations of dissolved solids ranged from 209 to 3,380 milligrams per liter, and the median concentration was 409.5 milligrams per liter. There is evidence that the overall chemical composition of ground water in the study area may be affected by several processes, including cation exchange, feldspar weathering, calcite dissolution and precipitation, dissolution of volcanic glass, and microbial activity. Several chemical constituents in ground water showed relatively distinct spatial patterns that appear to be related to one or more of these processes.

INTRODUCTION

The U.S. Geological Survey began full implementation of the National Water-Quality Assessment (NAWQA) program in 1991. This program is designed to describe the status of and trends in the quality of a large part of the Nation's surface- and ground-water resources. The program also aims to improve understanding of the natural and human factors that affect water-quality conditions. Ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, referred to as study units, are the building blocks of the NAWQA program. In each study unit, physical, chemical, and biological data are collected and analyzed in a nationally consistent manner to allow for regional and national comparisons. The study units are proposed to operate on 10-year cycles, alternating periods of high-intensity sampling with periods of low-intensity sampling. The Rio Grande Valley study unit (fig. 1) is one of 20 that began assessment activities in 1991.

The data presented in this report were collected to satisfy the study-unit survey component of the NAWQA program. The primary objective of the study-unit survey is to provide a broad overview of ground-water quality within each study unit (Gilliom and others, 1995). On a study-unit scale, the survey identifies the contaminants of greatest concern within the study unit and characterizes their general spatial distributions. The survey also identifies the absence of certain contaminants, which can be an important result. On a national scale, the study-unit survey provides information that can be used to determine broad areas of the Nation where particular contaminants are common in ground water due to natural or anthropogenic causes (Lehn Franke and Wayne Lapham, U.S. Geological Survey, written commun., 1994).

In general, study units are divided into aquifer subunits that each represent a relatively homogeneous hydrogeologic setting. These subunits may be further divided on the basis of other important characteristics, including land use. These various subunits often are sampled in separate high-intensity sampling phases of the study unit. The highest priority for sampling is given to those aquifer systems that provide the largest amount of water for drinking-water supply and that serve the largest population. Each subunit survey is designed to include samples from at least 30 existing wells, which are subjected to a standard list of analyses. The wells selected need to provide good spatial distribution, both areally and with depth, of ground-water samples from the aquifer system. Because various types of wells (such as domestic, public-supply, or irrigation wells) are biased in different ways, as few types of wells as possible are chosen to obtain this distribution (Gilliom and others, 1995).



Alluvial basins derived from:
New Mexico-Dane and Bachman, 1965;
Colorado--Tweto,1979

Physiographic provinces digitized from
Fenneman and Johnson, 1946,
scale 1:7,000,000

Study-unit boundary digitized from
1:24,000- and 1:100,000-scale maps

Base from U.S. Geological Survey digital
data, 1:100,000 scale, various dates

Universal Transverse Mercator projection,
zone 13

Figure 1.--General features of the Rio Grande Valley National Water-Quality Assessment (NAWQA) study unit and location of the study area.

Purpose and Scope

This report presents an assessment of ground-water quality for a subunit of the Rio Grande Valley NAWQA study unit based on samples collected in March to May 1995 from 30 wells. The study area chosen for this subunit survey includes the flood plain of that part of the main stem of the Rio Grande that lies within the Basin and Range physiographic province (fig. 1). Concentrations of specific constituents are compared to drinking-water standards established by the U.S. Environmental Protection Agency (EPA). Also, spatial variations of constituent concentrations are assessed. Potential factors, primarily hydrogeology and land use, that may affect variability in ground-water quality in selected areas of the subunit are considered, and evidence of their influence is presented. Water from 26 of the 30 wells in the survey currently (1995) is used for drinking water and other domestic purposes (1 of these wells is a public-supply well), and water from 2 wells is used for domestic purposes, not including drinking water. The remaining two wells are observation wells. All 30 wells were sampled for selected field parameters, major constituents, nutrients, dissolved organic carbon (DOC), trace elements, radionuclides, pesticides, and volatile organic compounds (VOC's).

Well-Numbering Systems

The New Mexico system of numbering wells is based on the common subdivision of public lands into sections (fig. 2). The well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land network. The number is divided by periods into four segments. The first segment denotes the township north (N.) or south (S.) of the New Mexico Base Line; the second segment denotes the range east (E.) or west (W.) of the New Mexico Principal Meridian; and the third segment denotes the section (sec.) within the township. The fourth segment consists of three digits that denote the 160-, 40-, or 10-acre tract, respectively, in which the well is located. The section is divided into four quarters, numbered 1, 2, 3, and 4, for the northwest, northeast, southwest, and southeast quarters, respectively. The first digit of the fourth segment is the quarter section, which is a tract of 160 acres. Similarly, the 160-acre tract is divided into four 40-acre tracts denoted by the second digit and numbered in the same manner. Finally, the 40-acre tract is divided into four 10-acre tracts that are denoted by the third digit. If a well cannot be located accurately within a particular section or tract, a zero is used for that part of the location number.

The Texas well-numbering system assigns well numbers that include five segments. The first segment consists of a two-letter prefix that identifies the county. The prefix for El Paso County is JL. The second segment of the well number is a two-digit code that identifies the 1-degree quadrangle. The State is divided into 89 1-degree quadrangles, numbered as indicated in figure 3. Each 1-degree quadrangle is divided into $7^1/_2$-minute quadrangles numbered from 01 to 64. The number of the $7^1/_2$-minute quadrangle forms the third segment of the well number. Each $7^1/_2$-minute quadrangle is divided into nine $2^1/_2$-minute quadrangles. The fourth segment of the well number consists of one digit indicating the $2^1/_2$-minute quadrangle. The final two digits of the well number are assigned in the order in which the wells in that $2^1/_2$-minute quadrangle are registered, beginning with 01.

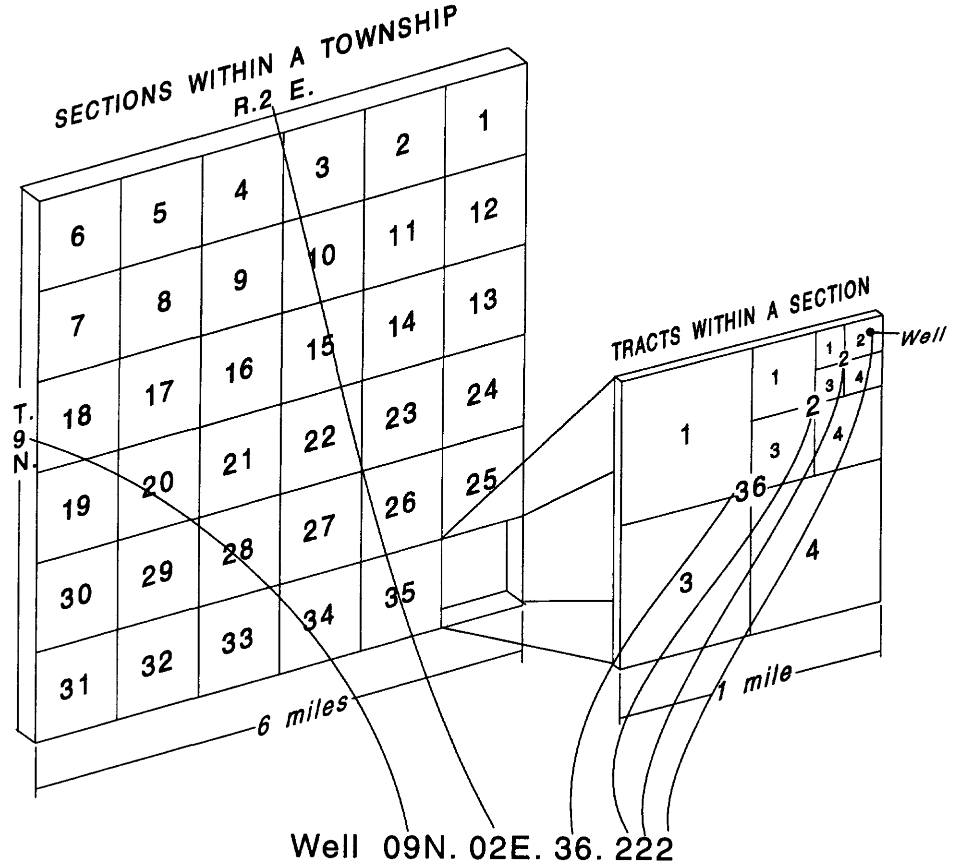


Figure 2.--Well-numbering system in New Mexico.

In addition to a well number determined in accordance with the systems described above, each well included in this study also has been given a station number that is based on the latitude and longitude of the well as determined by a Global Positioning System. The first six digits of the station number are the latitude in degrees, minutes, and seconds; the next seven digits are the longitude in degrees, minutes, and seconds. The last two digits are a sequence number that is used to differentiate wells that have been assigned the same latitude and longitude. The station number represents the best location available at the time the site was registered, but thereafter is used only as an identifier (not a locator) that will not change even if a more accurate location is determined in the future.

Acknowledgments

The authors thank the numerous private citizens who allowed access to their property and their wells so that this study could be conducted. Appreciation also is extended to individuals from several Federal and State agencies for their help in locating and obtaining permission to sample wells under their jurisdiction. Among these individuals are the following: John Nixon, Jim Smith, and others with the New Mexico State Engineer Office; Phillip McClelland with the New Mexico State Park and Recreation Division; Leroy Saavedra with the U.S. Fish and Wildlife Service; Clarence Seagraves with the Bureau of Land Management; Ed Gerber with the U.S. Border Patrol; and Ed Nickerson with the U.S. Geological Survey.

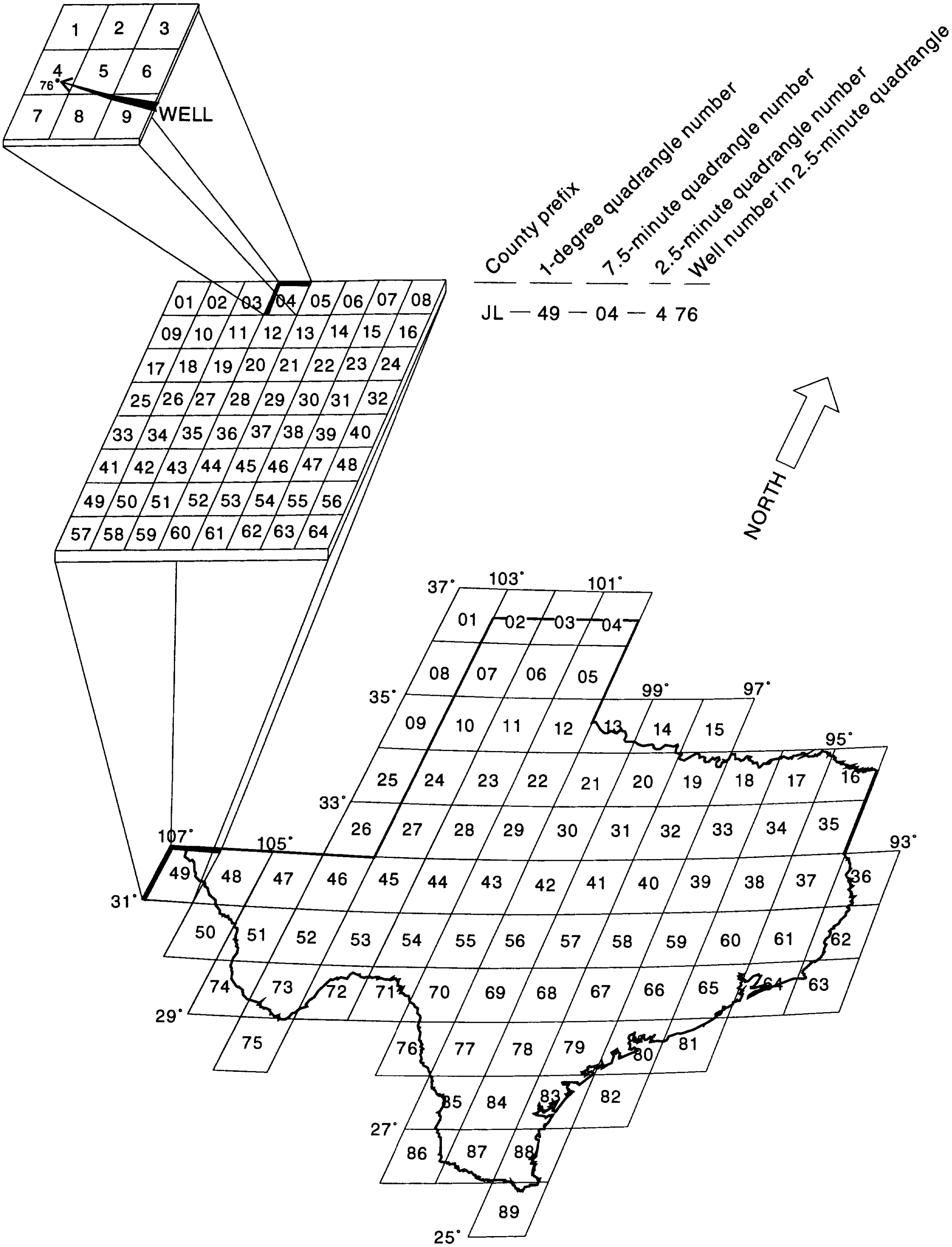


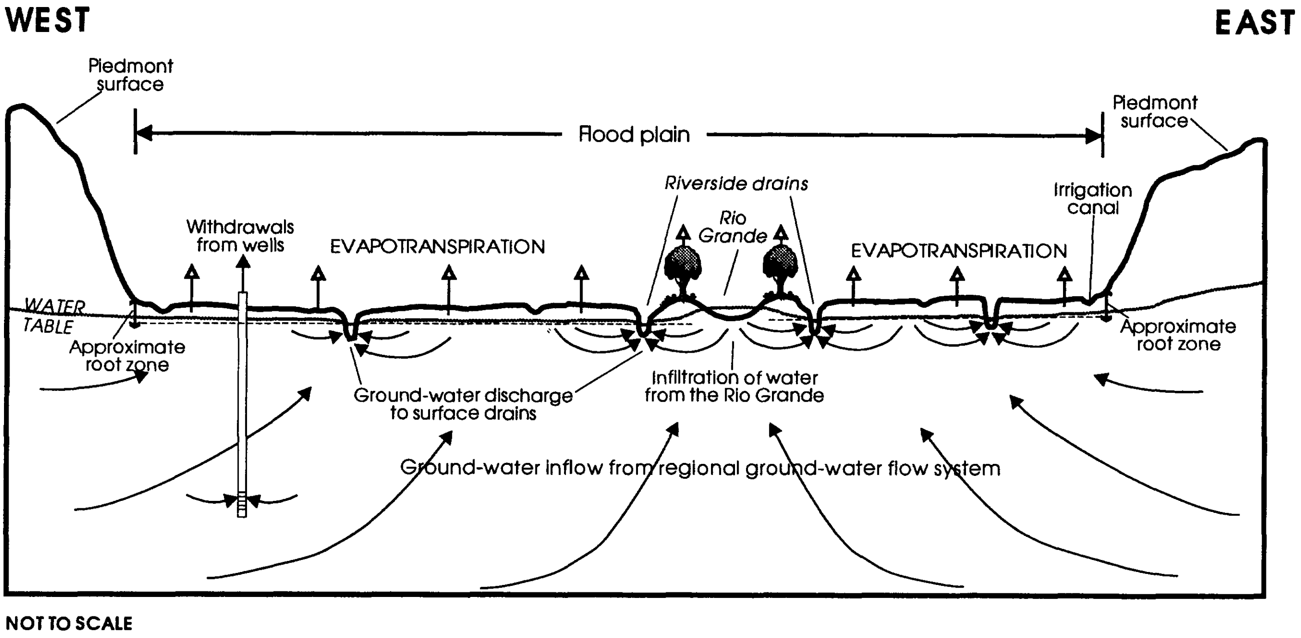
Figure 3.--Well-numbering system in Texas.

DESCRIPTION OF THE STUDY AREA

The study area is the flood plain of that portion of the Rio Grande located within the Basin and Range physiographic province (fig. 1). By definition, this physiographic province is relatively homogeneous in hydrogeology and climate. Therefore, mean annual precipitation and mean monthly temperatures vary little at different locations along the length of the study area. With respect to hydrogeology, the Basin and Range physiographic province is characterized by alternating, roughly parallel mountain ranges and alluvial basins. The mountain ranges that bound the alluvial basins originate from uplifted fault blocks or from volcanic activity and are composed of igneous, metamorphic, and sedimentary rock types. The alluvial basins contain large thicknesses (to as much as 18,000 feet) (Anderholm, 1988) of basin-fill deposits, which constitute important aquifers. Although the study area consists of a series of such basins, these basins all contain the same general aquifer material and all have similar recharge and discharge mechanisms (Ellis and others, 1993). The study area was limited to these relatively homogeneous alluvial basins in the Basin and Range Province that are drained by the Rio Grande because most of the population and therefore most ground-water use for public/domestic supply in the Rio Grande Valley NAWQA study unit are located along this reach of the Rio Grande (Richey and Ellis, 1993). The study area was further limited to the area of the present Rio Grande flood plain because recharge to the basin-fill aquifer is thought to occur in this area, where depths to water generally are less than 50 feet (Ellis and others, 1993). The flood plain has a relatively large population density and a large concentration of irrigated agriculture, which together contribute recharge to the aquifer through means such as septic-tank effluent and irrigation water. The relatively shallow depths to ground water in the area provide a greater possibility of measuring the effects from these land uses on the quality of ground water.

The study area extends almost 300 miles from Cochiti Lake, New Mexico, to El Paso, Texas, and includes about 700 square miles (fig. 1). The areas of Cochiti Lake and Elephant Butte and Caballo Reservoirs are not included. The study area generally is only a few miles wide and typically is bounded by the outermost irrigation canals located on either side of the Rio Grande (fig. 4). These irrigation canals run along the bases of mesas that separate the Rio Grande flood plain from the piedmont surfaces extending from adjacent uplands. The Rio Grande generally is about 200 to 500 feet below these piedmont surfaces. Little or no recharge is believed to occur on these surfaces except along the alluvial-basin/mountain-range boundaries (basin boundaries); the depths to water in the basin-fill aquifer under the piedmont surfaces typically are greater than 200 feet and can be as much as 1,000 feet. The altitude of the study area ranges from about 5,300 feet above sea level near Cochiti Lake at the northern end to about 3,700 feet above sea level at the southern end of the study area.

(A) NONIRRIGATION SEASON



(B) IRRIGATION SEASON

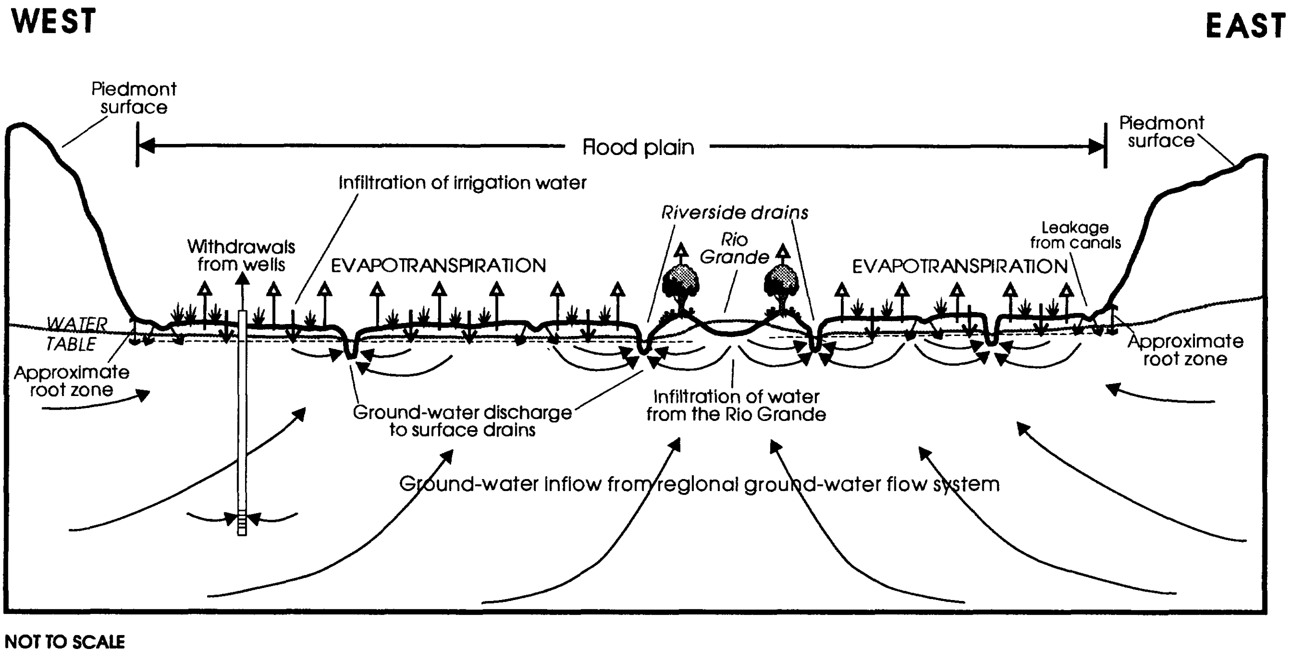


Figure 4. -- Generalized hydrologic sections showing local and regional ground-water flow along the Rio Grande flood plain during the (A) nonirrigation season and (B) irrigation season (modified from Anderholm, 1987).

Climate

The climate in the region of the Rio Grande Valley between Cochiti Lake and El Paso is arid to semiarid and is characterized by sunny days, large daily temperature changes, and mean annual potential evapotranspiration that exceeds mean annual precipitation. Mean monthly temperatures for the period of 1961 to 1990 ranged from about 34 °F in January to about 78 °F in July at the Albuquerque International Airport; from about 36 °F in January to about 77 °F in July at Socorro; and from about 42 °F in January to about 80 °F in July at New Mexico State University in Las Cruces (National Oceanic and Atmospheric Administration [1994]). Mean annual precipitation for the same time period was about 8.9 inches at the Albuquerque International Airport, about 9.8 inches at Socorro, and about 9.4 inches at New Mexico State University in Las Cruces (National Oceanic and Atmospheric Administration [1994]). At all three locations, precipitation tends to be greatest from July through September, when about half of the mean annual precipitation generally falls. Precipitation is greater in the mountainous areas adjacent to the alluvial basins. Mean annual potential evapotranspiration from 1951 to 1980 ranged from about 55 inches in the northern part of the study area to about 75 inches in the southern part (Farnsworth and others, 1982).

Surface Water

The quality of water in the Rio Grande can be an important factor affecting the quality of ground water in the study area. In addition to the infiltration of water through the riverbed, the infiltration of water diverted from the river for irrigation can be quite large. Of the tributaries to the Rio Grande for which detailed streamflow records are available, the Jemez River (located between Cochiti Lake and Albuquerque) contributes a yearly average of about 62 cubic feet per second (ft^3/sec) to the Rio Grande, and the Rio Puerco (located between Belen and Socorro) contributes a yearly average of about 44 ft^3/sec; these streamflows are far greater than those of any other tributaries in the study area (fig. 1) (Borland and Ong, 1995). Few perennial streams flow into the Rio Grande between Cochiti Lake and El Paso, but numerous ephemeral channels carry water to the river in response to runoff from storms. These ephemeral channels, along with the Rio Puerco, commonly contribute inflows containing substantial amounts of dissolved constituents and suspended sediment (Borland and Ong, 1995). Discharge into the Rio Grande also can come from drains that intercept shallow ground water.

The mean annual streamflow of the Rio Grande for water years 1981-90 was about 1,570 ft^3/sec downstream from Cochiti Dam, about 1,150 ft^3/sec downstream from Elephant Butte Dam, and about 720 ft^3/sec at El Paso, Texas (Anderholm and others, 1995). Evaporation, infiltration, and irrigation diversions are major causes of the decrease in streamflow with distance downstream from Cochiti Dam. Evapotranspiration increases the dissolved-solids concentrations in both river water and shallow ground water, contributing to an increase in the average dissolved-solids concentration in the Rio Grande with distance downstream. Average dissolved-solids concentrations in the Rio Grande also are increased by inflows to the Rio Grande of more mineralized water from the Jemez River, Rio Puerco, and Rio Salado (fig. 1) and by the return of irrigation water from agricultural drains (Anderholm, 1988). The annual amount of water diverted from the Rio Grande during the irrigation season is quite large, totaling about 1,280 ft^3/sec within the study area (Anderholm and others, 1995). Much of this diverted water recharges the aquifer as leakage from irrigation canals and laterals or as irrigation water. Therefore, this diverted water can substantially affect ground-water quality.

Hydrogeology

The basin-fill aquifer within the boundaries of the Rio Grande flood plain is composed of the Tertiary and Quaternary Santa Fe Group and Holocene flood-plain alluvium. These deposits consist mainly of unconsolidated to moderately consolidated sediments, including alternating and interfingering layers of gravel, sand, silt, and clay that were deposited by fluvial, alluvial, and lacustrine processes. Volcanic rocks are locally interbedded with the sedimentary deposits.

The characteristics of the hydrologic cycle within a regional aquifer system affect the quality of ground water in that system. Recharge to the basin-fill aquifer along the Rio Grande occurs mostly at the margins of the alluvial basins shown in figure 1. Recharge processes in these areas include infiltration of surface-water inflow from adjacent areas, ground-water inflow from adjacent bedrock units, and ground-water inflow from upgradient alluvial basins. Infiltration of surface-water inflow from adjacent areas is the main source of recharge to the basin-fill aquifers along the basin margins (Kernodle and others, 1995). Much of this recharge occurs along ephemeral channels in response to intense local storms. This recharge is essentially runoff of precipitation from the relatively impermeable mountainous areas adjacent to alluvial basins. Other recharge processes that occur in most of the alluvial basins include infiltration of surface water through riverbeds (mainly the Rio Grande) and infiltration of precipitation falling on the land surface. Given the recharge processes that are of greatest importance to the study area, most ground water in the area probably originated at its source--whether inside or outside of individual basin boundaries--as precipitation or surface water.

On a regional scale, the direction of ground-water flow in the alluvial basins of the study area is from the basin margins toward the Rio Grande and southward from one basin to the next (fig. 1). Most ground-water discharge occurs near the center of the basins or in the subsurface to the adjacent downstream alluvial basin. Two important processes of ground-water discharge in the study area are evapotranspiration and ground-water pumpage. The discharge of ground water through evapotranspiration is especially substantial in the flood plain along the Rio Grande because of the shallow depth to ground water in this area. The movement of ground water from recharge to discharge areas can take thousands of years because of the distance traveled and the aquifer characteristics (Anderholm and others, 1995).

Local flow systems that can affect ground-water quality have developed as a result of irrigation practices (fig. 4). Irrigated fields and the unlined canals and laterals carrying water to them provide local recharge of surface water diverted from the Rio Grande to the aquifer. Irrigation wells, evapotranspiration from fields, and ground-water drains (including riverside drains in the northern and middle regions of the study area) constructed to keep the water table below a certain level provide means of discharge from the relatively shallow parts of the ground-water system. Local recharge and discharge vary in importance seasonally and are more substantial during the irrigation season.

An essential concept to a full understanding of ground-water quality in the study area is that the flood plain of the Rio Grande is a major point of discharge for both the deeper regional and shallower local flow systems through evaporation and transpiration. Evaporation takes place near and at land surface, whereas transpiration occurs throughout the root zone. During the growing season, at the same location on the land surface where irrigation water is infiltrating to recharge the aquifer at one depth, upward-moving regional ground water could be evaporating or transpiring at a different depth below the surface (fig. 4). This upward movement of regional ground water allows little of the irrigation water recharging the shallow aquifer to move to deeper parts of the aquifer. Therefore, water recharging through the flood plain has little effect on water quality at depth. This very transient system results in solutes being concentrated near the land surface and throughout the root zone (shallow parts of the aquifer) because of the large amounts of evaporation and transpiration in these areas.

Land and Water Use

Land use can affect ground-water quality in a variety of ways. For example, a growing population increases the potential for water quality to be affected by septic-tank effluent or by release of industrial solvents or fuels to the ground-water system. Agricultural activities can potentially affect water quality because of the concentration of solutes in irrigation water or the use of fertilizers and pesticides.

The main uses of land in the study area are urban and agricultural (fig. 5). Parts of two major population centers are within the study area. According to the 1990 census (U.S. Department of Commerce, 1993), Albuquerque has a population of about 385,000 people (and a population of about 520,000 people in the Albuquerque metropolitan area), and Las Cruces has a population of about 62,000 people. All other cities within the study area have populations less than 50,000 (El Paso is located downstream from the study area boundary).

Outside of population centers, land use is mainly agricultural interspersed with residential areas. The major crops grown between Cochiti Lake and Elephant Butte Dam are pasture grasses, alfalfa, wheat, and small grains; the major crops grown south of Elephant Butte Dam are pasture grasses, alfalfa, cotton, chile, orchards (primarily pecans), and grains (Ellis and others, 1993). Cattle feedlots and dairies also are substantial agricultural uses of land in and adjacent to the study area. Some areas of forest (such as bosque along the Rio Grande, generally consisting of dense vegetation including grasses, shrubs, and large trees) and rangeland also exist within the study area. Special designated areas include several Indian reservations, Federal and State wildlife refuges, and State parks.

Irrigation of crops is the largest use of water in the study area, and the Rio Grande is the primary source of irrigation water. Ground water also is used locally, most commonly to supplement supplies of irrigation water in years when surface-water supplies are low. Flood irrigation is the primary method of irrigation and is accomplished using a system of canals, laterals, and drains that has been in place since the 1920's and 1930's. All of the communities in the study area rely primarily on ground water for domestic and industrial water supplies. Ground-water withdrawals have substantially altered the ground-water flow system in and around Albuquerque.

METHODS

The study area has been divided arbitrarily into northern, middle, and southern regions to simplify presentation and discussion (fig. 6). For convenience, the divisions were located between alluvial basins, even though all basins were expected to be relatively homogeneous, as discussed in the Description of the Study Area section. To facilitate reference to specific wells, the wells sampled have each been assigned a reference number from 1 to 30 (fig. 6).

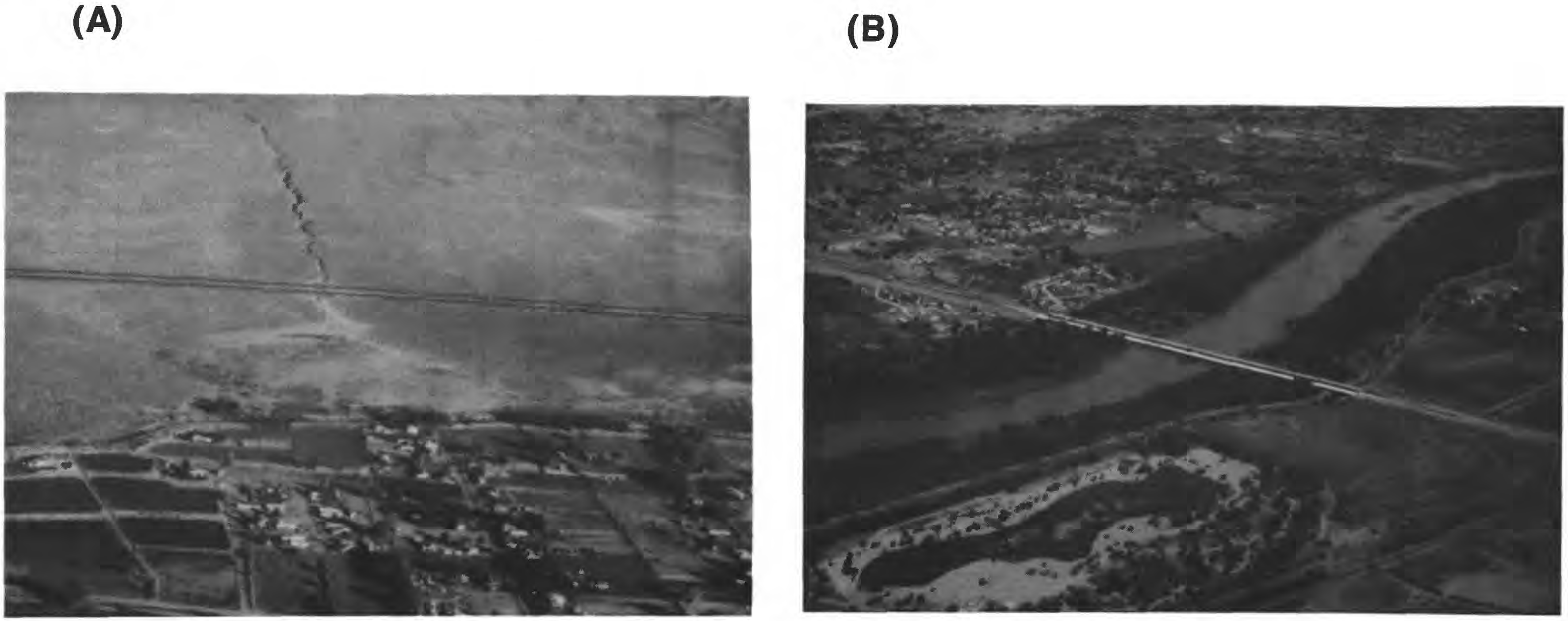


Figure 5.--(A) Contrast of land use between the Rio Grande flood plain and an adjacent piedmont slope near Belen, New Mexico, and (B) typical variation of land use across the Rio Grande flood plain near Albuquerque, New Mexico (photographs by Scott Anderholm and Sherman Ellis, U.S. Geological Survey).

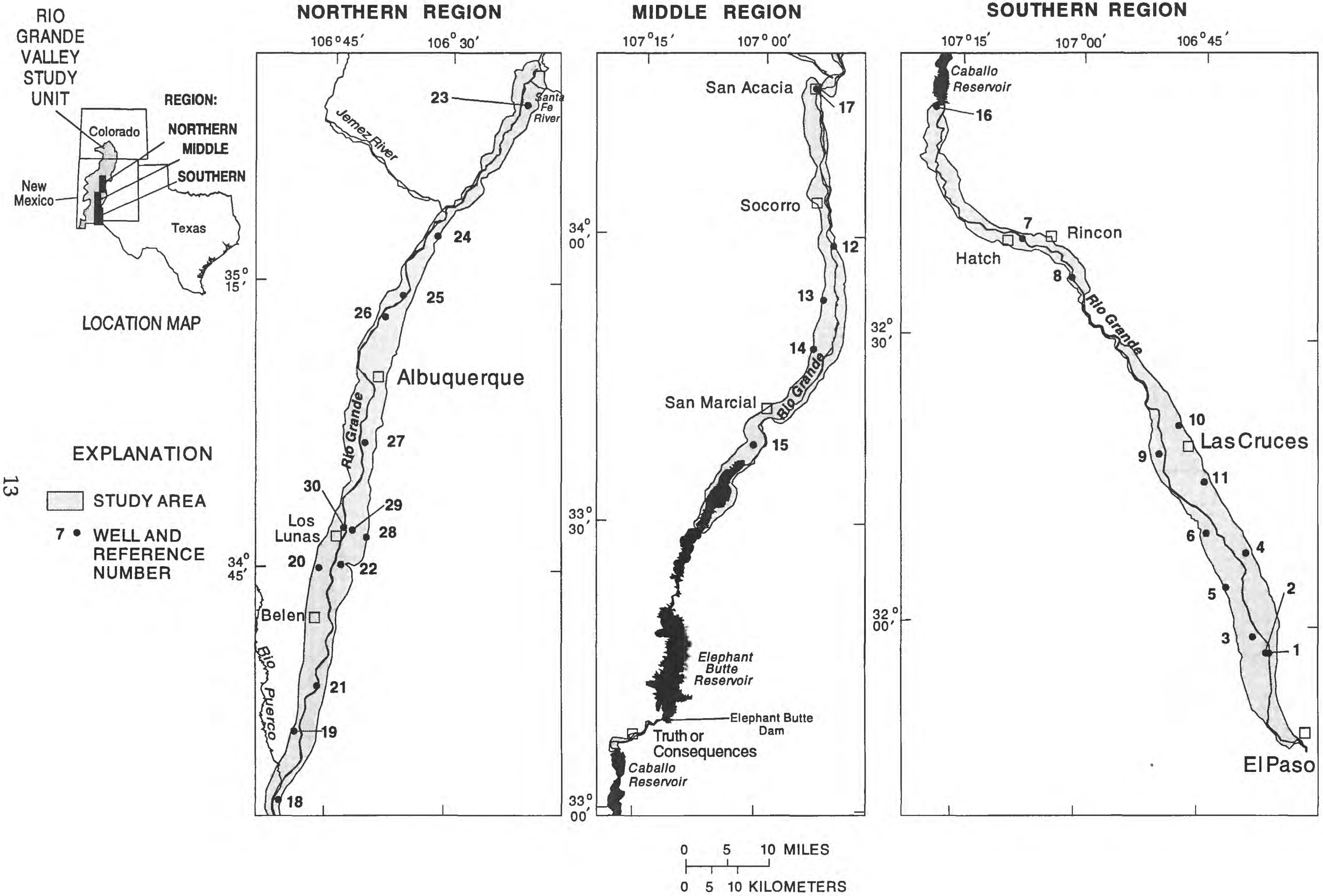


Figure 6.--Locations and reference numbers of the wells sampled.

Well Selection

Locations for the wells sampled in this study were chosen by a stratified random sampling procedure described by Scott (1990). This computer procedure divided the study area into 30 irregular cells of equal area and then randomly selected a primary location in each cell, accompanied by four alternate locations. Criteria used in the selection of wells in each cell were:

(1) The well was located within the boundaries defined for that cell;
(2) the total depth of the well and the depth of the perforated interval were known;
(3) the well owner could be contacted and was willing to allow the well to be sampled;
(4) the sample could be collected before the water passed through a pressure tank or any type of water treatment system;
(5) the well had a submersible pump; and
(6) the water was being used for domestic purposes or drinking water.

Beginning with the primary location chosen for each cell, wells that met specific criteria were searched for in the vicinity. If a suitable well that met most or all of the criteria could not be found near the primary location, the search was moved to the vicinity of the first alternate location, and so on.

Well reference numbers, well numbers, station numbers, and well-completion/water-level information for the 30 wells chosen for sampling are listed in table 1. (All tables are located at the back of this report.) Twenty-three of the sampled wells were constructed with casings made of polyvinyl chloride (a type of plastic), and seven wells were constructed with metal casings. The depths to the tops of the sampling intervals ranged from 10 to 345 feet below land surface, with a median of 161.5 feet (see table 6). Lengths of the sampling intervals ranged from 4 to 40 feet, and 20 of the wells had sampling intervals about 10 feet or less, allowing for relatively small zones of the aquifer to be sampled (table 1). Depths to water were measured in 20 wells and ranged from 2.55 to 62.85 feet below land surface at the time of sampling. Depths to water in 14 of these 20 wells were less than 25 feet. The sampling intervals of most wells were located more than 50 feet below land surface and below the water table (where known). Most of the wells sampled were drilled for drinking water; therefore, the study may be biased with respect to the depths of the sampling intervals and the quality of the water sampled because the wells were completed in parts of the aquifer where potable water typically could be found.

Data Collection

All 30 wells included in this study were sampled between March and May of 1995. Water samples from all of the wells generally were analyzed for major constituents, nutrients, DOC, selected trace elements, radionuclides, pesticides, and VOC's. However, well 7 was not sampled for VOC's because the well was equipped with a suction-type pump and rubber tubing, which could affect the results of the analyses. Well 24 was not sampled for radon because it was sampled on a Friday, and the half-life of radon gas would not allow for an accurate analysis to be performed when the lab processed the sample on the following Monday. Also, one of two pesticide samples from well 24 was accidentally destroyed prior to analysis.

The constituents included in each of the above seven categories except pesticides are listed in table 2, along with their typical minimum reporting levels (MRL's) as established by the U.S. Geological Survey National Water Quality Laboratory (NWQL), where all analyses were conducted. The MRL is the minimum concentration of an analyte that can be reliably measured and reported by the laboratory using a given analytical method. The pesticides (table 3) are divided into two groups according to the method used to detect each pesticide. The compounds listed in the first column are hereafter referred to as group A pesticides; the compounds in the second column are referred to as group B pesticides. Table 3 also includes the method detection limit (MDL) for each pesticide. The MDL, which is generally smaller and more well defined statistically than the MRL, is the minimum concentration of a substance that can be identified, measured, and reported with 99-percent confidence that the compound concentration is greater than zero (Zaugg and others, 1995). The MRL or MDL for a given constituent can vary for a specific sample because of a change in the method used or because of a change in the performance of the usual method due to a change in analyst or other factors. Therefore, a few constituents listed in table 1 show MRL's (represented by values preceded by a less-than sign) for one or two samples that are different from those for the other samples and from those listed in table 2.

Specific conductance, pH, water temperature, dissolved oxygen, and alkalinity were determined in the field for all 30 wells. Hydrogen sulfide concentrations were determined in the field for five wells where hydrogen sulfide was thought to be present. The concentrations determined were near or at the detection limit of 0.01 milligram per liter (mg/L) for the method used.

Each well was sampled in accordance with protocols and procedures recommended for the NAWQA program (Koterba and others, 1995). A minimum of the equivalent of approximately three well casings of water was purged from each well before sampling. Field parameters were recorded every 5 minutes during purging, and sampling was not initiated until all field parameters had stabilized for three consecutive 5-minute intervals.

Twenty-eight of the wells were sampled using the pump and plumbing that were present at the site. The two wells that were not equipped with pumps were sampled using a Grundfos Redi-Flo2 submersible pump. In both cases, Teflon tubing and stainless steel quick-connects were used to convey the water to a manifold. The manifold could direct flow to a sampling chamber (PVC frame enclosed in a plastic bag), to a flow-through chamber where most field parameters were measured, or to a bypass hose. With the exception of radon, all samples were collected in the sampling chamber located inside the sampling van. Selected samples were preserved with ultra-pure nitric acid in a separate chamber similar to the sampling chamber. Radon samples were collected from a port attached to the manifold.

Gelman 0.45-micron-pore-size cartridge filters were used to filter major constituent, nutrient, radionuclide, and trace-element samples. DOC was filtered in a stainless steel filtering apparatus using 0.45-micron silver filters. Nitrogen gas was used to force the water through the filter. Aluminum filter plates and 0.7-micron-pore-size baked glass filters were used to filter the pesticide samples. With the exception of DOC, all samples were filtered inside the sampling chamber. Nutrient, DOC, pesticide, and VOC samples were chilled on ice; these chilled samples and radon samples were shipped to the NWQL (overnight delivery) the day they were collected or the following day. All other samples generally were shipped within a few days of collection.

After each well was sampled, all Teflon tubing was cleaned with a 0.1-percent solution of liquinox that was circulated by a portable ceramic pump for about 10 minutes. The tubing was then rinsed by pumping approximately 3 gallons of deionized water through it. After rinsing, the tubing was stored in a clean, sealed plastic bag. For the two wells that required the use of the Grundfos pump, the pump and tubing were cleaned using this same process. The aluminum filter plates for pesticide sampling were washed with a 0.2-percent liquinox solution, rinsed with tap water followed by deionized water, and then rinsed with pesticide-grade methanol. The filter units were allowed to dry, then wrapped in aluminum foil and placed in plastic bags. The syringes used to collect radon samples were washed with 0.2-percent liquinox, rinsed with tap water, and then rinsed with deionized water. The DOC filter unit was disassembled, rinsed with organic-free water, air dried, reassembled, and wrapped in aluminum foil.

Quality Control of Samples

In addition to the environmental samples (the collection of which was described in the previous section), quality-control samples were collected at three wells to determine whether the protocols for sampling and analysis were giving an accurate representation of the composition of each water sample. The quality-control samples consisted of field blanks, duplicate samples, and samples to which field spikes and laboratory spikes were added. Data for the field blanks and duplicate samples are given in table 4. Selected statistics summarizing the spike-recovery data are listed in table 5. In addition to these quality-control samples, the NWQL routinely conducts a separate quality-control program, as discussed by Friedman and Erdmann (1982) and Pritt and Raese (1992).

Field blanks were collected and analyzed to ensure that chemical constituents were not being introduced to samples as a result of cleaning, sampling, handling, or shipping procedures. Field blanks generally were obtained by using a portable ceramic pump to force inorganic- and organic-free water from their original containers through the standard tubing configuration and into the sampling chamber where the samples were collected. The blank samples then were filtered, preserved, and shipped to the NWQL for analysis as though they were environmental water samples.

For the three field blanks collected in connection with this study, concentrations of most constituents were less than their MRL's or MDL's, which indicates that the cleaning, sampling, handling, and shipping procedures did not introduce measurable contamination. However, the concentrations of nitrite, nitrite plus nitrate, phosphorus, DOC, aluminum, and zinc in the field blanks were greater than the MRL and in the same general range as the concentrations measured in some specific environmental samples. The validity of concentrations of these constituents in these specific environmental samples is questionable because it cannot be determined if the concentrations were introduced by the sampling procedure or if they actually do exist in the ground water. DOC is known to exist in measurable quantities in some blank water (Michael Koterba, U.S. Geological Survey, written commun., 1995), but the detection in the field blanks of the other constituents above their MRL's has no apparent explanation. Silica was detected in one field blank above the MRL but at a much smaller concentration than those in the environmental samples. This indicates that small differences in concentration for that constituent in different environmental samples may not be true differences, but instead may be a result of sampling and analytical procedures. Iron was detected well above the MRL in one field blank; this detection probably was due to a new stainless steel fitting used only to pump the blank water (not used during collection of environmental samples). Subsequent blanks collected using this fitting did not have iron concentrations above the MRL. Although this fitting had been cleaned with 1-percent hydrochloric acid before use, iron could have been leaching from the fitting at the time the field blank was collected. Methylene chloride and chloroform also were detected in one field blank, but not in any of the environmental samples. Methylene chloride is a common lab contaminant (U.S. Environmental Protection Agency, 1991), but the source of the chloroform is not known.

Duplicate samples were collected at slightly later times than environmental samples, and were analyzed to determine the precision of sample analysis for an individual well and conditions. Precision can be affected by poor sampling or analytical procedures, or changes in the chemical composition of water removed from the well during the period of sampling. Analytical results for the duplicate samples generally showed good agreement with those for the environmental water samples, indicating good precision. Relatively large variations in concentrations of aluminum and zinc were detected between the duplicate samples and environmental water samples. The reason for the variation in aluminum and zinc concentrations is not known, but the combined results of the field blanks and duplicates indicate that little confidence should be placed on the concentrations reported for these two constituents. A variation of more than 10 percent in concentrations also was apparent in the results for the environmental and duplicate samples from at least one well for ammonia, iron, nickel, and radon. Again, the reason for this variation is unknown.

Field and laboratory spikes of selected pesticides and VOC's were added to environmental samples to determine the precision and accuracy of analyte recovery in the sample matrix and to determine if the analytical methods used for selected compounds were appropriate. For each sample and compound, the percent recovery was determined using the known quantity spiked into the sample and the known total volume of the sample collected. The median recoveries for the spiked VOC's ranged from 50 to 88 percent for nine samples (three laboratory spikes, three field spikes, and three field spike replicates). These results generally indicate that the method was appropriate and matrix effects were minimal. The four VOC's that showed median spike recoveries of less than 60 percent were benzene (50 percent), MTBE (53 percent), methylene chloride (56 percent), and 1,1-dichloroethylene (58 percent).

For group A pesticides (table 5), the median spike recoveries ranged from 17 to 152 percent. The smallest median recoveries occurred for permethrin (17 percent), deethyl atrazine (50 percent), and p,p'-DDE (57 percent). The largest median recoveries occurred for carbaryl (152 percent), carbofuran (128 percent), and tebuthiuron (124 percent). For the group B pesticides (table 5), the median spike recoveries ranged from 13 to 111 percent. The smallest median recoveries for this group of spiked pesticides occurred for oxamyl (13 percent), carbaryl (15 percent), aldicarb sulfone (18 percent), methiocarb (23 percent), 1-naphthol (28 percent), chlorothalonil (30 percent), and 2,4-DB (49 percent). None of the compounds listed above were detected in the environmental samples. However, the possibility exists that a compound was present at a concentration slightly above the MDL or MRL in one or more of the water samples, but was not detected at a sufficient level to be reported because of its low recovery rate.

In addition to the spikes added to selected quality-control samples, surrogate compounds for pesticides and VOC's were added to most environmental samples at the NWQL for the same purposes listed above for the field and laboratory spikes. The surrogate recoveries for each environmental sample are included at the end of table 1. Recoveries for the three volatile organic compound surrogates (ethane, toluene, and benzene surrogates) ranged from 96 to 100 percent. Recoveries for the three group A pesticide surrogates (diazinon, terbuthylazine, and HCH alpha surrogates) ranged from 65 to 117 percent. These results generally indicate that the methods were appropriate and matrix effects were minimal. Recoveries for the one group B pesticide surrogate compound (BDMC surrogate) ranged from 5 to 103 percent; the values less than about 60 percent indicate possible problems with the surrogate or the method of analysis.

RELATION OF CONSTITUENT CONCENTRATIONS TO DRINKING-WATER STANDARDS

The data in table 1 and the statistics in tables 6 and 7 indicate large variation in the chemical composition of ground water throughout the study area. All concentrations given in this report are dissolved concentrations, with the exception of radon and VOC concentrations and alkalinity as determined by a gran titration. Despite the variation observed in chemical composition, the concentrations of constituents generally were less than the current (1996) enforceable drinking-water standards (U.S. Congress, 1996; U.S. Environmental Protection Agency, 1996). These standards include maximum contaminant levels (MCL's), which are health-based standards that are enforceable for all public water systems (not for private wells). A proposed MCL is a standard that has not received final approval and is not enforceable. Secondary maximum contaminant levels (SMCL's) are nonenforceable standards that are based on aesthetics, not on health effects. Lifetime health advisories are nonregulatory estimates of concentrations that, over a lifetime of exposure, would result in no known or anticipated adverse health effects. Table 8 gives the EPA standards for each constituent and the wells that produced water exceeding them.

Field Parameters

Field pH of water from the 30 wells sampled varied from 7.31 to 8.58; the median was 8.00 (tables 1 and 6). Water from wells 1, 2, and 20 exceeded the SMCL of 8.5 for pH (fig. 6 and table 8). Field specific conductance ranged from 280 to 4,110 microsiemens per centimeter at 25 degrees Celsius (µS/cm), with a median of 644 µS/cm. Water temperature varied from 14.5 to 24.0 degrees Celsius, with a median of 18.5 degrees Celsius. Dissolved oxygen ranged from less than 0.05 to 7.8 mg/L; the median was 0.1 mg/L. Alkalinity, as determined by a gran titration, ranged from 50 to 329 mg/L as calcium carbonate; the median was 142 mg/L. There are no EPA standards for specific conductance, water temperature, dissolved oxygen, or alkalinity.

Major Constituents

Concentrations of dissolved solids in water from the wells sampled ranged from 209 to 3,380 mg/L, with a median of 409.5 mg/L. Water from 12 wells exceeded the SMCL of 500 mg/L for dissolved solids. Fluoride concentrations ranged from 0.20 to 4.6 mg/L; the median concentration was 0.50 mg/L. The fluoride concentrations in wells 4 and 14 exceeded the SMCL of 2 mg/L; the concentration in well 4 also exceeded the MCL of 4 mg/L. Chloride concentrations ranged from 7.1 to 430 mg/L, with a median of 44 mg/L. Water from wells 8 and 18 exceeded the SMCL of 250 mg/L for chloride. Sulfate concentrations varied from 26 to 1,500 mg/L; the median concentration was 98.5 mg/L. Water from wells 4, 6, 7, 8, 10, 18, and 24 exceeded the SMCL of 250 mg/L for sulfate; water from wells 8 and 10 also exceeded the proposed MCL of 500 mg/L. The minimum, maximum, and median concentrations of the other major constituents (calcium, magnesium, sodium, potassium, bicarbonate, carbonate, bromide, and silica) are in table 6; no MCL's or SMCL's have been established by the EPA for these major constituents.

Nutrients and Dissolved Organic Carbon

Most nutrient species analyzed for generally were detected at concentrations at or very near the MRL. The most dominant nutrient species detected in ground water was nitrite plus nitrate, followed by ammonia. Nitrite plus nitrate concentrations ranged from less than 0.05 to 1.9 mg/L (smaller than the MCL of 10 mg/L). The median concentration was less than the MRL of 0.05 mg/L because water from 19 wells contained concentrations of nitrite plus nitrate less than this level (table 6). Ammonia concentrations varied from less than 0.015 mg/L to 0.250 mg/L (smaller than the lifetime health advisory of 30 mg/L); the median concentration was 0.020 mg/L. Water from 14 wells contained concentrations less than the MRL of 0.015 mg/L. DOC varied from less than 0.1 to 2.6 mg/L; the median was 0.4 mg/L. There is no EPA standard for DOC.

Trace Elements

Concentrations of several trace elements (antimony, beryllium, cadmium, chromium, cobalt, copper, lead, selenium, and silver) generally were close to or at their respective MRL's in water from most wells and did not exceed any EPA standards (tables 1 and 8). Because these trace elements generally were detected only in very small concentrations and only in a small number of wells, they are not discussed further in this report. By comparison, median concentrations of aluminum, arsenic, barium, manganese, molybdenum, nickel, uranium, and zinc were greater than their respective MRL's (table 7). Although iron concentrations were above the MRL in fewer than half of the wells, iron is further discussed in this report because it was detected in some wells at relatively large concentrations, and in two wells exceeded EPA standards.

Aluminum concentrations ranged from 3 to 15 μg/L and did not exceed any EPA standards. Arsenic concentrations ranged from less than 1 to 48 μg/L, all smaller than the MCL of 50 μg/L. Barium concentrations ranged from 12 to 212 μg/L, considerably below the MCL of 2,000 μg/L. Iron concentrations ranged from less than 3 to 550 μg/L. Water from 16 wells contained no detectable iron, but water from wells 7 and 18 exceeded the SMCL of 300 μg/L. Manganese concentrations varied from less than 1 to 654 μg/L. Water from 10 wells had no detectable concentrations of manganese, whereas water from another 10 wells exceeded the SMCL of 50 μg/L. Molybdenum concentrations varied from 2 to 59 μg/L; the molybdenum concentration in the sample from well 4 exceeded the lifetime health advisory of 40 μg/L. Nickel concentrations ranged from less than 1 to 15 μg/L and did not exceed any EPA standards. Uranium concentrations ranged from less than 1 to 102 μg/L; the concentration in the sample from well 10 exceeded the proposed MCL of 20 μg/L. Zinc concentrations ranged from less than 1 to 65 μg/L, below any standards established by the EPA.

Radiochemicals

Gross alpha particle activity (or gross alpha) is a measure of the alpha radiation, or positively charged helium nuclei, emitted by radionuclides in a sample; gross beta particle activity (or gross beta) is a measure of the beta radiation, electrons or positrons, emitted by radionuclides in a sample. The measurement of gross alpha particle activity or gross beta particle activity of a particular sample is the sum of all alpha- or beta-emitting radionuclides. Gross alpha and gross beta particle activities each are quantified in terms of the equivalent quantities of two different alpha- or beta-emitting radionuclides (tables 1 and 7). Gross alpha particle activities in the wells sampled ranged from less than 3 to 46 picocuries per liter (pCi/L) as thorium-230, and from less than 3 to 48 µg/L as natural uranium. Water from 14 of the wells had gross alpha particle activities at or below the MRL's of 3 µg/L or 3 pCi/L. Water from well 10 had gross alpha particle activity above the MCL of 15 pCi/L. Gross beta particle activities ranged from less than 4 to 120 pCi/L as cesium-137, and from less than 4 to 56 pCi/L as strontium-90/yttrium-90. Water from only three wells contained levels below both MRL's of 4 pCi/L. Water from well 10 may exceed the MCL of 4 millirem per year for beta particle and photon activity, but further testing to determine the concentrations of specific radioactive elements would be necessary to determine that for certain. The gross alpha particle activity due to radon-222 gas is not included in the gross alpha particle activity for a sample because the analytical method for gross alpha excludes gases. Twenty-nine wells were sampled for radon-222, and the concentrations ranged from 190 to 2,300 pCi/L; the median concentration was 380 pCi/L. There is no EPA standard for radon.

Pesticides and Volatile Organic Compounds

Of all VOC's and pesticides analyzed for (tables 2 and 3), the herbicide prometon was detected in only one water sample at a concentration of 0.038 µg/L; none of the other compounds were detected in any of the samples. The EPA has not established an MCL for prometon, but has established a lifetime health advisory of 100 µg/L.

FACTORS AFFECTING GROUND-WATER QUALITY

Concentrations of the various chemical constituents found in ground water are the result of the individual sources of those constituents and the chemical reactions that have occurred along individual ground-water flow paths. The sources and processes, or factors, that affect ground-water quality can occur naturally or can be the result of human activities. For example, natural sources of chemical constituents can include precipitation, surface water, and minerals present in subsurface materials. Natural processes can include evaporation and mineral dissolution. Anthropogenic sources of chemical constituents can include agricultural chemicals and industrial waste. Also, certain chemical reactions can occur because of the addition to ground water of reagents through human activities. Constituent concentrations and spatial variations in those concentrations can be used to determine the most likely sources and processes affecting water quality in a given area. Certain sources and processes can be more likely to act on one flow-system scale than another (for example, the leaching of fertilizers is more likely to be important on a local scale than on a regional scale). Therefore, recognizing the factors that are most likely to affect ground-water quality in a given area can help to determine the dominant flow system in that area.

In the discussion below, the Sources and Processes sections provide background on common natural and anthropogenic sources of constituents to ground water. They also introduce hydrologic and geochemical processes that generally have been cited in previous studies as possible factors affecting constituent concentrations in the study area. The sections titled Relation of Sources and Processes to Occurrence and Distribution discuss spatial variations in constituent concentrations and provide evidence of how certain factors may have influenced constituents in ground water of the study area to produce the ground-water quality that was observed.

Major Constituents

Sources and Processes

Water recharging the aquifer can be an important source of major constituents found in ground water. As stated earlier, most ground water in the study area probably originated at its source as precipitation or as surface water, which in ephemeral channels near the Basin margins consists largely of runoff of precipitation from adjacent areas. As precipitation falls on the land surface and begins to infiltrate, it tends to dissolve any dry particulate matter that has been deposited from the atmosphere, which increases major constituent concentrations in the infiltrating precipitation. In addition, as precipitation or surface water infiltrates, solutes are concentrated in the water by evaporation and transpiration (evapotranspiration). The large amount of potential evapotranspiration in the study area can result in considerable increases in concentrations of solutes in recharge water. If no chemical reactions occur concurrently, as the water is evaporated from the soil or transpired by plants, the ratios between the various solutes do not change although the solute concentrations increase.

Once precipitation or surface water infiltrates into the subsurface, chemical and biological reactions in both the unsaturated and saturated zones can alter the concentration of one or more solutes relative to the other solutes. Several chemical reactions have been cited as possible processes occurring within the study area (Anderholm, 1988). These processes include the dissolution and precipitation of calcite, which would affect concentrations of calcium and bicarbonate, and the dissolution and precipitation of gypsum, which would affect concentrations of calcium and sulfate. The alteration of silicate minerals also may be occurring, which would affect concentrations of several ions, including sodium, silica, and bicarbonate. Another important process may be cation exchange, which would exchange calcium or magnesium ions in solution for sodium ions on clay minerals, resulting in increases in sodium concentrations and decreases in calcium and magnesium concentrations in solution. One of the main factors that determine which, if any, of these reactions could affect the ground-water composition of an area is the minerals present in materials of the unsaturated and saturated zones. For example, in areas where gypsum is present in the unsaturated zone and aquifer, ground water might have large concentrations of dissolved calcium and sulfate as the result of gypsum dissolution.

Relation of Sources and Processes to Occurrence and Distribution

The overall composition of ground water with respect to major ions varies considerably throughout the study area, as shown by the Piper diagram (fig. 7). A Piper diagram uses a point in each of three fields to represent the composition of a water sample in terms of the percentages of specific cations and anions in milliequivalents per liter (meq/L). Milliequivalents per liter are calculated as follows:

$$\text{concentration in meq/L} = \frac{\text{concentration of ion in mg/L x valence of ion}}{\text{molecular weight of ion}} \qquad (1)$$

The left triangular field of a Piper diagram shows the percentage of each cation or group of cations present in the sample; the right triangular field shows the percentage of each anion or group of anions present; and the diamond-shaped field shows the overall percentage of each general group of ions present. Water types with respect to both cations and anions can be defined using the four quadrants of the diamond-shaped field. Differences in the composition of water from wells in separate areas could indicate that ground water in these areas is affected by water from different recharge sources or by various chemical reactions.

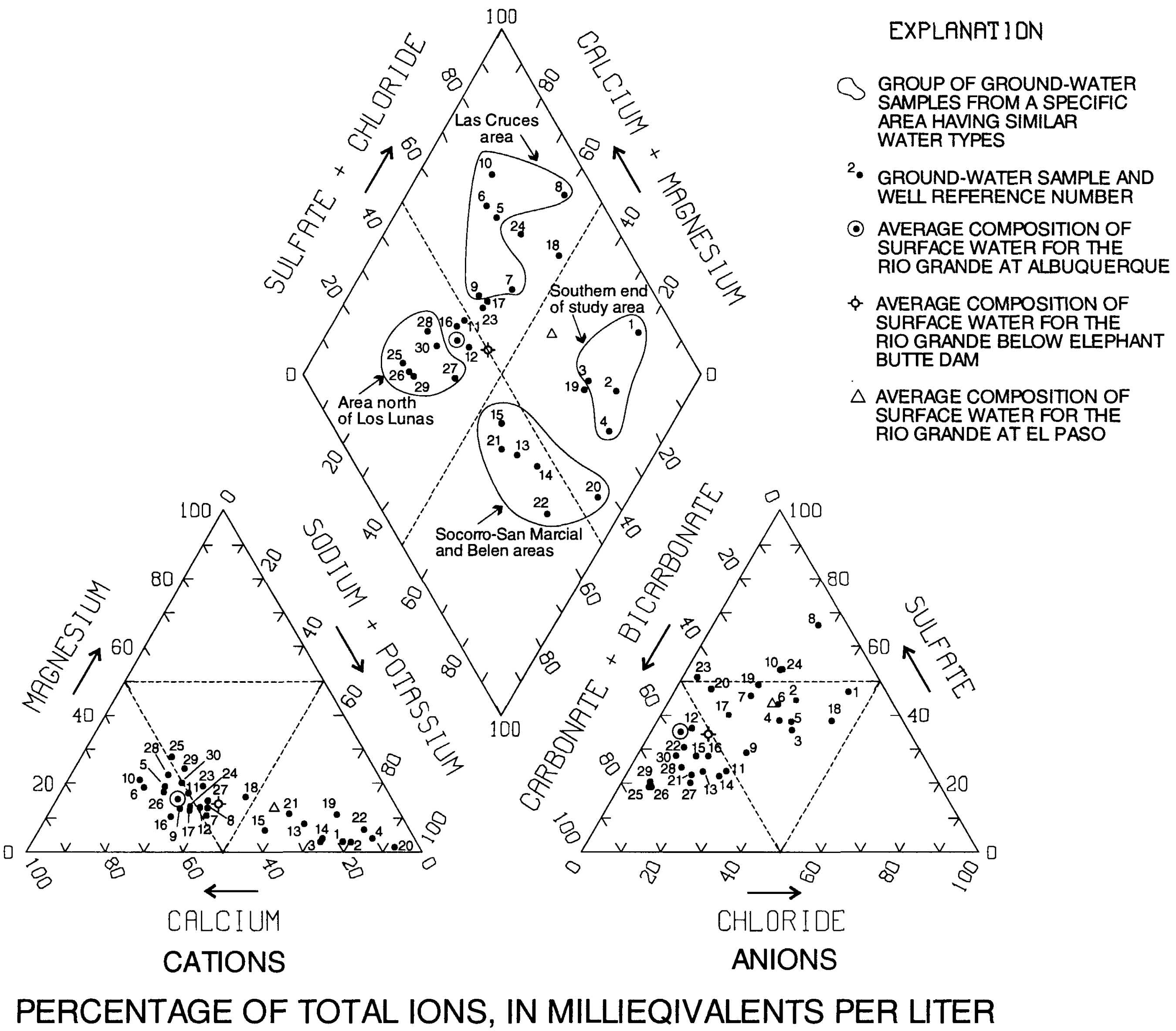


Figure 7. --Piper diagram showing compositions of ground water and surface water with respect to major ions.

The spatial distribution of water types as defined using the diamond-shaped field of the Piper diagram shows that, in general, water from wells in specific parts of the study area tend to group together with respect to chemical composition (figs. 7 and 8). Many of the water samples from the area north of Los Lunas are of the calcium magnesium carbonate bicarbonate type. Water in the Socorro-San Marcial area generally is of the sodium potassium carbonate bicarbonate type. Samples from wells around Belen also are of this type. In the southern region (Caballo Reservoir to El Paso), water from the area north of Las Cruces generally is of the calcium magnesium sulfate chloride type. This water type also is found south of Las Cruces, along the western edge of the study area. Water at the southern end of the study area generally is of the sodium potassium sulfate chloride type. These variations in water types across the study area indicate that recharge water with different compositions and (or) various chemical reactions are affecting the water quality in different areas.

Water with the largest dissolved-solids concentrations generally is in the southern region and generally contains sulfate and chloride as dominant anions (fig. 8). Nine of the 12 wells in the southern region produced water having dissolved-solids concentrations greater than the median value of 409.5 mg/L. Relatively large dissolved-solids concentrations also are found in water from the two wells (23 and 24) in the extreme northernmost part of the study area and in the three wells (17, 18, and 19) nearest the boundary between the northern and middle regions (well 17 in the middle region and wells 18 and 19 in the northern region) (fig. 8). Fourteen of the 15 wells with dissolved-solids concentrations greater than the median produced water containing sulfate and chloride as dominant anions.

Average concentrations of major constituents in surface water from the Rio Grande at Albuquerque, Rio Grande below Elephant Butte Dam, and Rio Grande at El Paso were determined for the period 1980 to 1992 (table 9). These average surface-water compositions were plotted against the ground-water samples on the Piper diagram (fig. 7) The diagram shows that the composition of surface water from each of these various sites along the Rio Grande is similar to the composition of some of the ground-water samples. The Piper diagram could not be used to compare the composition of precipitation with that of ground water because magnesium, potassium, and bicarbonate were not included in the available chemical analyses performed by Popp and others (1984) for precipitation in the area.

Figure 9 compares various ion compositions of ground water throughout the study area with the compositions in precipitation and surface water of the region. This comparison can be used to determine the recharge sources and chemical reactions that could be affecting ground-water quality. Figures 9A, 9B, and 9C show the relations of sulfate, sodium, and calcium concentrations to chloride concentrations. Chloride concentration was used as the independent variable on these plots because chloride ions generally are not affected as much as other major ions by chemical reactions occurring in the unsaturated zone or aquifer (Hem, 1985). Figure 9 also includes the average ion concentrations determined by Popp and others (1984) for bulk precipitation, which includes both wet and dry deposition, collected in Albuquerque and Socorro. Also plotted are the average ion concentrations determined at the three surface-water sites (Rio Grande at Albuquerque, Rio Grande below Elephant Butte Dam, and Rio Grande at El Paso). Evaporation trends are shown for the precipitation and surface-water compositions. The evaporation trends represent the compositions of the various precipitation and surface-water samples that could result if each evaporated and if no chemical reactions occurred during evaporation. Ground-water compositions that deviate from the compositions of precipitation and surface water, or their evaporation trends, could indicate that chemical reactions are affecting ground-water compositions.

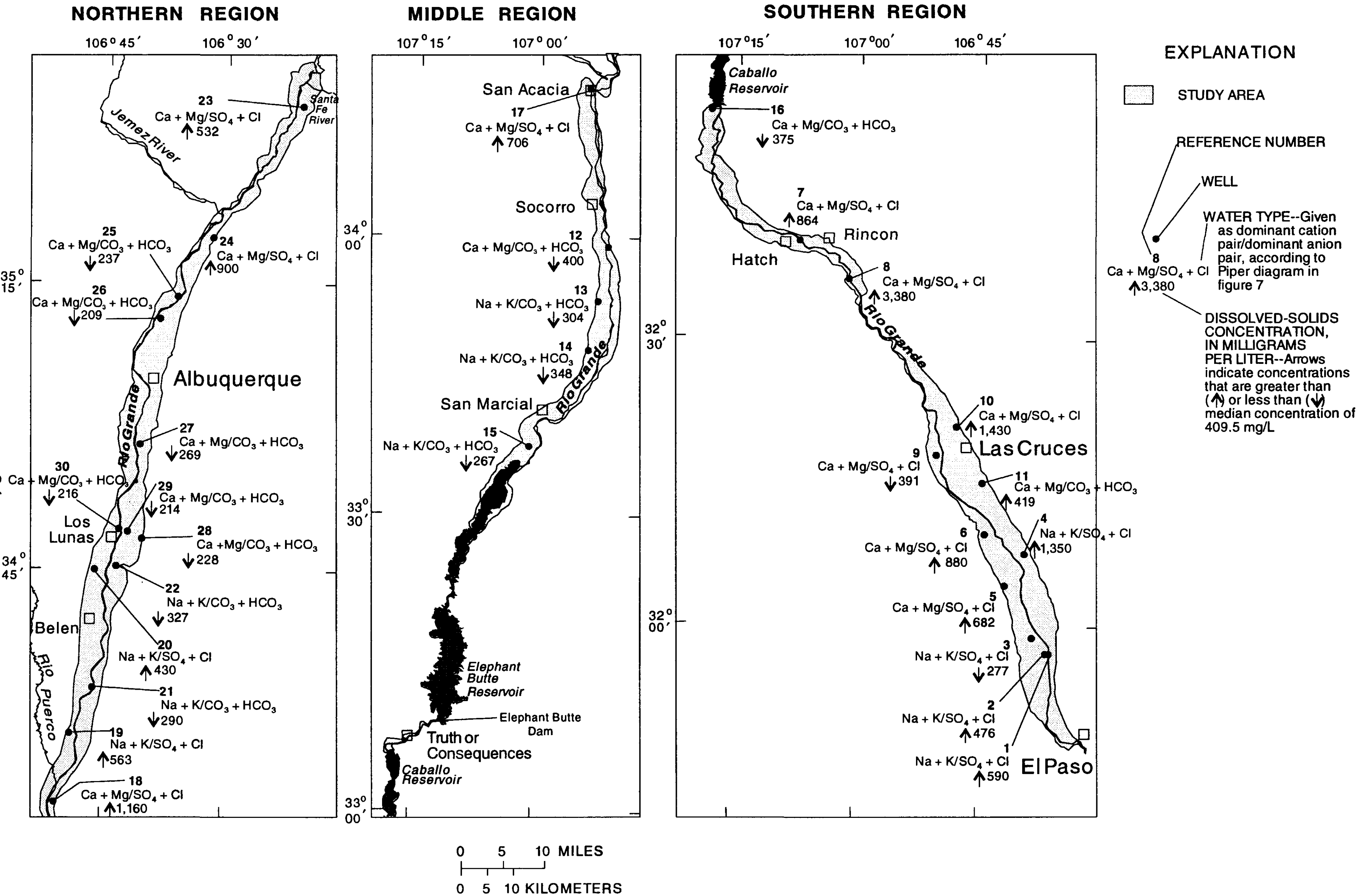


Figure 8.--Spatial distributions of water types and dissolved-solids concentrations.

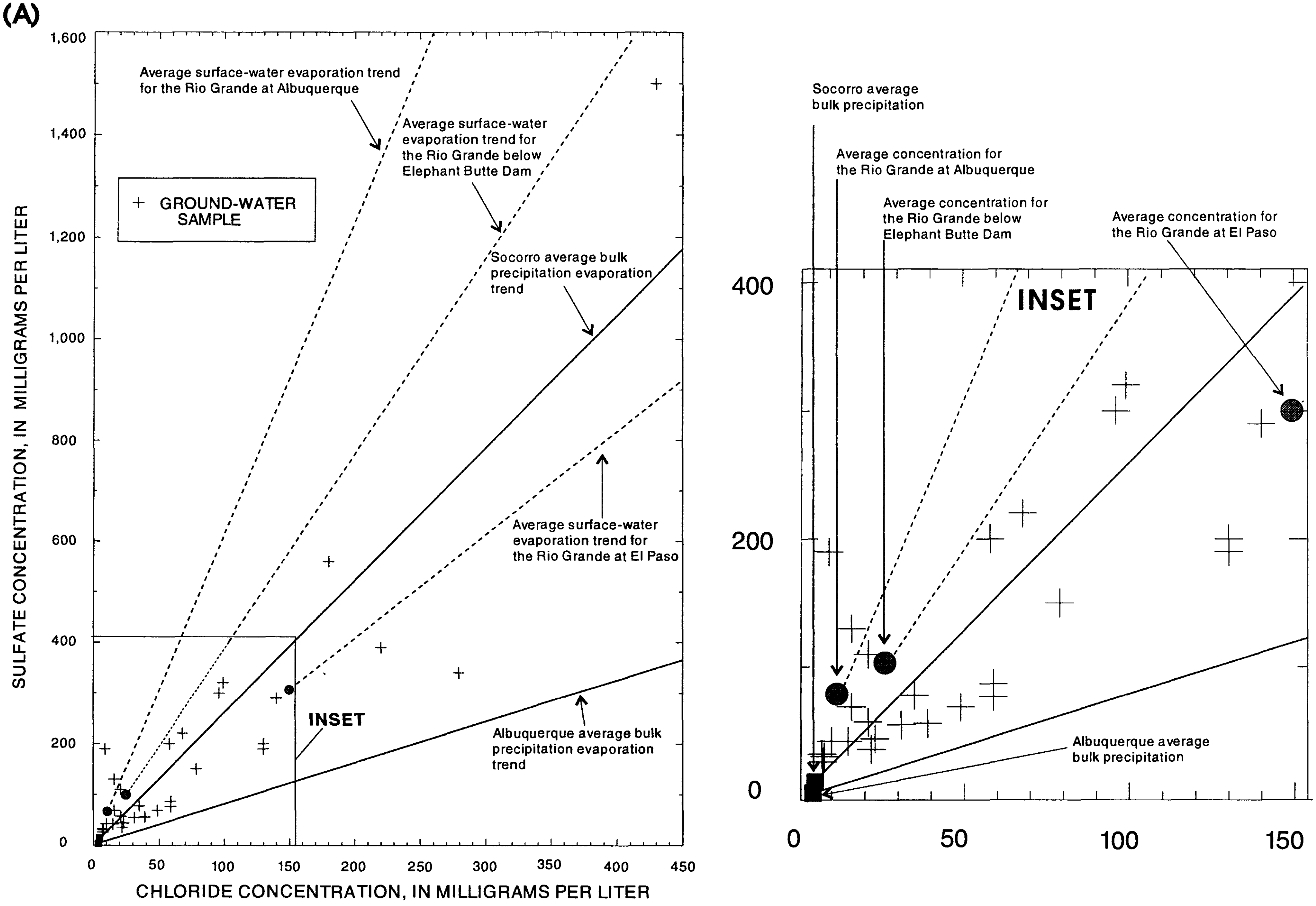


Figure 9.--Relation of (A) sulfate, (B) sodium, and (C) calcium concentrations to chloride concentration in area precipitation, surface water, and ground water. Data for Albuquerque and Socorro bulk precipitation evaporation trends from Popp and others (1984).

(B)

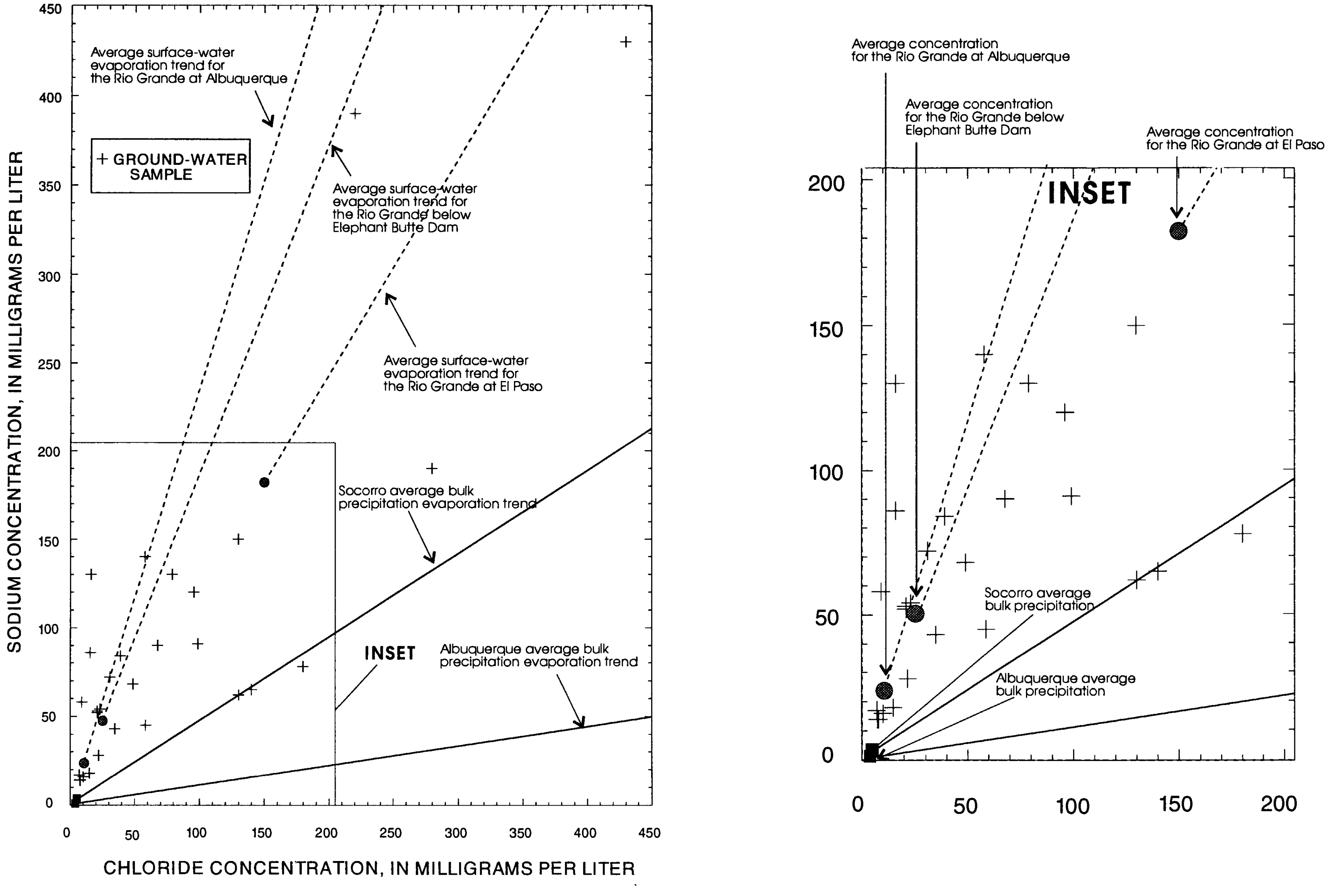


Figure 9.--Relation of (A) sulfate, (B) sodium, and (C) calcium concentrations to chloride concentration in area precipitation, surface water, and ground water. Data for Albuquerque and Socorro bulk precipitation evaporation trends from Popp and others (1984)--Continued.

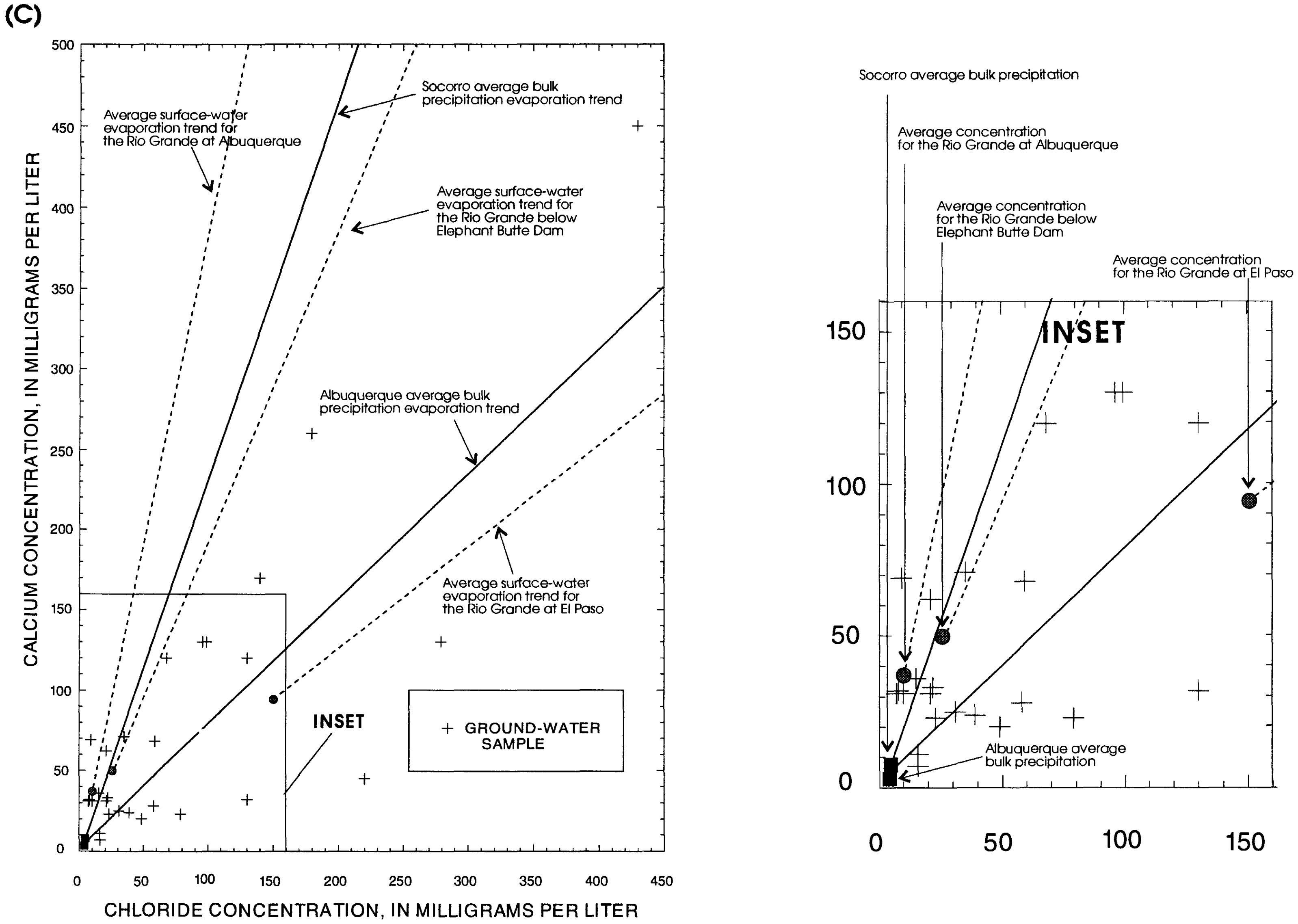


Figure 9.--Relation of (A) sulfate, (B) sodium, and (C) calcium concentrations to chloride concentration in area precipitation, surface water, and ground water. Data for Albuquerque and Socorro bulk precipitation evaporation trends from Popp and others (1984)--Concluded.

The sulfate and chloride data indicate that most ground-water samples plot between the evaporation trends for precipitation and below the evaporation trends for surface water in the Rio Grande at Albuquerque and the Rio Grande below Elephant Butte Dam (fig. 9A). Many of the ground-water samples also plot below the evaporation trend for surface water in the Rio Grande at El Paso. Because the ground-water compositions appear to be more similar to the compositions that could result from evaporation of precipitation than those that could result from evaporation of surface water, the plot indicates that precipitation could be the main source of recharge of the ground water sampled. Many ground-water samples contain smaller sulfate concentrations, and in some cases smaller chloride concentrations, than surface water. For example, all but three of the ground-water samples from the southern region of the study area have smaller concentrations of sulfate and chloride than the average concentrations of these ions in the Rio Grande at El Paso. Because these ground-water samples are more dilute than the average surface water of the region, this implies that surface water from the Rio Grande is not the major source of the ground water. However, the possibility exists that surface water from the Rio Grande that infiltrates and recharges the ground water could be more dilute than the average surface-water compositions as determined for the Rio Grande during 1980 to 1992 or that the surface water mixes with the more dilute water from precipitation. Another possibility is that surface water in tributaries to the Rio Grande with compositions similar to precipitation infiltrates and recharges the ground water. This could occur along the basin margins or through channels in the basin.

Saturation indices for gypsum, which is known to exist in the unsaturated zone of the study area (Anderholm, 1985), and several other minerals were calculated for the ground-water samples using PHREEQE, a computer program designed for geochemical calculations (Parkhurst and others, 1980). All saturation indices for gypsum in the ground water sampled were less than zero, indicating that gypsum (where present) would tend to dissolve in ground water rather than precipitate. If gypsum was dissolving in the unsaturated or saturated zone, the sulfate concentrations in the recharge water or ground water would increase relative to chloride, causing ground-water samples to plot above the evaporation trends of recharge water (precipitation and surface water). Figure 9A shows that the ground-water samples all plot above the evaporation trend for Albuquerque average bulk precipitation and most plot below the evaporation trend for average surface water from the Rio Grande. For ground water to have a greater concentration of sulfate relative to chloride than recharge water, gypsum would have to be precipitating. Because the calculated saturation indices indicate that gypsum is not precipitating, the ground-water samples that plot below the evaporation trend for surface water again indicate that surface water from the Rio Grande is not the major source of recharge to ground water.

Figure 9B shows that most ground-water samples have more sodium relative to chloride than would be expected based on the evaporation trends of precipitation (data plot above the evaporation trends). However, the ground-water samples trend along or below the evaporation trends for surface water. Cation exchange and alteration of silicate minerals are two processes that would result in increases in sodium concentrations relative to chloride in ground water. Calcium smectite and mixed-layer illite-smectite clays, which generally have large ion-exchange capacities, were identified in basin-fill deposits of the study area by Anderholm (1985). These clays commonly exchange two sodium ions into solution for every calcium or magnesium ion removed from solution. Anderholm (1988) also identified feldspar weathering as a major chemical process that is likely to occur in the region. Therefore, cation exchange and alteration of silicate minerals could explain the greater concentrations of sodium relative to chloride in ground water of the study area compared to precipitation evaporation trends. There are few natural processes, however, that would cause sodium to be removed from recharge water or ground water relative to chloride. Therefore, the observation that most ground-water samples plot above the evaporation trends for precipitation and below the evaporation trends for surface water again implies that surface water from the Rio Grande is not the major source of recharge to ground water.

Figure 9C indicates that several of the ground-water samples have less calcium relative to chloride than would be expected based on the evaporation trends of surface water and precipitation (data plot below the evaporation trends for surface water and precipitation). As discussed above, the process of cation exchange removes calcium ions from solution. Therefore, the generally larger concentrations of sodium relative to chloride combined with the generally smaller concentrations of calcium relative to chloride in ground water as opposed to recharge water (precipitation and surface water) indicate that cation exchange probably is affecting the composition of the ground water sampled. However, calcite dissolution and precipitation also could be affecting the concentrations of calcium relative to chloride. The dissolution of calcite occurs in the following manner:

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca^{+2} + 2HCO_3^-, \qquad (2)$$

resulting in the addition of calcium and bicarbonate ions to solution. Recharge water infiltrating through the unsaturated zone would tend to dissolve calcite because the partial pressure of carbon dioxide is greater in the soil zone than in the atmosphere. Evapotranspiration would also tend to increase the concentrations of calcium and bicarbonate in the unsaturated zone. In addition, bicarbonate concentrations could increase as the result of other processes, such as the alteration of silicate minerals. If the concentrations of calcium and bicarbonate became large enough, the water would become saturated with respect to calcite and calcite would precipitate. Saturation indices for calcite in the ground water sampled were greater than zero in 29 of the samples (table 10), indicating that water throughout most of the study area is above saturation with respect to calcite and would tend to precipitate calcite. Precipitation of calcite would tend to cause calcium concentrations to decrease relative to chloride concentrations, but the resulting decreases in calcium concentrations probably would not be sufficient to explain the ratios of calcium to chloride that were observed. Therefore, cation exchange probably is also causing decreases in calcium concentrations in the water.

Silica concentrations are largest in the northern region of the study area, where water in 12 of 13 wells contains concentrations greater than the median concentration of 36.5 mg/L (fig. 10). This spatial pattern indicates that processes that result in increasing silica concentrations could be occurring to a greater extent in the northern region of the study area than in the other regions. A plot of sodium and silica concentrations in ground water shows that the water can be classified into one of two groups (fig. 11). Water from the wells in group 1 has a ratio of silica to sodium concentration of 0.72 or less, and all but one of the samples have a ratio equal to or less than 0.58. Water from the wells in group 2 has a ratio of silica to sodium concentration of 0.85 or greater, and all but one of the samples have a ratio equal to or greater than 1.09. The smaller silica to sodium ratios in water from the wells in group 1 could be consistent with the alteration of silicate minerals, such as plagioclase feldspars, which would result in increases in both dissolved-silica and dissolved-sodium concentrations. Conversely, the larger silica to sodium ratios in water from the wells in group 2 could indicate a process whereby silica is released in ground water without the release of sodium. All wells in group 2 are in the northern region of the study area, and the larger silica concentrations in ground water in this area relative to other ground water sampled in the study area could be due to dissolution of volcanic glass or pumice in the aquifer. Hawley and Haase (1992) indicated that pumice is common in some of the aquifer material in the northern region of the study area. Experimental dissolution of volcanic glass by White and others (1980) showed the release of large quantities of silica into solution, with an accompanying release of only small quantities of sodium.

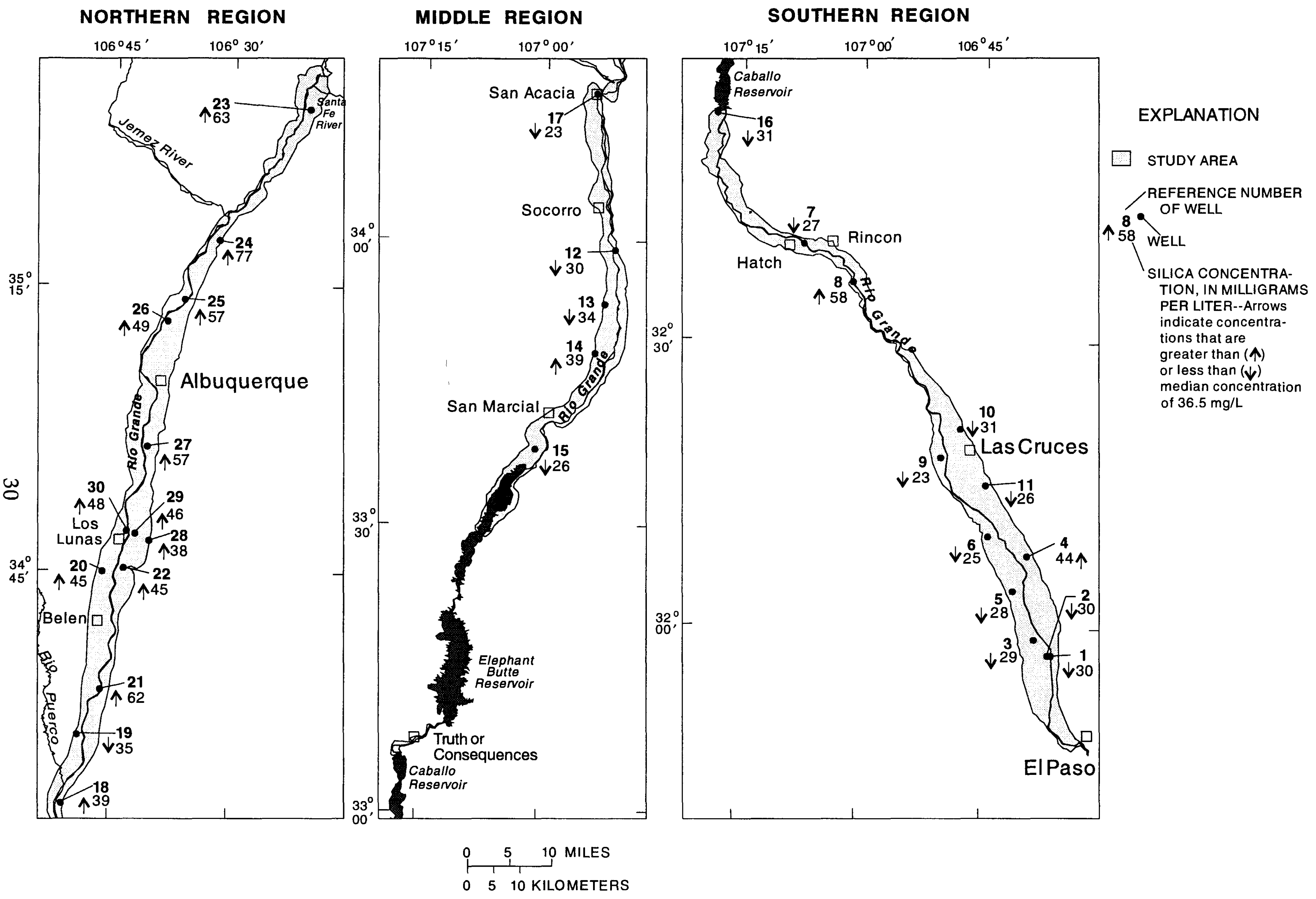


Figure 10.--Spatial distribution of silica concentrations.

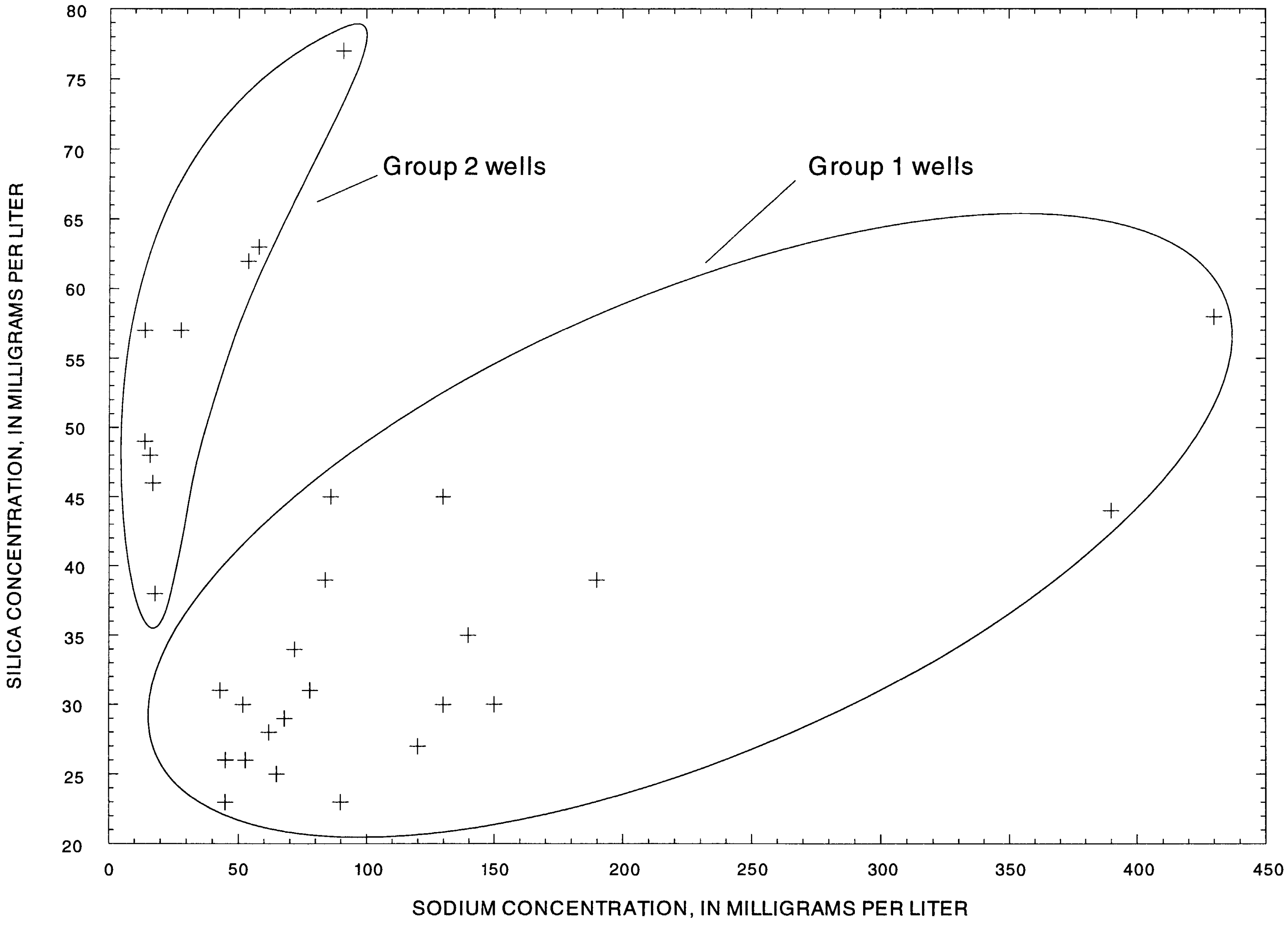


Figure 11. -- Relation of silica concentration to sodium concentration.

On the basis of the plots of sulfate, sodium, and calcium concentrations to chloride concentrations, precipitation seems to be the more likely source of recharge to the ground water sampled during this study than surface water from the Rio Grande. Processes that appear to affect the composition of ground water in the study area include evaporation, cation exchange, feldspar weathering, calcite dissolution and precipitation, and dissolution of volcanic glass.

Nutrients and Dissolved Organic Carbon

Sources and Processes

A variety of sources contribute nutrients or DOC to ground water. Precipitation that infiltrates into the subsurface can be a substantial source of nitrate, nitrite, and ammonium ions. However, a greater portion of these ions in the subsurface are thought to be a result of microbial activity (Atlas and Bartha, 1987). Nitrogen fixation, the conversion of dinitrogen (N_2) (which makes up over three-quarters of the Earth's atmosphere) to ammonium ions, is conducted by certain bacteria living in soil. Ammonification, the conversion of organic nitrogen to ammonia or ammonium ions, also occurs through biological processes. Nitrification, the oxidation of ammonium ions to nitrite ions and then to nitrate ions, is a two-step process. The two separate steps are carried out by different microbial populations working in close tandem, such that an accumulation of nitrite typically does not occur. Under both aerobic (oxygen present) and anaerobic (oxygen not present) conditions, nitrate ions can be incorporated into organic matter by a variety of microorganisms, resulting in the release of dinitrogen or other oxidized nitrogen gases.

Phosphorus, like nitrogen, is cycled by microbial activity. However, microbial activity typically does not alter the oxidation state of phosphorus, but instead converts phosphorus from inorganic to organic phosphate, or from insoluble forms to more soluble forms. Relatively large quantities of phosphate are found in aquatic sediments, and smaller quantities are found in soils. Phosphate also is found in the rock apatite and in dust particles in the atmosphere, but is not found in large concentrations in precipitation because most naturally occurring phosphorous compounds are not very soluble.

The presence or absence of DOC in ground water largely is due to biological processes that have occurred over a period of time. If the rate of primary production (conversion of inorganic carbon to organic compounds) is greater than the rate of respiration (conversion of organic compounds back into inorganic carbon) in an ecosystem, organic matter may accumulate and be buried over geologic time to become part of the aquifer material. Some of this organic matter will subsequently be dissolved by ground water, resulting in DOC. The presence of organic matter (including DOC) provides the potential for respiration to occur if oxygen, nitrate, or another suitable electron acceptor is present and the appropriate microorganisms also are present. If all other requirements are fulfilled, respiration will continue as long as organic matter is present in a form simple enough to be used by the microorganisms.

Anthropogenic sources of nutrients or DOC in ground water include fertilizers, septic tanks, and feedlots. Fertilizers used on agricultural and urban lands commonly contain nitrate, ammonia or ammonium ions, and phosphorus. Nitrate is very soluble and is easily leached from soils to ground water. Ammonium also is quite soluble, but is not leached as quickly and easily as nitrate because it is strongly adsorbed on mineral surfaces (Hem, 1985). Phosphorus in fertilizer is converted rapidly to immobile forms, and rarely migrates a substantial distance from its location of application (O'Neill, 1985). Septic tank and animal feedlot effluents typically contain elevated concentrations of nitrogen, phosphorus, and organic carbon that may affect ground-water quality. Sewage effluent and soluble polyphosphates used in detergents are more likely than fertilizers to increase concentrations of dissolved phosphorus in natural waters (O'Neill, 1985).

The amount of dissolved oxygen in ground water controls the forms of nitrogen and phosphorus and the amount of DOC that may be present. Precipitation or surface water recharging the aquifer commonly is rich in dissolved oxygen. In such an oxidized environment, nitrogen and phosphorus occur in their more oxidized forms, nitrate and phosphate. However, the residence time of oxygen in ground water tends to be fairly short when oxidizable materials or respiring microorganisms are present. Microbial activity quickly depletes oxygen from ground water because the greatest energy yield can be acquired by microorganisms that use oxygen in respiration. Microbial activity will continue to deplete oxygen from the aquifer (assuming no additional input of oxygen) as long as any necessary nutrients and organic carbon are available in forms that can be used. Once all available oxygen has been consumed and if available nutrients and organic carbon are still present in the aquifer, microorganisms will reduce nitrate, sulfate, manganese, and iron, resulting in an increasingly reduced environment in the aquifer. As a result, larger concentrations of DOC in ground water typically are accompanied by smaller concentrations of dissolved oxygen and nitrate and larger concentrations of reduced species, such as dissolved iron and manganese.

Relation of Sources and Processes to Occurrence and Distribution

Figure 12 shows that the largest concentrations of DOC typically occur in the southern region of the study area, although the concentrations in water from wells 12 and 17 in the middle region also are relatively large. The relatively deep sampling intervals and the widespread occurrence of the larger DOC concentrations throughout the southern region and the northern part of the middle region indicate that these larger concentrations are not the result of site-specific activity, such as the infiltration of effluent from septic tanks or animal feedlots. They more likely result from a greater quantity of organic carbon within the aquifer materials. Why more organic carbon would have accumulated in the aquifer materials in these areas than in other areas is not known.

The larger concentrations of DOC generally are accompanied by dissolved-oxygen concentrations of 0.2 mg/L or less (fig. 12). Water from well 5, however, contains a greater concentration of dissolved oxygen than would be expected for its DOC concentration. The reason for this is not known. Water from well 8 also contains concentrations of dissolved oxygen and DOC larger than median concentrations for the study area. These concentrations could be caused by the relatively shallow depth of the screened interval relative to other wells. Some of the sampled water from well 8 likely is shallow ground water that receives both dissolved oxygen and DOC from recharge water. Respiration and the subsequent decrease in dissolved oxygen and DOC would not have proceeded to the extent that it would have in deeper ground water having a longer residence time.

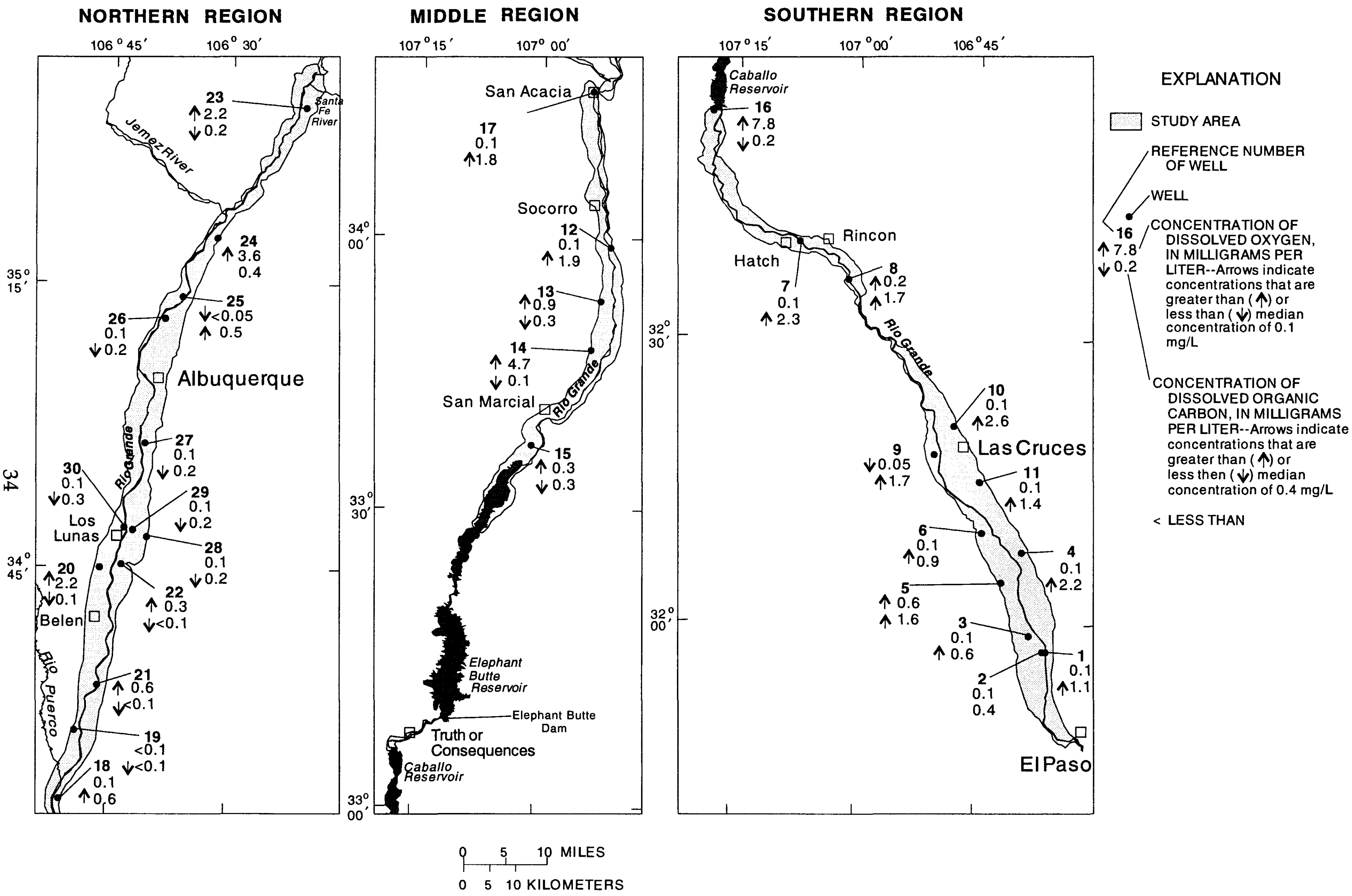


Figure 12.--Spatial distributions of concentrations of dissolved oxygen and dissolved organic carbon.

The spatial distributions of concentrations of nitrite plus nitrate (nearly equivalent to nitrate concentrations because nitrite concentrations are near or below the MRL in all wells) and ammonia are shown in figure 13. The percentage of nitrite plus nitrate concentrations above the median concentration is higher in the northern and middle regions of the study area than in the southern region, whereas more ammonia concentrations are above the median concentration in the southern region than in the other two regions. Larger nitrite plus nitrate concentrations generally are in water from wells that also contain concentrations of dissolved oxygen greater than the median concentration, but with little DOC. One exception is well 19, which yields water having a nitrite plus nitrate concentration that is relatively large but a dissolved-oxygen concentration only equal to the median concentration of 0.1 mg/L. The reason for the relative lack of dissolved oxygen given the relatively large nitrite plus nitrate concentration for this well is not evident. Well 8 is again an exception--containing water with both nitrite plus nitrate and DOC concentrations greater than the median concentrations--probably because of the well's relatively shallow sampling interval. Larger ammonia concentrations generally are in water from wells that contain dissolved-oxygen concentrations less than or equal to the median concentration but DOC concentrations greater than the median concentration. Water from six wells in the northern region and one well in the middle region contain concentrations of nitrite plus nitrate and ammonia less than their respective MRL's, possibly because nitrogen was never present in detectable quantities or was transformed along the ground-water flow path. Overall, the relatively small concentrations of both dissolved oxygen and nitrite plus nitrate in most of the wells indicate that most of the ground water sampled is reduced. Microbial activity probably is an important factor contributing to these reduced environments.

Concentrations of nitrite plus nitrate and ammonia in the study area probably are not associated with the use of septic tanks, feedlots, or fertilizers. The following observations support this conclusion: no VOC's or elevated phosphorus concentrations (normally associated with septic tank effluent) were detected; larger nitrite plus nitrate concentrations generally were not detected in combination with the larger DOC concentrations normally associated with septic tank or feedlot effluent; and pesticides associated directly with agriculture were not found.

Trace Elements

Sources and Processes

Trace elements generally are present only in small quantities in natural systems, each typically occurring in concentrations less than 1.0 mg/L in natural waters (Hem, 1985). Trace elements typically are most abundant in the lithosphere, and only relatively small concentrations are found in the atmosphere. Therefore, the major source of trace elements in ground water is the minerals in the aquifer materials through which the water flows. The dissolution of these minerals by ground water can depend on whether oxidizing or reducing conditions exist. For example, iron and manganese are more soluble in a reducing environment, whereas arsenic, molybdenum, and uranium typically are more soluble in an oxidizing environment (Robertson, 1991). In specific areas where substantial quantities of trace elements do not exist in the aquifer, they may be introduced by the mixing of waters infiltrated from the land surface with water from geothermal sources, which can contain dissolved trace elements.

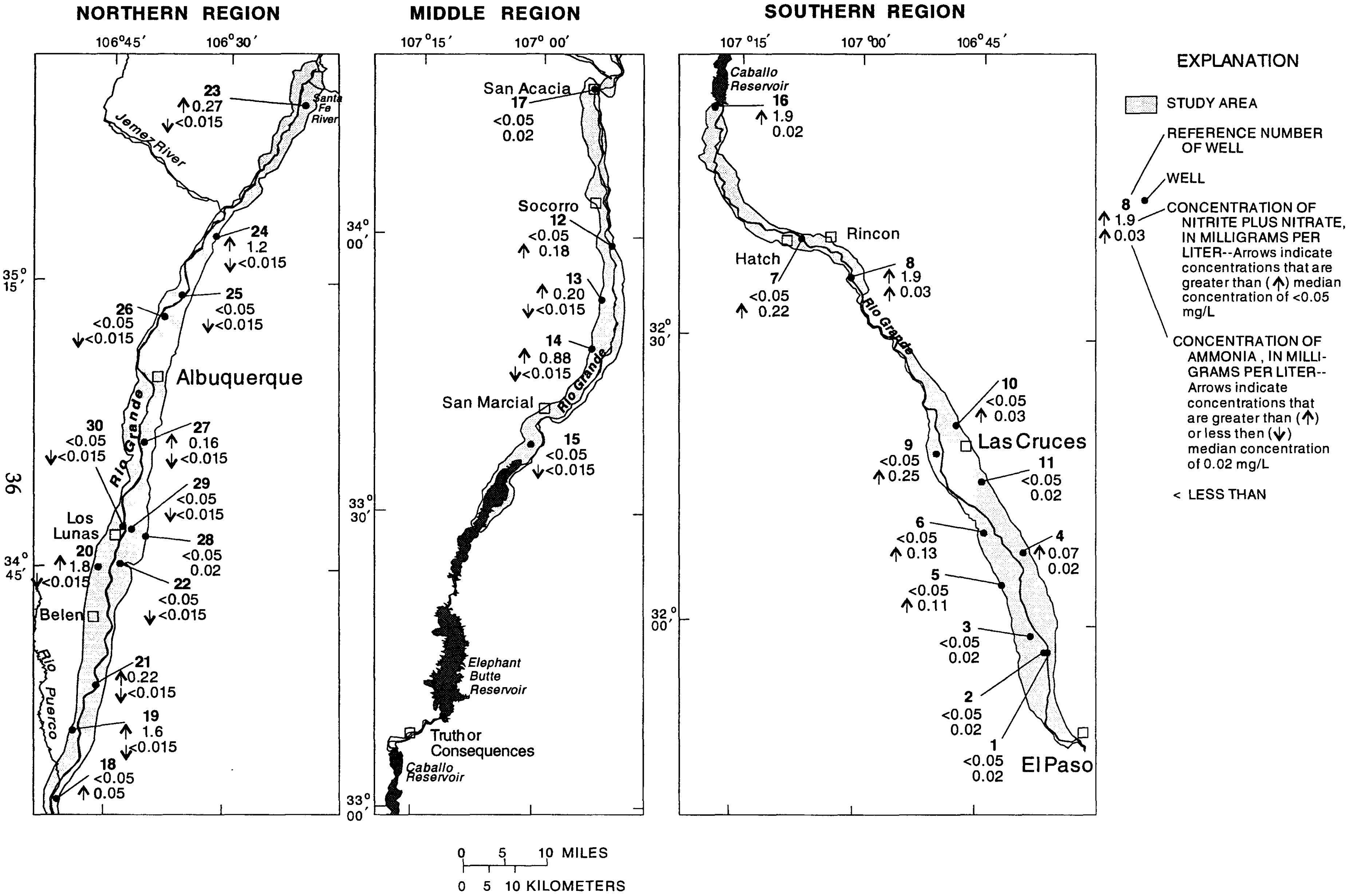


Figure 13.--Spatial distributions of concentrations of nitrite plus nitrate and ammonia.

Iron and manganese concentrations in ground water can be affected greatly by biological activity that occurs under reducing conditions. Many microorganisms are capable of using iron or manganese (where present in minerals in the aquifer) as a terminal electron acceptor for respiration in the absence of oxygen, provided that all other requirements, such as the presence of sufficient DOC, are satisfied. This results in the reduction of large quantities of iron and manganese to their more soluble forms, which subsequently occur as dissolved species in ground water (Atlas and Bartha, 1987).

Trace elements also can be introduced to ground water through contamination caused by human activities. All of the eight trace elements included in this study having median concentrations greater than their respective MRL's (aluminum, arsenic, barium, manganese, molybdenum, nickel, uranium, and zinc) plus iron are processed for various purposes. For example, arsenic and nickel are added to various kinds of batteries. Barium is used in the medical and electrical industries. Aluminum, iron, manganese, molybdenum, and zinc are used in various metal alloys. Zinc also is a common ingredient in fertilizers, paints, and dyes (O'Neill, 1985). Uranium is used in explosives and as fuel in nuclear power generation and is associated with petroleum activities. Although no trace elements or petroleum products are known to be mined in the study area, the potential for contamination of ground water exists because products containing them are manufactured, used, or disposed of in the study area.

The metal well casings used to complete seven of the wells sampled create the potential for concentrations of iron or manganese in samples from these wells to be larger than actual concentrations of these trace elements in ground water because of contact with the well casings. However, in four of these wells (1, 2, 14, and 16) the concentrations of iron and (or) manganese were near or below the MRL's of 3 μg/L for iron and 1 μg/L for manganese (see fig. 18), indicating that the addition of trace elements to ground water from the well casing probably is not significant. Therefore, the concentrations of iron and manganese in samples from these wells and wells 7, 15, and 18 probably represent the true concentrations in ground water.

Relation of Sources and Processes to Occurrence and Distribution

Spatial distributions of arsenic and barium concentrations are shown in figure 14. Concentrations of arsenic greater than the median concentration are more prevalent in the northern and middle regions of the study area than in the southern region. Although few data are available, this spatial pattern could be a result of sediments in this part of the basin-fill aquifer that are related to the Jemez volcanic complex and that are relatively rich in arsenic. Barium concentrations do not exhibit any clear spatial pattern. Because water from most wells in the study area is near or above saturation with respect to barite (table 10), barium concentrations likely are controlled by the dissolution and precipitation of this mineral.

Figure 15 shows that water from 12 of the 13 wells in the northern region of the study area have relatively small iron and manganese concentrations. The larger concentrations of iron and manganese typically are found in the middle and southern regions of the study area. The reason for this spatial distribution is not evident, although it may be a combination of factors, including differences in the availability of iron and manganese in the minerals in the aquifer, as well as the availability of the DOC necessary to allow microbial reduction of these two elements. As expected, the large concentrations of iron and manganese generally were detected in water from wells that contain relatively large concentrations of DOC (generally greater than about 1.4 mg/L; fig. 16A) and relatively small concentrations of dissolved oxygen (generally less than about 0.4 mg/L; fig. 16B). Therefore, the large concentrations of iron and manganese are consistent with reduced conditions, likely influenced by microbial activity. Water from well 5 contains an inexplicably larger concentration of dissolved oxygen than would be expected given the relatively large concentration of manganese.

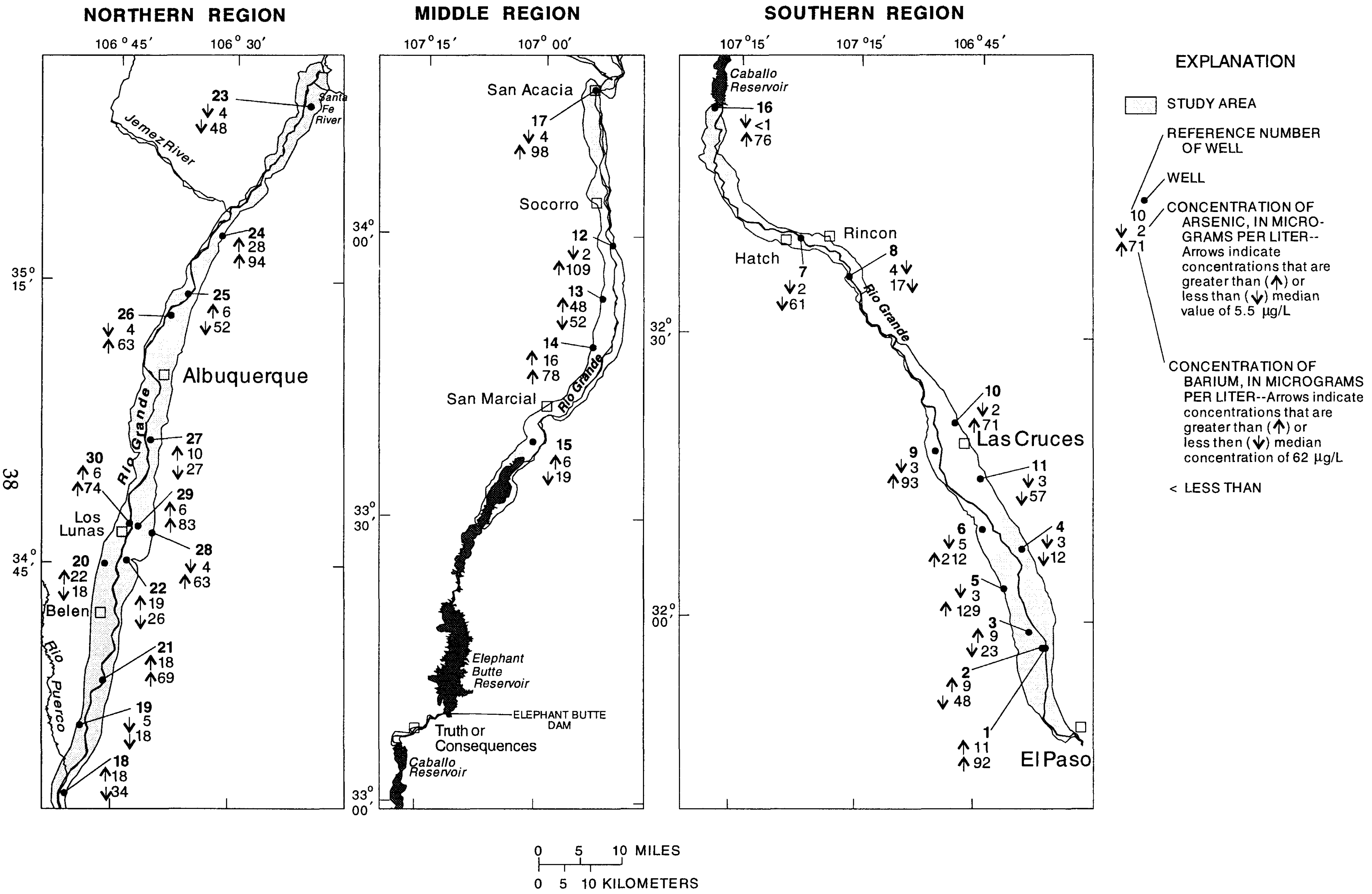


Figure 14.--Spatial distributions of concentrations of arsenic and barium.

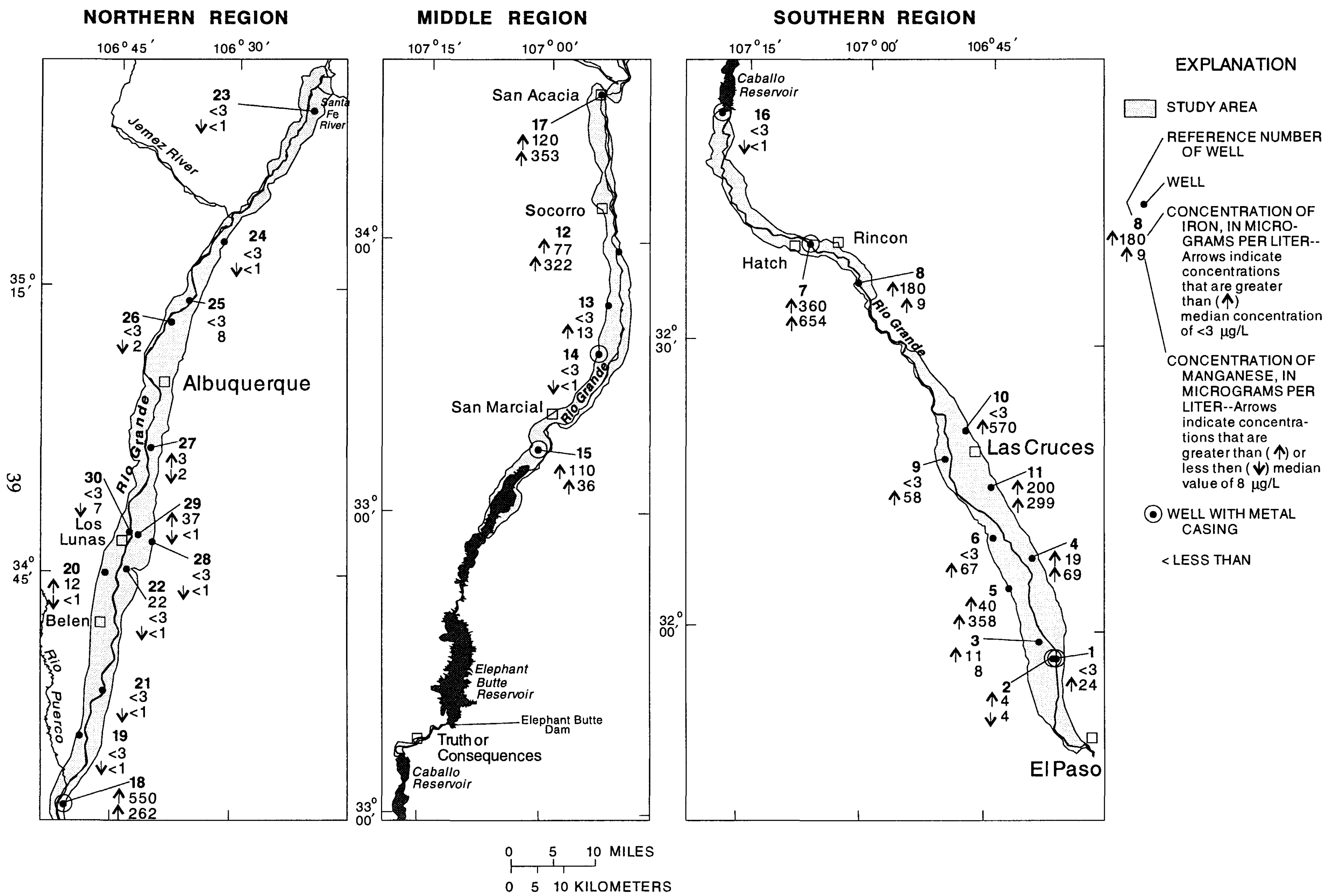


Figure 15.--Spatial distributions of concentrations of iron and manganese.

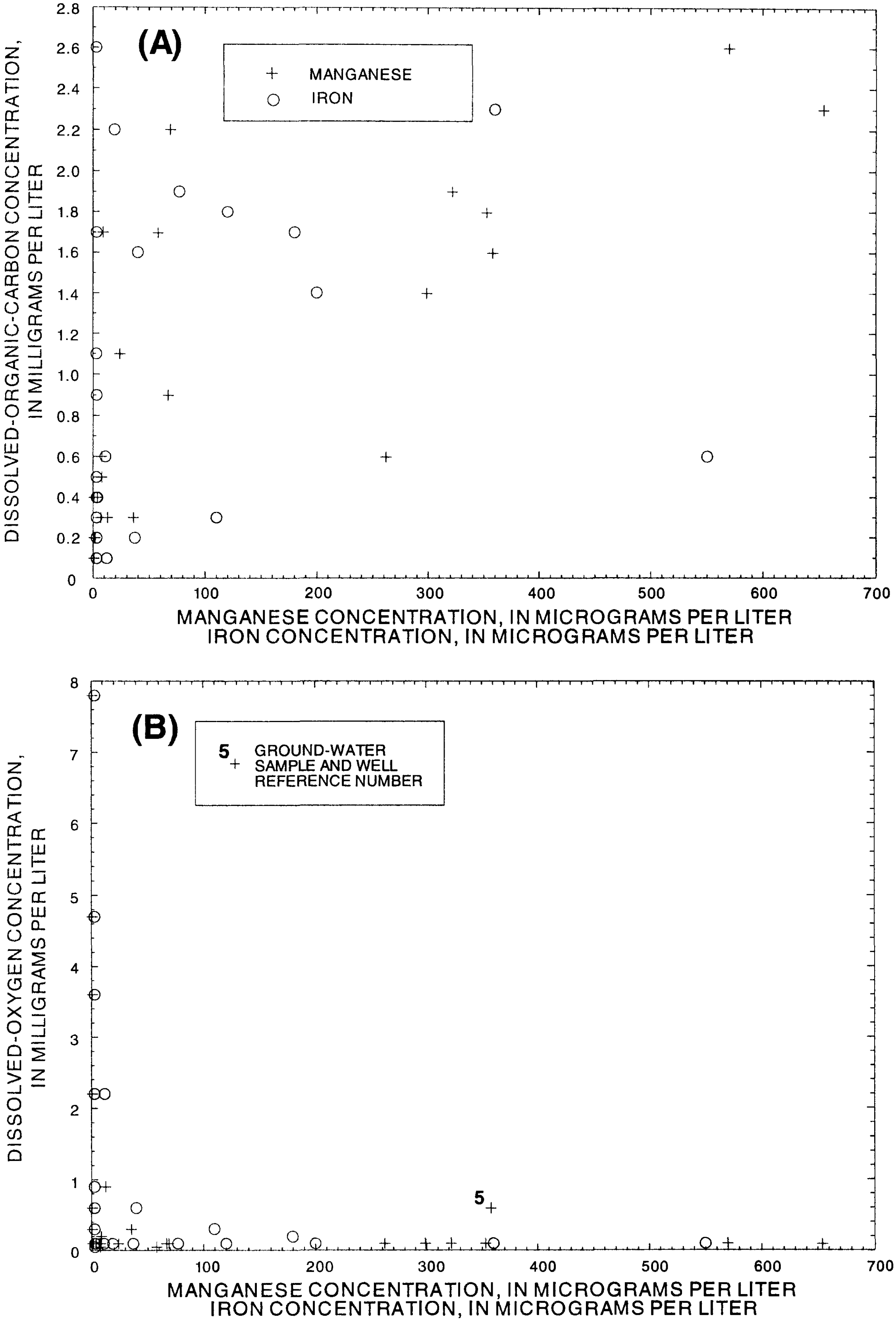


Figure 16. -- Relation of concentrations of (A) dissolved organic carbon and (B) dissolved oxygen to manganese and iron concentrations.

Concentrations of aluminum, molybdenum, nickel, uranium, and zinc showed no clear spatial patterns or relations to dissolved-oxygen concentrations. Also, concentrations of these constituents generally were not large. The concentration of uranium in well 10 is anomalously high, but cannot be explained with the current data. There is no evidence for the wells sampled that the concentrations of any of the trace elements are the result of human activities. Rather, they are the likely result of naturally occurring minerals in the aquifer.

Radiochemicals

Sources and Processes

Radionuclides in ground water can be derived from natural sources, such as the weathering of rocks and the interaction of cosmic rays with atmospheric particles, or from human activities, such as the testing of nuclear weapons and the industrial/medical use of radionuclides. The main alpha-emitting substances in ground water are the decay products of uranium and thorium, which generally occur naturally. The main beta-emitting substances in ground water are potassium-40, which occurs naturally, and cesium-137 and strontium-90, which are related to human activities. Radon-222 concentrations in ground water result primarily from the radioactive decay of radium-226 in aquifer materials or ground water; radium-226 is part of the radioactive decay series of uranium-238. Therefore, the amount of radon-222 in ground water is related to the amount of uranium and radium-226 present in aquifer materials and ground water (Thomas and others, 1993). Radon-222 is a gas at the temperature and pressure of ground water at the depths sampled for this study.

Relation of Sources and Processes to Occurrence and Distribution

Gross alpha particle activities as natural uranium and gross beta particle activities as strontium-90/yttrium-90 occur in no particular spatial pattern across the study area (fig. 17). Most of the ground-water samples plot very close to a line representing the expected gross alpha particle activity based on the concentration of uranium (fig. 18), assuming an activity ratio of uranium-234 to uranium-238 of 1.0 (Thomas and others, 1993). This indicates that most measured gross alpha particle activities probably can be accounted for by the quantities of uranium present in the samples. This relation is expected because uranium generally is the largest alpha-emitting radionuclide. In water from wells 8, 10, 17, 18, and 22, the gross alpha particle activity deviates from the expected value by more than about 3 µg/L as natural uranium. These deviations may be due to counting errors in the analysis, which are presented in table 1 as the two-sigma precision estimate for each analysis. The two-sigma precision estimate indicates the range on either side of the reported value within which the actual value is 95 percent likely to occur.

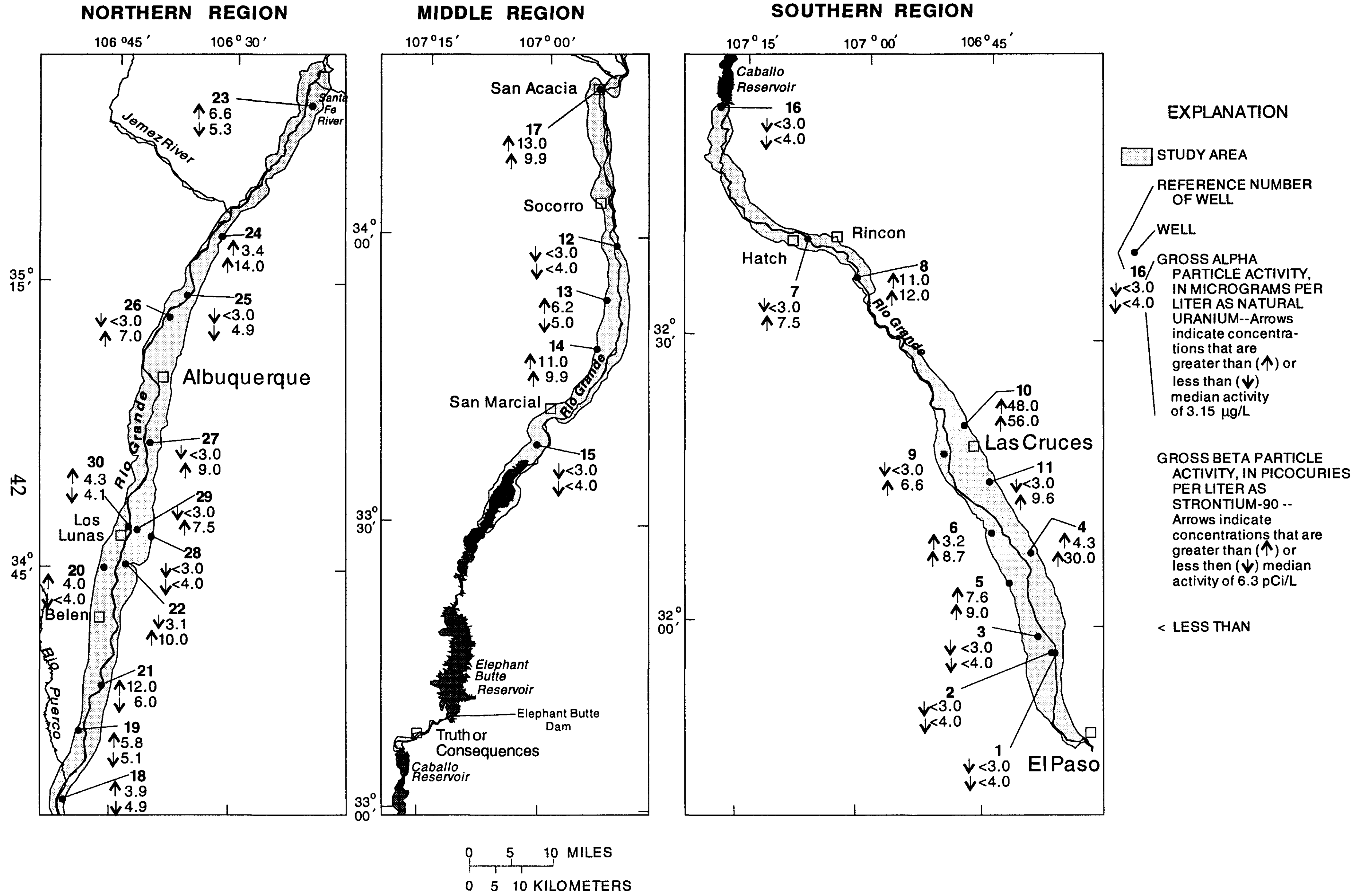


Figure 17.--Spatial distributions of gross alpha particle activities as natural uranium and gross beta particle activities as strontium-90/yttrium-90.

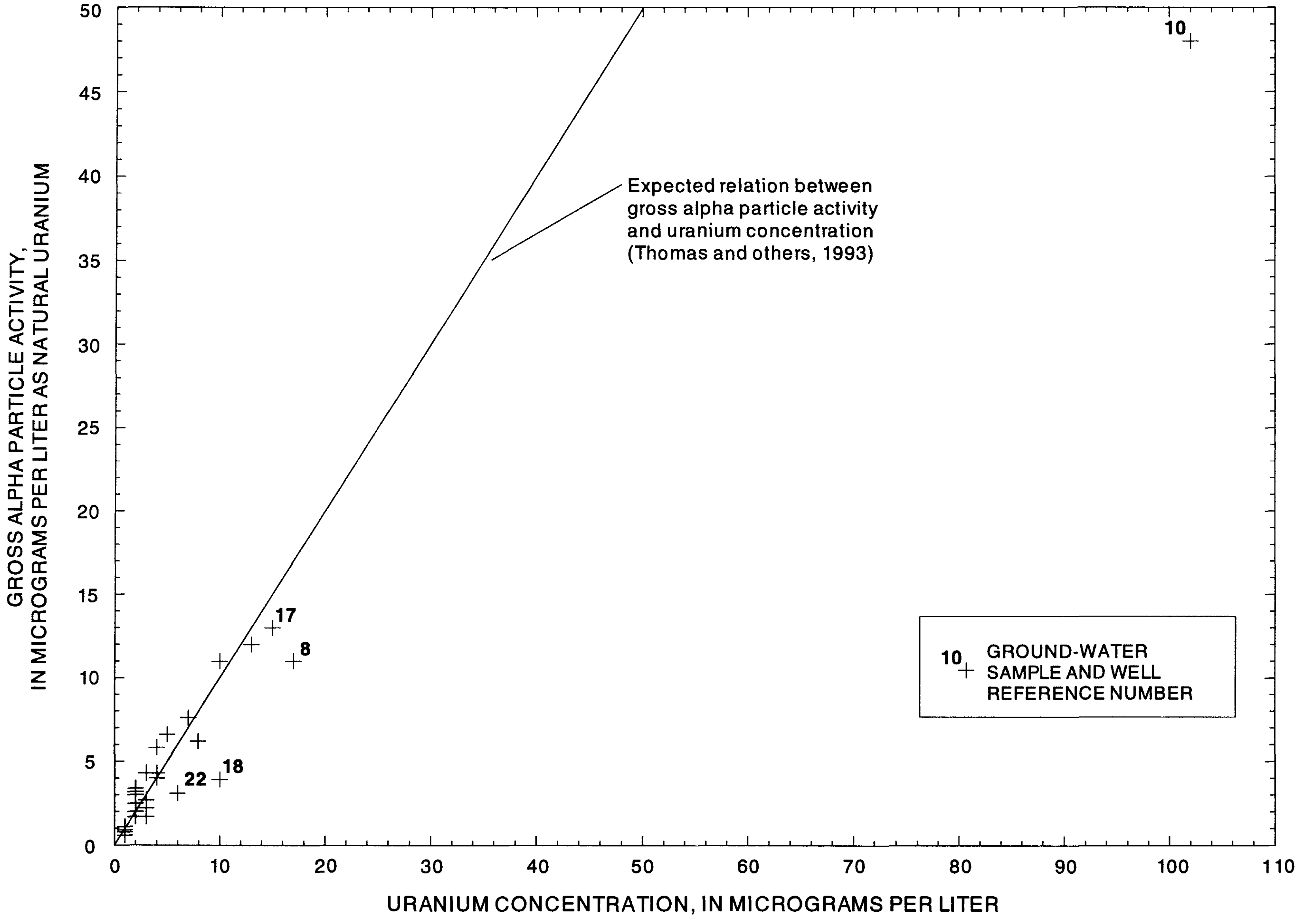


Figure 18. -- Relation of gross alpha particle activity as natural uranium to uranium concentration.

The adjusted gross beta particle activity as strontium-90/yttrium-90 for each water sample, as shown in figure 19, was determined by subtracting the quantity of beta particle activity calculated to result from the concentration of potassium-40 in the sample from the total dissolved gross beta particle activity. The beta activity as strontium-90/yttrium-90, in picocuries per liter, contributed by potassium-40 was estimated by multiplying the potassium concentration, in milligrams per liter, by 0.818 (Thomas and others, 1993). By considering counting errors, which have a median of about 3 pCi/L (fig. 19), most of the adjusted gross beta particle activities as strontium-90/yttrium-90 shown in figure 19 are near zero. Most of the gross beta particle activities measured probably result from the quantities of potassium-40 in the water samples. However, 11 samples (from wells 4, 5, 6, 8, 9, 10, 14, 17, 22, 26, and 27) have adjusted gross beta particle activities greater than 3 pCi/L. Thomas and others (1993) indicated that uranium-238 progeny grow continuously in samples between the time of collection and time of analysis and can result in significant beta activity that is distinct from the beta activity of water in the aquifer. Eight of the samples shown in figure 19 with adjusted gross beta particle activities as strontium-90/yttrium-90 greater than 3 pCi/L have concentrations of uranium equal to or greater than the median concentration of 3 μg/L. This may account for their additional gross beta activities not due to potassium-40 concentrations.

Compared with samples from the northern and middle regions of the study area, more samples from the southern region have radon-222 concentrations greater than the median value (fig. 20). The reason for this spatial pattern is not known, especially given that the gross alpha particle activities as natural uranium do not exhibit any such pattern. The larger radon values generally are not associated with larger concentrations of dissolved uranium. However, large radon-222 concentrations could indicate areas where large uranium concentrations occur in the aquifer materials but where conditions are not favorable for uranium to exist in solution. There is no evidence to indicate that any of the gross beta or gross alpha particle activities or radon concentrations detected in this study are the result of land use rather than natural conditions in the aquifer.

Pesticides and Volatile Organic Compounds

Sources and Processes

When pesticides or VOC's are present in ground water, they indicate that human activities have adversely affected the water quality of the aquifer. The potential for either pesticides or VOC's to reach ground water can result from several activities, including manufacture, storage, or transportation of a compound; use of a compound for its intended purpose; or disposal of a compound. Glue used in the construction of the polyvinyl chloride well casings in 23 of the wells sampled creates the potential for ground water from these wells to acquire VOC's as a result of contact with the well casings; no VOC's, however, were detected in any of the ground-water samples.

Relation of Sources and Processes to Occurrence and Distribution

The data indicate no major contamination by pesticides or VOC's in the wells sampled for this study. The herbicide prometon was the only synthetic compound that was detected in any ground-water samples. Because prometon is a nonselective herbicide with a long persistence, it probably is not commonly used on agricultural fields (Meister, 1994). Well 8, the only well that produced water containing prometon at a concentration above the MDL, has a screened interval starting at only 10 feet below land surface (the shallowest of any well sampled). The concentration of prometon in well 8 (0.038 μg/L) is much less than the lifetime health advisory of 100 μg/L established by the EPA, demonstrating the small magnitude of this concentration.

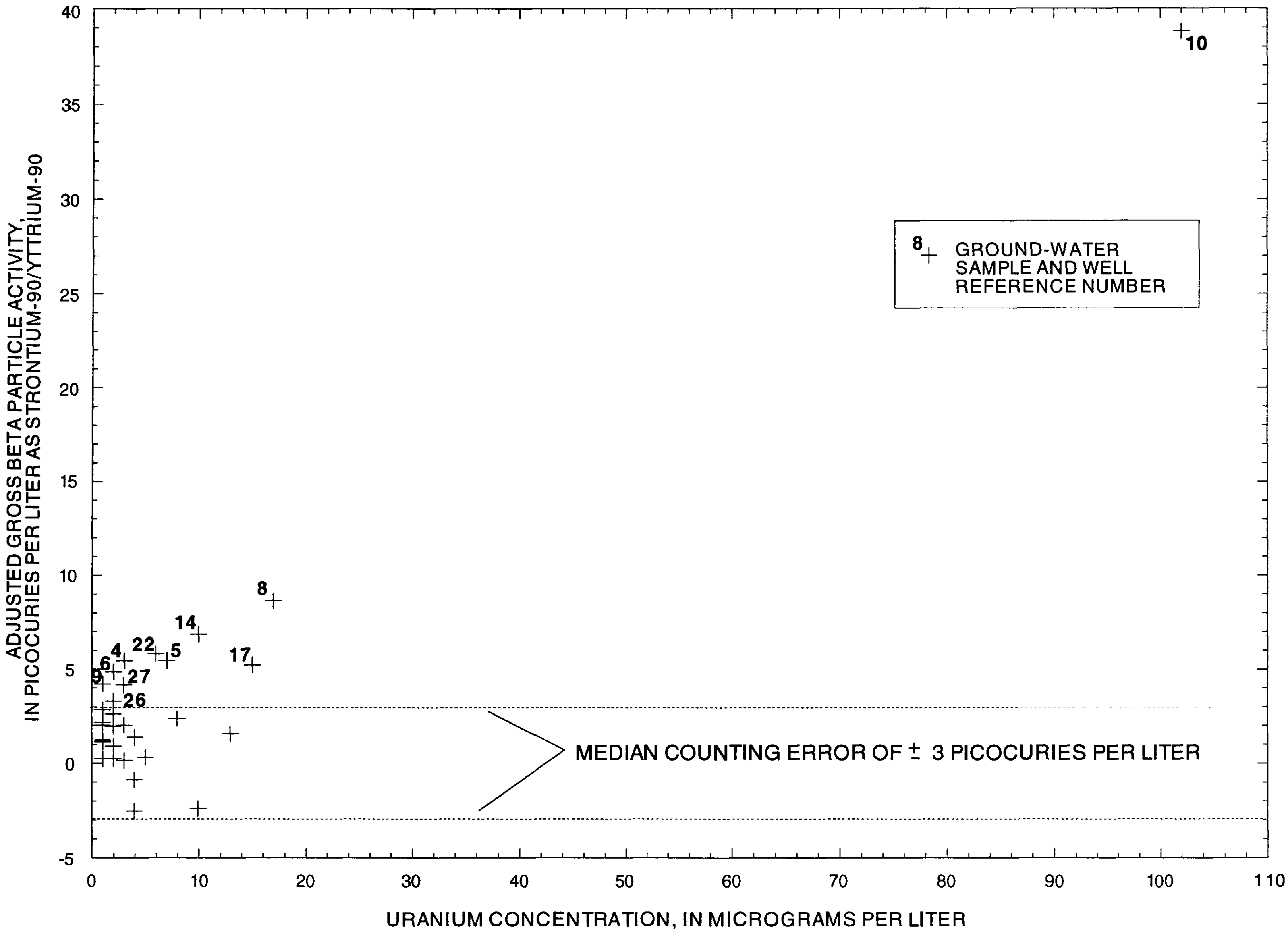


Figure 19. -- Relation of adjusted gross beta particle activity as strontium-90/yttrium-90 to uranium concentration.

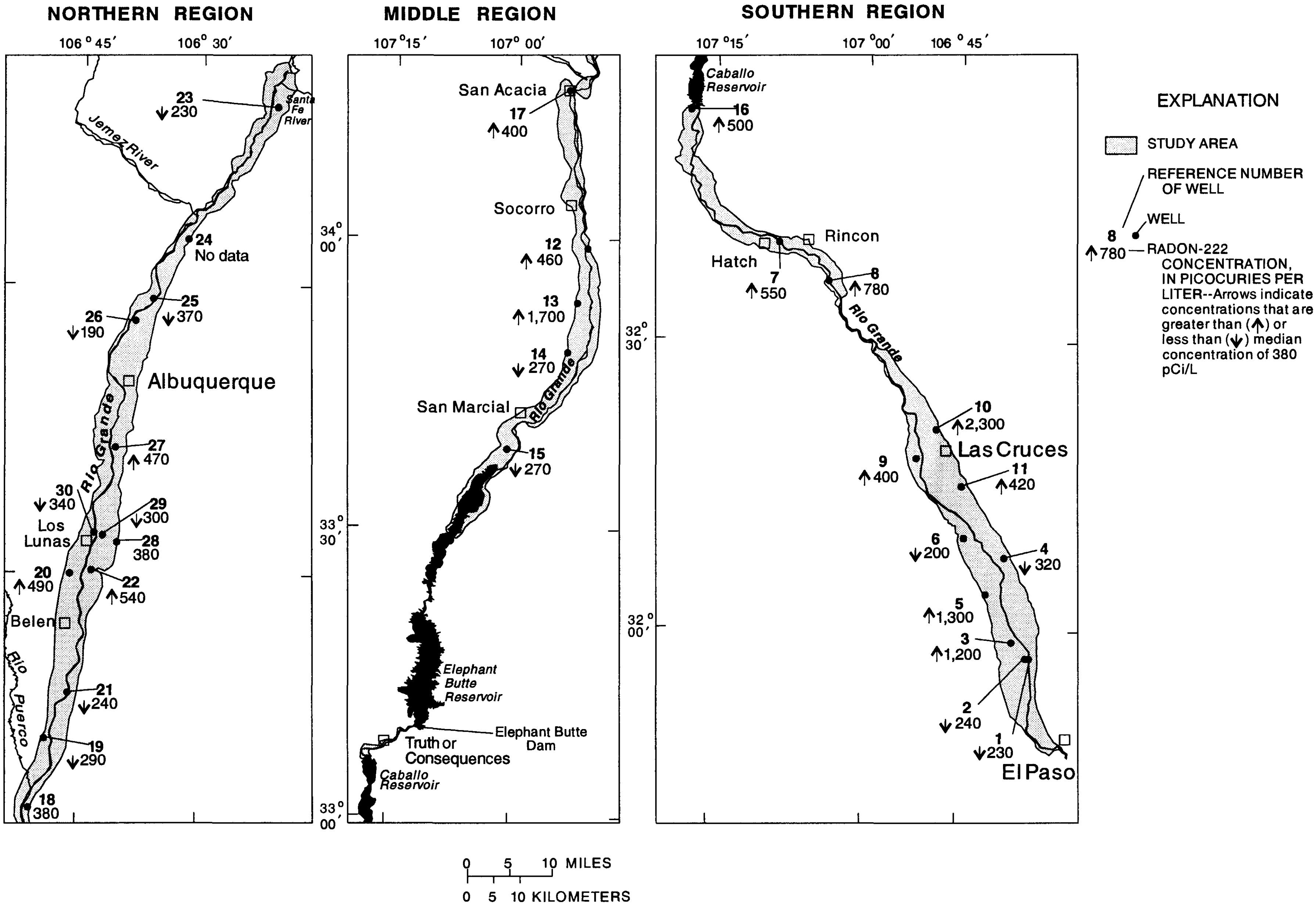


Figure 20.--Spatial distribution of radon concentrations.

That a synthetic organic compound was detected in only one ground-water sample indicates that most of the water sampled for this study probably is not recent recharge from the flood plain. If the source of the ground water were the infiltration of irrigation water or effluent produced by other human activities, synthetic organic compounds associated with these activities likely would have been more widespread in the samples. Also, if the source were the recent infiltration of precipitation or surface water through the flood plain occurring since human development began in the area, synthetic organic compounds likely would have been found in more than one sample. The general absence of such compounds indicates that most of the water sampled probably recharged at the margins of the alluvial basins or recharged through the flood plain before human development began.

SUMMARY

From March to May of 1995, water samples were collected from 30 wells located in the flood plain of the Rio Grande between Cochiti Lake, New Mexico, and El Paso, Texas. These samples were analyzed for a broad range of constituents, including field parameters, major constituents, nutrients, DOC, trace elements, radiochemicals, pesticides, and volatile organic compounds. The main purpose of the study was to assess the quality of the ground water in this part of the Rio Grande Valley study unit of the U.S. Geological Survey NAWQA program. The sampling effort was limited to the basin-fill aquifer beneath the above-defined reach of the Rio Grande flood plain because of the relative homogeneity of the hydrogeology, the large amount of ground-water use for public supply, and the potential for land-use activities to affect the quality of ground water. Most of the wells sampled for the study are used for domestic purposes, including drinking water. Depths to the tops of the sampling intervals in the 30 wells ranged from 10 to 345 feet below land surface, and the median was 161.5 feet; the sampling intervals in most of the wells spanned about 10 feet or less.

A significant amount of variation was found in the chemical composition of ground water sampled throughout the study area, but the water generally was found to be of suitable chemical quality for use as drinking water, according to standards established by the EPA. Dissolved-solids concentrations ranged from 209 to 3,380 mg/L, and the median was 409.5 mg/L. The larger concentrations of dissolved solids typically were found in the southern region of the study area.

Graphical comparison of the ratios of certain major constituents in the ground water sampled with the ratios of the same ions detected in surface water from the Rio Grande and bulk precipitation indicated that precipitation was the more likely source of recharge to the ground water sampled during this study. Processes that appear to affect the composition of ground water in the study area include cation exchange, feldspar weathering, calcite dissolution and precipitation, and dissolution of volcanic glass.

Nutrients in ground water across the study area generally were measured at concentrations near or below their MRL's. The most dominant nutrient species was nitrite plus nitrate. The maximum nitrite plus nitrate concentration of 1.9 mg/L is well below the MCL of 10 mg/L established by the EPA. Dissolved-oxygen concentrations ranged from less than 0.05 to 7.8 mg/L, and the median was 0.1 mg/L. The median concentration of DOC was 0.4 mg/L; the largest concentrations were in the southern region of the study area. Ground water in most of the wells sampled appeared to be reduced, as indicated by small concentrations of both dissolved oxygen and nitrite plus nitrate. Microbial activity probably is an important factor contributing to these reduced environments. However, ground-water samples from several wells, especially those with relatively small concentrations of DOC, did contain measurable concentrations of both dissolved oxygen and nitrite plus nitrate. None of the nutrient or DOC data indicated contamination of ground water due to effluent from septic tanks, feedlots, or agricultural activities.

Concentrations of several trace elements generally were close to or at their respective MRL's in water from most wells and did not exceed any EPA standards. However, eight trace elements had median concentrations greater than their MRL's. Arsenic concentrations generally were found to be largest in the northern and middle regions of the study area, possibly due to sediments in this part of the basin-fill aquifer related to the Jemez volcanic complex. Barium concentrations in ground water throughout the study area were shown to probably be controlled by the dissolution and precipitation of barite. Dissolved iron and manganese were detected in samples from several wells, especially in the middle and southern regions of the study area, again indicating reduced conditions and the influence of microbial activity. Water from 2 wells exceeded the SMCL established by the EPA for iron, and water from 10 wells exceeded the SMCL for manganese. Although large molybdenum and uranium concentrations were not common across the study area, water from one well exceeded the lifetime health advisory established by the EPA for molybdenum, and water from a different well exceeded the proposed MCL for uranium.

Gross alpha and gross beta particle activities generally appeared to be strongly correlated with the quantities of uranium and potassium, respectively, detected in ground water. Water from one well, however, exceeded the MCL established by the EPA for gross alpha particle activity and may exceed the MCL for beta particle and photon activity, although current data on gross beta particle activities are not conclusive. None of the data indicated elevated values of gross alpha or gross beta due to human activities. Radon concentrations did not appear to be directly correlated with dissolved-uranium concentrations.

Chemical analyses provided no evidence of major contamination of ground water in the study area by the pesticides or VOC's analyzed for in the samples. The only synthetic compound detected in ground water was the herbicide prometon, which was measured at a concentration of 0.038 µg/L. The one well in which prometon was detected has well screens near the land surface and is not used for drinking water. That a synthetic organic compound was detected in only one ground-water sample indicates that most of the water sampled for this study probably was not substantially affected by human activities. Therefore, most of the water sampled probably recharged at the margins of the alluvial basins or recharged through the flood plain before human development began.

REFERENCES

Anderholm, S.K., 1985, Clay-size fraction and powdered whole-rock X-ray analyses of alluvial-basin deposits in central and southern New Mexico: U.S. Geological Survey Open-File Report 85-173, 18 p.

______1987, Hydrogeology of the Socorro and La Jencia basins, Socorro County, New Mexico: U.S. Geological Survey Water-Resources Investigations Report 84-4342, 62 p.

______1988, Ground-water geochemistry of the Albuquerque-Belen Basin, central New Mexico: U.S. Geological Survey Water-Resources Investigations Report 86-4094, 110 p.

______1992, Water quality and geochemistry of the Mesilla Basin, *in* Frenzel, P.F., and Kaehler, C.A., Geohydrology and simulation of ground-water flow in the Mesilla Basin, Doña Ana County, New Mexico, and El Paso County, Texas: U.S. Geological Survey Professional Paper 1407-C, 105 p.

Anderholm, S.K., Radell, M.J., and Richey, S.F., 1995, Water-quality assessment of the Rio Grande Valley study unit, Colorado, New Mexico, and Texas--Analysis of selected nutrient, suspended-sediment, and pesticide data: U.S. Geological Survey Water-Resources Investigations Report 94-4061, 203 p.

Atlas, R.M., and Bartha, Richard, 1987, Microbial ecology--Fundamentals and applications, 2d ed.: Menlo Park, Calif., The Benjamin/Cummings Publishing Company, Inc., 533 p.

Borland, J.P., and Ong, Kim, 1995, Water resources data, New Mexico, water year 1994: U.S. Geological Survey Water-Data Report NM-94-1, 581 p.

Dane, C.H., and Bachman, G.O., 1965, Geologic map of New Mexico: U.S. Geological Survey, two sheets, scale 1:500,000.

Ellis, S.R., Levings, G.W., Carter, L.F., Richey, S.F., and Radell, M.J., 1993, Rio Grande Valley, Colorado, New Mexico, and Texas: American Water Resources Association, Water Resources Bulletin, v. 29, no. 4, August 1993, p. 617-646.

Farnsworth, R.K., Thompson, E.S., and Peck, E.L., 1982, Evaporation atlas for the contiguous 48 United States: National Oceanic and Atmospheric Administration and National Weather Service, NOAA Technical Report NWS33, June 1982, map 3.

Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey, scale 1:7,000,000.

Friedman, L.C., and Erdmann, D.E., 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.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment program--Occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Hawley, J.W., and Haase, C.S., 1992, Hydrogeologic framework of the northern Albuquerque Basin: Socorro, New Mexico Bureau of Mines and Mineral Resources Open-File Report 387, variously paged.

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

REFERENCES--Continued

Kernodle, J.M., McAda, D.P., and Thorn, C.R., 1995, Simulation of ground-water flow in the Albuquerque Basin, central New Mexico, 1901-1994, with projections to 2020: U.S. Geological Survey Water-Resources Investigations Report 94-4251, 114 p.

Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment program--Collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95-399, 113 p.

Meister, R.T., ed., 1994, Farm chemicals handbook '94: Willoughby, Ohio, Meister Publishing Co., variously paged.

National Oceanic and Atmospheric Administration [1994], Climatological data, New Mexico: National Oceanic and Atmospheric Administration, v. 98, nos. 1-12, for January-December 1994.

O'Neill, Peter, 1985, Environmental chemistry: London, Unwin Hyman Ltd., 232 p.

Parkhurst, D.L., Thorstenson, D.C., and Plummer, L.N., 1980, PHREEQE--A computer program for geochemical calculations: U.S. Geological Survey Water-Resources Investigations 80-96, 216 p.

Popp, C.J., Ohline, R.W., Brandvold, D.K., and Brandvold, L.A., 1984, Nature of precipitation and atmospheric particulates in central and northern New Mexico, *in* Hicks, B.B., ed., Deposition both wet and dry--Acid Precipitation Series: Boston, Butterworth Publishers, v. 4, p. 79-95.

Pritt, J.W., and Raese, J.W., 1992, Quality assurance/quality control manual, National Water Quality Laboratory: U.S. Geological Survey Open-File Report 92-495, 33 p.

Rankama, Kalervo, and Sahama, T.G., 1950, Geochemistry: Chicago, The University of Chicago Press, 912 p.

Richey, S.F., and Ellis, S.R., 1993, National Water-Quality Assessment program--Water use in the Rio Grande Valley, 1990: U.S. Geological Survey Open-File Report 93-456, 2 p.

Robertson, F.N., 1991, Geochemistry of ground water in alluvial basins of Arizona and adjacent parts of Nevada, New Mexico, and California: U.S. Geological Survey Professional Paper 1406-C, 90 p.

Scott, J.C., 1990, Computerized stratified random site-selection approaches for design of ground-water-quality sampling network: U.S. Geological Survey Water-Resources Investigations Report 90-4101, 109 p.

Thomas, J.M., Welch, A.H., Lico, M.S., Hughes, J.L., and Whitney, Rita, 1993, Radionuclides in ground water of the Carson River Basin, western Nevada and eastern California, U.S.A.: Applied Geochemistry, v. 8, p. 447-471.

Timme, P.J., 1995, National Water Quality Laboratory 1995 services catalog: U.S. Geological Survey Open-File Report 95-352.

Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey, scale 1:500,000.

U.S. Congress, 1996, Safe Drinking Water Act Amendments of 1996: U.S. Congress, 104th, Public Law No. 104-182, section 109b.

REFERENCES--Concluded

U.S. Department of Commerce, 1993, 1990 census of population and housing--Detailed housing characteristics, New Mexico: U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census publication 1990 CH-2-33, variously paged.

U.S. Environmental Protection Agency, 1991, USEPA Contract Laboratory Program -- National functional guidelines for organic data review: Washington, D.C., U.S. Environmental Protection Agency Report EPA/540/R-94/090, variously paged.

_____1996, Drinking water regulations and health advisories: Washington, D.C., U.S. Environmental Protection Agency, Office of Water, 11 p.

Werner, S.L., Burkhardt, M.R., and DeRusseau, S.N., 1996, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory--Determination of pesticides in water by Carbopak-B solid-phase extraction and high-performance liquid chromatography: U.S. Geological Survey Open-File Report 96-216, 42 p.

White, A.F., Claassen, H.C., and Benson, L.V., 1980, The effect of dissolution of volcanic glass on the water chemistry in a tuffaceous aquifer, Rainier Mesa, Nevada: U.S. Geological Survey Water-Supply Paper 1535-Q, 34 p.

White, D.E., 1960, Summary of chemical characteristics of some waters of deep origin, *in* Geological Survey Research 1960--Short papers in the geological sciences: U.S. Geological Survey Professional Paper 400-B, p. B452-B453.

Zaugg, S.D., Sandstrom, M.W., Smith, S.G., and Fehlberg, K.M., 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory--Determination of pesticides in water by C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry with selected-ion monitoring: U.S. Geological Survey Open-File Report 95-181, 49 p.

Table 1.--Selected water-quality data for wells sampled in the subunit survey

[--, no data; <, less than; gal/min, gallons per minute; µS/cm, microsiemens per centimeter at 25 degrees Celsius (deg C); mm of Hg, millimeters of mercury; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; bicarbonate water dis it field, bicarbonate in filtered sample as determined in the field by incremental titration; carbonate water dis it field, carbonate in filtered sample as determined in the field by incremental titration; alkalinity wat dis tot it field, alkalinity in filtered sample as determined in the field by incremental titration; alkalinity wat wh gran t, field $CaCO_3$, alkalinity in unfiltered sample as determined in the field by gran titration; NO_2, nitrite; NO_3, nitrate; dis, dissolved; +, plus; µg/L, micrograms per liter; gross alpha, dissolved (µg/L as U-nat), dissolved gross alpha particle activity reported in micrograms per liter of equivalent natural uranium; alpha count, 2 sigma wat, dis as nat U, 2 sigma precision estimate of indicated analysis; 2 sigma precision estimate, range on either side of reported value within which the actual value is 95 percent likely to occur; gross alpha water, dis as Th-230, dissolved gross alpha particle activity reported in picocuries per liter as equivalent thorium-230; alpha count, 2 sigma wat, dis as Th-230, 2 sigma precision estimate of indicated analysis; pCi/L, picocuries per liter; gross beta, dissolved (pCi/L as Sr-90/Y-90), dissolved gross beta particle activity reported in picocuries per liter as equivalent strontium-90/yttrium-90; beta, 2 sigma water, dis as Sr-90/Y-90, 2 sigma precision estimate of indicated analysis; gross beta, dissolved (pCi/L as Cs-137), dissolved gross beta particle activity reported as equivalent cesium-137; beta, 2 sigma water, dis as Cs-137, 2 sigma precision estimate of indicated analysis; Rn-222 2 sigma water, whole, total, 2 sigma precision estimate of indicated analysis; prometon, water, dis, rec, quantity of prometon recovered from sample filtered through 0.7-micron-pore-size filter; srg wat flt 0.7 u gf, rec (percent), percentage of specific pesticide group A surrogate recovered; surrog S2090 unfltrd rec (percent), percentage of specific VOC surrogate recovered; surrog, water, unfltrd rec (percent), percentage of specific pesticide group B surrogate recovered]

Well reference number (fig. 6)	Well number	Station number	Date	Elevation of land-surface datum (feet above sea level)	Depth of well, total (feet)	Depth to top of sample interval (feet)	Depth to bottom of sample interval (feet)	Water level (feet below land surface)	Flow rate, instantaneous (gal/min)
1	JL-49-04-476	315712106361803	03-22-95	3,774	300	293	298	44.50	3.6
2	JL-49-04-468	315712106364303	03-23-95	3,771	299	292	297	43.75	3.7
3	27S.03E.04.344	315852106382401	03-19-95	3,788	320	300	320	--	6.7
4	25S.03E.17.433	320738106392401	03-14-95	3,823	60	50	60	--	9.4
5	26S.02E.02.223	320445106421001	03-21-95	3,820	147	107	147	21.40	30
6	25S.02E.04.421	320939106441701	03-15-95	3,844	232	223	232	12.60	6.5
7	19S.03W.11.323	324007107072101	04-18-95	4,050	65	54	64	2.55	7.1
8	20S.02W.02.114	323611107011501	03-20-95	4,007	50	10	50	--	6.0
9	23S.01E.21.224	321753106501601	03-15-95	3,890	295	275	295	11.62	6.0
10	22S.01E.36.314	322054106475201	03-16-95	3,910	191	181	191	--	5.7
11	24S.02E.04.322	321501106443801	03-16-95	3,866	312	303	312	--	7.9
12	04S.01E.08.221	335903106511701	04-20-95	4,570	92	72	92	9.51	5.3
13	05S.01E.07.234	335326106522701	04-13-95	4,552	84	64	84	--	5.1
14	06S.01W.12.214	334818106533401	05-02-95	4,525	80	50	80	--	--
15	08S.02W.11.121	333810107005001	04-19-95	4,516	138	123	138	62.85	9.4
16	16S.05W.25.211	325335107182401	03-13-95	4,200	145	113	130	--	5.2
17	01S.01W.01.124	341519106535101	04-17-95	4,665	65	55	65	11.60	6.7
18	01N.01E.04.123	342041106504601	04-11-95	4,725	89	84	88	21.45	3.4
19	03N.01E.23.331	342753106485501	04-11-95	4,746	210	200	210	9.74	9.7
20	06N.02E.18.232	344500106460301	04-09-95	4,830	355	345	355	7.22	7.0

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Well number	Station number	Date	Elevation of land-surface datum (feet above sea level)	Depth of well, total (feet)	Depth to top of sample interval (feet)	Depth to bottom of sample interval (feet)	Water level (feet below land surface)	Flow rate, instantaneous (gal/min)
21	04N.02E.30.243	343238106460501	03-29-95	4,769	160	150	160	--	7.5
22	06N.02E.10.341	344522106432001	04-06-95	4,829	160	150	160	8.88	7.1
23	15N.06E.06.411	353329106204001	03-07-95	5,225	138	131	138	24.28	7.5
24	13N.04E.28.131	351948106314701	03-03-95	5,092	80	65	75	35.06	3.8
25	12N.03E.35.132	351338106360501	03-06-95	5,011	250	240	250	--	5.2
26	11N.03E.16.111	351120106381601	05-04-95	4,993	300	260	280	29.26	6.7
27	09N.02E.36.222	345810106403401	04-23-95	4,907	220	210	220	8.99	6.7
28	07N.03E.30.321	344817106401001	04-03-95	4,890	210	200	210	55.40	--
29	07N.02E.23.414	344900106415801	04-09-95	4,852	187	177	187	5.78	7.1
30	07N.02E.22.231	344916106430401	04-12-95	4,853	178	173	178	3.53	7.5

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Specific conductance (µS/cm)	pH water whole, field (standard units)	pH water whole, lab (standard units)	Temperature water (deg C)	Temperature air (deg C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
1	03-22-95	966	8.54	8.3	23.0	20.0	660	0.1	94	32	3.3
2	03-23-95	748	8.57	8.3	24.0	25.0	662	0.1	67	23	2.3
3	03-19-95	460	8.50	8.1	22.0	24.5	660	0.1	57	20	1.6
4	03-14-95	2,070	7.60	7.5	20.5	19.0	666	0.1	150	45	9.3
5	03-21-95	1,065	7.70	7.6	17.0	23.0	660	0.6	400	120	25
6	03-15-95	1,306	7.74	7.7	18.5	18.5	665	0.1	540	170	28
7	04-18-95	1,268	7.85	7.7	17.5	24.0	653	0.1	390	130	17
8	03-20-95	4,110	7.31	7.2	19.0	27.0	657	0.2	1,400	450	74
9	03-15-95	640	8.08	7.9	18.5	21.0	663	0.05	210	68	9.6
10	03-16-95	1,915	7.41	7.3	18.5	21.0	664	0.1	870	260	54
11	03-16-95	690	7.80	7.7	18.0	23.0	663	0.1	230	68	14
12	04-20-95	600	8.04	7.8	16.0	18.0	640	0.1	200	62	9.8
13	04-13-95	487	8.05	7.9	18.5	22.5	650	0.9	83	25	4.9
14	05-02-95	548	8.04	7.8	24.0	29.5	641	4.7	70	24	2.5
15	04-19-95	423	8.00	7.8	19.0	12.5	638	0.3	91	31	3.3
16	03-13-95	585	7.56	7.4	21.5	19.5	655	7.8	210	71	7.5
17	04-17-95	1,060	7.83	7.7	14.5	12.5	638	0.1	370	120	17
18	04-11-95	1,771	7.67	7.5	17.0	13.0	640	0.1	470	130	36
19	04-11-95	874	8.05	7.9	20.0	17.0	638	<0.1	120	28	11
20	04-09-95	648	8.58	8.3	18.0	19.0	624	2.2	25	7.1	1.7
21	03-29-95	413	8.07	7.9	18.5	14.5	640	0.6	80	23	5.4
22	04-06-95	479	8.39	8.1	17.5	21.0	638	0.3	43	11	3.7
23	03-07-95	724	7.33	7.5	17.0	7.5	634	2.2	250	69	18
24	03-03-95	1,219	7.59	7.5	19.0	12.5	634	3.6	410	130	21
25	03-06-95	317	8.00	7.8	15.0	11.0	625	<0.05	130	32	11

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Specific conductance (µS/cm)	pH water whole, field (standard units)	pH water whole, lab (standard units)	Temperature water (deg C)	Temperature air (deg C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
26	05-04-95	280	8.05	7.9	14.5	18.5	636	0.1	100	31	5.8
27	04-23-95	373	7.97	8.0	16.0	12.5	640	0.1	110	33	6.5
28	04-03-95	347	7.92	7.7	19.0	13.0	637	0.1	130	36	9.3
29	04-09-95	317	8.00	7.8	16.0	19.0	629	0.1	120	31	9.7
30	04-12-95	309	8.13	8.2	15.0	17.5	642	0.1	110	31	7.5

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Sodium, dis-solved (mg/L as Na)	Sodium ad-sorp-tion ratio	Sodium (percent)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate water dis it field (mg/L as HCO_3)	Car-bonate water dis it field (mg/L as CO_3)	Alka-linity wat dis tot it, field (mg/L as $CaCO_3$)	Alka-linity wat wh gran t, field $CaCO_3$ (mg/L)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)
1	03-22-95	150	7	77	4.6	50	6	51	50	190	130
2	03-23-95	130	7	80	3.5	103	3	89	87	150	79
3	03-19-95	68	4	72	1.4	72	6	69	69	69	49
4	03-14-95	390	14	82	30	405	0	332	329	390	220
5	03-21-95	62	1	25	4.3	189	0	155	154	200	130
6	03-15-95	65	1	21	4.7	254	0	208	206	290	140
7	04-18-95	120	3	39	6.7	290	0	238	237	300	96
8	03-20-95	430	5	40	4.1	230	0	189	186	1,500	430
9	03-15-95	45	1	31	2.9	169	0	139	136	87	59
10	03-16-95	78	1	16	21	314	0	257	255	560	180
11	03-16-95	45	1	29	9.1	216	0	177	174	77	59
12	04-20-95	52	2	36	3.4	210	0	172	170	110	21
13	04-13-95	72	3	64	3.2	173	0	142	142	55	31
14	05-02-95	84	4	71	3.7	174	0	143	142	56	39
15	04-19-95	53	2	54	4.7	148	0	121	119	57	21
16	03-13-95	43	1	31	1.7	192	0	157	157	78	35
17	04-17-95	90	2	34	5.7	300	0	246	244	220	68
18	04-11-95	190	4	46	8.9	202	0	166	165	340	280
19	04-11-95	140	6	71	7.3	164	0	134	131	200	58
20	04-09-95	130	11	91	3.2	156	6	138	136	130	16
21	03-29-95	54	3	58	5.4	152	0	125	125	44	23
22	04-06-95	86	6	79	5.1	170	3	143	142	69	16
23	03-07-95	58	2	33	6.1	214	0	175	175	190	9.2
24	03-03-95	91	2	31	16	188	0	154	154	320	99
25	03-06-95	14	0.5	19	5.7	148	0	121	119	30	7.9

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Sodium, dis-solved (mg/L as Na)	Sodium ad-sorp-tion ratio	Sodium (percent)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate water dis it field (mg/L as HCO_3)	Car-bonate water dis it field (mg/L as CO_3)	Alka-linity wat dis tot it, field (mg/L as $CaCO_3$)	Alka-linity wat wh gran t, field $CaCO_3$ (mg/L)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)
26	05-04-95	14	0.6	22	4.5	126	0	103	102	26	7.4
27	04-23-95	28	1	34	5.9	142	0	116	115	36	22
28	04-03-95	18	0.7	23	2.5	134	0	110	109	42	15
29	04-09-95	17	0.7	23	6.7	144	0	118	116	32	7.1
30	04-12-95	16	0.7	23	8.1	118	0	97	94	42	10

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Dissolved solids, residue at 180 deg C (mg/L)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia+ organic, dis (mg/L as N)	Phosphorus, dissolved (mg/L as P)
1	03-22-95	0.50	0.19	30	590	<0.01	<0.05	0.020	<0.20	<0.01
2	03-23-95	0.50	0.09	30	476	<0.01	<0.05	0.020	<0.20	<0.01
3	03-19-95	0.40	0.06	29	277	<0.01	<0.05	0.020	<0.20	<0.01
4	03-14-95	4.6	0.49	44	1,350	<0.01	0.07	0.020	<0.20	0.04
5	03-21-95	0.30	0.21	28	682	<0.01	<0.05	0.110	<0.20	<0.01
6	03-15-95	0.20	0.24	25	880	<0.01	<0.05	0.130	<0.20	0.02
7	04-18-95	0.30	0.21	27	864	<0.01	<0.05	0.220	0.30	0.02
8	03-20-95	1.8	0.62	58	3,380	<0.01	1.90	0.030	<0.20	0.01
9	03-15-95	0.30	0.09	23	391	<0.01	<0.05	0.250	0.30	<0.01
10	03-16-95	0.20	0.40	31	1,430	<0.01	<0.05	0.030	<0.20	<0.01
11	03-16-95	0.30	0.08	26	419	<0.01	<0.05	0.020	<0.20	<0.01
12	04-20-95	0.40	0.07	30	400	<0.01	<0.05	0.180	0.30	0.01
13	04-13-95	0.90	0.09	34	304	<0.01	0.20	<0.015	<0.20	0.11
14	05-02-95	2.5	0.15	39	348	0.02	0.88	<0.015	<0.20	<0.01
15	04-19-95	0.70	0.06	26	267	<0.01	<0.05	<0.015	<0.20	<0.01
16	03-13-95	0.80	0.13	31	375	<0.01	1.90	0.020	<0.20	0.02
17	04-17-95	0.30	0.14	23	706	<0.01	<0.05	0.020	<0.20	0.01
18	04-11-95	1.1	0.40	39	1,160	<0.01	<0.05	0.050	<0.20	0.03
19	04-11-95	1.0	0.18	35	563	<0.01	1.60	<0.015	<0.20	<0.01
20	04-09-95	1.3	0.13	45	430	<0.01	1.80	<0.015	<0.20	<0.01
21	03-29-95	0.50	0.12	62	290	<0.01	0.22	<0.015	<0.20	<0.01
22	04-06-95	1.0	0.09	45	327	<0.01	<0.05	<0.015	<0.20	0.03
23	03-07-95	0.40	0.11	63	532	<0.01	0.27	<0.015	<0.20	0.01
24	03-03-95	0.60	0.34	77	900	<0.01	1.20	<0.015	<0.20	<0.01
25	03-06-95	0.50	0.03	57	237	<0.01	<0.05	<0.015	<0.20	<0.01

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Dissolved solids, residue at 180 deg C (mg/L)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia+ organic, dis (mg/L as N)	Phosphorus, dissolved (mg/L as P)
26	05-04-95	0.30	0.04	49	209	<0.01	<0.05	<0.015	<0.20	0.02
27	04-23-95	0.50	0.08	57	269	<0.01	0.16	<0.015	<0.20	<0.01
28	04-03-95	0.40	0.07	38	228	0.01	<0.05	0.020	<0.20	<0.01
29	04-09-95	0.50	0.05	46	214	<0.01	<0.05	<0.015	<0.20	<0.01
30	04-12-95	0.30	0.05	48	216	<0.01	<0.05	<0.015	<0.20	<0.01

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Phosphorus ortho, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L as C)	Aluminum[1], dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)
1	03-22-95	<0.01	1.1	5	<1	11	92	<1	<1	<1	<1
2	03-23-95	<0.01	0.4	7	<1	9	48	<1	<1	<1	<1
3	03-19-95	<0.01	0.6	5	<1	9	23	<1	<1	<1	<1
4	03-14-95	0.04	2.2	3	<1	3	12	<1	<1	1	<1
5	03-21-95	0.01	1.6	3	<1	3	129	<1	<1	<1	<1
6	03-15-95	0.02	0.9	3	<1	5	212	<1	<1	<1	<1
7	04-18-95	0.04	2.3	4	<1	2	61	<1	<1	1	<1
8	03-20-95	0.01	1.7	4	<2	4	17	<2	<2	<2	<2
9	03-15-95	0.02	1.7	3	<1	3	93	<1	<1	<1	<1
10	03-16-95	<0.01	2.6	3	<1	2	71	<1	<1	<1	1
11	03-16-95	0.02	1.4	3	<1	3	57	<1	<1	<1	<1
12	04-20-95	0.04	1.9	4	<1	2	109	<1	<1	1	<1
13	04-13-95	0.14	0.3	4	<1	48	52	<1	<1	<1	<1
14	05-02-95	0.01	0.1	6	<1	16	78	<1	<1	5	<1
15	04-19-95	<0.01	0.3	3	<1	6	19	<1	<1	<1	<1
16	03-13-95	<0.01	0.2	3	<1	<1	76	<1	<1	<1	<1
17	04-17-95	0.02	1.8	4	<1	4	98	<1	<1	2	<1
18	04-11-95	0.04	0.6	4	<1	18	34	<1	<1	2	<1
19	04-11-95	<0.01	<0.1	4	<1	5	18	<1	<1	<1	<1
20	04-09-95	0.02	0.1	15	<1	22	18	<1	<1	12	<1
21	03-29-95	<0.01	<0.1	4	<1	18	69	<1	<1	2	<1
22	04-06-95	0.01	<0.1	3	<1	19	26	<1	<1	3	<1
23	03-07-95	0.03	0.2	3	<1	4	48	<1	<1	2	<1
24	03-03-95	0.01	0.4	3	<1	28	94	<1	<1	2	<1
25	03-06-95	<0.01	0.5	3	<1	6	52	<1	<1	<1	<1

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Phosphorus ortho, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L as C)	Aluminum[1], dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)
26	05-04-95	0.01	0.2	5	<1	4	63	<1	<1	1	<1
27	04-23-95	<0.01	0.2	3	<1	10	27	<1	<1	1	<1
28	04-03-95	<0.01	0.2	3	<1	4	63	<1	<1	<1	<1
29	04-09-95	<0.01	0.2	3	<1	6	83	<1	<1	<1	<1
30	04-12-95	<0.01	0.3	4	<1	6	74	<1	<1	<1	<1

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Copper, dis-solved (µg/L as Cu)	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)	Manga-nese, dis-solved (µg/L as Mn)	Molyb-denum, dis-solved (µg/L as Mo)	Nickel, dis-solved (µg/L as Ni)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Uranium, natural, dis-solved (µg/L as U)	Zinc[1], dis-solved (µg/L as Zn)
1	03-22-95	2	<3	1	24	8	2	<1	<1	<1	65
2	03-23-95	<1	4	<1	4	14	1	<1	<1	<1	13
3	03-19-95	<1	11	<1	8	5	<1	<1	<1	<1	2
4	03-14-95	2	19	<1	69	59	2	<1	<1	3	2
5	03-21-95	1	40	<1	358	3	5	<1	<1	7	14
6	03-15-95	1	<3	<1	67	2	6	<1	<1	2	2
7	04-18-95	1	360	<1	654	7	5	<1	<1	<1	5
8	03-20-95	6	180	<2	9	26	15	1	<2	17	46
9	03-15-95	<1	<3	<1	58	3	2	<1	<1	<1	4
10	03-16-95	2	<3	<1	570	4	8	<1	<1	102	8
11	03-16-95	<1	200	<1	299	3	2	<1	<1	<1	11
12	04-20-95	<1	77	<1	322	6	2	<1	<1	<1	6
13	04-13-95	<1	<3	<1	13	6	<1	2	<1	8	1
14	05-02-95	<1	<3	<1	<1	7	<1	2	<1	10	7
15	04-19-95	<1	110	<1	36	5	1	<1	<1	3	6
16	03-13-95	<1	<3	<1	<1	3	2	1	<1	2	<1
17	04-17-95	1	120	<1	353	6	4	<1	<1	15	3
18	04-11-95	2	550	1	262	12	4	<1	<1	10	4
19	04-11-95	1	<3	<1	<1	10	<1	2	<1	4	6
20	04-09-95	1	12	<1	<1	12	<1	2	<1	4	4
21	03-29-95	2	<3	<1	<1	4	<1	1	<1	13	2
22	04-06-95	<1	<3	<1	<1	4	<1	<1	<1	6	3
23	03-07-95	2	<3	<1	<1	5	2	2	<1	5	46
24	03-03-95	3	<3	2	<1	2	4	8	<1	2	3
25	03-06-95	<1	<3	<1	8	4	<1	<1	<1	2	28

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Copper, dis- solved (µg/L as Cu)	Iron, dis- solved (µg/L as Fe)	Lead, dis- solved (µg/L as Pb)	Manga- nese, dis- solved (µg/L as Mn)	Molyb- denum, dis- solved (µg/L as Mo)	Nickel, dis- solved (µg/L as Ni)	Sele- nium, dis- solved (µg/L as Se)	Silver, dis- solved (µg/L as Ag)	Uranium, natural, dis- solved (µg/L as U)	Zinc[1], dis- solved (µg/L as Zn)
26	05-04-95	<1	<3	<1	2	3	<1	<1	<1	2	3
27	04-23-95	<1	3	<1	2	3	<1	<1	<1	3	44
28	04-03-95	<1	<3	<1	<1	3	1	<1	<1	2	2
29	04-09-95	<1	37	<1	<1	4	1	<1	<1	3	1
30	04-12-95	<1	<3	<1	7	3	1	<1	<1	4	2

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Gross alpha, dis-solved (µg/L as U-nat)	Alpha count, 2 sigma wat, dis as nat U (µg/L)	Gross alpha water, dis as Th-230 (pCi/L)	Alpha count, 2 sigma wat, dis as Th-230 (pCi/L)	Gross beta, dis-solved (pCi/L as Sr-90/ Y-90)	Beta, 2 sigma water, dis as Sr-90/ Y-90 (pCi/L)	Gross beta, dis-solved (pCi/L as Cs-137)	Beta, 2 sigma water, dis as Cs-137 (pCi/L)	Radon-222, total (pCi/L)
1	03-22-95	<3.0	0.45	<3.0	0.43	<4.0	2.8	5.1	6.2	230
2	03-23-95	<3.0	0.52	<3.0	0.49	<4.0	2.2	<4.0	4.3	240
3	03-19-95	<3.0	0.43	<3.0	0.41	<4.0	1.6	<4.0	2.8	1,200
4	03-14-95	4.3	1.2	4.1	1.2	30	7.3	59	18	320
5	03-21-95	7.6	1.7	7.2	1.5	9.0	4.0	16	7.5	1,300
6	03-15-95	3.2	0.96	3.1	0.90	8.7	5.3	15	9.3	200
7	04-18-95	<3.0	0.63	<3.0	0.59	7.5	3.6	14	7.1	550
8	03-20-95	11	2.2	10	1.9	12	11	28	25	780
9	03-15-95	<3.0	0.60	<3.0	0.58	6.6	2.9	10	4.9	400
10	03-16-95	48	7.4	46	6.4	56	8.7	120	30	2,300
11	03-16-95	<3.0	0.49	<3.0	0.48	9.6	3.5	15	5.9	420
12	04-20-95	<3.0	0.41	<3.0	0.39	<4.0	2.2	4.5	3.7	460
13	04-13-95	6.2	1.5	5.9	1.3	5.0	1.6	9.3	3.4	1,700
14	05-02-95	11	2.1	10	1.9	9.9	2.1	17	4.9	270
15	04-19-95	<3.0	0.92	<3.0	0.87	<4.0	1.7	5.0	2.8	270
16	03-13-95	<3.0	0.83	<3.0	0.82	<4.0	1.5	8.3	4.0	500
17	04-17-95	13	2.5	12	2.2	9.9	3.7	18	7.3	400
18	04-11-95	3.9	1.1	3.8	1.0	4.9	1.7	7.3	2.8	380
19	04-11-95	5.8	1.5	5.3	1.3	5.1	4.2	11	9.1	290
20	04-09-95	4.0	1.1	3.9	1.1	<4.0	1.6	6.5	3.5	490
21	03-29-95	12	2.4	11	2.0	6.0	3.3	7.7	4.4	240
22	04-06-95	3.1	0.93	3.1	0.91	10	3.6	13	5.2	540
23	03-07-95	6.6	1.6	6.0	1.4	5.3	3.3	7.7	4.9	230
24	03-03-95	3.4	1.1	3.2	1.0	14	3.6	19	5.2	--
25	03-06-95	<3.0	0.79	<3.0	0.75	4.9	3.1	5.8	3.6	370

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Continued

Well reference number (fig. 6)	Date	Gross alpha, dis-solved (µg/L as U-nat)	Alpha count, 2 sigma wat, dis as nat U (µg/L)	Gross alpha water, dis as Th-230 (pCi/L)	Alpha count, 2 sigma wat, dis as Th-230 (pCi/L)	Gross beta, dis-solved (pCi/L as Sr-90/ Y-90)	Beta, 2 sigma water, dis as Sr-90/ Y-90 (pCi/L)	Gross beta, dis-solved (pCi/L as Cs-137)	Beta, 2 sigma water, dis as Cs-137 (pCi/L)	Radon-222, total (pCi/L)
26	05-04-95	<3.0	0.94	<3.0	0.88	7.0	1.9	11	3.4	190
27	04-23-95	<3.0	0.80	<3.0	0.75	9.0	2.1	14	4.1	470
28	04-03-95	<3.0	0.92	<3.0	0.81	<4.0	2.8	<4.0	3.5	380
29	04-09-95	<3.0	0.72	<3.0	0.68	7.5	3.4	9.4	4.5	300
30	04-12-95	4.3	1.2	4.0	1.1	4.1	2.3	7.6	4.5	340

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Concluded

Well reference number (fig. 6)	Date	Rn-222 2 sigma water, whole, total (pCi/L)	Pro- meton, water, dis, rec (µg/L)	Diaz- inon d10 srg wat flt 0.7 u gf, rec (percent)	Terbuth- ylazine srg wat flt 0.7 u gf, rec (percent)	HCH alpha d6 srg wat flt 0.7 u gf, rec (percent)	Ethane 12dicl surrog s2090 unfltrd rec (percent)	Toluene d8 surrog s2090 unfltrd rec (percent)	Benzene 14brfl- surrog s2090 unfltrd rec (percent)	BDMC, surrog, water, unfltrd rec (percent)
1	03-22-95	21	<0.018	116	104	84	--	100	--	92
2	03-23-95	19	<0.018	116	104	84	--	--	--	88
3	03-19-95	39	<0.018	115	109	84	--	97	100	84
4	03-14-95	21	<0.018	85	109	100	--	99	--	--
5	03-21-95	34	<0.018	116	101	83	--	99	--	--
6	03-15-95	19	<0.018	69	98	94	--	99	--	10
7	04-18-95	30	<0.018	90	98	90	--	--	--	--
8	03-20-95	30	0.038	118	105	86	--	96	100	87
9	03-15-95	22	<0.018	69	117	93	--	99	--	8
10	03-16-95	42	<0.018	67	106	96	--	100	--	22
11	03-16-95	21	<0.018	77	116	97	--	100	--	13
12	04-20-95	22	<0.018	90	101	91	100	99	--	--
13	04-13-95	37	<0.018	85	96	85	--	99	98	49
14	05-02-95	19	<0.018	112	86	95	--	98	98	69
15	04-19-95	22	<0.018	86	98	85	--	98	--	--
16	03-13-95	26	<0.018	79	96	94	--	100	--	35
17	04-17-95	22	<0.018	84	100	87	--	--	99	79
18	04-11-95	21	<0.018	90	108	92	--	99	--	81
19	04-11-95	19	<0.018	87	106	93	--	98	--	65
20	04-09-95	25	<0.018	85	97	89	--	99	--	79
21	03-29-95	19	<0.018	91	103	93	--	98	97	103
22	04-06-95	24	<0.018	90	106	83	--	99	--	69
23	03-07-95	19	<0.018	76	75	65	--	100	--	7
24	03-03-95	--	--	--	--	--	99	--	--	--
25	03-06-95	21	<0.018	88	92	74	100	98	99	5

Table 1.--Selected water-quality data for wells sampled in the study-unit survey--Concluded

Well reference number (fig. 6)	Date	Rn-222 2 sigma water, whole, total (pCi/L)	Pro-meton, water, dis, rec (µg/L)	Diaz-inon d10 srg wat flt 0.7 u gf, rec (percent)	Terbuth-ylazine srg wat flt 0.7 u gf, rec (percent)	HCH alpha d6 srg wat flt 0.7 u gf, rec (percent)	Ethane 12dicl surrog s2090 unfltrd rec (percent)	Toluene d8 surrog s2090 unfltrd rec (percent)	Benzene 14brfl-surrog s2090 unfltrd rec (percent)	BDMC, surrog, water, unfltrd rec (percent)
26	05-04-95	18	<0.018	111	111	93	97	98	100	79
27	04-23-95	25	<0.018	85	104	85	--	--	--	33
28	04-03-95	21	<0.018	90	105	80	97	96	--	44
29	04-09-95	23	<0.018	85	100	92	--	98	97	68
30	04-12-95	21	<0.018	84	96	89	--	100	--	56

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[1] The analysis of quality-control samples (field blanks and duplicate samples) indicates that little confidence should be placed on these data.

Table 2.--List of major constituents, nutrients and dissolved organic carbon, trace elements, radiochemicals, and volatile organic compounds included in the analyses

[Minimum reporting level, minimum concentration at which the constituent can be reliably measured and reported by the laboratory using a given analytical method; mg/L, milligrams per liter; μg/L, micrograms per liter; pCi/L, picocuries per liter (Timme, 1995)]

MAJOR CONSTITUENTS

Constituent	Minimum reporting level (mg/L)
Calcium	0.02
Magnesium	0.01
Sodium	0.20
Potassium	0.10
Bicarbonate	0.10
Carbonate	0.10
Sulfate	0.10
Chloride	0.10
Fluoride	0.10
Bromide	0.01
Silica	0.01

NUTRIENTS AND DISSOLVED ORGANIC CARBON

Constituent	Minimum reporting level (mg/L)
Nitrite as nitrogen	0.01
Nitrite plus nitrate as nitrogen	0.05
Ammonia as nitrogen	0.015
Ammonia plus organic nitrogen as nitrogen	0.20
Phosphorus	0.01
Orthophosphorus	0.01
Dissolved organic carbon	0.1

TRACE ELEMENTS

Constituent	Minimum reporting level (μg/L)
Aluminum	1
Antimony	1
Arsenic	1
Barium	1
Beryllium	1
Cadmium	1
Chromium	1
Cobalt	1
Copper	1
Iron	3
Lead	1
Manganese	1
Molybdenum	1
Nickel	1
Selenium	1
Silver	1
Uranium	1
Zinc	1

RADIOCHEMICALS

Constituent	Minimum reporting level
Gross alpha as natural uranium	3.0 μg/L
Gross alpha as thorium-230	3.0 pCi/L
Gross beta as strontium-90/yttrium-90	4.0 pCi/L
Gross beta as cesium-137	4.0 pCi/L
Radon-222	24 pCi/L

VOLATILE ORGANIC COMPOUNDS

Constituent	Minimum reporting level (μg/L)
Benzene	0.2
Bromobenzene	0.2
Bromochloromethane	0.2
Bromoform	0.2
Carbon tetrachloride	0.2
Chlorobenzene	0.2
Chlorodibromomethane	0.2
Chloroethane	0.2
Chloroform	0.2
Cis-1,2-dichloroethene	0.2
Cis-1,3-dichloropropene	0.2
Dibromochloropropane	1.0
1,2-Dibromoethane	0.2
Dibromomethane	0.2
1,3-Dichlorobenzene	0.2
1,4-Dichlorobenzene	0.2
Dichlorobromomethane	0.2
Dichlorodifluoromethane	0.2
1,1-Dichloroethane	0.2
1,2-Dichloroethane	0.2
1,1-Dichloroethylene	0.2
1,2-Dichloropropane	0.2
1,3-Dichloropropane	0.2
2,2-Dichloropropane	0.2
1,1-Dichloropropene	0.2
Ethylbenzene	0.2
Freon-113	0.2
Hexachlorobutadiene	0.2
Isopropylbenzene	0.2
Mesitylene	0.2
Methylbromide	0.2
Methylchloride	0.2
Methylene chloride	0.2
Methyl tert-butyl ether (MTBE)	0.2
Napthalene	0.2
N-butylbenzene	0.2
N-propylbenzene	0.2
O-chlorobenzene	0.2
O-chlorotoluene	0.2
P-chlorotoluene	0.2
P-isopropyltoluene	0.2
Pseudocumene	0.2
Sec-butylbenzene	0.2
Styrene	0.2
Tertbutylbenzene	0.2
1,1,1,2-Tetrachloroethane	0.2
1,1,2,2-Tetrachloroethane	0.2
Tetrachloroethylene	0.2
Toluene	0.2
1,2-Transdichloroethene	0.2
Trans-1,3-dichloropropene	0.2
1,2,3-Trichlorobenzene	0.2
1,2,4-Trichlorobenzene	0.2
1,1,1-Trichloroethane	0.2
1,1,2-Trichloroethane	0.2
Trichloroethylene	0.2
Trichlorofluoromethane	0.2
1,2,3-Tricloropropane	0.2
Vinyl chloride	0.2
Xylene	0.2

Table 3.--List of pesticides included in the analyses

[Pesticides listed in group A extracted by C-18 solid-phase extraction cartridge and analyzed by gas chromatography/mass spectrometric detector. Pesticides listed in group B extracted by Carbopak-B solid-phase extraction cartridge and analyzed by high-performance liquid chromatography. Method detection limit is minimum concentration at which the pesticide can be identified, measured, and reported with 99-percent confidence that the concentration is greater than zero (Zaugg and others, 1995). All pesticides reported in micrograms per liter (Werner and others, 1996)]

GROUP A	
Name	**Method detection limit**
Acetochlor	0.002
Alachlor	0.002
Atrazine	0.001
Benfluralin	0.002
Alpha HCH	0.002
Butylate	0.002
Carbaryl	0.003
Carbofuran	0.003
Chlorpyrifos	0.004
Cyanazine	0.004
DCPA	0.002
p,p' DDE	0.006
Deethyl atrazine	0.002
Diazinon	0.002
Dieldrin	0.001
2,6-Diethylaniline	0.003
Disulfoton	0.017
EPTC	0.002
Ethalfluralin	0.004
Ethoprop	0.003
Fonofos	0.003
Lindane	0.004
Linuron	0.002
Malathion	0.005
Methyl azinphos	0.001
Methyl parathion	0.006
Metolachlor	0.002
Metribuzin	0.004
Molinate	0.004
Napropamide	0.003
Parathion	0.004
Pebulate	0.004
Pendimethalin	0.004
Permethrin	0.005
Phorate	0.002
Prometon	0.018
Pronamide	0.003
Propachlor	0.007
Propargite	0.013
Propanil	0.004
Simazine	0.005
Tebuthiuron	0.010
Terbacil	0.007
Terbufos	0.013
Thiobencarb	0.002
Triallate	0.001
Trifuralin	0.002

GROUP B	
Name	**Method detection limit**
Acifluorfen	0.035
Aldicarb	0.016
Aldicarb sulfone	0.016
Aldicarb sulfoxide	0.021
Amiben	0.011
Bentazon	0.014
Bromacil	0.035
Bromoxynil	0.035
Carbaryl	0.008
Carbofuran	0.028
Chlorothalonil	0.035
Clopyralid	0.050
2,4-D	0.035
Dacthal mono-acid	0.017
2,4-DB	0.035
Dicamba	0.035
Dichlobenil	0.020
Dichlorprop	0.032
Dinoseb	0.035
Diuron	0.020
Esfenvalerate	0.019
Fenuron	0.013
Fluometuron	0.035
3-Hydroxycarbofuran	0.014
Linuron	0.018
MCPA	0.050
MCPB	0.035
Methiocarb	0.026
Methomyl	0.017
1-Naphthol	0.007
Neburon	0.015
Norflurazon	0.024
Ocresol	0.035
Oryzalin	0.019
Oxamyl	0.018
Picloram	0.050
Propham	0.035
Propoxur	0.035
Silvex	0.021
2,4,5-T	0.035
Triclopyr	0.050

Table 4.--Quality-control data for wells sampled in the subunit survey

[Field blanks and duplicates are grouped separately. <, less than; mg/L, milligrams per liter; deg C, degrees Celsius; NO_2, nitrite; NO_3, nitrate; µg/L, micrograms per liter; --, no data; gross alpha, dissolved (µg/L as U-nat), dissolved gross alpha particle activity reported in micrograms per liter of equivalent natural uranium; alpha count, 2 sigma wat dis as nat U, 2 sigma precision estimate of indicated analysis; pCi/L, picocuries per liter; gross alpha water, dis as Th-230, dissolved gross alpha particle activity reported in picocuries per liter as equivalent thorium-230; alpha count, 2 sigma wat dis as Th-230, 2 sigma precision estimate of indicated analysis; gross beta, dissolved (pCi/L as Sr-90/Y-90), dissolved gross beta particle activity reported in picocuries per liter as equivalent strontium-90/yttrium-90; beta, 2 sigma water, dis, as Sr-90/Y-90, 2 sigma precision estimate of indicated analysis; gross beta, dissolved (pCi/L as Cs-137), dissolved gross beta particle activity reported as equivalent cesium-137; beta, 2 sigma water, dis as Cs-137, 2 sigma precision estimate of indicated analysis; total or water, unfltrd, rec, quantity of specific compound recovered from unfiltered sample; water, dis, rec, quantity of specific compound recovered from samples filtered through 0.7-micron-pore-size filter; nat, native; dupl, duplicate; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mm of Hg, millimeters of mercury; $CaCO_3$, calcium carbonate; bicarbonate water dis it field, bicarbonate in unfiltered sample as determined in the field by incremental titration; alkalinity wat, dis tot it field, alkalinity in unfiltered sample as determined in the field by incremental titration; alkalinity wat wh gran t, field $CaCO_3$, alkalinity in unfiltered sample as determined in the field by gran titration; Rn-222 2 sigma water, whole, total, 2 sigma precision estimate of indicated analysis]

FIELD BLANKS

Station number	Date	Time	pH water whole, lab (standard units)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)
323611107011501	03-20-95	1108	7.8	<0.02	<0.01	<0.20	<0.10	<0.10	<0.10	<0.10	<0.01
334818106533401	05-02-95	1108	7.8	<0.02	<0.01	<0.20	<0.10	<0.10	<0.10	<0.10	<0.01
325335107182401	03-13-95	1348	7.8	<0.02	<0.01	<0.20	<0.10	<0.10	<0.10	<0.10	<0.01

Station number	Date	Silica, dissolved (mg/L as SiO_2)	Dissolved solids, residue at 180 deg C (mg/L)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, dis (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus ortho, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L as C)	Aluminum, dissolved (µg/L as Al)
323611107011501	03-20-95	0.02	<1	<0.01	<0.05	<0.015	<0.20	<0.01	<0.01	<0.1	3
334818106533401	05-02-95	<0.01	<1	0.02	<0.05	<0.015	<0.20	0.02	<0.01	0.2	4
325335107182401	03-13-95	<0.01	<1	<0.01	0.06	<0.015	<0.20	<0.01	<0.01	0.2	3

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)
323611107011501	03-20-95	<1	<1	<1	<1	<1	<1	<1	<1	<3	<1
334818106533401	05-02-95	<1	<1	<1	<1	<1	<1	<1	<1	<3	<1
325335107182401	03-13-95	<1	<1	<1	<1	<1	<1	<1	<1	15	<1

Station number	Date	Manganese, dissolved (µg/L as Mn)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Uranium, natural, dissolved µg/L as U)	Zinc, dissolved (µg/L as Zn)	Gross alpha, dissolved (µg/L as U-nat)	Alpha, count, 2 sigma wat dis as nat U (µg/L)	Gross alpha water, dis as Th-230 (pCi/L)
323611107011501	03-20-95	<1	<1	<1	<1	<1	<1	8	<3.0	0.25	<3.0
334818106533401	05-02-95	<1	<1	<1	<1	<1	<1	3	<3.0	0.32	<3.0
325335107182401	03-13-95	<1	<1	<1	<1	<1	<1	1	<3.0	0.52	<3.0

Station number	Date	Alpha count, 2 sigma wat dis as Th-230 (pCi/L)	Gross beta, dissolved (pCi/L as Sr-90/ Y-90)	Beta, 2 sigma water, dis as Sr-90 /Y-90 (pCi/L)	Gross beta, dissolved (pCi/L as Cs-137)	Beta, 2 sigma water, dis as Cs-137 (pCi/L)	Benzene, total (µg/L)	Bromobenzene water, unfltrd, rec (µg/L)	Bromo chloromethane water, unfltrd, rec (µg/L)	Bromoform, total (µg/L)	Carbon tetrachloride, total (µg/L)
323611107011501	03-20-95	0.25	<4.0	0.76	<4.0	0.80	<0.2	<0.2	<0.2	<0.2	<0.2
334818106533401	05-02-95	0.31	<4.0	1.7	<4.0	1.8	<0.2	<0.2	<0.2	<0.2	<0.2
325335107182401	03-13-95	0.51	<4.0	1.3	<4.0	1.3	<0.2	<0.2	<0.2	<0.2	<0.2

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Chlorobenzene, total (µg/L)	Chlorodibromomethane, total (µg/L)	Chloroethane, total (µg/L)	Chloroform, total (µg/L)	Cis-1,2-dichloroethene, total (µg/L)	Cis-1,3-dichloropropene, total (µg/L)	Dibromochloropropane water, unfltrd, rec (µg/L)	1,2-Dibromoethane water, unfltrd, rec (µg/L)	Dibromomethane water, unfltrd, rec (µg/L)	1,3-Dichlorobenzene water, unfltrd, rec (µg/L)
323611107011501	03-20-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0	<0.2	<0.2	<0.2
334818106533401	05-02-95	<0.2	<0.2	<0.2	0.5	<0.2	<0.2	<1.0	<0.2	<0.2	<0.2
325335107182401	03-13-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0	<0.2	<0.2	<0.2

Station number	Date	1,4-Dichlorobenzene water, unfltrd, rec (µg/L)	Dichlorobromomethane, total (µg/L)	Dichlorodifluoromethane, total (µg/L)	1,1-Dichloroethane, total (µg/L)	1,2-Dichloroethane, total (µg/L)	1,1-Dichloroethylene, total (µg/L)	1,2-Dichloropropane, total (µg/L)	1,3-Dichloropropane, total (µg/L)	2,2-Dichloropropane, total (µg/L)	1,1-Dichloropropene, total (µg/L)
323611107011501	03-20-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
334818106533401	05-02-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
325335107182401	03-13-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Station number	Date	Ethylbenzene, total (µg/L)	Freon-113 water, unfltrd, rec (µg/L)	Hexachlorobutadiene, total (µg/L)	Isopropylbenzene water, unfltrd, rec (µg/L)	Mesitylene water, unfltrd, rec (µg/L)	Methylbromide, total (µg/L)	Methylchloride, total (µg/L)	Methylene chloride, total (µg/L)	Methyl tert-butyl ether, total (µg/L)	Naphthalene, total (µg/L)
323611107011501	03-20-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
334818106533401	05-02-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	<0.2
325335107182401	03-13-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	N-butylbenzene water, unfltrd, rec (µg/L)	N-propylbenzene water, unfltrd, rec (µg/L)	O-chlorobenzene water, unfltrd, rec (µg/L)	O-chlorotoluene water, unfltrd, rec (µg/L)	P-chlorotoluene water, unfltrd, rec (µg/L)	P-isopropyltoluene water, unfltrd, rec (µg/L)	Pseudocumene water, unfltrd, rec (µg/L)	Sec-butylbenzene water, unfltrd, rec (µg/L)	Styrene, total (µg/L)	Tert-butylbenzene water, unfltrd, rec (µg/L)
3 23611107011501	03-20-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
334818106533401	05-02-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
325335107182401	03-13-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Station number	Date	1,1,1,2-Tetrachloroethane, total (µg/L)	1,1,2,2-Tetrachloroethane, total (µg/L)	Tetrachloroethylene, total (µg/L)	Toluene, total (µg/L)	1,2-Transdichloroethene, total (µg/L)	Trans-1,3-dichloropropene, total (µg/L)	1,2,3-Trichlorobenzene, total (µg/L)	1,2,4-Trichlorobenzene, total (µg/L)	1,1,1-Trichloroethane, total (µg/L)	1,1,2-Trichloroethane, total (µg/L)
323611107011501	03-20-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
334818106533401	05-02-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
325335107182401	03-13-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Station number	Date	Trichloroethylene, total (µg/L)	Trichlorofluoromethane, total (µg/L)	1,2,3-Tri chloropropane water, unfltrd, rec (µg/L)	Vinyl chloride, total (µg/L)	Xylene water, unfltrd, rec (µg/L)	Acetochlor water, dis, rec (µg/L)	Alachlor water, dis, rec (µg/L)	Atrazine water, dis, rec (µg/L)	Benfluralin water, dis, rec (µg/L)	Alpha HCH water, dis, rec (µg/L)
323611107011501	03-20-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.002	<0.002	<0.001	<0.002	<0.002
334818106533401	05-02-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.002	<0.002	<0.001	<0.002	<0.002
325335107182401	03-13-95	<0.2	<0.2	<0.2	<0.2	<0.2	<0.002	<0.002	<0.001	<0.002	<0.002

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Butylate water, dis, rec (µg/L)	Carbaryl water, dis, rec (µg/L)	Carbofuran water, dis, rec (µg/L)	Chlorpyrifos water, dis, rec (µg/L)	Cyanazine water, dis, rec (µg/L)	DCPA water, dis, rec (µg/L)	p,p' DDE water, dis, rec (µg/L)	Deethyl atrazine water, dis, rec (µg/L)	Diazinon water, dis, rec (µg/L)	Dieldrin water, dis, rec (µg/L)
323611107011501	03-20-95	<0.002	<0.003	<0.003	<0.004	<0.004	<0.002	<0.006	<0.002	<0.002	<0.001
334818106533401	05-02-95	<0.002	<0.003	<0.003	<0.004	<0.004	<0.002	<0.006	<0.002	<0.002	<0.001
325335107182401	03-13-95	<0.002	<0.003	<0.003	<0.004	<0.004	<0.002	<0.006	<0.002	<0.002	<0.001

Station number	Date	2,6-Diethylaniline water, dis, rec (µg/L)	Disulfoton water, dis, rec (µg/L)	EPTC water, dis, rec (µg/L)	Ethalfluralin water, dis, rec (µg/L)	Ethoprop water, dis, rec (µg/L)	Fonofos water, dis, rec (µg/L)	Lindane water, dis, rec (µg/L)	Linuron water, dis, rec (µg/L)	Malathion water, dis, rec (µg/L)	Methyl azinphos water, dis, rec (µg/L)
323611107011501	03-20-95	<0.003	<0.017	<0.002	<0.004	<0.003	<0.003	<0.004	<0.002	<0.005	<0.001
334818106533401	05-02-95	<0.003	<0.017	<0.002	<0.004	<0.003	<0.003	<0.004	<0.002	<0.005	<0.001
325335107182401	03-13-95	<0.003	<0.017	<0.002	<0.004	<0.003	<0.003	<0.004	<0.002	<0.005	<0.001

Station number	Date	Methyl parathion water, dis, rec (µg/L)	Metolachlor water, dis, rec (µg/L)	Metribuzin water, dis, rec (µg/L)	Molinate water, dis, rec (µg/L)	Napropamide water, dis, rec (µg/L)	Parathion water, dis, rec (µg/L)	Pebulate water, dis, rec (µg/L)	Pendimethalin water, dis, rec (µg/L)	Permethrin cis water, dis, rec (µg/L)	Phorate water, dis, rec (µg/L)
323611107011501	03-20-95	<0.006	<0.002	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.005	<0.002
334818106533401	05-02-95	<0.006	<0.002	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.005	<0.002
325335107182401	03-13-95	<0.006	<0.002	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.005	<0.002

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Prometon water, dis, rec (µg/L)	Pronamide water, dis, rec (µg/L)	Propachlor water, dis, rec (µg/L)	Propargite water, dis, rec (µg/L)	Propanil water, dis, rec (µg/L)	Simazine water, dis, rec (µg/L)	Tebuthiuron water, dis, rec (µg/L)	Terbacil water, dis, rec (µg/L)	Terbufos water, dis, rec (µg/L)	Thiobencarb water, dis, rec (µg/L)
323611107011501	03-20-95	<0.018	<0.003	<0.007	<0.013	<0.004	<0.005	<0.010	<0.007	<0.013	<0.002
334818106533401	05-02-95	<0.018	<0.003	<0.007	<0.013	<0.004	<0.005	<0.010	<0.007	<0.013	<0.002
325335107182401	03-13-95	<0.018	<0.003	<0.007	<0.013	<0.004	<0.005	<0.010	<0.007	<0.013	<0.002

Station number	Date	Triallate water, dis, rec (µg/L)	Trifluralin water, dis, rec (µg/L)	Acifluorfen water, dis, rec (µg/L)	Aldicarb water, dis, rec (µg/L)	Aldicarb sulfone water, dis, rec (µg/L)	Aldicarb sulfoxide water, dis, rec (µg/L)	Amiben water, dis, rec (µg/L)	Bentazon water, dis, rec (µg/L)	Bromacil, water, dis, rec (µg/L)
323611107011501	03-20-95	<0.001	<0.002	<0.035	<0.016	<0.016	<0.021	<0.011	<0.014	<0.035
334818106533401	05-02-95	<0.001	<0.002	<0.035	<0.016	<0.016	<0.021	<0.011	<0.014	<0.035
325335107182401	03-13-95	<0.001	<0.002	<0.035	<0.016	<0.016	<0.021	<0.011	<0.014	<0.035

Station number	Date	Bromoxynil water, dis, rec (µg/L)	Carbaryl water, dis, rec (µg/L)	Carbofuran water, dis, rec (µg/L)	Chlorothalonil water, dis, rec (µg/L)	Clopyralid water, dis, rec (µg/L)	2,4-D water, dis, rec (µg/L)	Dacthal monoacid, water, dis, rec (µg/L)	2,4-DB water, dis, rec (µg/L)	Dicamba water, dis, rec (µg/L)
323611107011501	03-20-95	<0.035	<0.008	<0.028	<0.035	<0.050	<0.035	<0.017	<0.035	<0.035
334818106533401	05-02-95	<0.035	<0.008	<0.028	<0.035	<0.050	<0.035	<0.017	<0.035	<0.035
325335107182401	03-13-95	<0.035	<0.008	<0.028	<0.035	<0.050	<0.035	<0.017	<0.035	<0.035

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Dichlobenil water, dis, rec (µg/L)	Dichlorprop water, dis, rec (µg/L)	Dinoseb water, dis, rec (µg/L)	Diuron water, dis, rec (µg/L)	Esfenvalerate, water, dis, rec (µg/L)	Fenuron water, dis, rec (µg/L)	Fluometuron water, dis, rec (µg/L)	3-Hydroxycarbofuran water, dis, rec (µg/L)	Linuron water, dis, rec (µg/L)
323611107011501	03-20-95	<0.020	<0.032	<0.035	<0.020	<0.019	<0.013	<0.035	<0.014	<0.018
334818106533401	05-02-95	<0.020	<0.032	<0.035	<0.020	<0.019	<0.013	<0.035	<0.014	<0.018
325335107182401	03-13-95	<0.020	<0.032	<0.035	<0.020	<0.019	<0.013	<0.035	<0.014	<0.018

Station number	Date	MCPA water, dis, rec (µg/L)	MCPB water, dis, rec (µg/L)	Methiocarb water, dis, rec (µg/L)	Methomyl water, dis, rec (µg/L)	1-Naphthol water, dis, rec (µg/L)	Neburon water, dis, rec (µg/L)	Norflurazon water, dis, rec (µg/L)	Ocresol water, dis, rec (µg/L)	Oryzalin water, dis, rec (µg/L)
323611107011501	03-20-95	<0.050	<0.035	<0.026	<0.017	<0.007	<0.015	<0.024	<0.035	<0.019
334818106533401	05-02-95	<0.050	<0.035	<0.026	<0.017	<0.007	<0.015	<0.024	<0.035	<0.019
325335107182401	03-13-95	<0.050	<0.035	<0.026	<0.017	<0.007	<0.015	<0.024	<0.035	<0.019

Station number	Date	Oxamyl water, dis, rec (µg/L)	Picloram water, dis, rec (µg/L)	Propham water, dis, rec (µg/L)	Propoxur water, dis, rec (µg/L)	Silvex water, dis, rec (µg/L)	2,4,5-T water, dis, rec (µg/L)	Triclopyr water, dis, rec (µg/L)
323611107011501	03-20-95	<0.018	<0.050	<0.035	<0.035	<0.021	<0.035	<0.050
334818106533401	05-02-95	<0.018	<0.050	<0.035	<0.035	<0.021	<0.035	<0.050
325335107182401	03-13-95	<0.018	<0.050	<0.035	<0.035	<0.021	<0.035	<0.050

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

DUPLICATES

Station number	Date	Time	Sample type	Specific conductance (µS/cm)	pH water whole, field (standard units)	pH water whole, lab (standard units)	Temperature water (deg C)	Temperature air (deg C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)
323611107011501	03-20-95	1100	Nat	4,110	7.3	7.2	19.0	27.0	657	0.2	1,400
	03-20-95	1105	Nat	4,110	7.3	7.4	19.0	27.0	657	0.2	--
	03-20-95	1101	Dupl	4,110	7.3	7.2	19.0	27.0	657	0.2	1,400
	03-20-95	1106	Dupl	4,110	7.3	7.4	19.0	27.0	657	0.2	--
334818106533401	05-02-95	1100	Nat	548	8.0	7.8	24.0	29.5	641	4.7	70
	05-02-95	1105	Nat	548	8.0	7.9	24.0	29.5	641	4.7	--
	05-02-95	1101	Dupl	548	8.0	7.9	24.0	29.5	641	4.7	70
	05-02-95	1106	Dupl	548	8.0	7.9	24.0	29.5	641	4.7	--
325335107182401	03-13-95	1340	Nat	585	7.6	7.4	21.5	19.5	655	7.8	210
	03-13-95	1345	Nat	585	7.6	7.7	21.5	19.5	655	7.8	--
	03-13-95	1341	Dupl	585	7.6	7.5	21.5	19.5	655	7.8	210
	03-13-95	1346	Dupl	585	7.6	7.9	21.5	19.5	655	7.8	--

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Sample type	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Sodium ad-sorp-tion ratio	Sodium percent	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate water, dis it field (mg/L as HCO_3)	Car-bonate water, dis it field (mg/L as CO_3)	Alka-linity wat, dis tot it field (mg/L as $CaCO_3$)
323611107011501	03-20-95	Nat	450	74	430	5	40	4.1	230	0	189
	03-20-95	Nat	--	--	--	--	--	--	230	0	189
	03-20-95	Dupl	450	74	420	5	39	4.0	230	0	189
	03-20-95	Dupl	--	--	--	--	--	--	230	0	189
334818106533401	05-02-95	Nat	24	2.5	84	4	71	3.7	174	0	143
	05-02-95	Nat	--	--	--	--	--	--	174	0	143
	05-02-95	Dupl	24	2.5	83	4	71	3.7	174	0	143
	05-02-95	Dupl	--	--	--	--	--	--	174	0	143
325335107182401	03-13-95	Nat	71	7.5	43	1	31	1.7	192	0	157
	03-13-95	Nat	--	--	--	--	--	--	192	0	157
	03-13-95	Dupl	71	7.5	42	1	30	1.7	192	0	157
	03-13-95	Dupl	--	--	--	--	--	--	192	0	157

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Sample type	Alka-linity wat wh gran t, field $CaCO_3$ (mg/L)	Sulfate. dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Bromide, dis-solved (mg/L as Br)	Silica, dis-solved (mg/L as SiO_2)	Solids, residue at 180 deg C, dis-solved (mg/L)	Solids, sum of constit-uents, dis-solved (mg/L)	Nitro-gen, nitrite, dis-solved (mg/L as N)
323611107011501	03-20-95	Nat	190	1,500	430	1.8	0.62	58	3,380	3,070	<0.01
	03-20-95	Nat	190	--	--	--	--	--	--	--	--
	03-20-95	Dupl	190	1,500	430	1.8	0.62	58	3,380	3,060	<0.01
	03-20-95	Dupl	190	--	--	--	--	--	--	--	--
334818106533401	05-02-95	Nat	140	56	39	2.5	0.15	39	348	340	0.02
	05-02-95	Nat	140	--	--	--	--	--	--	--	--
	05-02-95	Dupl	140	57	40	2.5	0.15	39	348	341	0.01
	05-02-95	Dupl	140	--	--	--	--	--	--	--	--
325335107182401	03-13-95	Nat	160	78	35	0.80	0.13	31	375	371	<0.01
	03-13-95	Nat	160	--	--	--	--	--	--	--	--
	03-13-95	Dupl	160	78	35	0.80	0.13	31	375	370	<0.01
	03-13-95	Dupl	160	--	--	--	--	--	--	--	--

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Sample type	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, dis (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus ortho, dissolved (mg/L as P)	Carbon, organic, dissolved (mg/L as C)	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)
323611107011501	03-20-95	Nat	1.90	0.030	<0.20	0.01	0.01	1.7	--	--	--
	03-20-95	Nat	--	--	--	--	--	--	4	<2	4
	03-20-95	Dupl	1.90	0.050	<0.20	<0.01	0.01	1.7	--	--	--
	03-20-95	Dupl	--	--	--	--	--	--	4	<2	4
334818106533401	05-02-95	Nat	0.88	<0.015	<0.20	<0.01	0.01	0.1	--	--	--
	05-02-95	Nat	--	--	--	--	--	--	6	<1	16
	05-02-95	Dupl	0.88	<0.015	<0.20	<0.01	<0.01	0.1	--	--	--
	05-02-95	Dupl	--	--	--	--	--	--	6	<1	15
325335107182401	03-13-95	Nat	1.90	0.020	<0.20	0.02	<0.01	0.2	--	--	--
	03-13-95	Nat	--	--	--	--	--	--	3	<1	<1
	03-13-95	Dupl	1.90	<0.015	<0.20	<0.01	<0.01	0.2	--	--	--
	03-13-95	Dupl	--	--	--	--	--	--	5	<1	<1

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Sample type	Barium, dis- solved (µg/L as Ba)	Beryl- lium, dis- solved (µg/L as Be)	Cadmium, dis- solved (µg/L as Cd)	Chro- mium, dis- solved (µg/L as Cr)	Cobalt, dis- solved (µg/L as Co)	Copper, dis- solved (µg/L as Cu)	Iron, dis- solved (µg/L as Fe)	Lead, dis- solved (µg/L as Pb)	Manga- nese, dis- solved (µg/L as Mn)
323611107011 501	03-20-95	Nat	--	--	--	--	--	--	180	--	13
	03-20-95	Nat	17	<2	<2	<2	<2	6	--	<2	9
	03-20-95	Dupl	--	--	--	--	--	--	160	--	10
	03-20-95	Dupl	18	<2	<2	<2	<2	6	--	<2	9
334818106533401	05-02-95	Nat	--	--	--	--	--	--	<3	--	<1
	05-02-95	Nat	78	<1	<1	5	<1	<1	--	<1	<1
	05-02-95	Dupl	--	--	--	--	--	--	<3	--	<1
	05-02-95	Dupl	77	<1	<1	5	<1	<1	--	<1	<1
325335107182401	03-13-95	Nat	--	--	--	--	--	--	<3	--	<1
	03-13-95	Nat	76	<1	<1	<1	<1	<1	--	<1	<1
	03-13-95	Dupl	--	--	--	--	--	--	<3	--	<1
	03-13-95	Dupl	75	<1	<1	<1	<1	<1	--	<1	<1

Table 4.--Quality-control data for wells sampled in the study-unit survey--Continued

Station number	Date	Sample type	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Uranium, natural, dissolved (µg/L as U)	Zinc, dissolved (µg/L as Zn)	Gross alpha, dissolved (µg/L as U-nat)	Alpha count, 2 sigma wat dis as nat U (µg/L)
323611107011501	03-20-95	Nat	--	--	--	--	--	--	11	2.2
	03-20-95	Nat	26	15	1	<2	17	46	--	--
	03-20-95	Dupl	--	--	--	--	--	--	15	2.9
	03-20-95	Dupl	25	17	1	<2	16	47	--	--
334818106533401	05-02-95	Nat	--	--	--	--	--	--	11	2.1
	05-02-95	Nat	7	<1	2	<1	10	7	--	--
	05-02-95	Dupl	--	--	--	--	--	--	13	2.4
	05-02-95	Dupl	7	<1	2	<1	10	15	--	--
325335107182401	03-13-95	Nat	--	--	--	--	--	--	<3.0	0.83
	03-13-95	Nat	3	2	1	<1	2	<1	--	--
	03-13-95	Dupl	--	--	--	--	--	--	<3.0	0.88
	03-13-95	Dupl	3	2	1	<1	2	<1	--	--

Table 4.--Quality-control data for wells sampled in the study-unit survey--Concluded

Station number	Date	Sample type	Gross alpha water, dis as Th-230 (pCi/L)	Alpha count, 2 sigma wat, dis as Th-230 (pCi/L)	Gross beta, dis- solved (pCi/L as Sr-90/ Y-90)	Beta, 2 sigma water, dis as Sr-90 /Y-90 (pCi/L)	Gross beta, dis- solved (pCi/L as Cs-137)	Beta, 2 sigma water, dis as Cs-137 (pCi/L)	Radon-222, total (pCi/L)	Rn-222 2 sigma water, whole, total (pCi/L)
323611107011501	03-20-95	Nat	10	1.9	12	11	28	25	780	30
	03-20-95	Nat	--	--	--	--	--	--	--	--
	03-20-95	Dupl	14	2.5	10	6.9	26	18	770	30
	03-20-95	Dupl	--	--	--	--	--	--	--	--
334818106533401	05-02-95	Nat	10	1.9	9.9	2.1	17	4.9	270	19
	05-02-95	Nat	--	--	--	--	--	--	--	--
	05-02-95	Dupl	12	2.2	9.9	2.1	18	5.0	290	19
	05-02-95	Dupl	--	--	--	--	--	--	--	--
325335107182401	03-13-95	Nat	<3.0	0.82	<4.0	1.5	8.3	4.0	500	26
	03-13-95	Nat	--	--	--	--	--	--	--	--
	03-13-95	Dupl	<3.0	0.84	4.2	1.6	9.5	4.1	440	25
	03-13-95	Dupl	--	--	--	--	--	--	--	--

Table 5.--Selected statistics for spike recoveries

[Given as the percentage (%) of the actual concentration spiked]

Constituent	Number of samples	Mean	Quartiles				
			100% (maximum)	75%	50% (median)	25%	0% (minimum)
Volatile organic compounds							
Benzene	9	64	112	88	50	50	25
Bromoform	9	100	141	118	88	82	71
Carbon tetrachloride	9	74	95	85	75	70	50
Chlorodibromomethane	9	93	132	111	84	79	63
1,4-Dichlorobenzene	9	73	96	83	74	65	48
Dichlorobromomethane	9	80	95	90	80	75	55
1,2-Dichlorethane	9	79	91	91	82	77	54
1,1-Dichloroethylene	9	57	77	69	58	50	35
Ethylbenzene	9	70	96	79	71	58	50
Methylene chloride	9	58	111	67	56	33	22
Methyl tert-butyl ether (MTBE)	9	57	87	73	53	42	35
Tetrachlorethylene	9	64	91	73	68	55	41
1,1,1,-Trichloroethane	9	71	90	86	71	67	48
Trichloroethylene	9	71	86	82	73	68	45
Vinyl chloride	9	66	91	91	65	52	35
Group A pesticides							
Alachlor	9	101	116	110	97	97	89
Alpha HCH	9	89	107	97	83	81	77
Atrazine	9	100	107	106	102	92	89
Benfluralin	9	72	88	83	80	53	49
Butylate	9	100	107	106	101	97	87
Carbaryl	9	126	185	156	152	87	74
Carbofuran	9	129	185	143	128	98	85
Chlorpyrifos	9	76	83	80	76	72	71
Cyanazine	9	100	125	105	98	92	88
DCPA	9	99	116	115	102	81	80

Table 5.--Selected statistics for spike recoveries--Continued

Constituent	Number of samples	Mean	Quartiles 100% (maximum)	75%	50% (median)	25%	0% (minimum)
Group A pesticides--Continued							
Deethyl atrazine	9	52	60	55	50	49	48
Diazinon	9	77	88	88	75	70	69
Dieldrin	9	74	87	79	74	71	59
2,6-Diethylaniline	9	93	107	97	89	88	81
Disulfoton	9	98	134	124	106	65	57
EPTC	9	98	107	106	97	93	88
Ethalfluralin	9	84	101	95	88	76	64
Ethoprop	9	92	107	97	90	87	82
Fonofos	9	87	91	89	87	85	81
Lindane	9	88	98	97	83	82	81
Linuron	9	93	107	98	88	88	86
Malathion	9	86	105	98	87	71	69
Methyl azinphos	9	90	169	86	84	74	60
Methyl parathion	9	94	107	102	98	79	76
Metolachlor	9	99	114	107	97	89	88
Metribuzin	9	82	92	89	88	70	65
Molinate	9	100	107	106	98	97	93
Napropamide	9	93	107	105	98	82	78
Parathion	9	97	114	107	97	88	85
Pebulate	9	95	107	106	93	88	85
Pendimethalin	9	85	101	98	89	66	62
Permethrin	9	16	20	18	17	14	14
Phorate	9	74	87	77	72	69	67
p,p'-DDE	9	59	70	58	57	56	53
Prometon	9	101	112	107	106	89	88

Table 5.--Selected statistics for spike recoveries--Continued

Constituent	Number of samples	Mean	Quartiles 100% (maximum)	75%	50% (median)	25%	0% (minimum)
Group A pesticides--Continued							
Pronamide	9	90	98	94	89	88	81
Propachlor	9	106	115	107	106	102	98
Propanil	9	103	116	115	101	98	88
Propargite	9	66	85	78	64	53	50
Simazine	9	103	107	106	106	101	95
Tebuthiuron	9	125	147	143	124	107	102
Terbacil	9	90	107	97	88	80	79
Terbufos	9	87	107	101	83	80	64
Thiobencarb	9	97	115	98	95	92	88
Triallate	9	84	97	89	86	72	71
Trifluralin	9	74	88	83	79	62	54
Group B pesticides							
Aldicarb	6	69	84	73	72	62	49
Aldicarb sulfone	6	18	32	21	18	17	6
Aldicarb sulfoxide	6	78	92	87	79	67	63
Bentazon	6	90	104	99	91	79	79
Bromacil	6	85	100	87	85	83	72
Bromoxynil	6	82	95	90	82	73	68
Carbaryl	6	16	28	24	15	6	6
Carbofuran	6	60	72	71	61	53	42
Chlorothalonil	6	33	76	54	30	6	5
2,4-D	6	75	86	83	76	66	64
2,4-DB	6	51	58	57	49	47	47
Dicamba	6	69	87	76	74	61	41
Dichlorprop	6	81	95	90	80	70	68
Dinoseb	6	78	89	87	79	70	66
Diuron	6	71	87	86	69	61	56

Table 5.--Selected statistics for spike recoveries--Concluded

Constituent	Number of samples	Mean	Quartiles 100% (maximum)	75%	50% (median)	25%	0% (minimum)
Group B pesticides--Continued							
Fenuron	6	90	105	100	91	78	75
Fluometuron	6	86	100	89	87	86	66
Linuron	3	86	88	88	86	83	83
MCPA	6	76	87	81	77	67	67
Methiocarb	3	23	26	26	23	19	19
Methomyl	6	90	107	96	91	83	75
1-Naphthol	6	28	41	36	28	24	9
Neburon	6	68	76	72	67	65	62
Ocresol	6	110	127	117	111	103	90
Oxamyl	6	17	50	15	13	8	5
Picloram	6	66	79	73	65	62	51
Propham	6	91	168	167	73	37	31
Propoxur	6	60	76	67	61	49	45
Silvex	6	82	90	89	84	76	70
2,4,5-T	6	69	73	72	70	67	62

Table 6.--Selected statistics for well construction data, field parameters, major constituents, and nutrients

[MRL, minimum reporting level listed in table 2; --, not applicable; %, percent; <, less than; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter]

Constituent	Number of samples	Number less than MRL	Unit of measurement	Quartiles				
				100 % (maximum)	75%	50% (median)	25%	0% (minimum)
Depth to top of sample interval	30	--	Feet	345	231.5	161.5	78	10
Depth to bottom of sample interval	30	--	Feet	355	241	169	90	50
Depth to water	20	--	Feet	62.85	32.16	12.11	8.94	2.55
Dissolved solids	30	--	mg/L	3,380	706	409.5	277	209
Specific conductance	30	--	µS/cm	4,110	1,065	644	423	280
pH (field)	30	--	Standard units	8.58	8.07	8.00	7.70	7.31
Water temperature	30	--	°C	24.0	19.0	18.5	17.0	14.5
Dissolved oxygen	30	2	mg/L	7.8	0.6	0.1	0.1	<0.05
Calcium	30	0	mg/L	450	120	34.5	28	7.1
Magnesium	30	0	mg/L	74	17	9.45	4.9	1.6
Sodium	30	0	mg/L	430	120	66.5	45	14
Potassium	30	0	mg/L	30	6.7	4.9	3.5	1.4
Bicarbonate	30	0	mg/L	05	214	171.5	144	50
Carbonate	30	0	mg/L	6	0	0	0	0
Alkalinity (gran titration)	30	--	mg/L as $CaCO_3$	329	174	142	116	50
Sulfate	30	0	mg/L	1,500	220	98.5	55	26
Chloride	30	0	mg/L	430	99	44	16	7.1
Fluoride	30	0	mg/L	4.6	0.90	0.50	0.30	0.20
Bromide	30	0	mg/L	0.62	0.21	0.115	0.07	0.030
Silica	30	0	mg/L	77	48	36.5	29	23
Ammonia as nitrogen	30	14	mg/L	0.250	0.030	0.020	<0.015	<0.015
Nitrite as nitrogen	30	28	mg/L	0.02	<0.01	<0.01	<0.01	<0.01
Ammonia plus organic nitrogen as nitrogen	30	27	mg/L	0.30	<0.20	<0.20	<0.20	<0.20
Nitrite plus nitrate as nitrogen	30	19	mg/L	1.90	0.22	<0.05	<0.05	<0.05
Phosphorus	30	18	mg/L	0.11	0.02	<0.01	<0.01	<0.01
Orthophosphorus	30	13	mg/L	0.14	0.02	0.01	<0.01	<0.01
Dissolved organic carbon	30	3	mg/L	2.6	1.6	0.4	0.2	<0.1

Table 7.--Selected statistics for trace elements and radiochemicals

[MRL, minimum reporting level listed in table 2; µg/L, micrograms per liter; pCi/L, picocuries per liter; %, percent; <, less than]

Constituent	Number of samples	Number less than MRL	Unit of measurement	Quartiles				
				100 % (maximum)	75%	50% (median)	25%	0 % (minimum)
Aluminum	30	0	µg/L	15	4	3.5	3	3
Antimony	30	30	µg/L	<2	<1	<1	<1	<1
Arsenic	30	1	µg/L	48	11	5.5	3	<1
Barium	30	0	µg/L	212	83	62	27	12
Beryllium	30	30	µg/L	<2	<1	<1	<1	<1
Cadmium	30	30	µg/L	<2	<1	<1	<1	<1
Chromium	30	17	µg/L	12	2	<1	<1	<1
Cobalt	30	29	µg/L	1	<1	<1	<1	<1
Copper	30	16	µg/L	6	2	<1	<1	<1
Iron	30	16	µg/L	550	40	<3	<3	<3
Lead	30	27	µg/L	2	<1	<1	<1	<1
Manganese	30	10	µg/L	654	69	8	<1	<1
Molybdenum	30	0	µg/L	59	7	4.5	3	2
Nickel	30	10	µg/L	15	4	1.5	<1	<1
Selenium	30	21	µg/L	8	1	<1	<1	<1
Silver	30	30	µg/L	<2	<1	<1	<1	<1
Uranium	30	7	µg/L	102	7	3	2	<1
Zinc	30	1	µg/L	65	11	4	2	<1
Gross alpha as natural uranium	30	14	µg/L	48	6.2	3.15	<3	<3
Gross alpha as thorium-230	30	14	pCi/L	46	5.9	3.1	<3	<3
Gross beta as strontium-90/ yttrium-90	30	8	pCi/L	56	9.6	6.3	<4	<4
Gross beta as cesium-137	30	3	pCi/L	120	15	9.7	6.5	<4
Radon-222	29	0	pCi/L	2,300	500	380	270	190

Table 8.--Selected U.S. Environmental Protection Agency drinking-water standards and samples exceeding them

[All values are in milligrams per liter, unless stated otherwise. --, none; pCi/L, picocuries per liter; mrem, millirem; <, less than; >, greater than; U.S. Environmental Protection Agency, 1996 and U.S. Congress, 1996]

Constituent	Maximum contaminant level		Secondary maximum contaminant level		Lifetime health advisory	
	Value	Well reference numbers of samples exceeding	Value	Well reference numbers of samples exceeding	Value	Well reference numbers of samples exceeding
Aluminum	--	--	<0.05 or >0.2	--	--	--
Ammonia (as N)	--	--	--	--	30	--
Antimony	0.006	--	--	--	0.003	--
Arsenic	0.05	--	--	--	--	--
Barium	2	--	--	--	2	--
Beryllium	0.004	--	--	--	--	--
Cadmium	0.005	--	--	--	0.005	--
Chloride	--	--	250	8, 18	--	--
Chromium (total)	0.1	--	--	--	0.1	--
Copper	1.3	--	1.0	--	--	--
Dissolved solids	--	--	500	1, 4-8, 10, 17-19, 23, 24	--	--
Fluoride	4	4	2	4, 14	--	--
Gross alpha particle activity	15 pCi/L	10	--	--	--	--
Beta particle and photon activity	4 mrem	--^{2}	--	--	--	--
Iron	--	--	0.3	7, 18	--	--
Lead	0.015	--	--	--	--	--
Manganese	--	--	0.05	4-7, 9-12, 17, 18	--	--
Molybdenum	--	--	--	--	0.04	4
Nickel	0.1	--	--	--	0.1	--
Nitrite (as N)	1	--	--	--	--	--
Nitrite plus nitrate (as N)	10	--	--	--	--	--
pH	--	--	<6.5 or >8.5	1, 2, 20	--	--
Prometon	--	--	--	--	0.1	--
Radon^3	--	--	--	--	--	--
Selenium	0.05	--	--	--	--	--
Silver	--	--	0.1	--	0.1	--
Sulfate	500^1	8, 10	250	4, 6-8, 10, 18, 24	--	--
Uranium	0.02^1	10	--	--	--	--
Zinc	--	--	5	--	2	--

[1] Proposed standard.

[2] Compliance with this standard cannot be determined from current data.

[3] Previously proposed standard of 300 pCi/L rescinded (U.S. Congress, 1996).

Table 9.--Average concentrations of major constituents in area surface water (1980 to 1992) and precipitation

[All concentrations are dissolved and are given in milligrams per liter]

Constituent	Average concentration for Rio Grande at Albuquerque	Average concentration for Rio Grande below Elephant Butte Dam	Average concentration for Rio Grande at El Paso	Average concentration for Albuquerque bulk precipitation	Average concentration for Socorro bulk precipitation
Calcium	41.3	50.8	94.9	2.1	8.0
Magnesium	7.1	9.8	20.8	--	--
Sodium	25.1	49.0	181.8	0.30	1.6
Potassium	3.3	4.4	8.2	--	--
Bicarbonate	--	--	170.3	--	--
Carbonate	--	--	2.8	--	--
Sulfate	66.0	101.4	306.8	2.2	8.9
Chloride	10.7	26.3	150.0	2.7	3.4
Fluoride	0.4	0.4	0.6	--	--
Silica	19.2	15.9	19.5	--	--

Table 10.--Saturation indices of selected minerals in the study area

[Also included are values for total carbon, in millimoles, and for the partial pressure of carbon dioxide (pCO_2), in atmospheres. The saturation indices are unitless. If the saturation index is negative, the ground water is undersaturated with respect to that mineral and the mineral could dissolve. If the saturation index is greater than zero, the ground water is saturated or supersaturated with respect to that mineral and the mineral could precipitate]

Well reference number (fig. 6)	Total carbon	Calcite $CaCO_3$	Dolomite $CaMg(CO_3)_2$	Gypsum $CaSO_4$	Barite $BaSO_4$	Fluorite CaF_2	pCO_2
1	0.94	0.22	-0.23	-1.69	0.58	-1.98	-3.82
2	1.66	0.39	0.11	-1.90	0.23	-2.12	-3.60
3	1.33	0.21	-0.37	-2.20	-0.27	-2.27	-3.62
4	6.86	0.13	-0.14	-1.42	-0.17	-0.03	-2.06
5	3.18	0.37	0.30	-1.19	0.76	-1.84	-2.51
6	4.23	0.66	0.80	-0.96	1.02	-2.11	-2.42
7	4.82	0.70	0.76	-1.03	0.54	-1.84	-2.48
8	4.04	0.38	0.24	-0.18	0.18	-0.08	-2.07
9	2.72	0.54	0.49	-1.67	0.39	-2.00	-2.92
10	3.92	0.42	0.43	-0.77	0.54	-2.00	-2.16
11	3.56	0.36	0.29	-1.73	0.12	-2.01	-2.54
12	3.42	0.51	0.44	-1.61	0.60	-1.76	-2.80
13	2.86	0.13	-0.18	-2.22	0.03	-1.43	-2.86
14	2.85	0.17	-0.30	-2.23	0.12	-0.63	-2.82
15	2.40	0.11	-0.48	-2.10	-0.38	-1.55	-2.89
16	3.29	0.15	-0.37	-1.70	0.21	-1.16	-2.32
17	4.99	0.65	0.66	-1.15	0.72	-1.81	-2.45
18	3.40	0.33	0.36	-1.03	0.28	-0.76	-2.46
19	2.63	0.08	0.04	-1.73	-0.07	-1.42	-2.90
20	2.63	0.02	-0.32	-2.43	-0.12	-1.70	-3.43
21	2.51	0.08	-0.21	-2.32	0.09	-1.96	-2.94
22	2.80	0.08	-0.05	-2.46	-0.14	-1.69	-3.22
23	2.62	-0.25	-0.84	-2.22	-0.40	-1.71	-2.24
24	3.18	0.28	0.04	-1.00	0.71	-1.26	-2.39
25	2.40	0.09	-0.07	-2.34	-0.12	-1.76	-2.91

Table 10.--Saturation indices of selected minerals in the study area--Concluded

Well reference number (fig. 6)	Total carbon	Calcite $CaCO_3$	Dolomite $CaMg(CO_3)_2$	Gypsum $CaSO_4$	Barite $BaSO_4$	Fluorite CaF_2	pCO_2
26	2.05	0.06	-0.40	-2.38	0.06	-2.18	-3.03
27	2.33	0.07	-0.33	-2.25	-0.35	-1.76	-2.89
28	2.21	0.07	-0.17	-2.16	0.02	-1.96	-2.84
29	2.34	0.08	-0.13	-2.32	0.10	-1.78	-2.91
30	1.88	0.10	-0.21	-2.20	0.18	-2.21	-3.14

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