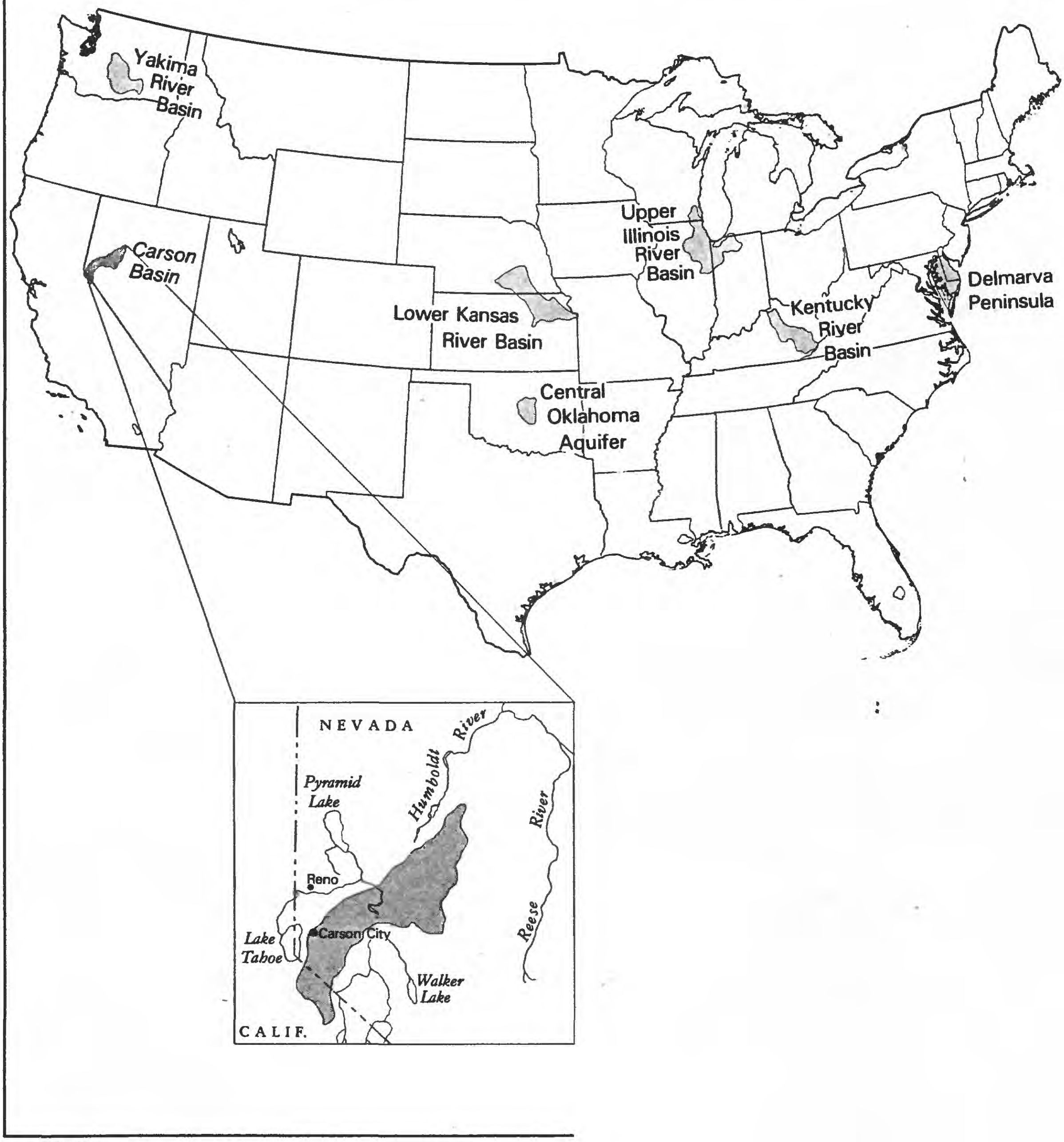
GROUND-WATER-QUALITY ASSESSMENT OF THE CARSON RIVER BASIN, NEVADA AND CALIFORNIA: ANALYSIS OF AVAILABLE WATER-QUALITY DATA THROUGH 1987



U.S. GEOLOGICAL SURVEY
Open-File Report 89—382

NATIONAL WATER - QUALITY ASSESSMENT PROGRAM

CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to metric (International system) units by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
Acre	0.4047	Square hectometer (hm^2)
Acre-foot (acre-ft)	0.001233	Cubic hectometer (hm^3)
Acre-foot per year (acre-ft/yr)	1,233	Cubic meter per year (m^3/yr)
Cubic foot per second (ft^3/s)	0.0283	Cubic meter per second (m^3/s)
Foot (ft)	0.3048	Meter (m)
Gallon (gal)	0.003785	Cubic meter (m^3)
Inch (in.)	25.40	Millimeter (mm)
Inch per year (in/yr)	25.40	Millimeter per year (mm/yr)
Mile (mi)	1.609	Kilometer (km)
Square mile (mi^2)	2.590	Square kilometer (km^2)

For temperature, degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [(1.8) (°C)] + 32.

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

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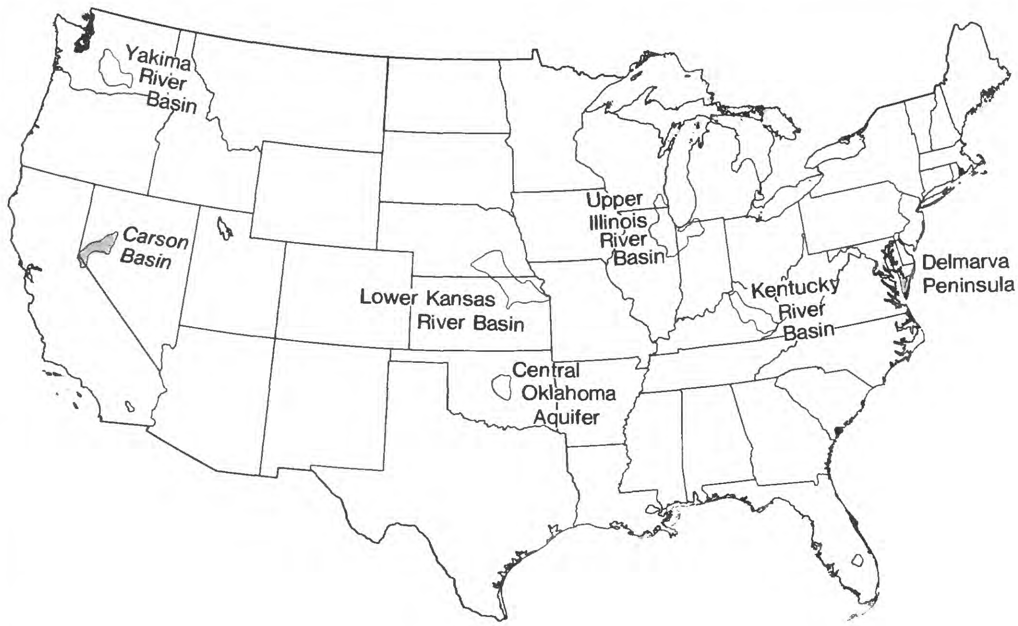
By Alan H. Welch, Russell W. Plume, Elizabeth A. Frick, and Jennifer L. Hughes



U.S. GEOLOGICAL SURVEY
Open-File Report 89—382

1989

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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FOREWORD

One of the great challenges faced by water-resources scientists is providing reliable water-quality information to guide the management and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resources agencies and by academic institutions. Many of these organizations are collecting water-quality data for a host of purposes, including compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research to advance our understanding of water-quality processes. In fact, during the past two decades, tens of billions of dollars have been spent on water-quality data-collection programs. Unfortunately, the utility of these data for present and future regional and national assessments is limited by such factors as the areal extent of the sampling network, the frequency of sample collection, the varied collection and analytical procedures, and the types of water-quality characteristics determined.

To address this deficiency, the Congress appropriated funds for the U.S. Geological Survey, beginning in 1986, to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program that, if fully implemented, would:

1. Provide a nationally consistent description of water-quality conditions for a large part of the Nation's water resources;

2. Define long-term trends (or lack of trends) in water quality; and

3. Identify, describe, and explain, as possible, the major factors that affect observed water-quality conditions and trends.

As presently envisioned, a full-scale NAWQA Program would be accomplished through investigations of a large set of major river basins and aquifer systems that are distributed throughout the Nation and that account for a large percentage of the Nation's population and freshwater use. Each investigation would be conducted by a small team that is familiar with the river basin or aquifer system. Thus, the investigations would take full advantage of the region-specific knowledge of persons in the areas under study.

Four surface-water projects and three ground-water projects are being conducted as part of the pilot program to test and refine the assessment methods and to help determine the need for and the feasibility of a full-scale program. An initial activity of each pilot project is to compile, screen, and interpret available data to provide an initial description of water-quality conditions and trends in the study area. The results of this analysis of available data are presented in individual reports for each project.

The pilot studies depend heavily on cooperation and information from many Federal, State, interstate, and local agencies. The assistance and suggestions of all are gratefully acknowledged.

Philip Cohen
Chief Hydrologist

(p. v follows)

CONTENTS

ILLUSTRATIONS

[Plate is in pocket at back of report]

Page

TABLES

Page

GROUND-WATER-QUALITY ASSESSMENT OF THE CARSON RIVER BASIN, NEVADA AND CALIFORNIA: ANALYSIS OF AVAILABLE WATER-QUALITY DATA THROUGH 1987

By Alan H. Welch, Russell W. Plume, Elizabeth A. Frick, and Jennifer L. Hughes

EXECUTIVE SUMMARY

Background

Beginning in 1986, the Congress has annually appropriated funds for the U.S. Geological Survey to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program. The long-term goals of a full-scale program would be to (1) provide a nationally consistent description of current water-quality conditions for a large part of the Nation's surface- and ground-water resources, (2) define long-term trends (or lack of trends) in water quality, and (3) identify, describe, and explain, as possible, the major factors that affect the observed water-quality conditions and trends.

At present (1988), the assessment program is in a pilot phase in seven project areas throughout the country that represent diverse hydrologic environments and water-quality conditions. One of these is the Carson River basin of western Nevada and eastern California (fig. 1). This report summarizes ground-water quality in the Carson River basin on the basis of data available through 1987. The report also provides an overview of the hydrogeologic framework of the basin and land and water uses within the basin.

Initial activities of the Carson River basin pilot project have focused on compiling, screening, and analyzing existing data on ground-water quality within the basin. Considerable data on inorganic constituents in ground water, and much smaller amounts of data on manmade organic compounds, have been collected in the basin by several organizations and agencies of Federal, State, and local government for a variety of reasons. The purposes of this part of the pilot project are to (1) obtain data on ground-water quality for the Carson River basin from various sources; (2) consolidate and organize the information into a usable data base stored on a computer; (3) define the hydrogeologic setting and the land and water uses of the Carson River basin; and (4) define ground-water quality and, to the extent possible, relate the quality to present knowledge of geologic, hydrologic, and land-use and water-use factors.

At present, available water-quality data are not sufficient to fully define the quality of ground water in the Carson River basin because sample sites are not distributed throughout the basin and many samples were analyzed for only a limited set of constituents. Thus, this part of the pilot project provides a preliminary overview of ground-water quality in the basin. The knowledge gained is being used to guide later phases of the project.

The Carson River basin encompasses 3,980 square miles in the western Great Basin and eastern Sierra Nevada. Most of the region is arid to semiarid, having an annual precipitation that ranges from about 2 to 15 inches. The only exceptions are the mountainous areas along the western boundary where annual precipitation is 30 inches or more. The basin consists of six hydrographic areas: a mountainous Headwaters Area, mostly in California, and five downstream hydrographic areas, each generally corresponding to an alluvial valley with bordering hills or mountains, through which the Carson River flows. The hydrographic areas (fig. 2) are, in downstream order, Headwaters Area, Carson Valley, Eagle Valley, Dayton Valley, Churchill Valley, and the Carson Desert.

Each of the alluvial valleys is underlain by a structural basin bounded by consolidated rocks of adjacent mountain ranges. Basin-fill deposits have accumulated in these structural basins to depths of as much as 5,000 feet in Carson Valley and 12,000 feet in the Carson Desert. Most aquifers in the the Carson River basin are in basin-fill sedimentary deposits, except for a basalt aquifer that is interbedded with the basin fill near Fallon in the Carson Desert. The ground-water system in each valley generally consists of a shallow water-table aquifer, which is hydraulically connected to the Carson River, and one or more deeper confined aquifers. The degree to which these ground-water systems are understood differs from valley to valley. The ground-water systems in Carson and Eagle Valleys and in the southern Carson Desert have been studied in detail and are fairly well understood. In contrast, other parts of the basin have been studied only at the reconnaissance level and are poorly understood.

Land use in the Carson River basin is dominated by rangeland (46 percent), barren land (25 percent), and forest land (18 percent). Forest land predominates in the upstream part of the basin, whereas range and barren lands predominate in the downstream part.

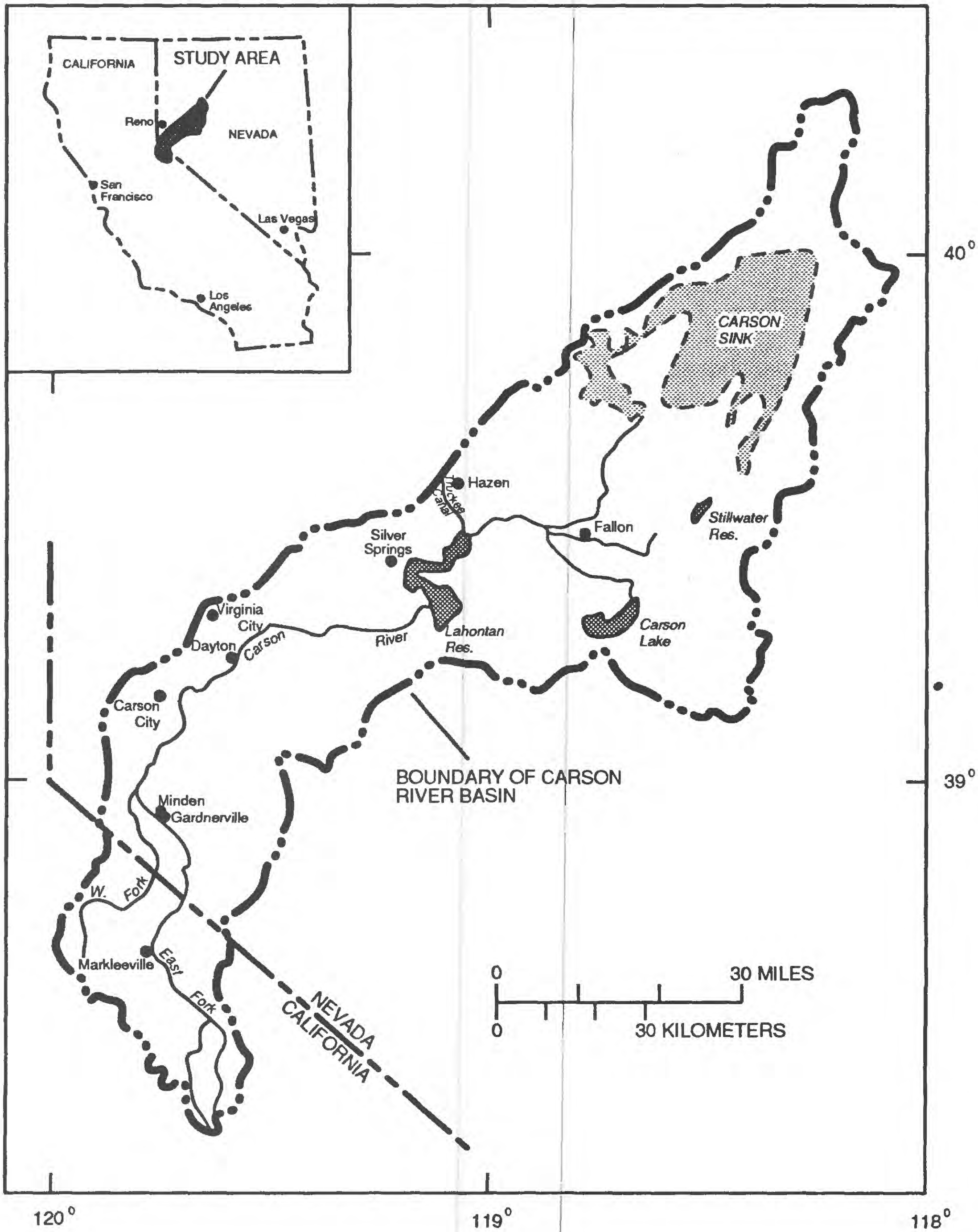

Figure 1.—Location of the Carson River basin.

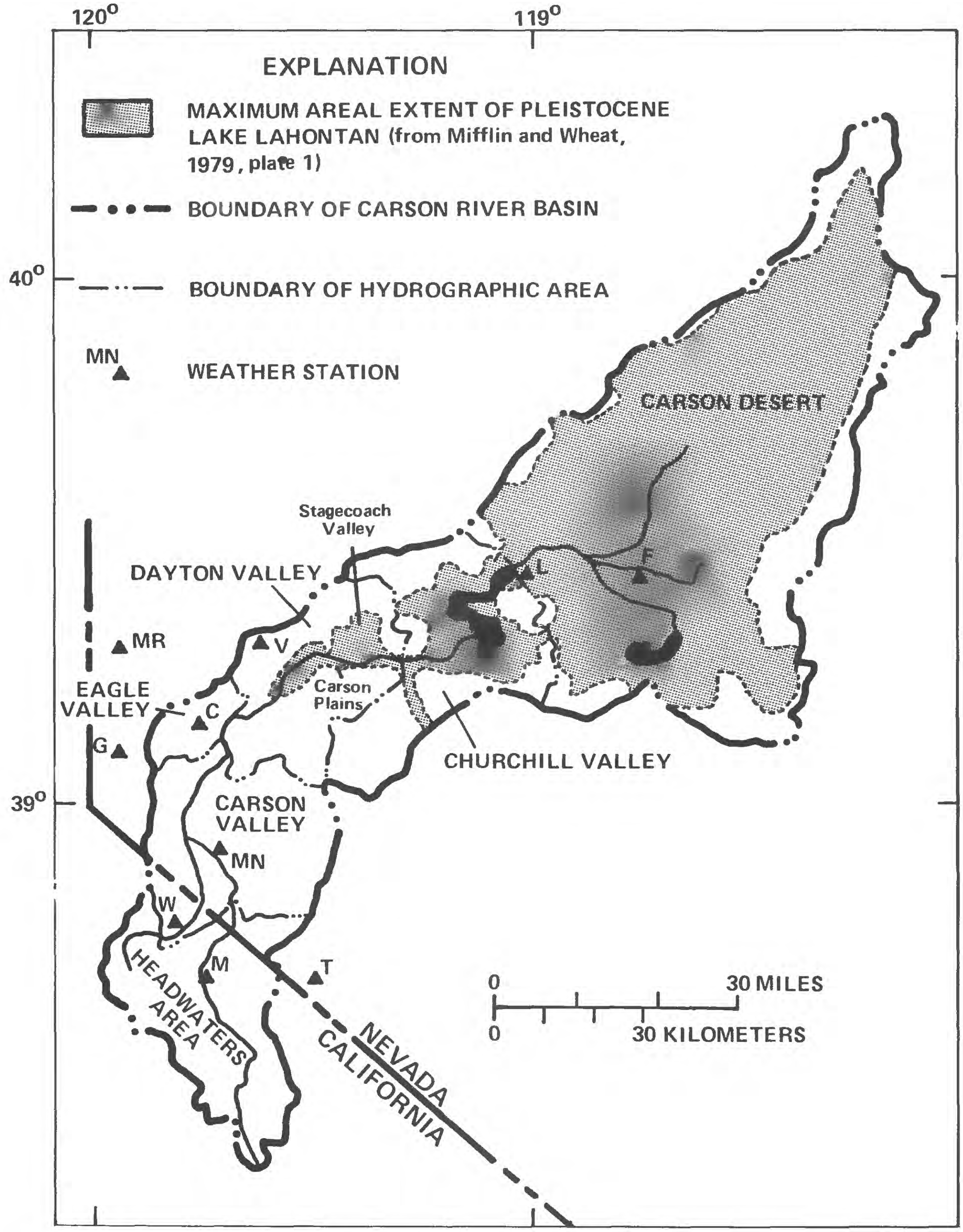

Figure 2.—Hydrographic areas in the Carson River basin and weather stations in and adjacent thereto. Abbreviations for the weather stations: C, Carson City; F, Fallon; G, Glenbrook; L, Lahontan Dam; M, Markleeville; MN, Minden; MR, Mount Rose; T, Topaz Lake; V, Virginia City; W, Woodfords.

The extent of water bodies and wetlands is highly variable within a year and among years, particularly in the Carson Desert. Over 90 percent of the agricultural land in the basin is in Carson Valley and Carson Desert, and approximately 90 percent of the urban or built-up land is in Carson Valley, Eagle Valley, and the Carson Desert. The main change in land use within the basin in the last 25 years has been the conversion of agricultural and rangeland to urban land.

In 1985, the estimated total water withdrawal in the Carson River basin was 640,000 acre-feet, which included reclaimed sewage imports from the Lake Tahoe basin west of the study area and surface-water imports from the Truckee River basin to the north. Approximately 93 percent of withdrawal was surface water, 6 percent was ground water, and less than 1 percent was reclaimed sewage. Although ground water accounts for only a small percentage of the total water withdrawal, it supplies 85 percent (17,000 acre-feet) of the water withdrawn for public water supply and for self-supplied domestic use. Eighty percent of ground-water withdrawal was in Carson, Eagle, and Dayton Valleys, and over 90 percent of total water withdrawal was in Carson Valley and the Carson Desert where the agricultural land is concentrated.

Sources of Water-Quality Data

Data for inorganic constituents and properties of ground water are from three principal sources: the Nevada State Health Laboratory; the U.S. Geological Survey; and the Desert Research Institute, which is part of the University of Nevada system. Data from sources other than these comprise a small part of the total available.

The available data for inorganic compounds and properties were compiled into a computer data base. The system used for this purpose was the National Water Information System (NWIS), which is routinely employed to store water data collected by the U.S. Geological Survey. Data were tested against two criteria to qualify for storage in the computer data base: (1) the site location for each sample was verifiable, and (2) the sampled water had not been treated by chlorination or softening. Verification of site location was generally unambiguous. However, some of the analyses used for this study could represent treated water.

In spite of the precautions taken, the uses of the compiled data are limited. This mainly is a result of the methods used to collect and preserve samples, which, in turn, are a reflection of the differing reasons for taking the samples. Samples that are sent to the Nevada State Health Laboratory are collected to determine water quality at the point of human consumption. Such samples may be collected by individual homeowners and may not always be collected or preserved using standardized methods that are necessary for assessment of water quality in the aquifer. In contrast, the U.S. Geological Survey and Desert Research Institute attempt to collect a sample representative of water from the aquifer. Parts of the sample may be filtered, chemically preserved, and chilled during shipment. Because of these differences in collection and preservation procedures, samples collected for the Nevada State Health Laboratory may be more representative of the quality of water at its point of use, whereas samples collected by the U.S. Geological Survey and Desert Research Institute may be more representative of the quality in the aquifer.

Arsenic, iron, and manganese values from samples collected in Carson Valley for analysis by the Nevada State Health Division and the U.S. Geological Survey laboratories were compared statistically in an effort to determine whether the different sample-collection and preservation methods make a difference in the analytical results. These constituents were chosen because they are believed to be sensitive to differences in sampling and preservation methods. The data from Carson Valley were used because all the samples appear to have come from the same ground-water system. The comparisons suggest that differences in sample collection and preservation methods do not have a substantial effect on arsenic and manganese values, but can affect values for iron.

Analysis of Available Water-Quality Data

Because of the limitations in the available data, interpretations of the data compiled for this study were limited to describing the general chemical quality of ground water, its suitability for irrigation use, and its suitability for human consumption on the basis of State and Federal drinking-water standards. Compiled water-quality data indicate, in a very broad sense, that solute concentrations in ground water are progressively greater proceeding from the upper to the lower hydrographic areas (table 1). In addition to generally increasing concentrations of the major constituents, the concentrations of arsenic, iron, manganese, and fluoride also are greater in the lower part of the river basin. For the reasons cited earlier, the iron data in table 1 are for unfiltered samples only (most of the available iron analyses were made on unfiltered samples), whereas all other data reflect analyses of both filtered and unfiltered samples.

Table 1.—*Median values for selected water-quality constituents and properties in nonthermal ground water, by hydrographic area*[1]

[Concentrations are in milligrams per liter; sodium-absorption ratio is a dimensionless quantity]

Constituent or property[2]	Carson Valley	Eagle Valley	Dayton Valley	Churchill Valley	Carson Desert
Arsenic	<0.005	<0.005	<0.005	0.015	0.065
Boron	0.1	<0.05	0.25	0.10	9.8
Chloride	7	4	16	15	63
Dissolved solids	200	150	490	340	700
Fluoride	0.2	0.2	0.3	0.3	0.7
Iron, unfiltered samples	0.07	0.08	0.11	0.17	0.145
Manganese	0.010	0.020	0.010	0.10	0.035
Nitrate, as N	0.7	0.6	0.7	0.2	0.1
Sodium-absorption ratio	0.6	0.5	0.7	0.7	11
Sulfate	23	5	160	92	77

[1]Median values are not listed for Headwaters Area or for iron on filtered samples because of the small number of available determinations. Values listed herein are based on numbers of available determinations that range from 22 to 302.

[2]Except for iron, determinations were made on both filtered and unfiltered samples.

Although the data in table 1 indicate generally increasing concentrations in a downstream direction, only broad comparisons of the ground-water quality may be drawn because the data do not represent a consistent sampling strategy with respect to hydrogeologic and geochemical characteristics of the various hydrographic areas—for instance, shallow ground water has been sampled to a much greater extent in the Carson Desert than in most of the other hydrographic areas. Nonetheless, the compiled data are believed to be adequate for the purpose of broadly describing the inorganic ground-water quality of major and some minor constituents in the Carson River basin.

The relative proportions of major ions in ground water in the Carson River basin does not appear to differ greatly from valley to valley, except for the Carson Desert. Major cations in all but the Carson Desert are, in order of abundance, calcium, magnesium, sodium, and potassium. Major anions in all but the Carson Desert are, in order of abundance, bicarbonate, sulfate, and chloride. In contrast, ground water in the Carson Desert generally is dominated by sodium and chloride. The main reason for these differences is that for the past several tens of thousands of years, the Carson River and, at times, other streams carried salts that were deposited with lake sediments in the Carson Desert. Shallow aquifers in this valley are partly composed of these sediments.

Table 2 lists inorganic constituents and properties that exceeded State drinking-water standards, and those that did not, in each hydrographic area of the Carson River basin. Figure 3 shows the frequencies with which standards for inorganic constituents and properties were exceeded in each hydrographic area. In Carson and Eagle Valleys, iron and manganese concentrations exceed State drinking-water standards in more than 5 percent of the compiled analyses. In Dayton and Churchill Valleys, dissolved-solids, iron, manganese, and sulfate concentrations exceed the State drinking-water standards in more than 10 percent of the samples. The analyses of ground water from the Carson Desert indicate a high frequency of standard exceedance for arsenic, chloride, dissolved solids, fluoride, iron, manganese, pH, and sulfate. The general increase in inorganic constituent concentrations in a downstream direction is reflected in a general increase in the frequency of exceedance of drinking-water standards in this direction as shown in figure 3C.

Natural geochemical reactions, rather than introduction of pollutants by man, appear to be the primary factors responsible for the presence of concentrations of inorganic constituents that exceed the drinking-water standards. High concentrations of some of these constituents are associated with particular parts of the Carson River basin, whereas others generally are scattered throughout most of the basin.

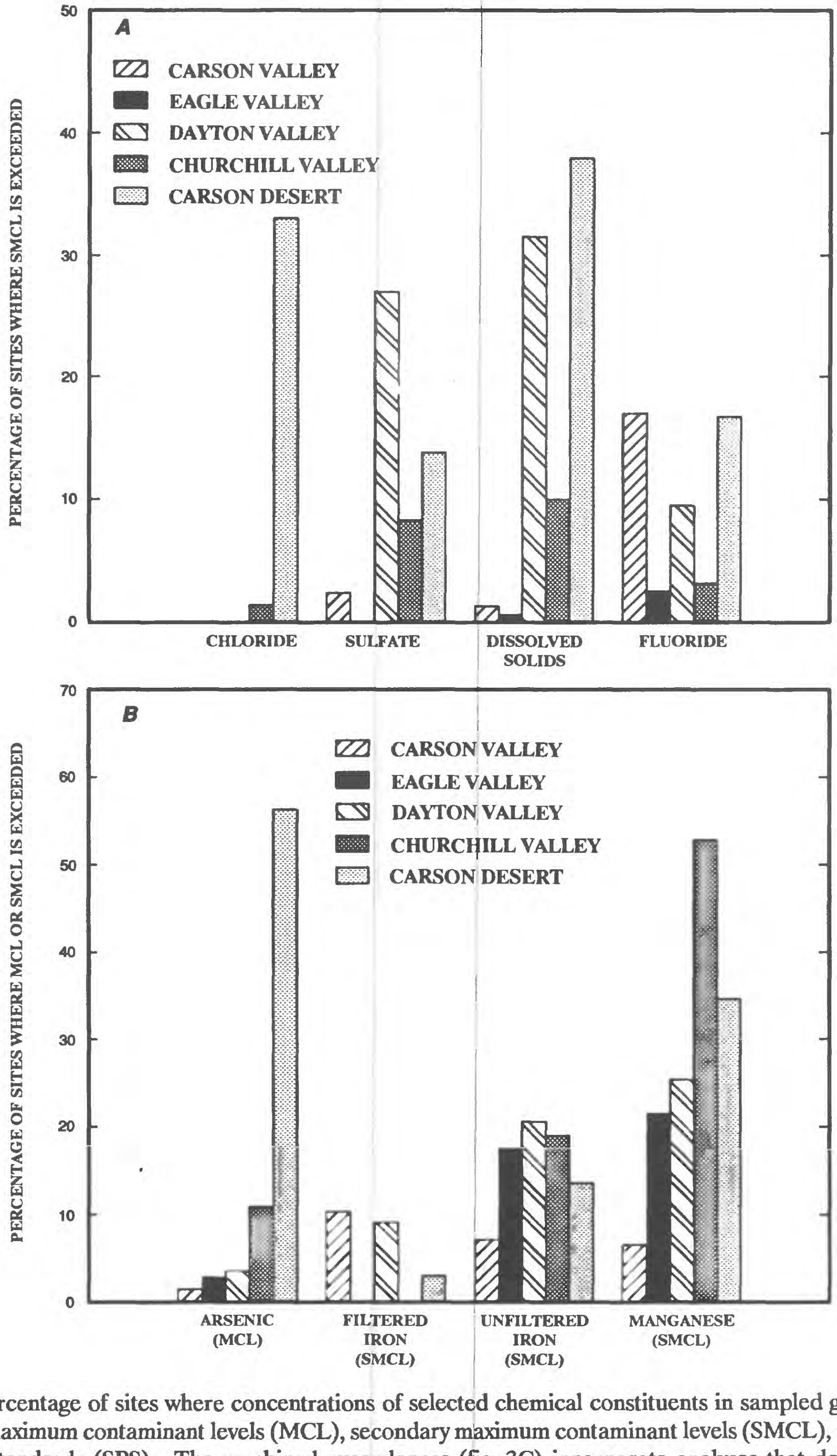

Figure 3.—Percentage of sites where concentrations of selected chemical constituents in sampled ground water exceeded maximum contaminant levels (MCL), secondary maximum contaminant levels (SMCL), or secondary preferred standards (SPS). The combined exceedances (fig. 3C) incorporate analyses that do not include determinations for all the inorganic constituents having drinking-water standards. Therefore, the percentages may underestimate the frequency with which sampled ground water exceeds one or more inorganic standards.

High concentrations of fluoride and sulfate, for example, commonly are found in association with thermal water in Carson and Dayton Valleys. High sulfate concentrations also are present in the vicinity of gypsum (calcium sulfate) and gypsite deposits in the western part of Dayton Valley. High iron and manganese concentrations are scattered throughout most of the hydrographic areas. Ground water with high chloride and dissolved-solids concentrations is common in the Carson Desert because of high evapotranspiration rates and, probably, dissolution of soluble salts in the basin-fill deposits. In general, the number of constituents that exceed drinking-water standards and the frequencies with which they exceed those standards increase in areas downstream from Carson and Eagle Valleys. A contributing factor is the presence of sediments deposited during high levels of Pleistocene Lake Lahontan which, at its maximum extent, covered areas as far west as Carson Plains (fig. 2).

In addition to the constituents discussed above, a number of others have been detected in ground water in the basin. These other constituents are not discussed in detail because concentrations seldom exceed drinking-water standards or because few analyses are available. Inorganic constituents that seldom exceed drinking-water standards include barium, copper, nitrate, and zinc. Except for Carson Valley, each of the hydrographic areas in the Carson River basin has fewer than 30 analyses for cadmium, chromium, lead, mercury, selenium, and silver.

Existing data are not sufficient to describe concentrations of manmade organic compounds throughout the Carson River basin. In the few areas with such data, concentrations exceeding established drinking-water standards are associated with accidental spills and leaks of fuels and solvents. Places where these compounds have been found in ground water include urban and industrial areas, a waste-disposal

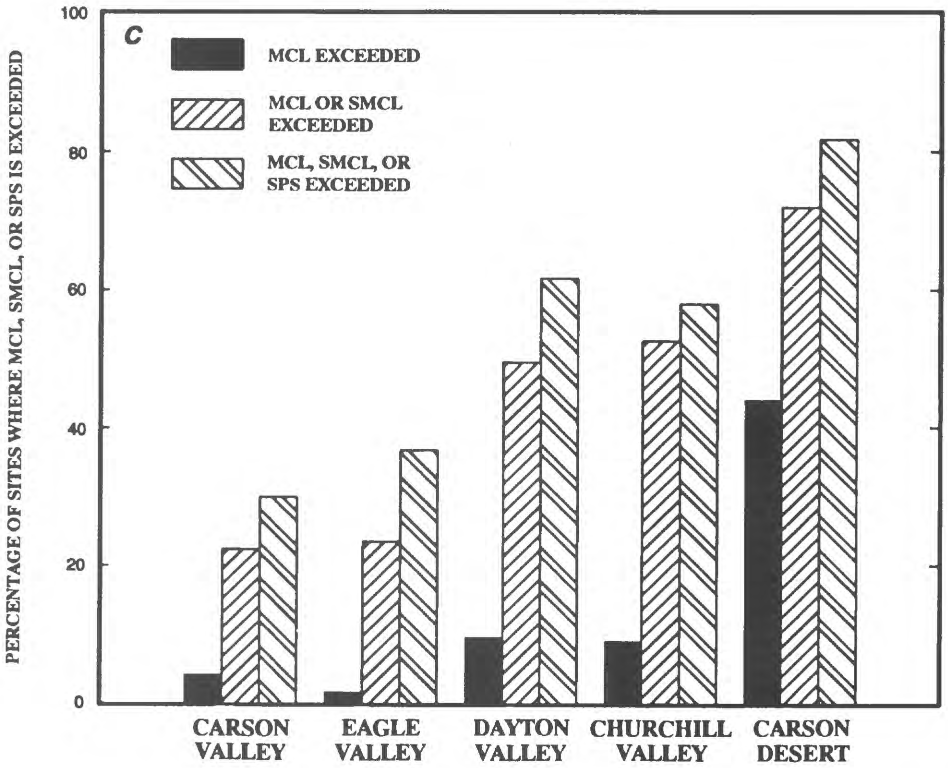

Figure 3.—Continued.

Table 2.—*Summary of ground-water constituents and properties, by hydrographic area*[1], *that exeed and do not exceed State maximum contaminant levels (MCL) or secondary maximum contaminant levels (SMCL)*

[Constituents having MCL's are capitalized and listed first; constituents and properties having SMCL's are lowercase and listed last]

Hydrographic area	30 or more sample sites per hydrographic area: MCL or SMCL exceeded at less than 5 percent of sites	30 or more sample sites per hydrographic area: MCL or SMCL exceeded at more than 5 percent of sites	Less than 30 sample sites per hydrographic area
Carson Valley	ARSENIC, BARIUM, CADMIUM, CHROMIUM, LEAD, MERCURY, NITRATE, SELENIUM, SILVER, chloride, copper, dissolved solids, magnesium, sulfate	FLUORIDE, iron, manganese, pH	[None]
Eagle Valley	ARSENIC, BARIUM, FLUORIDE, NITRATE, chloride, copper, dissolved solids, magnesium, pH, sulfate	Iron, manganese	CADMIUM, CHROMIUM, LEAD, MERCURY, SELENIUM, SILVER
Dayton Valley	ARSENIC, BARIUM, NITRATE, chloride, copper, magnesium, pH	FLUORIDE, dissolved solids, iron, manganese, sulfate	CADMIUM, CHROMIUM, LEAD, MERCURY, SELENIUM, SILVER
Churchill Valley	FLUORIDE, NITRATE, chloride, magnesium, pH	ARSENIC, dissolved solids, iron, manganese, sulfate	BARIUM, CADMIUM, CHROMIUM, LEAD, MERCURY, SELENIUM, SILVER, copper
Carson Desert	NITRATE, magnesium	ARSENIC, FLUORIDE, chloride, dissolved solids, iron, manganese, pH, sulfate	BARIUM, CADMIUM, CHROMIUM, LEAD, MERCURY, SELENIUM, SILVER, copper

[1]Headwaters Area not included because number of sample sites is small.

site, and a military base. The limited available data, principally in Carson Valley, do not indicate a widespread distribution of volatile organic compounds in ground water. Pesticides are used for agricultural purposes in the basin and are applied either aerially or on the ground. Sources of data on aerial applications are Agricultural Extension Agents and different agencies in each of the counties in the basin. Ground applications of pesticides are not routinely reported, however, so estimates of total application rates were not made.

Limited data for radon indicate that concentrations are high in ground water along the western part of the valley (Michael S. Lico, U.S. Geological Survey, written commun., 1988), with some values exceeding 10,000 picoCuries per liter. Analyses for gross alpha and beta activities are not available for ground water in the Carson River basin.

INTRODUCTION

Background

Beginning in 1986, the Congress has annually appropriated funds for the U.S. Geological Survey to test and refine concepts for a National Water-Quality Assessment (NAWQA) Program. The long-term goals of a full-scale program would be to

1. Provide a nationally consistent description of current water-quality conditions for a large part of the Nation's surface- and ground-water resources,
2. Define long-term trends (or lack of trends) in water quality, and
3. Identify, describe, and explain, as possible, the major factors that affect the observed water-quality conditions and trends.

The information obtained will be furnished to water managers, policy makers, and the public to provide an improved scientific basis for evaluating the effectiveness of water-quality management programs and to provide a data base for assessing the likely effects of contemplated changes in land- and water-management practices. Concepts for a full-scale NAWQA Program are described by Hirsch and others (1988).

The NAWQA Program is organized into study units based on specific hydrologic systems. For ground water, the study units are large parts of aquifers or aquifer systems, and for surface water, the study units are major river basins. The study units are large, involving areas of a few thousand to several tens of thousands of square miles.

At present (1988), the assessment program is in a pilot phase in seven project areas throughout the country that represent diverse hydrologic environments and water-quality conditions. The seven pilot project areas include four that focus primarily on surface water and three that focus primarily on ground water. The surface-water project areas are the Yakima River basin in Washington; the lower Kansas River basin in Kansas and Nebraska; the upper Illinois River basin in Illinois, Indiana, and Wisconsin; and the Kentucky River basin in Kentucky. The ground-water project areas are the Carson River basin in Nevada and California (fig. 1); the Central Oklahoma aquifer in Oklahoma; and the Delmarva Peninsula in Delaware, Maryland, and Virginia.

Large quantities of water-quality data have been collected in the United States by different organizations for widely different purposes. One of the first activities to be undertaken in each pilot project is to assess available data for the study unit to help establish priorities and formulate plans for the project field activities. This report presents the results of an analysis of ground-water quality data in the Carson River basin.

Purpose and Scope

The purposes of this report are to define the hydrogeologic setting, the land and water uses, and the ground-water quality of the Carson River basin on the basis of available data. The report includes an evaluation of the relation between ground-water quality and present knowledge of geologic, hydrologic, land-use, and water-use factors. The scope of the report is limited to the ground water in the Carson River basin of western Nevada and eastern California. Only those data (water quality, hydrogeologic, and land- and water-use) collected or published before 1988 have been used for this part of the project. No further data have been collected to accomplish the objective stated above. Additional water-quality, land-use, and hydrogeologic data are being collected to supplement the existing data and accomplish the overall goals of the project.

Acknowledgments

Much of this report is based on an evaluation of analyses of several thousand ground-water samples from several agencies in addition to the Geological Survey. Two main tasks had to be accomplished before the data could be used: first, the analyses were obtained from the various sources, and then they were screened to ensure that only those analyses considered reliable were used. Neither task could have been accomplished without the assistance and cooperation of the people who work in the many local, State, and Federal agencies in the Carson River basin. One of the more difficult parts of this study was the task of verifying sample locations in the field; however, this job was made much easier because of the cooperation of the numerous landowners in the Carson River basin.

The principal sources of data on ground-water quality for the Carson River basin are described in a later section of this report. Many other agencies and people, however, provided supporting data or were otherwise helpful. These sources include organizations and agencies of local, State, and Federal government. They are listed below.

Local Agencies

Cooperative Extension Agents, Churchill, Douglas, and Lyon Counties
Weed Control, Douglas County

Mosquito Abatement, Churchill and Douglas Counties
Truckee-Carson Irrigation District
Public Utility District, South Lake Tahoe
Public Works, Carson City
Assessors' Offices, Carson City, Churchill, Lyon, and Storey Counties

Organizations

Desert Research Institute, University of Nevada
Nevada Agricultural Statistical Service, University of Nevada
Plant Science Department, University of Nevada
Resource Concepts, Inc.

State Agencies

Nevada Bureau of Consumer Health Protection Services
Nevada Department of Agriculture
Nevada Division of Parks
Nevada Division of Environmental Protection
California Department of Water Resources
Lahontan Water-Quality Control Board

DESCRIPTION OF THE STUDY AREA

Location and Physiography

The Carson River basin encompasses an area of 3,980 mi^2 in parts of the western Great Basin and eastern Sierra Nevada. The project area is mostly in western Nevada, but includes a small part of far eastern California (fig. 1). The Carson River basin is subdivided into six areas that generally correspond to hydrographic areas delineated by the Nevada State Engineer and California Department of Water Resources for management and allocation of water resources (fig. 2). In downstream order through the basin, the areas consist of a mountainous Headwaters Area, Carson Valley, Eagle Valley, Dayton Valley, Churchill Valley, and the Carson Desert (fig. 2). These areas are interconnected by the Carson River and, with three exceptions, the lowland part of each corresponds to a single alluvial valley that contains one or more aquifers. Exceptions are the Headwaters Area, Carson Valley, and Dayton Valley. The Headwaters Area is composed of the East and West Forks of the Carson River and contains no areally extensive alluvial aquifers. Carson Valley, as defined for this study, includes Diamond Valley, a small basin adjacent to the south end of the geographic boundary of Carson Valley. From southwest to northeast, the Dayton Valley hydrographic area consists of a small basin adjacent to the east side of Eagle Valley, informally referred to as the Riverview area; the Mound House area; Carson Plains; and Stagecoach Valley.

The valleys of the Carson River basin generally are flat-bottomed and surrounded by steeply rising high mountains. Altitudes of valley floors range from about 3,800 ft above sea level in the Carson Desert to nearly 5,000 ft in Carson Valley, whereas altitudes in adjacent mountains are 6,000 to 8,700 ft along the basin divides of Carson Plains, Stagecoach and Churchill Valleys, and Carson Desert, and 9,000 to 11,000 ft in Carson and Eagle Valleys.

The valleys of the Carson River basin have similar physiographic features, although the areal extent of these features can differ markedly among valleys. The major features are mountains, alluvial fans and pediments, valley lowlands, and the flood plain of the Carson River. Alluvial fans and pediments extend from the mountain front along valley margins toward the center of each valley. In some places, they merge with valley lowlands and in others they are truncated by the flood plain of the Carson River. The width of the flood plain ranges from less than 1 mi in Carson Plains and Stagecoach Valley to several miles in parts of Carson Valley. The lowlands of Stagecoach Valley consist, in part, of a playa.

The major hydrographic features of the Carson River basin (fig. 2) are (1) the East and West Forks of the Carson River in the Headwaters Area; (2) a network of ditches, drains, sloughs, and channels of the Carson River in Carson Valley; (3) the main stem of the Carson River; (4) Lahontan Reservoir on the lower part of the Carson River; (5) the Truckee Canal, which transports water from the Truckee River to Lahontan Reservoir; (6) an extensive system of irrigation ditches and drains of the Newlands Irrigation Project near Fallon; and (7) distributary channels, marshes, shallow intermittent lakes, and salt flats in the Carson Desert, which is the terminal sink of the Carson River. Many small tributary streams enter the Carson River from adjacent mountains. Some of the streams are perennial in valleys as far downstream as Eagle Valley, but all are ephemeral beyond. Most of the flow of the Carson River and its perennial tributaries comes from the spring snowmelt each year.

Climate

The climate of the Carson River basin is dominated by the Sierra Nevada mountain range, which receives as much as 25 to 50 in/yr of precipitation at higher altitudes (Twiss and others, 1971, p. 3). The region to the east, however, is dry because much of the moisture carried by winter storms from the Pacific Ocean falls as snow or rain in the mountains. This eastern region, including most of the Carson River basin, lies in what is called the Sierra Nevada rainshadow (Houghton and others, 1975, p. 6). Climatic zones in the Carson River basin range from high alpine in the Headwaters Area and Carson Range to arid desert at the terminus of the river in the Carson Desert.

The climate of the Carson River basin is fairly mild except for areas of high altitude. Mean air temperatures during January 1986 were 38 °F (degrees Fahrenheit) at Minden, 40 °F at Carson City, 41 °F at Lahontan Dam, and 38 °F at Fallon (National Climatic Center, 1986, p. 6). Mean temperatures during July 1986 at the same four stations were 65, 67, 77, and 69 °F, respectively (National Climatic Center, 1986, p. 6). Temperatures are typically warmer at lower altitudes, but can be colder during the winter when temperature inversions develop.

Precipitation in the Carson River basin falls as winter snow at high altitude, as winter snow and rain at lower altitudes, and as summer thundershowers throughout the area. Total precipitation for 1986 at five weather stations in the Carson River basin ranged from 2.55 in. at Fallon to 14.88 in. at Carson City and 15.92 in. at Virginia City (National Climatic Center, 1986, p. 3). Areas of higher altitude, including much of the headwaters, probably receive as much as 25 in/yr or more. Valley floors and other areas of lower altitude receive 3 to 11 in/yr (National Climatic Center, 1986, p. 3). The effect of the Sierra Nevada rainshadow is demonstrated by comparing long-term precipitation totals at Virginia City to those at Glenbrook (along the east shore of Lake Tahoe west of the study area), Markleeville, Calif., and Woodfords, Calif. (Glancy and Katzer, 1976, p. 18). The altitude at the Virginia City station is nearly the same as that at the Glenbrook station and is higher than the Markleeville and Woodfords stations. In spite of this, the Virginia City station receives from 11 to 13 in/yr less than any of the other three stations.

Hydrogeologic Setting

Each of the alluvial valleys in the Carson River basin consists of a structural basin that formed as a result of extensional faulting during the Tertiary and Quaternary periods of geologic time. These basins are bounded laterally by consolidated rocks of the adjacent mountain blocks, at depth by consolidated rocks of the down-faulted valley block, and contain basin-fill deposits with maximum thicknesses of 5,000 to 10,000 ft. Aquifers in the Carson River basin are mostly restricted to these basin-fill deposits.

On the basis of differences in lithology and rock chemistry, consolidated rocks are grouped into five hydrogeologic units (pl. 1): (1) Metasedimentary and metavolcanic rocks of Triassic and Jurassic age; (2) basic igneous rocks of Jurassic age that consist of diorite, gabbro, and marine volcanic rock; (3) granodiorite and quartz monzonite of Jurassic to Tertiary age; (4) silicic volcanic rocks of Tertiary and Quaternary age that consist of rhyolite, latite, and dacite; and (5) basic volcanic rocks of Tertiary and Quaternary age that consist of basalt, andesite, and trachyte. Except for basic igneous rocks of Jurassic age, which are found only in the West Humboldt and Stillwater Ranges, each of the units described above is widespread in the Carson River basin.

Basin-fill deposits are grouped into three hydrogeologic units: An older unit of Tertiary age, and two younger units, both of which are of approximately equivalent Quaternary and Tertiary age. The older unit consists of clays, silts, sands, and gravels that were deposited in basins which, in some places, were of greater extent than the modern basins. These deposits are exposed in mountain blocks and along basin margins, and presumably constitute the deeper part of the basin fill in each valley.

The two younger units are at and near land surface in each valley. One consists of poorly sorted to unsorted clay, silt, sand, and gravel of alluvial fans, pediments, and valley lowlands. The other consists of sorted clay, silt, sand, and gravel of Pleistocene Lake Lahontan, ancient Carson River deltas, and past and present flood plains of the river.

The three geologic maps from which plate 1 and figures 15 and 35 are compiled join at 39° and 40° latitude (Johnson, 1977; Stewart and others, 1982; J.H. Stewart, U.S. Geological Survey, written commun., 1987). The levels of geologic detail in the three maps are sufficiently different to prevent reconciliation of across-the-join discrepancies without further field mapping (which was beyond the scope of this project).

The dominant hydrologic feature of the Carson River basin is the Carson River, because it provides a connection between the valleys of the basin. The river flows through and physically connects the Headwaters Area, Carson Valley, Dayton Valley, Churchill Valley, and the Carson Desert. The river is hydraulically connected to shallow aquifers in these valleys and can be a source of either ground-water recharge or discharge, depending on the stage and stretch of the river and on irrigation practices. The Carson River does not enter Eagle Valley or Stagecoach Valley, although both are hydraulically connected to the river, either by tributary streams (Eagle Valley) or by ground-water underflow (Stagecoach Valley).

The principal sources of recharge to aquifers in the Carson River basin are direct infiltration of precipitation or snowmelt on soils in upland areas and infiltration of surface water through the channels of the Carson River and its major tributaries. Both mechanisms are significant sources of recharge in upper parts of the basin (Headwaters Area, and Carson and Eagle Valleys); however, in lower parts of the basin (Dayton and Churchill Valleys, and Carson Desert), infiltration from the Carson River becomes the dominant source of recharge because annual precipitation decreases markedly with distance from the Sierra Nevada.

Headwaters Area

The headwaters area of the East and West Forks of the Carson River is rugged and has extremes of altitude and relief. Drainages are typically narrow with steep sides, and the canyons are at least 1,000 ft deep in places. The bottom of each canyon is filled by a lens of stream-deposited boulders, cobbles, and gravel probably no more than a few tens of feet thick and usually no more than a few hundred feet wide (pl. 1). Exceptions include Hope Valley on the West Fork, the valley of Silver King Creek on the East Fork, and Pleasant Valley, which is tributary to the East Fork. The deposits in these valleys are as much as 1 to 2 mi in width, but probably are not much thicker than those along the narrower canyons.

The main hydrologic features of the Headwaters Area are the East and West Forks of the Carson River and their numerous tributaries. On the basis of records for the period 1919-69, the average annual flow of the West Fork was 70,000 acre-ft and that of the East Fork was 245,000 acre-ft (Glancy and Katzer, 1976, p. 31).

The only aquifers of any extent in the Headwaters Area are in alluvial fill along canyon bottoms, where ground-water levels are controlled by the stage of the adjacent stream. Possible exceptions are Hope, Silver King, and Pleasant Valleys, where the deposit of fill is wider and ground-water levels may not be as dependent on the stage of the stream.

In upland areas, the presence of ground water depends on the permeability of consolidated rocks. Permeability is controlled mostly by the depth to which rocks are weathered and, beneath the weathered zone, by the degree to which they are fractured. Both of these factors probably differ throughout the area, and the degree to which consolidated rocks are saturated with water and will yield water to wells also differs accordingly. Water probably can be found in consolidated rocks over most of the area, although productive aquifers are believed to be mostly restricted to canyon bottoms.

Carson Valley

Carson Valley is a north-south trending basin bounded to the west by the Carson Range, to the east by the Pine Nut Mountains, and to the north by an alluvial divide that separates the valley from Eagle Valley (pl. 1). The valley floor is underlain by a structural basin that is as much as 5,000 ft deep along the west side and that becomes progressively shallower eastward (Maurer, 1985, p. 5).

The East and West Forks of the Carson River enter the valley at its south end and join near the west margin of the valley floor about 3 mi northwest of Minden. Just north of this confluence of the two forks the river turns and exits the valley at its northeast corner. Average annual outflow, measured at a gage just north of here, was 272,000 acre-ft for the period 1919-69 (Glancy and Katzer, 1976, p. 30). Other surface-water features include several small streams that enter the valley from the Carson Range, sloughs and abandoned channels of the river, and a network of irrigation ditches and drains.

Older basin-fill deposits in Carson Valley, which are of Tertiary age, consist of lacustrine and fluvial sandstone, mudstone, shale, marl, and limestone that are exposed extensively along the east side of the valley and in parts of the Pine Nut Mountains. The deposits are as thick as 1,000 ft or more on the east side of the valley (Moore, 1969, p. 12; Maurer, 1986, p. 12) and, because they dip westward beneath younger fill, also underlie the central part of the valley at depth. These deposits are overlain along the east side of the valley by younger deposits of Quaternary and Tertiary age that consist mostly of fluvial gravels as thick as 50 ft (Moore, 1969, p. 14, 15). The youngest deposits in the valley, which are of Quaternary age, consist of boulder and cobble gravels of alluvial fans adjacent to mountains and extensive areas of fluvial clay, silt, sand, and gravel deposited in the Carson River flood plain (Moore, 1969, pl. 1).

The ground-water basin in Carson Valley contains two discontinuous confined alluvial aquifers and a shallow water-table aquifer. The confined aquifers are in deposits of alluvial fans along the west margin of the valley and beneath the central part of the valley, respectively. Contours indicating the altitude of the water table are shown in plate 1. The contours reveal that ground water moves toward the Carson River from both sides of the valley, and then generally northward along the axis of the valley, which coincides with the river. The water-table aquifer is hydraulically connected to the river throughout most, if not all, of the valley. Accordingly, water moves between the river and aquifer in either direction, depending mostly on the stage of the river.

A water budget for the basin-fill reservoir in Carson Valley indicates that both inflow and outflow equal about 170,000 acre-ft/yr (Maurer, 1986, p. 60). The ground-water system is dominated by the river, which accounts for much of the inflow of ground water to the basin. Other sources of recharge include precipitation on the valley floor and ground-water underflow into the basin-fill deposits from permeable bedrock. Discharge occurs mostly as evapotranspiration and pumpage.

Eagle Valley

Eagle Valley is bordered on the west by the Carson Range, on the north by the Virginia Range, and on the east by Prison Hill and a low topographic divide that separates the valley from the Riverview area of the Dayton Valley hydrographic area (pl. 1). The Carson River does not flow through Eagle Valley; however, small streams from Ash and Kings Canyons and Clear Creek cross the valley on their way to the Carson River. The combined mean annual flow of the three streams was about 7,000 acre-ft/yr for the period 1919-69 (Glancy and Katzer, 1976, p. 31).

The structural basin beneath Eagle Valley consists of several north-northeast trending fault blocks (Arteaga, 1982, p. 26). Fault scarps in the basin fill mapped by Bingler (1977) and Trexler (1977) approximately coincide with the margins of these fault blocks. The structural basin is divided into two smaller basins by a horst – an uplifted block – of bedrock that extends from C Hill northeast beneath Lone Mountain to the main mass of the Virginia Range (Arteaga, 1982, p. 26). The western structural basin is bounded on the east by this horst of bedrock and on the west by the Carson Range block. The maximum depth of this basin is about 1,200 ft (Arteaga, 1982, p. 26).

A larger basin underlies the east part of the valley; it is bounded on the west by the horst of bedrock, C Hill, and Lone Mountain, and on the east by Prison Hill and its north-trending subsurface extension. This basin is as deep as 2,000 ft (Arteaga, 1982, p. 26).

Exposures of basin-fill deposits in the valley are of Quaternary age (Bingler, 1977; Trexler, 1977); deposits of Tertiary age are probably at greater, though uncertain, depths. Kings, Ash, and Vicee Canyons are deeply incised in the Carson Range, and large fans at the mouth of each canyon have merged into one broad fan slope of sand and gravel along the west side of the valley. This fan slope extends as much as a mile east of the mountain front. On the basis of data from well logs, these deposits persist to depths of at least 500 ft in this part of the valley and probably extend to bedrock. Similar but less extensive fans and pediments border the valley to the north along the Virginia Range and to the east along Prison Hill (Bingler, 1977; Trexler, 1977).

Deposits on valley lowlands consist of fine sands, silty and muddy sands, and gravels (Bingler, 1977; Trexler, 1977). Well logs indicate that, compared to fan slopes, lowland deposits consist of a greater proportion of clay and silt, either intermixed with sand and gravel or as discrete beds; however, sands and gravels also extend basinward beneath lowlands from the margins of the valley. Logs for three wells near the center of the valley in sections 16 and 17, T. 15 N., R. 20 E., show that clays and silts become more common in the basin fill at depths as great as 800 ft below land surface, but do not necessarily constitute the predominant lithology.

The Eagle Valley ground-water basin consists of a shallow water-table aquifer and one or more deeper alluvial aquifers that are confined to differing degrees (Arteaga, 1982, p. 8). The confining beds are composed of discontinuous clay lenses at different depths. Confined conditions are most pronounced in the area northwest of Prison Hill, where ground-water flow paths from the north, northwest, and southwest converge.

The water-level altitudes shown in plate 1 are based on measurements at shallow wells in some areas, and at deeper wells in others. Therefore, the altitudes shown do not necessarily represent the water table; instead, they represent a composite potentiometric surface that is in part, confined. Though ground-water movement is somewhat complex because of several consolidated-rock barriers, the movement is generally toward the Carson River in the adjacent Dayton Valley hydrographic area.

Streams on the west side of Eagle Valley are the principal sources of ground-water recharge. This is especially true of Clear Creek and the creeks in Kings and Ash Canyons; all are major recharge areas for the basin. Steady-state recharge as of 1964 was an estimated 4,900 acre-ft/yr (Arteaga, 1982, p. 18), mainly as runoff and underflow along the west side of the valley and infiltration of streamflow and irrigation water in other parts of the valley. Ground water discharges from the basin as evapotranspiration and as subsurface underflow to Carson Valley at Clear Creek and to the Riverview area of the Dayton Valley hydrographic area. Total discharge is an estimated 5,700 acre-ft/yr (Arteaga, 1982, p. 18-19).

Dayton Valley

The Dayton Valley hydrographic area consists of several basins or areas that extend from the east side of Eagle Valley to the west side of Churchill Valley. These areas consist of the flood plain of the Carson River immediately east of Eagle Valley (informally called the Riverview area), the Mound House area between Carson City and Dayton, the Carson Plains, and Stagecoach Valley (pl. 1). The entire hydrographic area is bounded on the north by the Virginia Range and on the south by the Pine Nut Mountains.

The Riverview area is the westernmost part of the Dayton Valley hydrographic area, and is along the flood plain of the Carson River adjacent to Eagle Valley. This part of the hydrographic area is a small structural basin filled with as much as 800 ft of sediment (Arteaga, 1982, p. 26). It is bounded on the west by a horst of bedrock that includes Prison Hill and its northeastward trending subsurface extension and on the east by the Pine Nut Mountains. The sediments in this small basin consist of poorly sorted, muddy gravels and sands of alluvial fans and pediments along basin margins and silty sand and sandy mud of the Carson River flood plain (Bingler, 1977).

The Carson River follows a rugged canyon through a mountainous area about 8 mi wide between the Riverview area and Dayton. Part of this mountainous area consists of a southeast-sloping upland referred to as the Mound House area. This upland constitutes a small basin a few hundred feet above the Carson River that is bordered to the north by the Virginia Range and to the south by low hills along the north side of the canyon. Basin fill in the Mound House area consists of poorly sorted muddy and sandy gravels of pediments and alluvial plains, well-sorted fine sand and silt, and gypsite (Bingler, 1977). The gypsite consists of fine-grained powdery gypsum weathered from nearby gypsum beds in metasedimentary rocks of Jurassic age (Bingler, 1977). Logs for wells in the Mound House area indicate that depths to consolidated rock beneath the central part of the area exceed 100 ft.

Carson Plains is the valley east of Dayton that is bounded to the north by the Virginia Range, to the east by Table Mountain, to the south by the Pine Nut Mountains, and to the west by the mountainous area between Carson City and Dayton. Carson Plains also includes a narrow strip of river flood plain and uplands of the Pine Nut Mountains south of Stagecoach Valley. Basin fill in the Carson Plains consists of poorly sorted, mostly coarse deposits of alluvial fans and pediments, sorted to poorly sorted, coarse and fine deposits of valley lowlands, and sorted coarse and fine deposits of the Carson River flood plain. The maximum depth of basin fill in this valley is unknown, but is at least 400 ft, according to logs of irrigation wells.

Stagecoach Valley is bounded to the north by the Virginia Range and to the south by the Carson River. This valley is separated from Carson Plains to the west by a low topographic divide of consolidated rocks and from Churchill Valley to the east by Churchill Butte. The structural basin contains as much as 2,000 to 3,000 ft of fill on the east side and as much as 1,000 ft on the west side (Donald S. Schaefer, U.S. Geological Survey, written and oral commun., 1987).

Basin fill in Stagecoach Valley consists of coarse deposits of alluvial fans and pediments that extend from mountain fronts toward valley lowlands. Valley lowlands are underlain by fine playa deposits that consist, at least in part, of lacustrine sediments of Pleistocene Lake Lahontan. Carson River flood-plain deposits are restricted to a narrow strip south of, and adjacent to, the valley.

At its highest stages, from about 12,000 to 40,000 or 50,000 years before present (Benson and Thompson, 1987, p. 84) Pleistocene Lake Lahontan covered much of the lowlands of Stagecoach Valley. The mountain blocks mostly remained above water, as did small areas of alluvium along the valley margins. Consequently, the upper few tens of feet of basin fill in the valley may consist of sorted sands and gravels toward valley margins and of fine sands, silts, and clays toward the center of the valley. These deposits probably form a pediment under a thin veneer of younger, poorly sorted deposits weathered from nearby mountains. Although these speculations have not been verified, they seem reasonable on the basis of known extent of the lake at its highest stands.

The four parts of the Dayton Valley hydrographic area are hydraulically connected either by the Carson River or by ground-water flow through consolidated rocks and alluvium. Ground-water levels in the Riverview area and Eagle Valley (pl. 1) show that ground water moves southward from the Virginia Range, eastward from Prison Hill and Eagle Valley, and westward from the Pine Nut Mountains generally toward the Carson River. Recharge to this small basin is provided by underflow from the Eagle Valley ground-water basin and by precipitation in the mountains to the north and east. Ground water discharges as pumpage, seepage into the Carson River, and as evapotranspiration. This stretch of the river gains about 1,500 acre-ft/yr from ground-water inflow

(Arteaga and Durbin, 1978, p. 32), and thus acts as a drain during normal and low-flow stages; however, the river probably acts as short-term source of recharge to aquifers in the basin during periods of high flow.

Little is known of ground-water conditions in the Mound House area. Water levels measured at two wells near the east side of the area in 1967 and 1969 were 45 and 30 ft below land surface, respectively (Glancy and Katzer, 1976, p. 104). Ground water recharges as high-altitude precipitation in the Virginia Range to the north, and discharges as pumpage and probably as underflow through consolidated rocks and basin fill in the east part of the area.

Carson Plains area is another area in which ground-water conditions are poorly understood. Depths to water range from less than 20 ft near the Carson River to 100 to 200 ft on fan slopes away from the river (Glancy and Katzer, 1976, p. 104). The aquifers are recharged by precipitation in the Virginia Range and Pine Nut Mountains, and they discharge by pumpage and evapotranspiration. In addition, shallow aquifers near the river may, at times, be recharged by the river, and, at other times, discharge to it, depending on the stage of the river.

Water levels in Stagecoach Valley indicate that shallow ground water moves east and south through the basin fill (pl. 1). Recharge is provided by precipitation in the Virginia Range to the north and by inflow from the Carson River flood plain in the east part of the Carson Plains. Evidence for this inflow is supported not only by contours of water-level altitudes in Stagecoach Valley, but also by the isotopic composition of the ground water (Harrill and others, 1984, p. 117). Aquifers in Stagecoach Valley discharge by way of pumpage, evapotranspiration on the valley floor, outflow to the river through basin fill, and possible outflow to Churchill Valley through the alluvial divide separating the two valleys. Recharge and predevelopment discharge are estimated to have been about 900 acre-ft/yr (James R. Harrill, U.S. Geological Survey, oral commun., 1988).

Churchill Valley

Churchill Valley is a northeast-trending valley bounded to the north by the eastern end of the Virginia Range, to the east by the Dead Camel Mountains, to the south by the Desert Mountains, to the southwest by the Pine Nut Mountains, and to the west by Churchill Butte (pl. 1). The Carson River enters the west side of the valley near Churchill Butte. Prior to the construction of Lahontan Dam, the river left the valley through a canyon, now submerged, in the Dead Camel Mountains. Lahontan Reservoir occupies an irregularly shaped area in the northeast part of the valley. Average annual flow of the Carson River into the valley was about 268,000 acre-ft/yr for the period 1919-69 (Glancy and Katzer, 1976, p. 31). During the same period, Lahontan Reservoir received an additional 170,000 acre-ft/yr of Truckee River water by way of the Truckee Canal (Glancy and Katzer, 1976, p. 31).

Thicknesses of basin fill in Churchill Valley are uncertain over most of the valley because no geophysical surveys or deep drilling have been done. Logs for two domestic wells in the northwest and north-central parts of the valley indicate depths to consolidated rock of 300 ft and 210 ft, respectively. In addition, Tertiary andesite crops out near the center of the valley. However, these rocks could be interbedded with the basin fill. If instead they constitute bedrock, then the basin fill in Churchill Valley may be relatively thin.

Surface exposures of basin fill in Churchill Valley consist of poorly sorted, coarse deposits of alluvial fans and pediments along valley margins and sorted fine sand, silt, and clay beneath valley lowlands (Moore, 1969). The fine-grained deposits accumulated mostly as lacustrine and deltaic sediments of Pleistocene Lake Lahontan and, depending on the level of the lake, as fluvial sediments of the Carson River flood plain. High stands of Lake Lahontan occupied nearly all the valley lowlands except for the alluvial divide between Churchill and Stagecoach Valleys. As in Stagecoach Valley, the depths to which deposits of Lahontan age extend are uncertain.

Except for a reconnaissance study (Glancy and Katzer, 1976), no ground-water studies have been made of Churchill Valley. Consequently, no detailed knowledge of ground-water levels is available. Ground-water levels range from 20 to 50 ft below land surface near the shores of Lahontan Reservoir and the Carson River flood plain to more than 200 ft near the margins of the basin (Glancy and Katzer, 1976, p. 105). Probable directions of ground-water movement are southward toward the river flood plain and eastward toward Lahontan Reservoir, which now covers much of the previous flood plain. Ground-water recharge to the valley is an estimated 1,300 acre-ft/yr (Glancy and Katzer, 1976, p. 48) and comes from precipitation in surrounding mountains and infiltration from the river and reservoir. Ground-water discharges primarily as pumpage and evapotranspiration.

Carson Desert

Carson Desert, the largest valley in the Carson River basin, is elongate in a northeast direction, with a maximum length of about 70 mi and a maximum width of about 25 mi. The basin is bounded to the northwest by the Hot Springs Mountains and the West Humboldt Range, to the east and southeast by the Stillwater and Sand Springs Ranges and the Bunejug and Cocoon Mountains, to the south by the Blow Sand and Desert Mountains, and to the west by the east end of the Virginia Range and the Dead Camel Mountains (pl. 1).

Carson Desert is the terminal sink of the Carson River, which enters the basin just below Lahontan Dam. Average flow of the river below the dam, including Truckee River water diverted to Lahontan Reservoir by way of the Truckee Canal, was 380,000 acre-ft/yr for the period 1919-69 (Glancy and Katzer, 1976, p. 30). Most of the Carson River flow is diverted for irrigation in the Fallon area. The rest, along with irrigation returns, flows to Carson Lake at the south end of the Carson Desert, Stillwater Lakes on the east side, and Carson Sink to the north. Carson Sink is a large salt flat during years of normal or below-normal precipitation, but during wet years it becomes a large shallow lake fed by the Carson River, irrigation runoff, and by overflow from the Humboldt River basin.

The structural basin beneath the Carson Desert consists of several smaller subbasins, some of which are oriented along regional structural trends. The northern part of the Carson Desert is underlain by a northeast-trending subbasin along the West Humboldt Range that is as deep as 6,000 ft, and by a north-trending subbasin along the Stillwater Range that is as deep as 12,000 ft. The two are separated by a northeast-trending horst of bedrock at a depth of about 2,000 ft (Hastings, 1979, p. 518). Unpublished gravity data indicate that a deep basin underlies the south part of the Carson Desert, where an exploration borehole penetrated more than 9,000 ft of basin fill without reaching bedrock (Franklin H. Olmsted, U.S. Geological Survey, written commun., 1987).

Basin fill of the Carson Desert consists of lacustrine, fluvial, subaerial, eolian, and volcaniclastic sediments and interbedded volcanic rocks. The upper 2,000 to 3,000 ft of the basin fill consists mostly of sediments and lesser amounts of volcanic rocks, whereas deeper parts of the basin fill consist of increasing proportions of volcanic rocks (Franklin H. Olmsted, U.S. Geological Survey, written commun., 1987).

Shallow basin fill in the Carson Desert can be separated into deposits that predate ancient Lake Lahontan, those that accumulated during the different stages of the lake, and those that postdate the lake. Pre-Lake-Lahontan sediments consist of mudstone, siliceous tuff, and tuffaceous sand and shale of Miocene and Pliocene age (Morrison, 1964, p. 11, 12; Willden and Speed, 1974, p. 26, 28). Volcanic rocks are interbedded with these sediments at depths of several hundred feet near Upsal Hogback (Franklin H. Olmsted, U.S. Geological Survey, written commun., 1988) and were penetrated at 75 ft in a Geological Survey test well about 1 mi west of the range front of the Bunejug Mountains. Basalt flows of Quaternary age are exposed at Rattlesnake Hill near Fallon and underlie an elongate, northeast trending area of about 3.5 by 10 mi at depths that range from land surface to 400 to 600 ft (Glancy, 1986, p. 14, 58).

Lake Lahontan was characterized by several shallow-and-deep cycles (Russell, 1885, p. 100-102; Morrison, 1964, p. 28; Benson and Thompson, 1987, p. 84). Sediments that accumulated during these stages of the lake were named the Lahontan Valley Group (Morrison, 1961, p. D111-D113). The sediments consist of: (1) lacustrine clay and silt that accumulated in deep to shallow water, and sand and gravel that accumulated along beaches; (2) interbedded clay, silt, sand, and gravel of river deltas and distributary channels; (3) eolian sands that accumulated during lake-stage recessions, and (4) alluvium and colluvium that accumulated in areas above shorelines (Morrison, 1964, p. 28-79). All these deposits are complexly interbedded and interfingered because of the variety of, and changes in, depositional environments. Sediments that were deposited after Lake Lahontan in the Carson Desert are named the Fallon Formation (Morrison, 1961, p. 113) and consist of thin beds of clay, silt, sand, and gravel that accumulated in shallow lakes, river deltas, and distributary channels, along with eolian sand and alluvium.

The ground-water system in the Carson Desert is the most complex in the Carson River basin. It has been investigated in the southern Carson Desert (Glancy, 1986) and in geothermal areas (Morgan, 1982; Olmsted and others, 1984; Olmsted, 1985). In the southern Carson Desert, the system consists of shallow, intermediate, and deep alluvial aquifers and a basalt aquifer (Glancy, 1986, p. 7-57). The basalt aquifer provides the principal municipal water supply for the area (see subsequent section on land and water use), whereas the shallow and intermediate alluvial aquifers provide water to domestic wells and, to a lesser extent, irrigation wells.

Directions of ground-water movement in the shallow-alluvial aquifer are generally northeastward and eastward toward the Carson Sink and Stillwater Lakes (pl. 1). Directions of movement in the intermediate-alluvial aquifer are similar, but in the basalt aquifer are uncertain because gradients in that aquifer are nearly flat (Glancy, 1986, p. 15-16). Vertical gradients between the different aquifers indicate upward movement of ground water in some parts of the Carson Desert and downward movement in other parts (Glancy, 1986, p. 27, 55). In addition, short-term reversals of vertical gradients have been recognized in the shallow alluvial aquifer near Upsal Hogback and Soda Lakes (Olmsted, 1985, p. 15-19).

The principal source of recharge to aquifers in the Carson Desert is infiltration from river channels, canals, and ditches (Glancy, 1986, p. 39). Other sources include local ponding of precipitation in low-lying areas after intense storms (Olmsted, 1985, p. 25) and precipitation in mountains surrounding the basin. The principal mechanism of natural discharge is evapotranspiration. However, some discharge also results from pumpage and from irrigation drains, which are ditches 10 to 15 ft deep that drain shallow ground water from irrigated areas.

Land and Water Use

Historical land use in the Carson River basin has been related mostly to agriculture and mining. The first historical settlement in the basin began in 1849 as a supply station in Carson Valley for migrants on their way to California. A sawmill built in 1853 and a flour mill built in 1854 were the first manufacturing establishments in the basin (Dangberg, 1972, p. 48, 51). In 1859, the Comstock gold and silver lode was discovered, and population of the basin grew rapidly until the 1880's (fig. 4). Irrigated agriculture, particularly in Carson Valley, also expanded during the mining boom.

The mining industry and population in the basin declined rapidly in the 1880's, but ranching and farming continued because of railroad access to other markets. After an unusually severe winter in 1889-90, most ranchers began raising supplemental hay for the first time to feed their cattle during the winter (Hulse, 1972, p. 158-160).

After the decline of mining in the basin, the next major change in land use was an increase in irrigated acreage in the Carson Desert prompted by the Newlands Project—the first Federal Reclamation Project in the United States. The initial phase of this project, construction of a 31-mi canal to divert Truckee River water to the Carson River, was completed in 1905. The second phase, construction of Lahontan Dam to store the diverted water and water from the Carson River, was finished in 1915 (Katzer, 1971). Prior to the Newlands Project, the small town of Stillwater and a few ranches were the only developed areas in the Carson Desert (Hulse, 1972, p. 223). As a result of the Newlands Project, the population of Churchill County increased from 830 people in 1900 to 4,649 people in 1920 (U.S. Bureau of the Census, 1910b, 1922). Since 1914, irrigated acreage in the Newlands Project area, which includes land along the Truckee Canal, has ranged from a low of 39,449 acres in 1916 to a high of 67,294 acres in 1979 (fig. 5). Total water diversions and the amounts of water actually delivered to farms also are shown in figure 5. Conveyance losses, the difference between total diversions and water delivered to farms, are a result of seepage from unlined canals, high evaporation rates, and nonagricultural releases. Because of the large amounts of irrigation drainage from the Newlands Project, the Fallon National Wildlife Refuge was established in 1931 and the Stillwater Wildlife Management Area and Stillwater National Wildlife Refuge were established in 1948 (pl. 1). Additional historical information on these wildlife areas is given by Hoffman and others (1990).

Other than changes associated with the Newlands Project, land use and population in the Carson River basin were relatively stable from the 1890's until about 1950. Urban and suburban development began in the 1950's and has been increasing rapidly since the 1960's. Minden, Gardnerville, Carson City, and Fallon have grown considerably, as have rural populations throughout much of the basin. Most of the urban and suburban development has been on land that was previously used for agriculture (either irrigated cropland or rangeland).

The local economy, and therefore urban land use, is dominated by the retail trade and service sectors—primarily casinos and associated businesses such as hotels, motels, and restaurants that cater to tourists. The Nevada Industrial Directory for 1985-86 (Nevada Commission on Economic Development, 1985) lists nine manufacturing firms in the study area which employ more than 100 people (none of these firms are in the Headwaters Area, Dayton Valley, or Churchill Valley). In Carson Valley, a manufacturer of monitoring and diagnostic equipment began operating in 1961. In Eagle Valley, seven large manufacturers produce a variety of metal and plastic parts and equipment, and computer components. These operations began between 1922 and 1983. In the Carson Desert, one large manufacturer has produced carbide and refined metal since 1950.

The distribution of land use in the Carson River basin is listed in table 3 and shown in figure 6. Because urban and suburban growth have been rapid since the compilation period for this land-use inventory (1973-80), the distribution and percentage of urban land are now outdated, although they represent the most current basinwide information available.

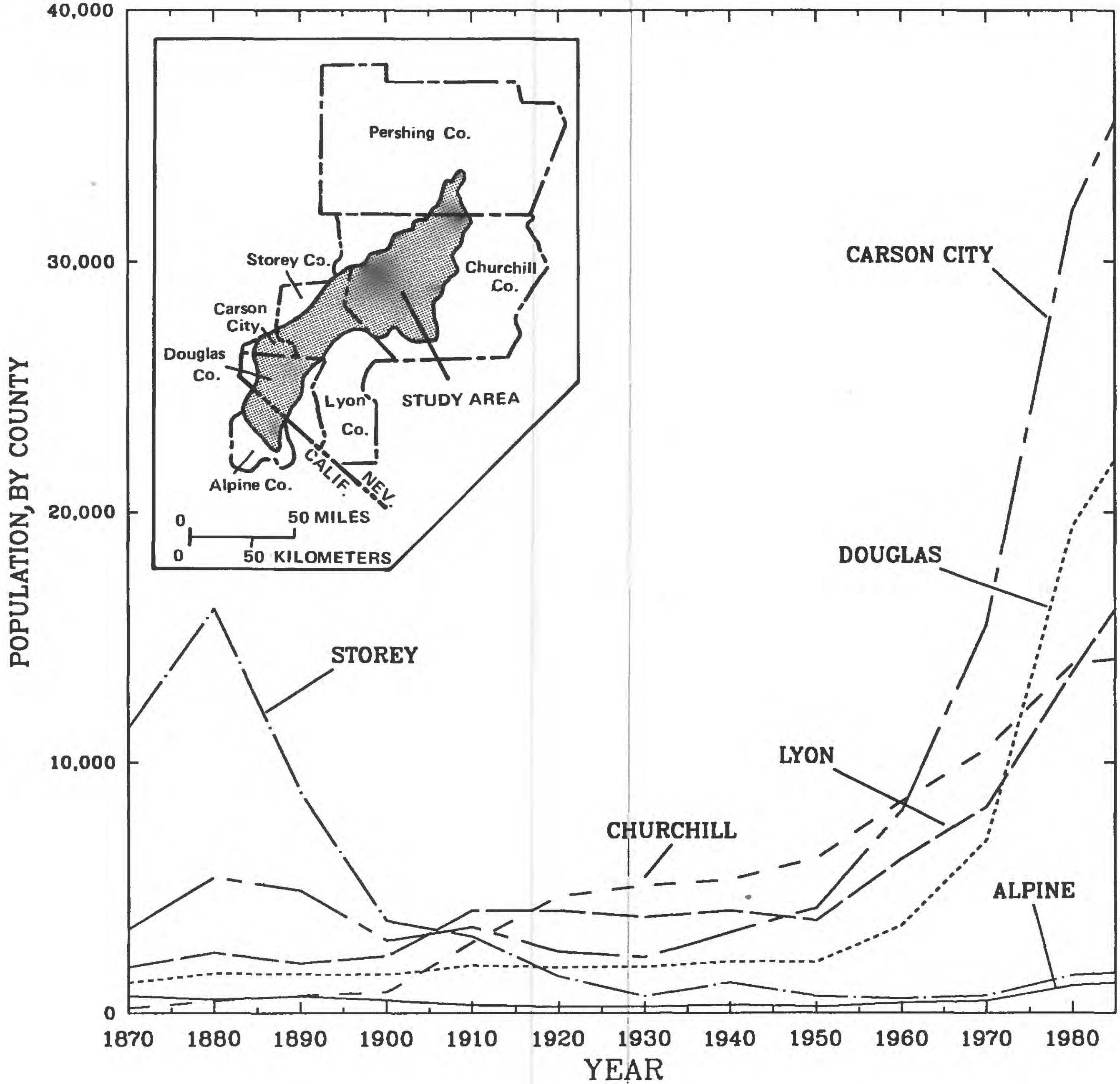

Figure 4.—Trends in population for counties in the study area, 1870-1985. For each county, populations shown are for entire county, including areas outside the Carson River basin. Data for Pershing County are not shown because this part of the study area is virtually unpopulated. Data sources: for 1860-1980, U.S. Census Office, 1883, and U.S. Bureau of the Census, 1910a, 1910b, 1922, 1952a, 1952b, 1983; for 1985, U.S. Bureau of the Census, written commun., 1986.

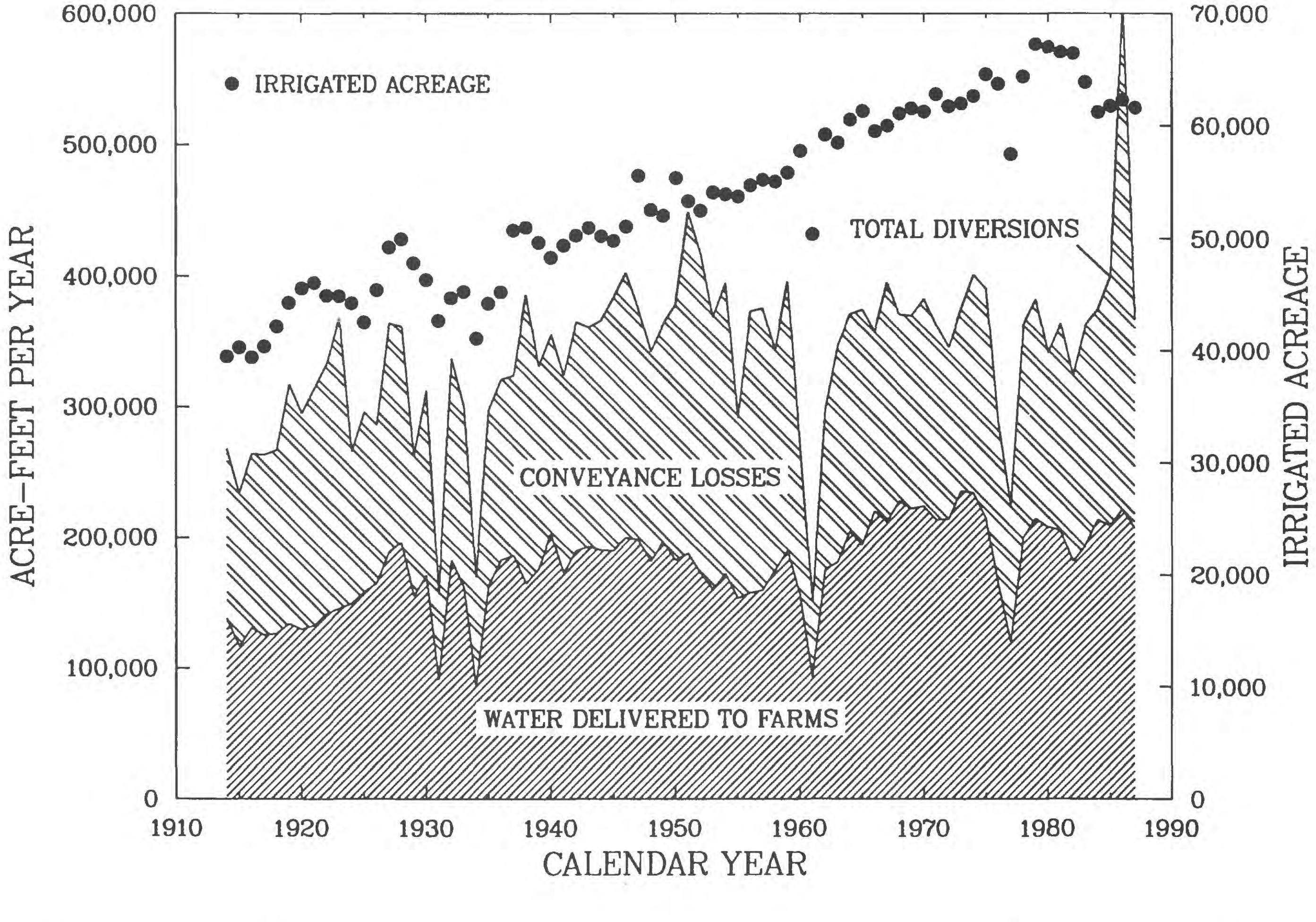

Figure 5.—Estimated irrigated acreage, water diversions, and water delivered to farms in the Carson Desert and along the Truckee Canal, 1914-87. Conveyance loss is the difference between the amount of water diverted and the amount delivered to fields. The total diversions compiled for 1986 include water that flowed over the flashboards in Lahontan Reservoir during a February flood; data for other years do not include such overflow. Data sources: for 1914-85, U.S. Bureau of Reclamation, written commun., 1960 and 1988; for 1986-87, Truckee Carson Irrigation District, oral commun., 1988.

Table 3.—*Land use and land cover, by hydrographic area, 1973-80*[1]

[Upper number: area, in acres. Lower number: area, as percentage of total acreage for each hydrographic area]

Hydrographic area (years for which data apply)	Urban	Agri-cul-tural	Range	Forest	Water	Wet-land	Barren	Tundra	Total (rounded) Acres	Total (rounded) Percent of Carson basin
Headwaters Area	49	0	62,000	190,000	410	300	2,500	8,800	270,000	11
(1973-79)	<0.1	0	23	72	0.2	0.1	0.9	3.3		
Carson Valley	3,400	47,000	98,000	130,000	470	5,300	1,400	1,600	280,000	11
(1973-79)	1.2	16	34	45	0.2	1.9	0.5	0.6		
Eagle Valley	[2]4,800	1,100	28,000	12,000	0	0	450	0	47,000	2
(1973)	10	2.3	60	26	0	0	1.0	0		
Dayton Valley	950	4,800	150,000	70,000	9	1,600	4,700	0	230,000	9
(1973)	0.4	2.0	65	30	<0.1	0.7	2.0	0		
Churchill Valley	720	1,700	250,000	21,000	7,500	7,000	28,000	0	320,000	12
(1973)	0.2	0.5	79	6.7	2.4	2.2	8.8	0		
Carson Desert	[2]5,600	79,000	580,000	30,000	23,000	62,000	600,000	0	1,400,000	55
(1973, 1980)	0.4	5.7	42	2.1	1.6	4.4	44	0		
Carson basin	15,000	130,000	1,200,000	450,000	31,000	76,000	640,000	10,000	2,500,000	100
totals (rounded)	0.6	5.2	46.1	17.9	1.2	3.0	25.2	0.4		

[1]Data sources: U.S. Geological Survey, 1979, 1980, 1983. (These maps were interpreted from photographs taken from 1973 to 1979 below 39 degrees latitude, 1973 between 39 and 40 degrees latitude, and 1980 above 40 degrees latitude.)

[2]The Carson Desert has less than half as many people as Eagle Valley, but it has more urban land because the Fallon Naval Air Station is classified as urban land.

More than 90 percent of agricultural land in the basin is either in Carson Valley or the Carson Desert. Forest land predominates in the Headwaters Area and in Carson Valley, and decreases markedly toward the downstream part of the study area. Rangeland increases from Dayton Valley to Churchill Valley to Carson Desert.

The areal extent of water bodies and wetlands is highly variable, both seasonally and from year to year. This is especially true in the Carson Desert. For example, between July 1984 and February 1985, following three unusually wet years, the water surface area of the Carson Sink was approximately 200,000 acres (Rowe and Hoffman, in press), yet by April 1988 (during a second consecutive drought year) the sink was dry (Ray J. Hoffman, U.S. Geological Survey, oral commun., 1988). Major water bodies in the basin are the Lahontan Reservoir in Churchill Valley and ephemeral lakes, reservoirs, and alkali flats in Carson Desert.

In the upstream part of the study area, barren land is primarily exposed bedrock, whereas in the downstream part of the basin, barren land is primarily dry salt flats and other sandy areas. Nearly 10,000 acres of land along the crest of the Sierra Nevada in the Headwaters Area and Carson Valley are classified as tundra.

The Headwaters Area remains largely undeveloped and sparsely populated. Over 70 percent of the area is forested land. Carson Valley has been a major agricultural area in Nevada since the 1850's and included approximately 47,000 irrigated acres in 1985 (Douglas K. Maurer, U.S. Geological Survey, oral commun., 1986). The urban area in Carson Valley, primarily in Minden and Gardnerville, has increased considerably since the 1973-80 inventory shown in table 3. Eagle Valley, which contains Carson City, has a large urban area and only a small amount of agricultural land (less than 700 acres in 1985). Dayton and Churchill Valleys, which have the smallest populations in the Nevada part of the basin, are primarily rangeland, with agricultural areas along the Carson River. Carson Desert has the largest percentage of barren land because of the Carson Sink and other alkali flats. The land-use and land-cover map (U.S. Geological Survey, 1979) estimates somewhat greater agricultural areas in the Carson Desert for 1973 (78,500 acres) in comparison to U.S. Bureau of Reclamation estimates of irrigated acreage in 1973 for the Newlands Project area of 62,000 acres. During 1980-87, the estimated irrigated acreage ranged from 67,000 to 61,000 acres (U.S. Bureau of Reclamation, written commun., 1988). Urban land in the Carson Desert consists of the city of Fallon and the Fallon Naval Air Station.

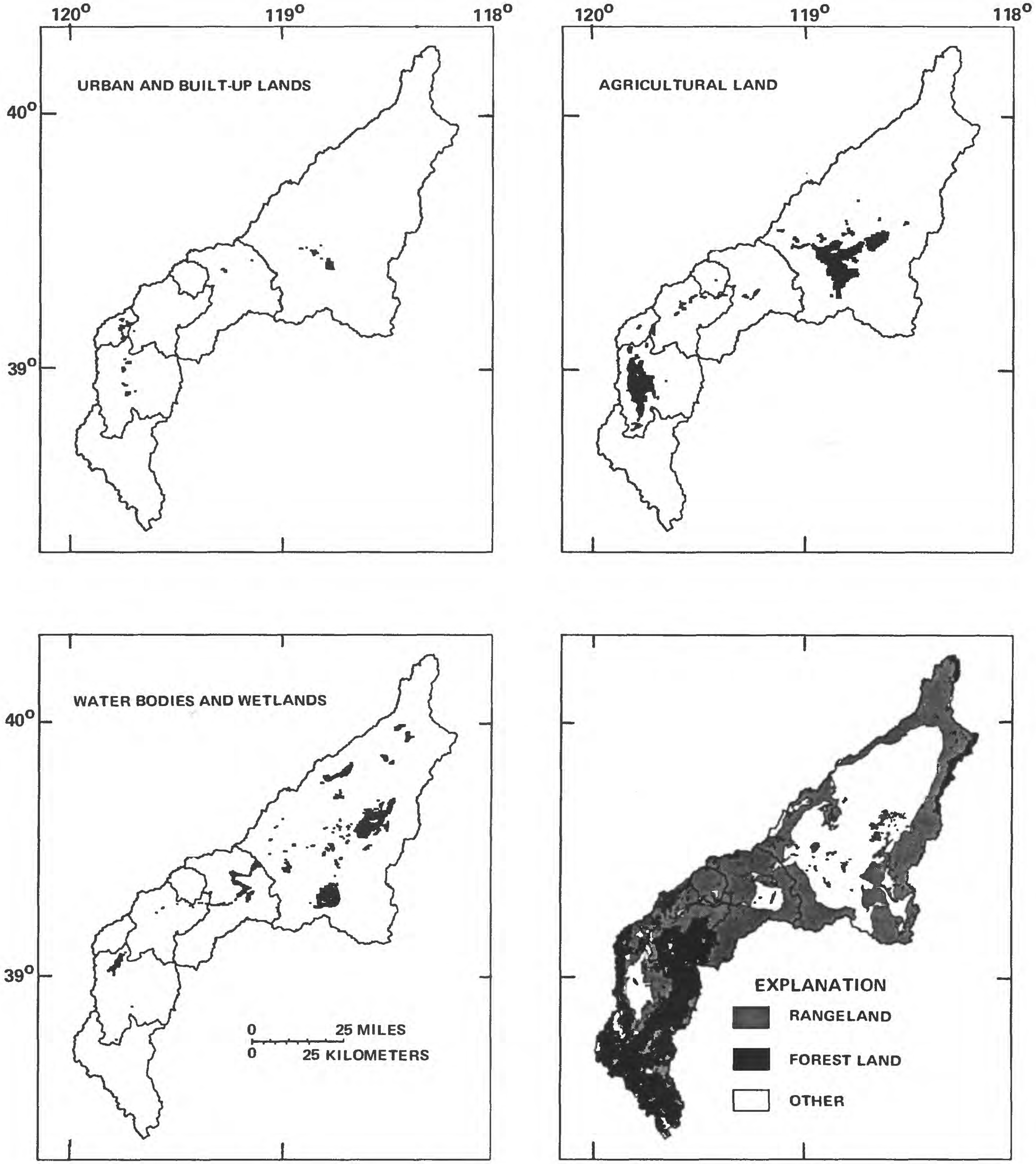

Figure 6.—Land use and land cover, 1973-80. Data sources: U.S. Geological Survey, 1979, 1980, 1983.

Historical water-use information is limited for most of the study area. During the 1850's and 1860's, most water development in the basin was in support of mining, although river-bottom lands adjacent to the ore-mill ditches were irrigated. Beginning in 1873, a dam on a mountain lake between Eagle Valley and Lake Tahoe, and a series of flumes and pipelines, were constructed to transfer water from the Sierra Nevada to Virginia City. Parts of this distribution system, which was built to supply water to the Comstock Lode, are still used today to supply Virginia City and parts of Carson City with water. In the late 1800's, the main users of Carson River water were farmers in Carson Valley, over 15 stamp mills along the river in the Dayton Valley hydrographic area that reduced ores from the Comstock Lode, and logging and cordwood interests that used the river to float wood cut in the Sierras to supply fuel for Carson and Virginia Cities and timbers for cribbing in the Comstock mines (Dangberg, 1972, p. 80).

Demand for water in the Carson River basin exceeded supply soon after the area was settled. Historically, court suits regarding water rights in the basin have followed drought years (Dangberg, 1975, p. 134-135 and unnumbered plate). In the 1980's, major water-management issues in the Carson River basin have included distributing available water and finding new sources of water to support urban and suburban growth, farming interests in Carson Valley and Carson Desert, and the Stillwater Wildlife Management Area. Many water-use and water-allocationdisputes in the Carson River basin and between the Truckee River and Carson River basins are still awaiting decision by the courts as of 1988.

Basinwide estimates of water withdrawals in 1969, 1975, and 1985 are listed in table 4. Long-term trends of surface-water use cannot be determined from only 3 years of data because the amount of available surface water fluctuates annually as a function of the quantity and timing of precipitation. Ground-water withdrawals for public water supply have increased from 2,700 acre-ft in 1969 to 14,000 acre-ft in 1985. The estimated ground-water withdrawal for self-supplieddomestic use has also more than doubled. The only long-term yearly estimates of ground-water withdrawal within the basin are for Carson City (fig. 7A) and the Fallon area (fig. 7B), where population and withdrawals have increased rapidly in the last 20 years. Since 1948, Fallon's sole source of municipal supply has been ground water pumped from the basalt aquifer. Cumulative pumpage from the basalt aquifer from 1941 to 1985 was 49,400 acre-ft. Historical estimates of ground-water pumpage in Carson Valley range from 7,400 acre-ft in 1982 to 22,000 acre-ft in 1968 (Walters, Ball, Hibdon & Shaw, 1970, p. 42; U.S. Bureau of Reclamation, 1980, p. 60; Maurer, 1986, p. 62-63; David L. Berger, U.S. Geological Survey, written commun., 1988). Over half the ground-water pumped in Carson Valley is used to supplement surface-water irrigation supplies, so withdrawal estimates differ widely from year to year. Annual estimates of water withdrawal prior to 1985 are not available for the Headwaters Area, Dayton Valley, and Churchill Valley.

Estimated total water withdrawals in the Carson River basin for 1985 were 640,000 acre-ft, of which over 90 percent (590,000 acre-ft) were surface-water withdrawals for irrigation (table 4). Although ground water accounts for only 6 percent (38,000 acre-ft) of the total water withdrawal (fig. 8A), it supplies 85 percent (17,000 acre-ft) of the amount withdrawn by public water supplies and for self-supplied domestic use (fig. 8B). Table 5 lists public water supplies, source of water, and estimated 1985 water withdrawal, by hydrographic area. A similar table for 1971 is given by Glancy and Katzer (1976, p. 56).

Sewage effluent returned to the ground-water and surface-water systems of the study area has the potential to affect regional ground-water quality. Estimates of effluent discharged in each hydrographic area in 1985 are listed in table 6. Four sewage-treatment facilities within the Lake Tahoe basin west of the study area began exporting effluent to the Carson River basin between 1968 and 1971 (Glancy and Katzer, 1976, p. 50-53); for over 10 years (as of 1988) all effluent from the Lake Tahoe basin has been exported to Carson Valley. Treated sewage effluent is used for irrigation in Carson Valley and Eagle Valley; similar applications are made on 20 acres in the Carson Desert.

SOURCES OF AVAILABLE DATA ON GROUND-WATER QUALITY

A variety of water-quality data have been collected in the Carson River basin by several organizations and agencies of Federal, State, and local government, usually either to comply with governmental regulations, or to accomplish the various objectives of water-resources investigations. Most of the data are for physical properties, inorganic constituents, nutrients, and a few trace elements. Most of the water-quality data used in this report were collected by one of three entities (fig. 9): The Nevada State Health Laboratory; the U.S. Geological Survey; and the Desert Research Institute, a part of the University of Nevada system. Water-quality data from the Nevada State Health Laboratory constitute 70 to 90 percent of the total

Table 4.—*Estimated water withdrawals, basinwide, 1969, 1975, and 1985*

[Estimated withdrawals, in acre-feet, are significant to no more than two figures; columns may not cross-total due to independent rounding. Abbreviations: GW, ground water; SW, surface water; RS, reclaimed sewage; --, no data]

	1969[1]				1975[2]				1985[3]			
Type of water use	GW	SW	RS	TOTAL	GW	SW	RS	TOTAL	GW	SW	RS	TOTAL
Public supply	2,700	1,200	0	3,900	5,900	480	0	6,400	14,000	3,000	0	17,000
Self-supplied domestic	1,200	40	0	1,200	1,700	50	0	1,800	3,000	90	0	3,100
Livestock (nonirrigated) agriculture	120	440	0	560	2,200 (4)	870	0	3,100	2,100 (5)	1,800	0	3,900
Irrigation	6,000	670,000 (6)	-- (7)	680,000	8,800	650,000	900 (8)	660,000	18,000	590,000	4,600	610,000
Thermoelectric power	0	0	0	0	0	0	0	0	0	0	0	0
Self-supplied commerical, industrial, and mining	1,200	430	0	1,600	1,300 (4)	300 (9)	-- (9)	1,600	1,300	100	0	1,400
Total withdrawal (rounded)	11,000	670,000	-- (7)	690,000	20,000	650,000	900	670,000	38,000	590,000	4,600	640,000
Percent of total												
Hydroelectric power (instream use)	0	260,000	0	260,000	0	320,000	0	320,000	0	230,000	0	230,000
Total consumed				320,000				(10)				290,000

[1]Smales and Harrill, 1971, p. 17, 29, and 30.

[2]James R. Harrill and Jon O. Nowlin, U.S. Geological Survey, written commun., 1976.

[3]U.S. Geological Survey files, 1988.

[4]For 1975, the estimate of self-supplied industrial water use includes 2,200 acre-feet of ground water withdrawn by the Lahontan Fish Hatchery on east fork, Carson River, south end of Carson Valley. For consistency with 1985 categories of water use, those 2,200 acre-feet are included in nonirrigated agriculture. A very small percentage of this water is consumed.

[5]Includes 1,900 acre-feet of ground water withdrawn by the Lahontan Fish Hatchery. A very small percentage of this water is consumed.

[6]Includes 114,000 acre-feet diverted from Truckee River into Truckee Canal.

[7]In 1969, 2,900 acre-feet of sewage effluent from the Lake Tahoe basin was imported to the Carson River basin, but the amount used for irrigation was not mentioned (Glancy and Katzer, 1976, p. 53).

[8]In 1975, the estimate of self-supplied industrial water use included 500 acre-feet of reclaimed sewage applied to the golf course on the east side of Carson City. For consistency with 1985 categories of water use, those 500 acre-feet are included in irrigation.

[9]In 1975, the estimate of self-supplied industrial water use included 2,000 acre-feet of surface water withdrawal by Huck Salt Company in Carson Desert. Water on the salt flats flows there naturally and is not diverted or withdrawn. Salt-mining operations do not affect natural evaporation rates; for consistency with 1985 estimates, therefore, the 2,000 acre-feet included in the original 1975 estimates are not included in above table.

[10]In 1975, estimated consumptive water use for Truckee and Carson River basins was 510,000 acre-feet. Estimates for the two basins cannot be separated on the basis of available files.

available in each hydrographic area of the Carson River basin except for the Carson Desert, where the data are almost evenly divided between this laboratory and that of the Geological Survey. Ground-water studies made by the Geological Survey in hydrographic areas of the Carson River basin have generated ground-water-quality data that account for less than 10 percent of the total available data (Eagle Valley) to nearly 50 percent (Carson Desert). Ground-water studies made by the Desert Research Institute in Carson, Eagle, Dayton, or Churchill Valleys, generated water-quality data that account for about 1 to 17 percent of the available total. Most of the Desert Research Institute data were collected for a study of the Eagle Valley area (Szecsody and others, 1983). Other sources of ground-water-quality data include the U.S. Forest Service, U.S. Bureau of Land Management, and private consultants working for local, State, or Federal agencies; these data account for 1 to 5 percent of the available total in Carson, Eagle, and Dayton Valleys and the Carson Desert. Table 7 shows the number of analyses compiled for each constituent or property (except manmade organic compounds) and the corresponding number of sites (mostly wells) from which samples were taken. Only a few samples have been analyzed for manmade organic compounds.

A.

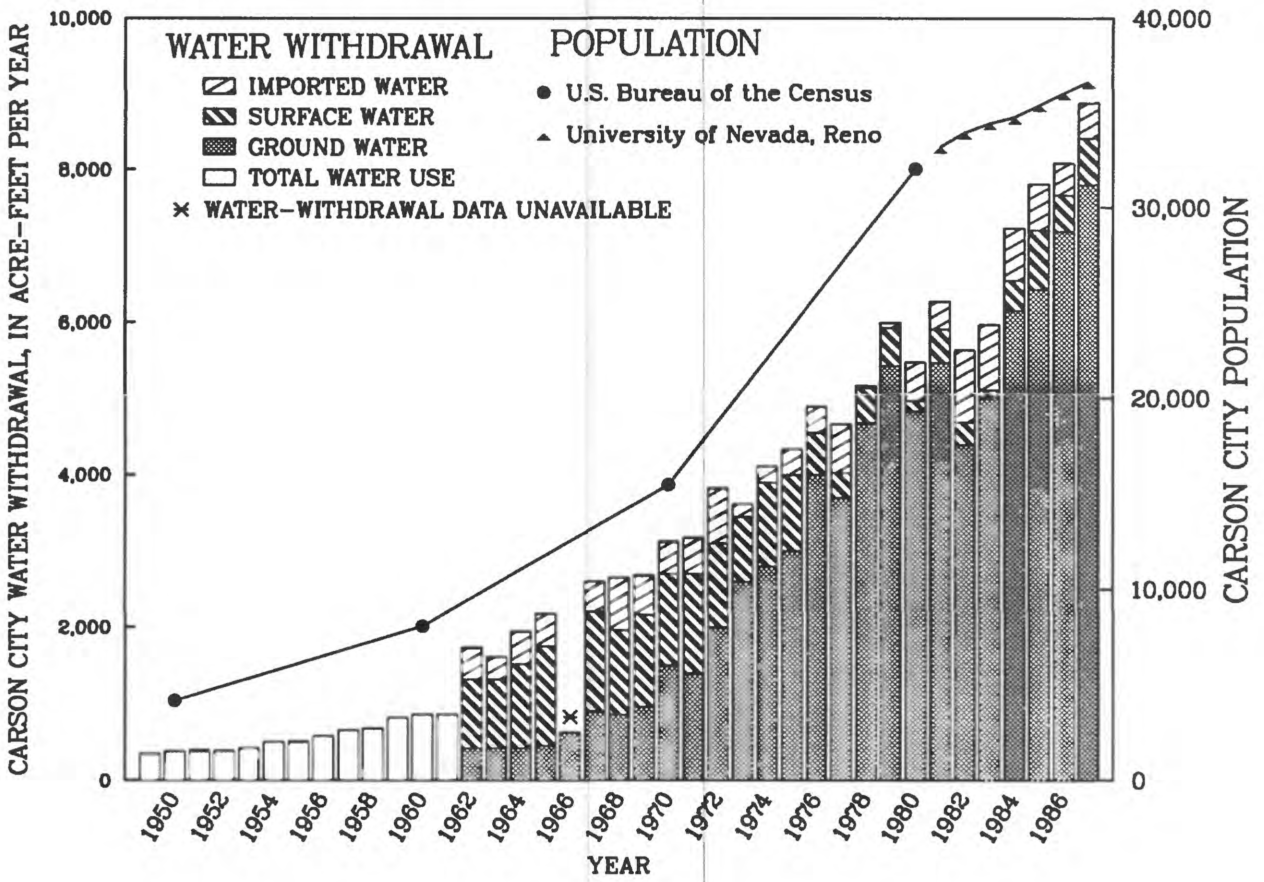

Figure 7.—Estimated water withdrawal and population in (A) Carson City, 1949-87, and (B) the Fallon area, 1940-87. Carson City water-withdrawal data sources: for 1949-65, Worts and Malmberg, 1966, p. 21, 23-24, and 31 (total water use + conveyance losses = total water withdrawal); for 1966, Arteaga, 1982, p. 37; for 1967-77, Arteaga and Durbin, 1978, p. 28; for 1978-87, Nancy Lamb, Carson City Public Works Department, written and oral commun., 1988. Fallon water-withdrawal data sources: for 1941-78, Glancy, 1986, p. 24-25; for 1979-85, Patrick A. Glancy, U.S. Geological Survey, written commun., 1987. Population data sources: for 1940-80, U.S. Bureau of the Census, 1952a, 1952b, and 1983; for 1981-87, University of Nevada, Reno, Bureau of Business and Economic Research, written commun., 1988.

B.

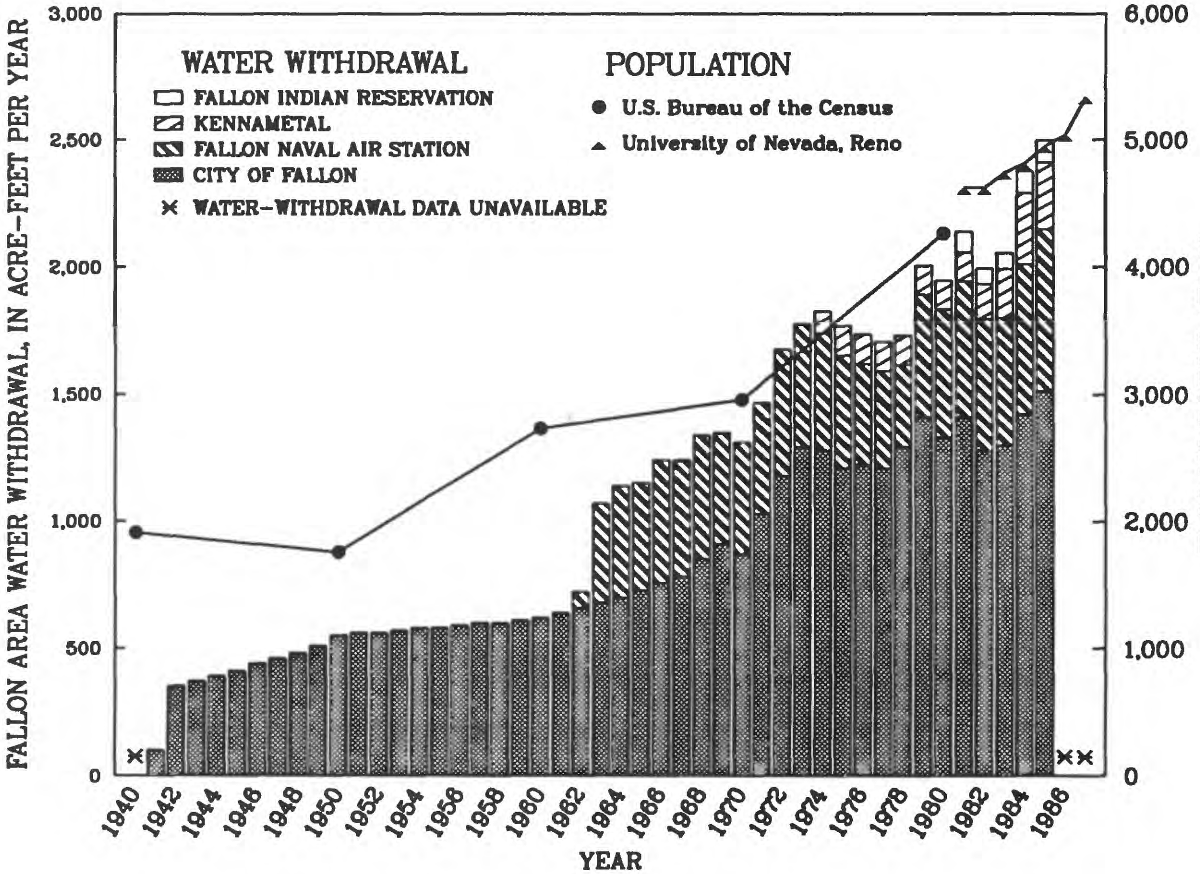

Figure 7.—Continued.

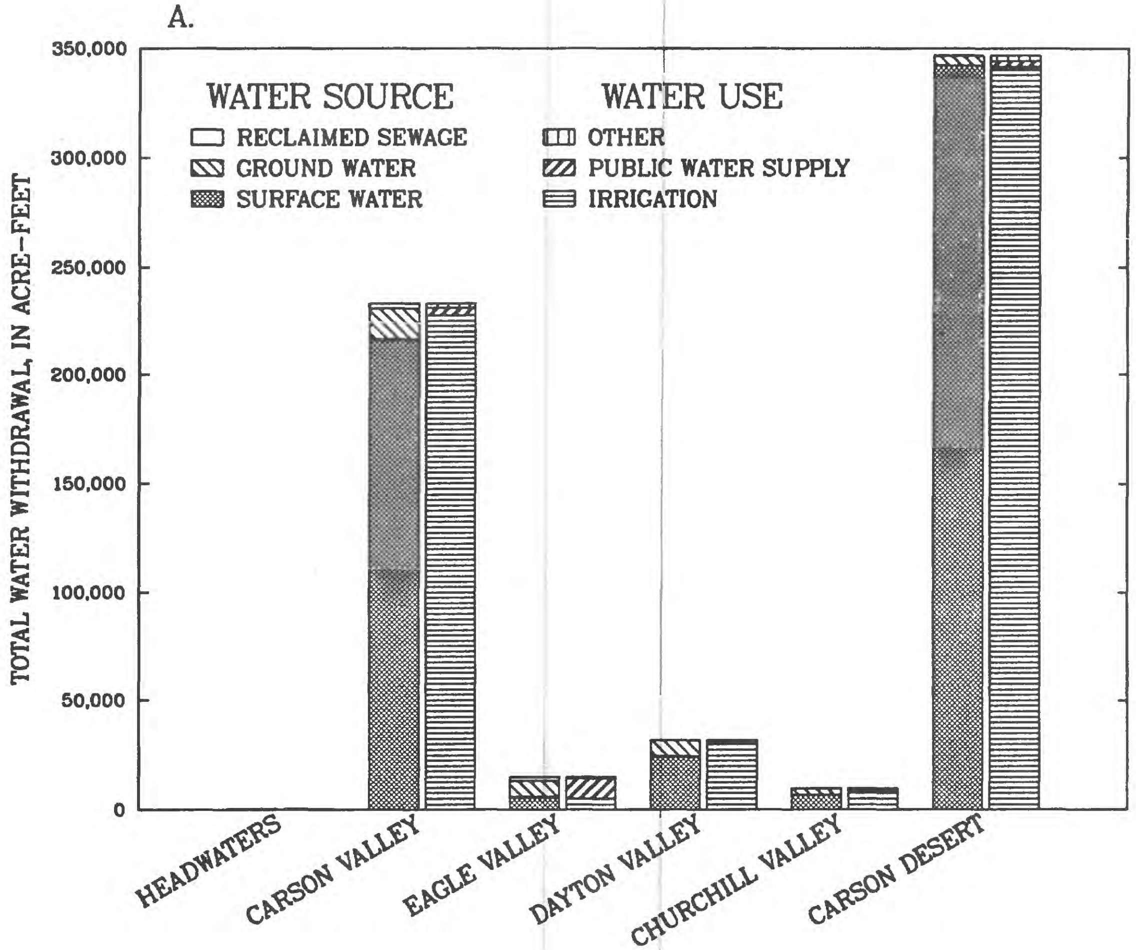

Figure 8.—Estimated water withdrawals in 1985, by hydrographic area. (A) Total withdrawals, by water source and use. (B) Ground-water withdrawals, by water use. Data sources: U.S. Geological Survey National Water-Data Storage and Retrieval System (WATSTORE); U.S. Geological Survey files, Carson City, Nev.

B.

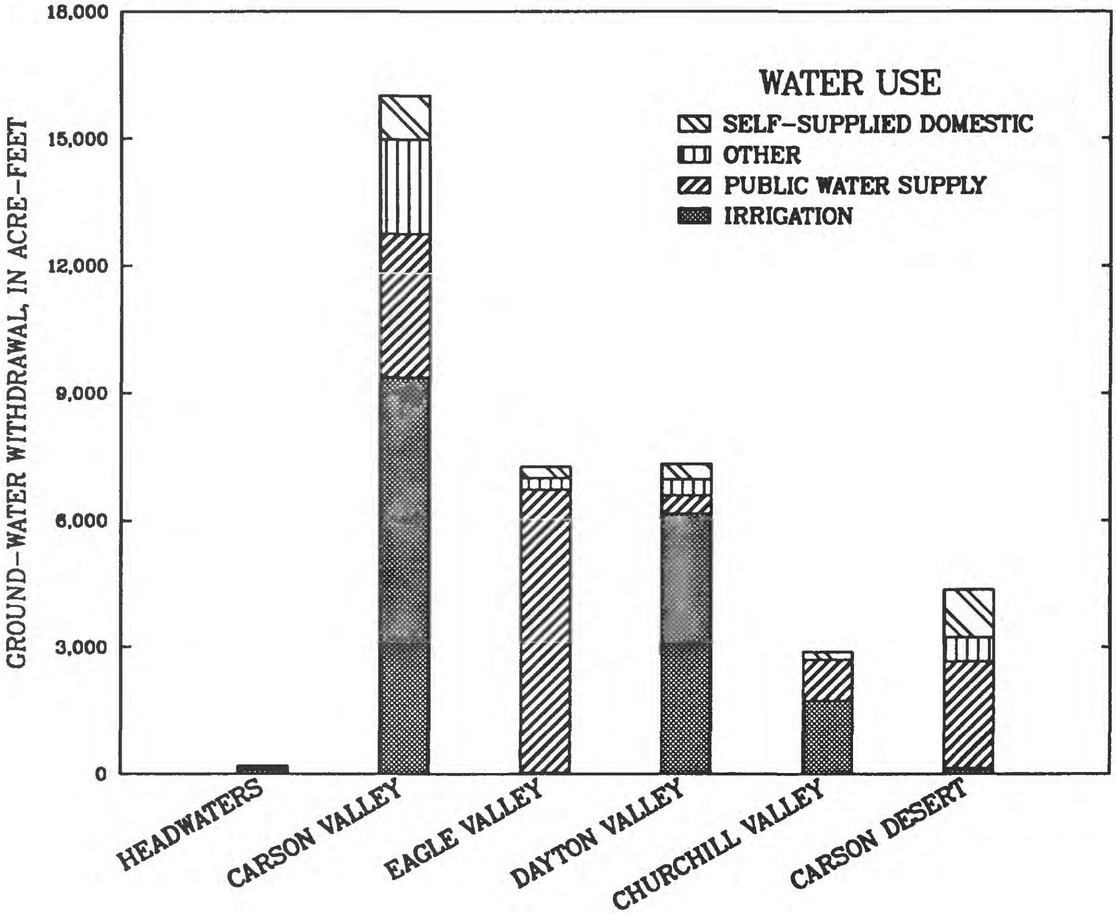

Figure 8.—Continued.

Table 5.—*Data for major public water supplies, by hydrographic area*[1]

[All information is for 1985 unless stated otherwise. Quantity data compiled primarily from operator records for individual water supplies. Some sites listed are outside study area or of such localized extent they are not shown on plate 1. Abbreviation: na, information not available]

Water supply	Water-supply source	Year began[2]	Estimated annual withdrawal (acre-feet)	Estimated number of connections: Domestic	Commercial	Other	Estimated population served
HEADWATERS AREA							
Markleeville Water Company[3]	Musser and Jarvis Creeks 1 well used for backup when high turbidity in creeks	1864 1963	112	145	0	0	500
CARSON VALLEY							
Minden Water Company	3 active wells 2 inactive wells	1905	754	353	58	0	1,000
Gardnerville Town Water[4]	5 active wells 1 inactive well 1 well being drilled in 1988	1929	1,100	765	75	0	2,000
Gardnerville Ranchos General Improvement District	5 wells	1965	1,800	1,200	0	0	3,600
Sierra Estates General Improvement District[5]	2 wells	1968	41	58	0	0	140
Indian Hills General Improvement District	8 wells (in 1985) 1 well drilled in 1986	1973	280	530	1	1	1,800
EAGLE VALLEY							
Nevada State Water System[6]	Import water from Marlette Lake and Hobart Reservoir (Lake Tahoe basin)	1873 1957 1963	950	0	0	20	5,000
Stewart Complex[7]	Clear Creek 6 wells, not all used	1926	20	0	0	14	450
Carson City Water Department[8]	16 active wells in 1985 Ash and Kings Canyons Purchase from Nevada State Water System	na 1971	7,810	7,700	800	200	34,600
DAYTON VALLEY							
Dayton Town Utilities[9]	3 wells	1855 1970	85	189	0	0	520
Storey County Water System[10]	Purchase from Nevada State Water System	1858 1873	225	368	116	0	1,000
Mound House Water Company[11]	7 wells Springs, not regularly used	1960's	30	93	0	0	280
American Flat Water[12]	2 wells	1960's	25	75	0	0	200
Stagecoach General Improvement District[13]	4 active wells Debate over who owns 5th well	1970's 1985	110	210	0	0	700
Dayton-Rosepeak Water Company[14]	2 active wells 1 well not yet in service	1975	36	96	0	0	260
Dayton Estates/Concord	2 wells	1978	84	142	0	0	400
Comstock Enterprises[15]	3 wells Not all wells are used	1970's	8	0	36	0	100
Village Builders[11]	2 active wells 3 heavily mineralized wells	1970's	15	0	44	0	120
CHURCHILL VALLEY							
Silver Springs Water Company	4 wells	1950's	860	420	0	0	1,300

Table 5. —*Data for major public water supplies, by hydrographic area*[1] —Continued

Water supply	Water-supply source	Year began[2]	Estimated annual withdrawal (acre-feet)	Estimated number of connections: Domestic	Commercial	Other	Estimated population served
		CARSON DESERT					
Hazen[14]	Diversions from Truckee Canal	1905	110	22	2	0	~60
Fallon Water Company[15]	3 wells	1920's 1941	1,500	2,600	na	na	5,000
U.S. Fallon Naval Air Station	3 wells	1944	630	na	na	na	~1,000
Fallon Indian Reservation[16]	1 well Emergency connection to Fallon Water Company system	1950's 1980	>86	177	1	6	670
Total (rounded)			~17,000	~12,500	>1,130	>250	~60,000

[1]Sources of information: Lynn Arndell, Stagecoach General Improvement District, Manager, oral commun., 1988; Ben Bartlette, Fallon City Manager, written commun., 1986; Dean Borges, Nevada State Water System, Engineer, oral commun., 1988; Barbara Bowers, Storey County, Public Works Clerk, written commun., 1986; Ed Burnett, Dayton Town Utilities, Manager, oral commun., 1988; Jeannie Cordes, Gardnerville Town Water Board, Secretary, oral commun., 1988; John Cowee, Bookkeeper, oral commun., 1988; Dave Creech, Dayton Estates/Concord, Bookkeeper, oral commun., 1988; Larry English, Sierra Estates General Improvement District, Chairman of the Board, oral commun., 1988; Paul Freitag, Hazen Water System, Owner, oral commun., 1988; Glancy, 1986, p. 7-13; Patrick Glancy, U.S. Geological Survey, written commun., 1988; Glancy and Katzer, 1976, p. 56; Tom Hoffert, Carson City Water Department, Maintenance Supervisor, oral commun., 1988; Joanne McLachlan, Storey County, Public Works Clerk, oral commun., 1988; Luke Neddenrip, Gardnerville Town Water Board, President of the Board, written commun., 1986 and oral commun., 1988; Resource Concepts, Inc., written commun., 1986; Sheila Robertson, Executive Technical Secretary to the Town Board, Minden Water Company, oral commun., 1988; H.L. Sage, Manager, Silver Springs Water Company, written commun., 1986, and oral commun., 1988; Bob Spellberge, Gardnerville Ranchos General Improvement District, District Manager, oral commun., 1988; Sam Stegeman, Fallon City Engineer, oral commun., 1988; Hazel Stone, Indian Hills General Improvement District, office personnel, oral commun., 1988; Doranna Tognolli, Markleeville Water Company, Secretary- Treasurer, oral commun., 1988; David Wallace, U.S. Indian Health Service, Sanitarian, oral commun., 1988; Walters Engineering and Chilton Engineering, 1972a, p. 147, and 1972b, p. 41; Larry White, Fallon City Engineer, oral commun., 1988.

[2]Multiple years refer to changes in sources of water, water-company name, or water-company ownership.

[3]Markleeville Water Company, formed in 1963, uses original system of ditches and reservoirs built in 1800's.

[4]In 1988, Gardnerville Town Water serviced 850 residential connections, 149 commercial connections, and 2,700 to 3,000 people.

[5]Sierra Estates General Improvement District was purchased from Southwest Gas in 1972.

[6]Original system was built in 1873, sold to Curtis-Wright Corporation in 1957, and sold to State of Nevada in 1964. Franktown Decree allows State to use 10 cubic feet per second from Marlette Lake, they are presently using approximately 2 cubic feet per second. Serve 20 institutional connections. The State maintains this system to Lakeview and Storey County maintains the system from Lakeview to Virginia City.

[7]Water withdrawn by Stewart Complex is used to water lawns, drinking water is provided by Carson City Water Department. In 1988, approximately 14 buildings are used.

[8]In 1971, a bond issue passed for Carson City to acquire Carson Water Company, which was owned by Southwest Gas (unknown when the Carson Water Company began). Distribution of active wells in 1985: 13 in Eagle Valley (5 of the 13 in Lakeview), 1 each in Dayton and Washoe Valleys, and 1 infiltration well in Eagle Valley.

[9]Water company that services Dayton became a county entity in 1970 and installed water meters in 1987. Estimated 1988 population, 800. Before wells were drilled, Carson River was source of drinking water.

[10]Water from Lake Tahoe basin was first delivered to Virginia City in 1873. Original Virginia and Gold Hill Water Company changed its name to Virginia City Water Company in 1933. In 1957, Curtis-Wright Corporation purchased water company, which was later sold to Marlette Lake Company, which in turn sold it to State of Nevada. Storey County purchased water company from private owners in 1974.

[11]Mound House Water Company, American Flat Water, Comstock Enterprises, and Village Builders were being merged into one company in 1988.

[12]Stagecoach Utilities went bankrupt in 1984. Stagecoach General Improvement District began operating in February 1985.

[13]Dayton-Rosepeak Water Company installed water meters in 1987. Estimated 1988 population, 316.

[14]Hazen Water System was built and originally operated by Southern Pacific Railroad Company to supply water for their steam engines. It is now privately owned.

[15]Fallon Water Department used water from shallow wells as early as 1920's. They began using their current wells which tap the Basalt aquifer in 1941.

[16]Wells for original Fallon Indian Reservation water system were built in 1950's. In 1980, the well they are currently using was built and water system also was linked with Fallon Water Company system for backup. In 1985, 86 acre-feet of water was supplied to reservation from Fallon Water Department; pumping records were not kept for Fallon Indian Reservation well.

Table 6.—*Data for public sewage-treatment facilities that discharge effluent within the Carson River basin, by hydrographic area*[1]

[All information is for 1985 unless stated otherwise. Quantity data compiled from operator records for individual treatment plants and the Nevada Division of Environmental Protection files. Some sites listed are outside study area or of such localized extent they are not shown on plate 1. Abbreviation: na, information not available from sewage-treatment facility or not applicable for 1988]

Sewage treatment facility	Year began[2]	Level of treatment	Design capacity (acre-feet per year)	Estimated quantity of effluent treated (acre-feet/year)	Estimated acres irrigated with effluent	Estimated resident population served
		HEADWATERS AREA				
No public sewage treatment facilities as of 1988.						
		CARSON VALLEY				
South Tahoe Public Utility District[3]	[4]1968	Tertiary	8,400	4,500	~2,000	29,000 89,000 peak
Minden-Gardenville Sanitation District[5]	1963 1976	Secondary	1,700	950	>2,000	4,200
Indian Hills General Improvement District[6]	1978	Secondary	400	<140	0	1,900
Douglas County Sewer Improvement District[7] (Round Hill)	[4]1969	Secondary	4,200	2,530 influent 2,430 effluent	560	3,000 100,000 peak
Incline Village General Improvement District[8]	[4]1971	Secondary	3,400	1,700	200	5,000 16,000 peak
Sand Harbor Package Treatment Plant[9]	[4]1971	Secondary	36	20	0	0 789,000 1985 visitors
Douglas County Industrial Wastewater Treatment Plant[10]	na	Secondary	na	Under construction in 1988	na	na
		EAGLE VALLEY				
Carson City Wastewater Treatment Plant[11]	1961	Secondary	5,900	4,200 influent 3,800 effluent	240	20,000
		DAYTON VALLEY				
Storey County Sewage Treatment Plant[12]	1982	Secondary	110	70	0	700
Dayton Wastewater Treatment Plant[13]	1987	Secondary	560	0 (in 1985)	na	na
North Dayton Valley Wastewater Treatment Facility (Comstock Enterprises)[14]	na	na	na	Proposed, 1988	na	na
Carson Highlands Package Treatment Plant	na	Secondary	na	Under construction in 1988	na	na
		CHURCHILL VALLEY				
No public sewage treatment facilities as of 1988.						
		CARSON DESERT				
City of Fallon Sewage Treatment Plant[15]	1912 1954	Secondary	1,300	670 influent 360 effluent	20	7,000
Fallon Naval Air Station Sewage Treatment Plant[16]	1940	Secondary	560	180 effluent	0	3,500
Total (rounded)			27,000	15,000	5,000	74,000

[1]Sources of information: Arteaga and Durbin, 1978, p. 28 and 30; Julian Bielawski, Nevada Division of Environmental Protection, oral commun., 1988; Brown and others, 1986, p. 9; Ed Burnett, Dayton Town Utilities, Manager, oral commun., 1988; John Cofer, South Tahoe Public Utility District, Engineering Manager, oral commun., 1988; Glancy and Katzer, 1976, p. 50-53; Gary Hoffman, Carson City Wastewater Treatment Plant, Treatment Plant Foreman, oral and written commun., 1988; David LaBarbara, Minden-Gardnerville Sanitation District, Superintendent, written commun., 1986; James Martin, Douglas County Sewer Improvement District, District Manager, written commun., 1986 and oral commun., 1988; Maurer, 1986, p. 65; Wendell McCurry, Nevada Division of Environmental Protection, oral commun., 1988; Tim Murphy, Sand Harbor State Park, Maintenance, oral commun., 1988; Lew Nagy, Storey County Sewage Treatment Plant, Contract Operator, written commun., 1986; URS Company, 1979, p. 120; Nevada Division of Environmental Protection, files, 1988; Steve Richards, Fallon Naval Air Station Sewage Treatment Plant, Plant Operator, written commun., 1986; Don Richey, Incline Village General Improvement

District, Superintendent, written commun., 1986; Paul Strasdin, City of Fallon Sewage Treatment Plant, Chief Operator, oral commun., 1988; Walters, Ball, Hibdon, & Shaw, 1970, p. 35; Walters Engineering and Chilton Engineering, 1972a, p. 69-70, 87-88, and 1972b, p. 30; Worts and Malmberg, 1966, p. 26.

[2]Multiple years refer to changes in design and (or) location.

[3]South Tahoe Public Utility District effluent is pumped approximately 1,500 vertical feet over a pass and piped 20 miles to Indian Creek Reservoir (36,000 acre-feet storage; T. 10 N., R. 20 E., sections 3 and 4) in Diamond Valley. In summer months, effluent is mixed with surface water and transported in an irrigation ditch to four Alpine County ranches in Carson Valley. Public utility district serves approximately 85 percent of South Lake Tahoe, Calif.

[4]Year began exporting effluent from Lake Tahoe basin to Carson basin.

[5]Original plant was built in approximately 1963; major expansion in 1976. Until fall of 1986, Minden-Gardnerville Sanitation District effluent was discharged in a slough which flows into East Fork of Carson River. Since then, effluent has been stored in ponds (T. 13 N., R. 20 E., section 30); in July and August, effluent is transported into a slough and used for irrigation.

[6]Indian Hills General Improvement District effluent is stored in ponds in northern Carson Valley. The sewage- treatment facility serves a school and over 500 residences.

[7]Douglas County Sewer Improvement District began transporting effluent from Lake Tahoe basin over a pass to a creek in the Carson basin on a trial basis in 1969 and full time in 1971. From 1968 to 1979, effluent was discharged directly to East Fork of Carson River. Since 1979, effluent has been applied by sprinkler in winter months at a ranch in northwestern Carson Valley and released to ditches during summer months. In 1988, estimated population of 7,500 served and 800 acres irrigated.

[8]Incline Village General Improvement District effluent is pumped over a summit to Carson Valley, where it is applied with sprinklers at a ranch from April to October. Effluent used to be piped to Carson River at north end of Carson Valley during winter months. It is now discharged to 770 acres of wetlands from November 1 to April 1 and at other times depending on irrigation needs.

[9]Sand Harbor Package Treatment Plant effluent is transferred to Incline Village General Improvement District's export line and then transported to wetlands in T. 14 N., R. 20 E., sections 16, 17, 20 and 21 in Carson Valley. Plant became operational in 1971.

[10]Douglas County Industrial Wastewater Treatment Plant will service an area near and to north of Douglas County Airport.

[11]Carson City Wastewater Treatment Plant effluent is used for irrigation as follows: Centennial Park Golf Course (East—100 acres) began receiving effluent August or September 1975; Medium Security Prison farm (140 acres) began receiving effluent May 20, 1985; and Centennial Park Golf Course (West—80 acres) began receiving effluent September 1, 1986. Effluent not used for irrigation was transported to Carson River 5 miles downstream from Carson City until September 1987, when discharge of effluent to river ceased. In 1988, 320 acres were irrigated with effluent.

[12]Storey County Sewage Treatment Plant discharges effluent into Six Mile Canyon (T. 17 N., R. 21 E., section 28, see fig. 25).

[13]Dayton Wastewater Treatment Plant services Dayton area and discharges effluent to two primary aeration ponds. They are changing facility to secondary treatment and have plans to eventually use effluent to irrigate two golf courses. Estimated 1988 population is 1,000, with 368 connections.

[14]North Dayton Valley Wastewater Treatment Facility has been in planning stages in 1987-88. It will service northeast area of Dayton Valley.

[15]Fallon's original collection system was constructed in approximately 1912. City of Fallon Sewage Treatment Plant was built in 1954. Effluent is discharged to an agricultural drain and flows through a series of canals and reservoirs to Carson Sink. During summer, approximately 0.4 million gallons per day of effluent is used for irrigation and very little effluent is discharged.

[16]Fallon Naval Air Station Sewage Treatment Plant discharges effluent to an agricultural drain which eventually flows into a reservoir.

Water-quality data from the sources described above were compiled into a computer data base using software developed for the Water-Quality File of the Geological Survey's National Water Information System. Data from Geological Survey projects and files were stored in one water-quality file, and data from other sources were entered into a similar but separate water-quality file. The two computer files presently (1988) contain analyses of about 2,300 samples collected between the late 1960's and 1987 from more than 1,000 wells and a few springs in the basin. Further data are stored in the National Water Information System site file, which contains geographic information associated with each site, and in the Ground-Water Site Inventory part of National Water Information System, which contains well-construction information, ground-water levels, and associated data.

The assembled water-quality data for the Carson River basin include multiple analyses of some well and spring waters. To avoid bias toward sites that have been repeatedly sampled, only the most recent analyses were used in the spatial description of ground-water quality. The most recent analyses (most of which are for samples collected between 1975 and

1987) were used because analytical precision and accuracy have generally been improving with time and because, during the past 10 years, the Nevada State Health Laboratory (the principal source of data) has expanded the number of constituents for which determinations are made.

Manmade organic compounds may affect ground-water quality as a result of spills or leaks or as a result of pesticides that are applied either on the ground or aerially in agricultural areas. Sources of data for spills and leaks include the Geological Survey, the Nevada Division of Environmental Protection, and private consultants.

Information on the types and quantities of pesticides aerially applied in the Carson River basin was assembled as a part of this study (table 8). The data are included as an indication of the types of compounds that may be present in ground water in agricultural areas. Ground applications of pesticides are not routinely reported, however, so accurate estimates of total pesticide application rates (ground and aerial combined) are not available for agricultural areas in the Carson River basin.

GENERAL CHARACTERISTICS OF DATA FOR REGIONAL ASSESSMENT OF GROUND-WATER QUALITY

Compilation and Screening

The data used for this study were screened to ensure that two minimum requirements could be met. The first requirement was that the location of each sample site was verifiable. Data were not used if the location of the site could not be verified with reasonable confidence. Once verified in the field, site locations were plotted on topographic maps so that the locations could be accurately described. In addition, an attempt was made to match a driller's well log to the sample site; however, this was not always successful and was not a criterion for acceptance or rejection of an analysis. Information for each site was stored in the Ground Water Site Inventory. The information stored, however, differs from well to well, mainly because logs could not always be obtained. The minimum information entered for each site includes location, based on public-land surveys, latitude and longitude, and the Geological Survey's standard and local site identifications. When a log could be matched to a site, more detailed information was entered, including owner and driller names, drilling dates, and well-construction data.

A second requirement was that no water-treatment process was determined or suspected to have been in use at the site when the sample was taken. Chlorination is used mostly at public-supply wells. Some analyses, initially thought to represent a sample from a domestic well, were later identified as treated water (filtered or chlorinated) from a public water supply and were therefore rejected because of the possible effects of the treatment on natural water quality. Water softeners are used in many households and their presence is sometimes, but not always, recorded on Nevada State Health Laboratory laboratory sheets. For a few sites, the presence of a softener was inferred from changes in concentrations of calcium, magnesium, and sodium for successive samples taken at the site. In spite of the precautions discussed here, some of the analyses entered into the data base may represent treated water, although such analyses are believed to constitute only a small part of the total.

The ionic balance of a comprehensive analysis is another possible criterion for determining whether or not a major ion analysis should be rejected. Ionic balance is a means of comparing abundance of positive and negative ions in a sample: the two groups of ions should be about equal in abundance to maintain electrical neutrality. The balance is useful for determining whether an analysis is complete and whether the analytical results for one or more constituents are in error. Thus, when the absolute value of the quantity $[(\text{cations} - \text{anions})/(\text{cations} + \text{anions})] \times 100$ was greater than 10 percent for a particular analysis, those analytical results were not used to describe the relative proportions of major ions in the hydrographic area. However, the ionic balance was not used herein as a criterion for complete rejection of an analysis because even partial analyses are useful for the purposes of this report, and ionic balance is not a relevant criterion for many trace constituents. For a more complete explanation, see Hem (1985, p. 55 and 56).

Limitations

Part of the water-quality data compiled for this study have several limitations with respect to interpretations regarding the chemical character of the water and its suitability for use on the basis of present drinking-water standards and criteria. The principal reason for these limitations is that standardized procedures were not used to collect and preserve all the samples. Once water is removed from an aquifer, its chemical composition can change rapidly. Thus, water in a well or a storage tank may no longer be representative of water in the aquifer. As a result, standardized procedures are used by the U.S. Geological Survey (Wood, 1981) and the Desert Research Institute to collect samples in support of

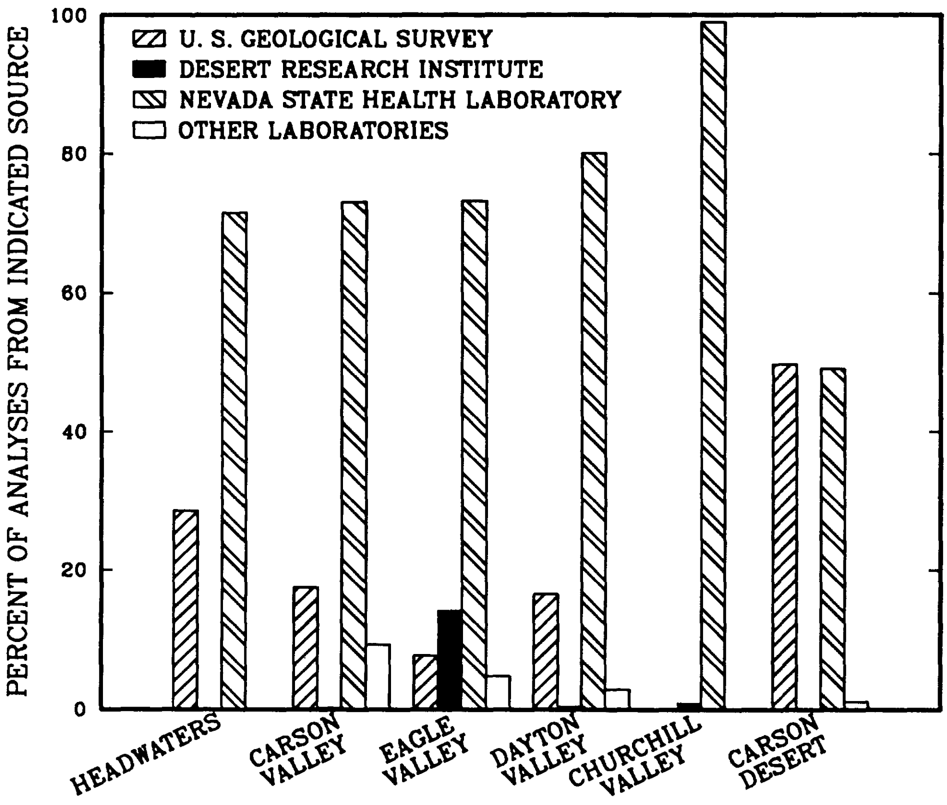

Figure 9.—Sources of data on ground-water quality, by hydrographic area.

water-resources assessments and geochemical studies. For example, an effort is always made to collect each sample, after several well volumes have been pumped and before the water enters a storage tank. In addition, parts of the sample are filtered and then stabilized with acid or other chemicals because concentrations of certain dissolved constituents can change as a result of chemical or biologic reactions in the sample container. Sampling procedures also require that several properties of water be measured onsite when the sample is taken. These properties include pH, specific conductance, alkalinity, and dissolved oxygen. In contrast, many samples sent to the Nevada State Health Laboratory were collected by individual well owners from a convenient faucet, and placed in containers that normally are not used for such purposes. Furthermore, most such samples were not filtered or preserved at the time of collection, nor were the onsite water-quality measurements made. Thus, many of the resulting analyses probably are not entirely representative of water in the aquifer.

Some of the analyses compiled for this study were compared statistically in an effort to determine whether the different methods of sample collection and preservation described above caused any identifiable differences in the data. Analyses of arsenic, iron, and manganese for Carson Valley were selected because all the samples were collected from the same ground-water system, and because the samples that were submitted to the Health Laboratory and those collected by the Geological Survey yielded data sets of similar size for each of the three constituents. The resulting data sets (two each for arsenic, iron, and manganese) were limited to results obtained after 1979 because analytical procedures and detection limits for each element have not changed at either laboratory since that time.

The data are summarized in table 9. The median values of constituents listed in table 9 indicate that differences in sample-collection and preservation methods may not be significant for arsenic and manganese, but are significant for iron. This possibility was tested statistically to further strengthen or reject this hypothesis.

A statistical hypothesis test was used to compare a "null hypothesis" against an alternate hypothesis. The null hypothesis is that the median values of each of the pairs of data sets are not significantly different from

Table 7.—*Compilation, by data source, of numbers of measurements available for inorganic constituents and properties, basinwide*

Constituent or property	U.S. Geological Survey		Nevada State Health Laboratory		Desert Research Institute		Other	
	Number of sites	Number of analyses	Number of sites	Number of analyses	Number of sites	Number of analyses	Number of sites	Number of analyses
Physical and chemical properties								
pH	239	401	813	1,221	33	132	42	435
Temperature	234	421	34	37	27	54	13	13
Specific conductance	246	430	20	21	33	132	38	433
Dissolved oxygen	17	33	0	0	0	0	0	0
Major inorganic constituents								
Calcium	227	399	809	1,220	28	28	19	30
Magnesium	227	398	795	1,200	28	28	19	30
Sodium	176	349	677	957	33	132	20	371
Potassium	174	348	675	938	29	32	14	14
Bicarbonate	224	386	813	1,220	28	28	23	89
Sulfate	228	401	808	1,218	28	28	33	62
Chloride	230	403	811	1,219	28	28	41	81
Silica	175	348	145	169	28	28	16	27
Dissolved solids	69	151	808	1,246	0	0	6	17
Nutrients								
Ammonium	86	204	10	10	0	0	1	1
Nitrate	48	52	799	1,207	2	2	14	25
Total nitrogen	0	0	5	5	0	0	0	0
Minor inorganic constituents								
Arsenic	146	253	691	1,006	2	2	20	34
Barium	91	115	178	222	1	1	12	13
Boron	146	217	137	157	0	0	14	19
Cadmium	98	122	23	28	1	1	4	6
Chromium	67	91	23	28	1	2	6	9
Copper	99	123	210	268	1	1	0	0
Fluoride	176	249	743	1,118	2	2	19	31
Iron	129	193	756	1,170	2	2	3	3
Lead	115	156	23	29	2	11	9	50
Lithium	98	116	0	0	1	1	12	12
Manganese	125	202	666	934	2	2	5	17
Mercury	101	125	24	30	1	1	0	0
Molybdenum	53	124	0	0	0	0	4	6
Nickel	7	7	0	0	1	1	4	7
Selenium	77	101	23	28	1	1	0	0
Vanadium	36	36	0	0	0	0	4	7
Radionuclides								
Radon-222	8	8	0	0	0	0	0	0
Uranium	8	8	0	0	0	0	0	0

each other. The alternate hypothesis is that the median values do differ significantly. If the null hypothesis cannot be rejected on the basis of the test results, the medians are not judged to be significantly different; thus, the different sample-collection and preservation methods have no apparent effect on the median values. If the alternate hypothesis is accepted (null hypothesis rejected), statistical evidence indicates that differences in sample-collection and preservation methods result in significant differences in the median concentrations for the tested constituents.

The test that was used is called the Wilcoxon-Mann-Whitney Test (Iman and Conover, 1983, p. 280-281; Ryan and others, 1985, p. 292-297). This test is appropriate because (1) the data are not normally distributed, and (2) as many as 50 values in two of the

Table 8. —*Types of pesticides applied aerially, by hydrographic area*

Pesticide	Hydrographic areas affected[1]	Use	Sources of information[2]
	Organophosphate		
Fenthion	CV,DV,CD	Mosquitoes	1,2,5,7
Naled	CD	Mosquitoes	1
Dimethoate	CV,EV,CD	Alfalfa hay (aphids, weevils)	1,7
Malathion	CV,EV,CD	Alfalfa hay (aphids, weevils)	1,2,8
Methyl parathion	DV,CD	Alfalfa hay (aphids)	1,7,8
Parathion	EV,DV,CH,CD	Alfalfa hay (aphids), mosquitoes	1,8
Rodeo	CD	Broadleaf weeds	4
Glyphosine	CV,CD	Broadleaf weeds	3,4
	Triazine and chlorophenoxy		
Atrazine	CV	Broadleaf weeds	3
Simazine	CV,CD	Broadleaf weeds	6,8
2,4-D	CV,DV,CD	Broadleaf weeds	1,3,8
	Carbamate		
Carbofuran	CV,DV,CD	Alfalfa hay (aphids, weevils)	1,6
	Miscellaneous		
Paraquat	CV,DV,CD	Weeds and grasses	1
Acrolein	CD	Irrigation ditches, moss control	4
Dicamba	CV	Broadleaf weeds	3
Velpar	CV,DV,CD	Annual grasses	1

[1]Hydrographic areas are listed in downstream order. Abbreviations: CV, Carson Valley; EV, Eagle Valley; DV, Dayton Valley; CH, Churchill Valley; CD, Carson Desert.

[2]Sources of information: 1, Nevada Department of Agriculture, monthly pesticide-use reports; 2, Ronald Lynch, Douglas County Mosquito Control, oral commun., 1988; 3, Phillip Nalder, Douglas County Weed Control, oral commun., 1988; 4, Olivia Ewing, Truckee Carson Irrigation District, oral commun., 1988; 5, Jennifer Penner, Churchill County Mosquito Abatement, oral commun., 1988; 6, Wally Petterson, Douglas County Agriculture Extension Agent, oral commun., 1988; 7, John Pursel, Lyon County Agriculture Extension Agent, oral commun., 1988; and 8, Alvin Miller, Churchill County Agriculture Extension Agent, oral commun., 1988.

data sets are at or below the detection limit and, thus, are not precisely known. The Health Laboratory's analytical detection limits were used for the three tests because they exceeded the corresponding limits for the Geological Survey laboratory (see table 9).

The result for each of the hypothesis tests is shown in table 9 as a probability, in percent, that the difference between median values is due only to chance. Thus, a low probability, such as that for iron, provides statistical evidence that differences between the median values are significant, presumably because of differences in sample-collection and preservation procedures. For manganese, in contrast, there is a high probability that the differences can be reliably attributed to chance. The results for arsenic and manganese do not necessarily indicate that the null hypothesis is true (that is, that different sample-collection and preservation techniques have no effect on the data); but, neither do they provide sufficient evidence that the null hypothesis can be rejected.

Most samples sent to the Health Laboratory for iron analyses were not filtered at the time of collection, whereas samples collected by the Geological Survey and Desert Research Institute for iron analyses were filtered. This probably is the principal reason for the observed differences between median iron concentrations for data from the two laboratories. Consequently, iron values from each of the laboratories are evaluated separately in this report. Iron values for samples submitted to the Health Laboratory are hereafter referred to as unfiltered and those values from Geological Survey and Desert Research Institute are referred to as filtered. Because almost all iron data throughout the Carson River basin are from these three laboratories, only these results were used in the description of iron concentrations.

Arsenic, iron, and manganese were selected for the statistical comparison because, among the inorganic constituents with established drinking-water standards, these three are believed to be most likely affected by field sampling procedures. Except for iron, the analytical results for samples collected using different field techniques are not considered separately in the following sections of this report.

Table 9. —*Statistical comparisons of analytical results from laboratories of the U.S. Geological Survey and Nevada State Health Division for arsenic, iron, and manganese in ground-water samples from Carson Valley*

[mg/L, milligrams per liter]

Constituent	U.S. Geological Survey	Nevada State Health Division	Probability, in percent, that the observed difference between laboratories is due only to chance
Arsenic			
Number of analyses	106	106	
Detection limit (mg/L)	0.001	0.003	
Median value (mg/L)	.007	.005	21
Iron			
Number of analyses	125	106	
Detection limit (mg/L)	0.003	0.010	
Median value (mg/L)	.009	.085	<1
Manganese			
Number of analyses	125	106	
Detection limit (mg/L)	0.003	0.010	
Median value (mg/L)	.009	.010	73

ANALYSIS OF AVAILABLE DATA ON GROUND-WATER QUALITY

This section consists of descriptions of ground-water quality in each of the hydrographic areas of the Carson River basin on the basis of the compiled and screened historical data. Only a simple analysis is attempted in this report because of limitations and uncertainties associated with some of the data. A primary focus of the NAWQA Program is that of examining water quality with respect to principal uses. Because human consumption is an important use of water, this analysis of the data will focus on constituents that can affect human health. Information also will be presented on the relative suitability of the water for irrigation—the dominant current water use in most lowland parts of the study area.

Nevada standards for public drinking water (table 10) are used herein as a basis for comparing reported concentrations with respect to human consumption. These standards consist of primary maximum contaminant levels (MCL's), secondary maximum contaminant levels (SMCL's), and secondary preferred standards (SPS's). The MCL's, which are health related and Federally enforceable, specify maximum permissible levels of constituents in water delivered to the user of a public water-supply system. The SMCL's relate to the esthetic quality of water and are intended to be guidelines for the State that are not Federally enforceable. The SPS's apply to public water suppliers unless water of that quality is not available, in which case the MCL's and SMCL's apply (Nevada Bureau of Consumer Health Protection Services, 1980, p. 8; and Jeffrey A. Fontaine, Nevada Bureau of Consumer Health Protection Services, oral commun., 1989).

The MCL's were adopted by the State of Nevada in 1988 from the U.S. Environmental Protection Agency's National Drinking Water Regulations, whereas the State secondary preferred standards (not the State MCL's) with the addition of 2.0 mg/L (milligrams per liter) for fluoride are based on the Federal SMCL's. Taken together, the MCL's, the SMCL's, and the SPS's are herein termed "drinking-water standards." The term "secondary standards" refers to both the SMCL's and the SPS's.

The differences between MCL's and SMCL's can be illustrated by a comparison of iron and manganese, both of which have SMCL's, with arsenic, which has an MCL. Iron and manganese can stain clothes and plumbing fixtures when present at concentrations greater than the standards, but have no known effect on human health. In contrast, the standard for arsenic was established as a result of scientific evidence that human health can be adversely affected by concentrations greater than the standard. Sources and possible effects, either health-related or esthetic, for several constituents in ground water of the Carson River basin are listed in table 11. These constituents (arsenic, chloride, dissolved solids, fluoride, iron, manganese, nitrate and sulfate) are those that most consistently exceed drinking-water standards in the basin. As discussed in the previous section, the analyses of total and dissolved concentrations are considered as a group for each constituent, except for iron. The drinking water standards do not distinguish between total and dissolved concentrations.

In each of the following individual discussions of hydrographic areas in the Carson River basin, several illustrations are presented that show various aspects of ground-water quality in the area. Depending on the hydrographic area, the illustrations include all or some of the following: (1) Maps that show all sampling sites and highlight those where concentrations of selected constituents exceed the Nevada State drinking-water standards; (2) a diagram that shows the general chemical character of the water; (3) a graph that illustrates the suitability of the water for irrigation; (4) a bar graph that shows percentages of exceedance for selected State drinking-water standards; and (5) a series of graphs that show the statistical distribution of concentrations, and the relation between concentration and sample depth for selected constituents.

Diagrams of the type represented by figures 10 and 11 display the general chemical ionic composition and individual pH and dissolved solids concentrations of water samples. The diagram consists of five fields—two triangular and three rectangular (Zaporozec, 1972, p. 38). For example, figure 10 shows data for eight water samples. Each chemical analysis is plotted as five points on the diagram. In combination, the five points plotted for each sample provide a general idea of the overall chemical character of the water. The relative proportions of major cations (calcium, magnesium, and sodium plus potassium) and major anions (sulfate, chloride, and carbonate plus bicarbonate) are shown on the left and upper triangles, respectively. The pH and dissolved-solids concentrations for the eight water samples are plotted in the bottom and right rectangles, respectively. The primary advantage of the type of diagram represented by figures 10 and 11 is that they provide a visual characterization, on a single illustration, of eight major chemical constituents, pH, and dissolved-solids content of the ground water in a particular area. The principal application of this type of diagram is to examine where the data points tend to

Table 10. —*Drinking-water standards for public water systems in Nevada*

[Units of measure: milligrams per liter, except as noted. --, standard does not exist for indicated constituent or property]

Constituent or property	Maximum contaminant level (MCL)[1]	Secondary maximum contaminant level (SMCL)[2]	Secondary preferred standard (SPS)[3]
	Inorganic constituents and properties		
Arsenic	0.05	--	--
Barium	1.0	--	--
Cadmium	.01	--	--
Chloride	--	400	250
Chromium	.05	--	--
Copper	--	--	1.0
Dissolved solids	--	1,000	500
Fluoride	4.0	2.0	--
Iron	--	.6	.3
Lead	.05	--	--
Magnesium	--	150	125
Manganese	--	.1	.05
Mercury	.002	--	--
Nitrate (as N)	10	--	--
Selenium	.01	--	--
Silver	.05	--	--
Sulfate	--	500	250
Zinc	--	--	5
pH	--	--	(4)
	Organic compounds		
Benzene	0.005	--	--
Carbon tetrachloride	.005	--	--
Endrin	.0002	--	--
Lindane	.004	--	--
Methoxychlor	.1	--	--
Trichloroethylene	.005	--	--
Toxaphene	.005	--	--
Trihalomethanes (total)	.1	--	--
Vinyl chloride	.002	--	--
1,2-Dichloroethane	.005	--	--
1,1-Dichloroethylene	.007	--	--
1,4-Dichlorobenzene	.75	--	--
1,1,1-Trichloroethane	.2	--	--
2,4-Dichlorophenoxyacetic acid	.1	--	--
2,4,5-Trichlorophenoxypropionic acid	.01	--	--
	Radionuclides		
Gross alpha (including radium-226 but excluding radon and uranium), in picoCuries per liter	15	--	--
Radium-226 and -228 (combined), in picoCuries per liter	5	--	--
Gross beta, in millirems per year	4	--	--

[1]Maximum contaminant levels (MCL's) are health related and Federally mandated. Best available technology as determined by U.S. Environmental Protection Agency must be utilized to achieve these levels (Jeffrey A. Fontaine, Nevada Bureau of Consumer Health Protection Services, oral commun., 1989). MCL's are adopted from the National Drinking Water Regulations (U.S. Environmental Protection Agency, 1986a, and 1986b).

[2]Secondary maximum contaminant levels (SMCL's) are based on esthetic qualities and are enforceable by State. Best available technology is determined by State (Jeffrey A. Fontaine, oral commun., 1989). SMCL's except that for magnesium are adopted from National Drinking Water Regulations (U.S. Environmental Protection Agency, 1986c, p. 587-590).

[3]Secondary preferred standards (SPS's) must be met unless water of that quality is not available, in which case the SMCL's must be met if they exist (Nevada Bureau of Consumer Health Protection Services, 1980, p. 8-9; SMCL's have not been established for copper, pH, and zinc).

[4]Standard for pH: upper limit, 8.5; lower limit, 6.5. For explanation of units of measure, see Hem (1985, p. 61-66).

Table 11.—*Source and significance of selected constituents and properties of ground water.*

[Modified from Nowlin (1982, table 2) and Garcia (1989, table 1), mg/L, milligrams per liter]

Constituent or property[1]	Major source	Significance for use
ARSENIC	Common in basin-fill aquifers derived from weathering of intermediate and acidic volcanic rocks (Welch and others, 1988, p. 334).	Two chemical forms: trivalent (arsenite) and pentavalent (arsenate). The former is more toxic. Epidemiologic studies have shown that arsenic can cause a variety of chronic and acute health problems, including cancer.
FLUORIDE	Dissolved in small amounts from most rocks and soils. Also common to most thermal water. Concentrations commonly exceed 2 mg/L in ground water having low concentrations of calcium. Added to many public water supplies to inhibit dental caries.	Concentrations between 0.6 and 1.7 mg/L may have beneficial effects on structure and resistance to decay of children's teeth. Concentrations in excess of 4 mg/L may cause mottling and pitting of teeth.
NITRATE	Sources include fixation of atmospheric nitrogen by plants, leaching of decaying organic matter, fertilizers, or industrial, agricultural, or domestic wastes.	Concentrations exceeding 10 mg/L may cause infant methemoglobinemia (blue-baby syndrome). High concentrations may indicate contamination from one or more man-caused sources.
Chloride	Dissolved in differing amounts from all rocks and soils. High concentrations may be derived from marine and desert evaporite minerals such as halite. May be derived from salts used for control of ice on streets and highways. May be concentrated by evapotranspiration.	May make water corrosive. Imparts salty taste at concentrations as low as 100 mg/L. Chloride ion is very stable in ground water and is often used as a tracer of movement of wastes in aquifers.
Dissolved solids	Sum of all minerals dissolved from rocks and soils. High dissolved-solids concentration generally is a result of dissolution of evaporite minerals (such as halite or gypsum) or concentration by evaporation.	General indicator of overall chemical concentration of water. Imparts unpleasant taste to water when concentrations exceed standards. Additional effects on water uses depend on concentrations of individual constituents.

Table 11.—*Source and significance of selected constituents and properties of ground water.* —Continued

Constituent or property[1]	Major source	Significance for use
Iron	Dissolved from iron minerals present in most rocks and soils. Found in some industrial wastes, and can be corroded from pipes, well casings, pumps, and other equipment. Also can be concentrated in wells and springs by certain bacteria.	Oxidizes to a reddish-brown precipitate. Stains utensils, enamelware, clothing, and plumbing fixtures. May be objectionable for food and beverage processing because of taste and odor problems.
Manganese	Dissolved from rocks, soils, and lake-bottom sediments. Generally associated with iron.	Oxidizes to form a dark brown or black precipitate. Problems similar to those caused by iron.
Sulfate	Dissolution of sulfate minerals such as gypsum or sulfide minerals such as pyrite. May be concentrated by evapotranspiration.	Forms boiler scale in combination with calcium. Causes bitter taste when combined in high concentrations with other ions, and may have laxative effects when first ingested in higher concentrations than those to which an individual is accustomed.

[1]Constituents having maximum contaminant levels (MCL's) are uppercase and listed first; constituents and properties having secondary maximum contaminant levels (SMCL's) are lowercase and listed last.

group in each of the five individual triangular or rectangular areas. The arrows in figure 10 show how the cation and anion points for a single analysis are projected from the cation and anion triangles to the central rectangle and then to the pH and dissolved solids rectangles. The central rectangle thus functions primarily as a transitional area to connect the four outside triangular and rectangular plots.

The general suitability of water for irrigation can be displayed with a graph of specific conductance (grouped by the relative degree of salinity hazard) plotted against sodium-adsorption ratio [(SAR); Hem, 1985, p. 217-218]. Specific conductance is a measure of the ability of water to conduct an electric current and is generally related to the dissolved-solids concentration of the water by the equation:

$$S = A \times K,$$

where K = specific conductance, in microsiemens per centimeter at 25 degrees Celsius;

S = concentration of dissolved solids, in milligrams per liter; and

A = a factor that ranges from 0.55 to 0.75 for most natural water (Hem, 1985, p. 66, 67).

Values of specific conductance were either measured in the field or laboratory or were estimated from the value reported for dissolved solids using the equation above with a value of 0.65 for A. SAR is a measure that predicts the degree to which dissolved sodium in an irrigation water might exchange with calcium and magnesium ions that are adsorbed onto soil particles (Hem, 1985, p. 161). The sodium-adsorption ratio is defined as:

$$SAR = \frac{(Na+)}{\sqrt{1/2\,[(Ca^{2+})+(Mg^{2+})]}}$$

where the ion concentrations are expressed in milliequivalents per liter.

A high SAR value indicates that sodium may eventually accumulate in the soil, which may eventually lead to soil structure damage (Hem, 1985, p. 161).

The plot such as that shown in figure 12 is divided into 16 fields of differing sodium hazard and salinity hazard, so that a number of samples can be quickly characterized as to their general suitability for irrigation use. Relative boron concentrations are also shown on these diagrams because boron in irrigation water can harm many plants. Each symbol on the diagram is plotted in one of five sizes that, from smallest to largest, indicate concentration ranges, in milligrams per liter, of less than 1.3 (this symbol also is used to indicate no boron analysis available), 1.3 to 2.5, 2.6 to 3.8, and more than 3.8, respectively, or that a boron analysis is not available. These ranges are based on tolerances of different plants to boron (Davis and DeWiest, 1966, p. 122).

The bar graphs (for example, fig. 13) show the frequencies with which available data for selected constituents exceed primary and secondary drinking-water standards. A constituent is shown only when more than 2 percent of the data exceed the standard.

In illustrations such as figure 14, the lower graphs in each pair show the relations between concentration and well depth for selected constituents. The criteria for determining which constituents to show is based on the number of analyses for that constituent and the frequency with which the analytical results exceed the appropriate drinking-water standard. Generally, the constituents shown are represented by at least 30 analyses in the hydrographic area, and at least 5 percent of these exceed the standard.

The upper graph in each pair uses boxplots (Tukey, 1977) to display statistics regarding the distribution of reported concentrations for the selected constituent. The statistical components are represented visually by features known as "boxes" and "whiskers," which can be described as follows: The box defines the spread of the middle 50 percent of the data (that is, the concentrations that lie between the 25th and 75th percentiles). The median value of the data (that is, the 50th percentile) is indicated by the vertical line within the box. The horizontal lines beyond each end of the box are called whiskers. They show the range of concentrations and extend beyond the ends of the box to the maximum and minimum data values.

Headwaters Area

Studies of ground-water quality in the Headwaters Area of the Carson River basin have focused on specific localized topics – for example, springs issuing from granitic rocks (Feth and others, 1964), geothermal springs (Mariner and others, 1974, 1975, 1976), and a spring draining a mined area (Ball and Nordstrom, 1985; Hammermeister and Walmsley, 1985), rather than on the entire area (pl. 1). Potential sources of ground-water contamination include mining, septic-tank effluent, and a few underground gasoline storage tanks.

Figure 10 shows the chemical character of eight water samples from wells and springs in the Headwaters Area. The water generally is dilute, having concentrations of dissolved solids less than 200 mg/L and values of pH that range from slightly acid to slightly alkaline (fig. 10). Major cations, in order of abundance, are calcium, sodium plus potassium, and magnesium; major anions are bicarbonate plus carbonate. The one sample on the diagram that deviates in its chemistry from the others (higher dissolved solids and lower percent calcium) represents spring discharge from a mined area.

Constituents that exceed State drinking-water standards in the Headwaters Area are listed in table 12. These data may not represent the overall quality of ground water in the area because of the small number of samples and because some of the samples are from geothermal springs and mineralized areas. The only MCL exceeded at more than one site is that for fluoride. SMCL's that are exceeded at more than one site are those for fluoride, chloride, dissolved solids, iron, manganese, and sulfate. The one zinc value that exceeds the secondary preferred standard is for water from a mineralized area in the upper part of the East Fork of the Carson River.

Analyses of ground water from springs in granitic rocks (Feth and others, 1964) may represent the general quality of ground water in nonmineralized granitic terrains of the Headwaters Area and the Carson Range to the west of Carson and Eagle Valleys. The water contains low concentrations of magnesium, potassium, chloride, and sulfate (median concentration of perennial springs are 1.0, 1.4, 0.45, and 1.6 mg/L, respectively) which is characteristic of ground-water quality in other parts of the Sierra Nevada (Feth and others, 1964, table 2).

The U.S. Forest Service has sampled one well and two springs at campgrounds in the Headwaters Area since 1981 for six pesticides: endrin, lindane, methoxychlor, silvex, toxaphene, and 2,4-D (samples analyzed by the Nevada State Health Laboratory); concentrations for all have been below detection limits.

Carson Valley

Early studies in Carson Valley discuss ground-water quality only briefly (Glancy and Katzer, 1976; Spane, 1977; U.S. Bureau of Reclamation, 1980).

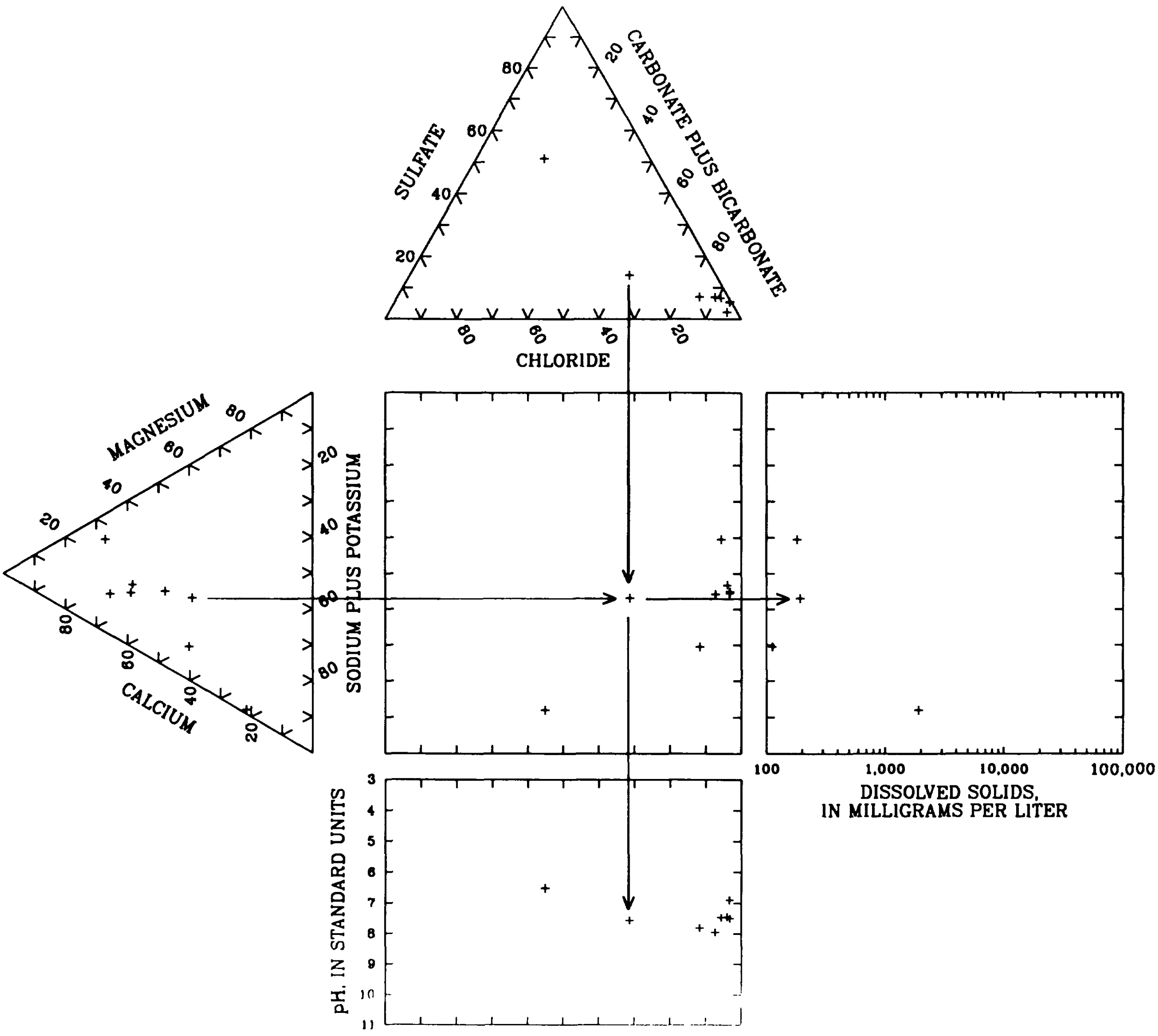

Figure 10.—General chemical character of sampled ground water in the Headwaters Area. Arrows show projection scheme for an individual chemical analysis.

Table 12.—*Summary of inorganic constituents and properties exceeding Nevada State drinking-water standards in the Headwaters Area*

[See table 10 and text for explanation of standards, --, standard does not exist for indicated constituent or property]

Constituent or property	Number of analyses (1)	Number of analyses exceeding State standard: Maximum contaminant level (2)	Secondary maximum contaminant level (3)	Secondary preferred standard (4)
Primary standards				
Arsenic	8	1	--	--
Barium	6	0	--	--
Cadmium	1	1	--	--
Chromium	1	1	--	--
Fluoride	10	2	3	--
Lead	1	0	--	--
Mercury	1	0	--	--
Nitrate	7	0	--	--
Selenium	0	0	--	--
Silver	0	0	--	--
Secondary standards				
Chloride	13	--	0	2
Copper	8	--	--	1
Dissolved solids	9	--	2	2
Iron, unfiltered	7	--	1	2
Magnesium	12	--	0	0
Manganese	9	--	1	2
pH	13	--	--	1
Sulfate	13	--	3	3
Zinc	7	--	--	1
Totals[1]	13	2	5	7

[1]Total for column (1) is the number of separate sample locations. Total for column (2) is the number of locations where one or more constituents exceed a maximum contaminant level. Total for column (3) is the number of locations where one or more constituents exceed a secondary maximum contaminant level. Total for column (4) is the number of locations where one or more constituents exceed secondary preferred standards.

More recent studies of ground-water quality have focused on the relation between water quality and water use (Garcia, 1989) and on geothermal systems (Garside and Schilling, 1979; Trexler and others, 1980). Prior to the present study, constituents reported to exceed drinking-water standards were arsenic, dissolved solids, fluoride, iron, manganese, nitrate, and sulfate.

Most of the data on ground-water quality compiled for this study represent samples collected at domestic wells and analyzed by the Nevada State Health Laboratory (about 72 percent) or collected and analyzed by the Geological Survey (about 28 percent). Sampling by the Geological Survey in Carson Valley was primarily during the period 1985-87 and includes analyses of all inorganic constituents for which MCL's had been established as of 1988. Most of the sample sites are distributed throughout the valley floor, although a few are scattered wells and springs in upland areas (pl. 1).

Most ground water in Carson Valley is dilute (dissolved solids less than 500 mg/L) and has pH values that range from near neutral to alkaline (pH values range from about 6.5 to 9.0; fig. 11). Major cations are, in general order of abundance, calcium, sodium plus potassium, and magnesium; most commonly, the dominant anion is bicarbonate, although sulfate is dominant in some water. Ground water in Carson Valley associated with thermal areas in the north part of the valley near Saratoga and Hobo Hot Springs and on the west side near Walleys Hot Springs is commonly higher in sodium (>100 mg/L), sulfate (about 130-600 mg/L), and chloride (about 40-450 mg/L) than the concentrations in the nonthermal water (Trexler and others, 1980, p. 50-51). Thermal water can affect the quality of ground water in the vicinity of these springs either as discharge that infiltrates downward or as upwelling flow that moves outward into an aquifer.

Ground water in Carson Valley generally is suitable for irrigation use. Figure 12 shows that most sampled water has a low sodium hazard, a low to medium salinity hazard, and a low to medium boron concentration. Water samples with a high sodium hazard were collected from springs or deep wells, whereas water samples with a high salinity hazard were collected from a variety of sources.

Ground water in Carson Valley exceeds drinking-water standards for one or more constituents at sites scattered throughout the valley, although the proportion of these sites is greater to the north (pl. 1). The total number of analyses available and the number that exceed the drinking-water standards for each constituent, are shown in table 13. Fluoride most commonly exceeds the MCL, whereas dissolved solids, iron, manganese, sulfate (fig. 13), and pH most commonly exceed the SPS's.

Concentrations of fluoride, iron, and manganese plotted against well depth and an accompanying plot that statistically summarizes the concentrations of each constituent are shown in figure 14. The plots do not indicate a strong relation between concentration and well depth.

The areal distribution of samples analyzed for fluoride, iron, and manganese and locations where the analytical results exceed MCL's or SMCL's are shown in figure 15. A spatial relation exists between high concentration of fluoride and areas where thermal

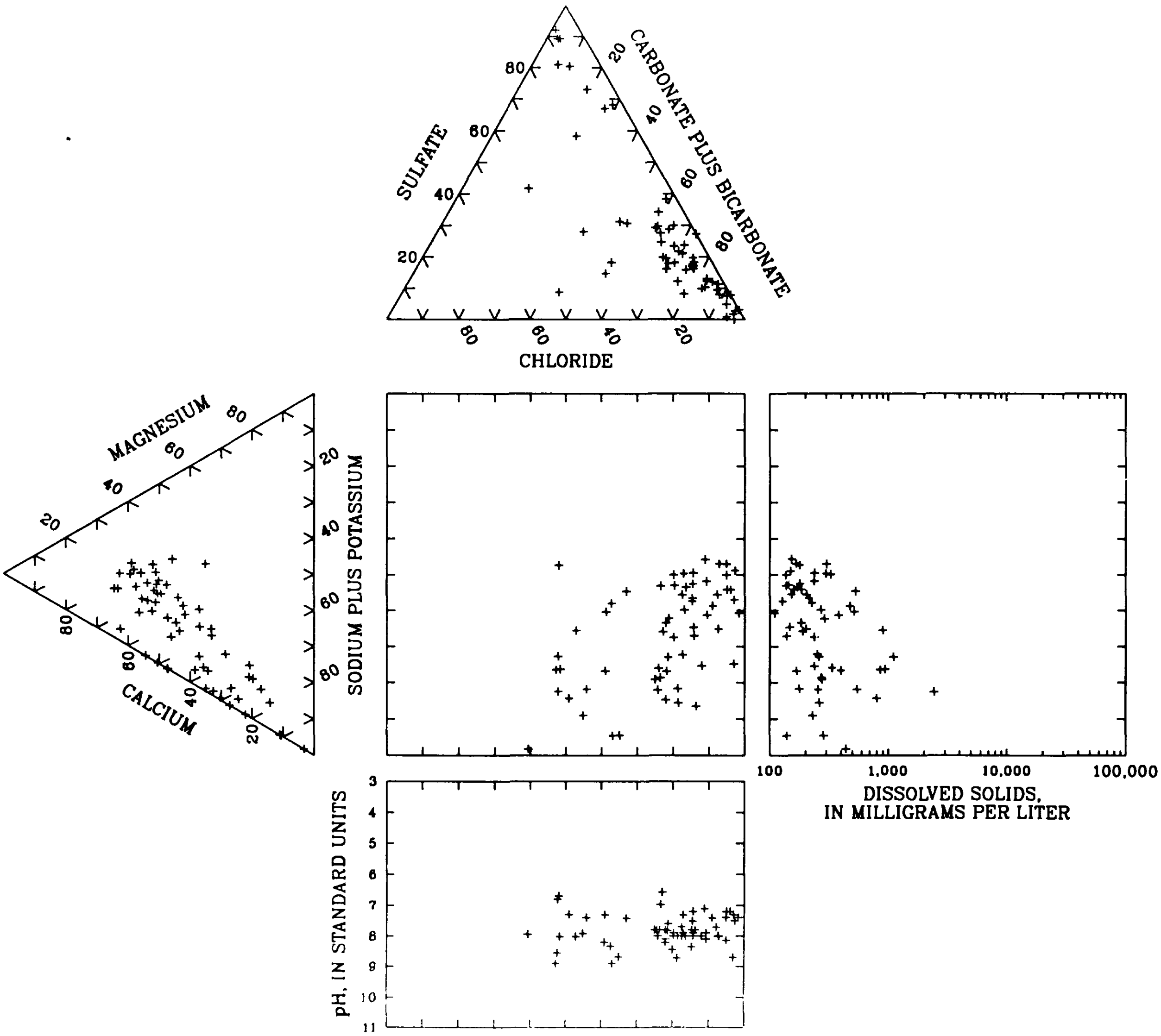

Figure 11.—General chemical character of sampled ground water in Carson Valley.

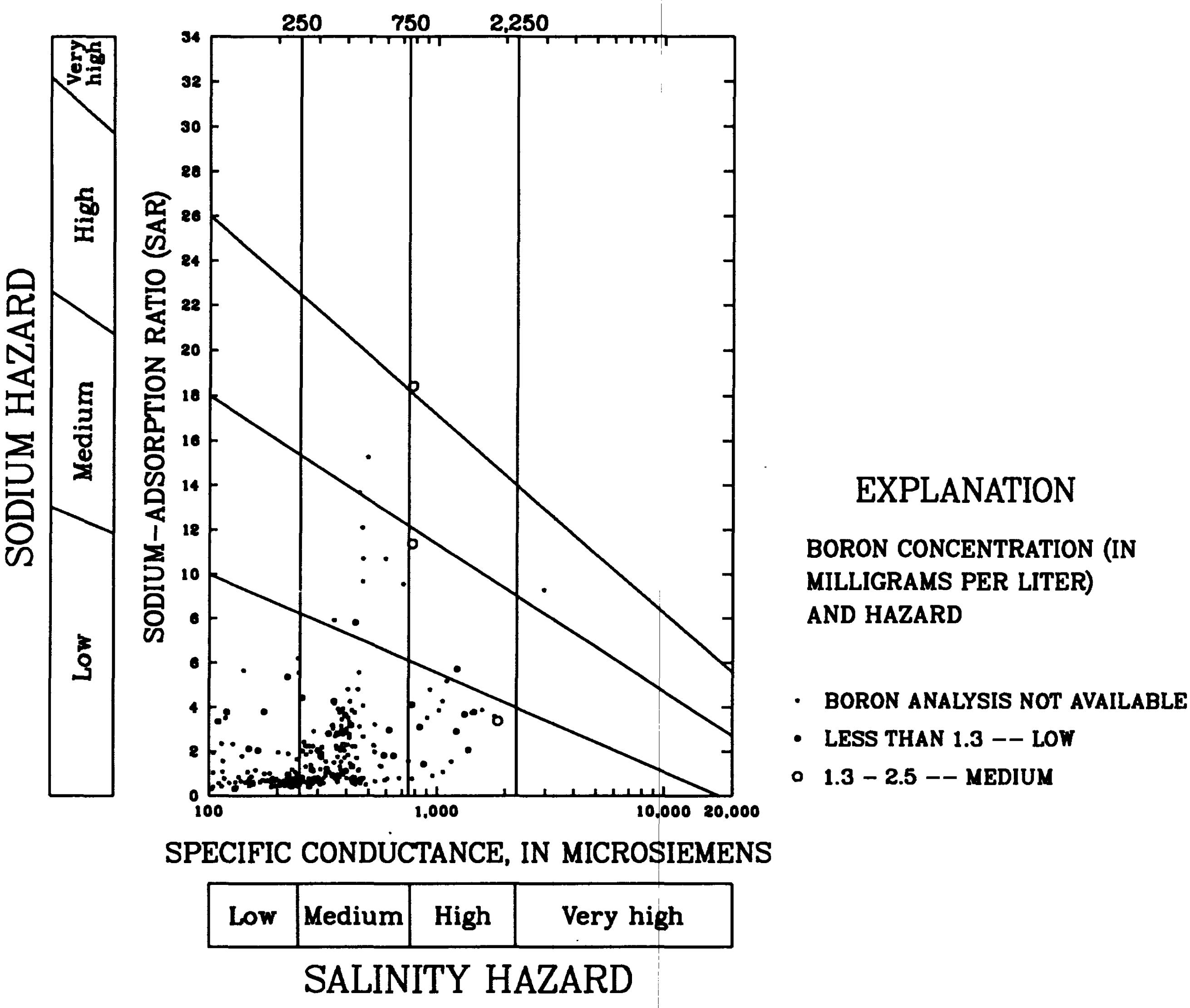

Figure 12.—General suitability of sampled ground water in Carson Valley for irrigation. Information on boron hazard from Davis and DeWiest (1966, p. 122).

Table 13.—*Summary of inorganic constituents and properties exceeding Nevada State drinking-water standards in Carson Valley*

[See table 10 and text for explanation of standards, --, standard does not exist for indicated constituent or property]

Constituent or property	Number of analyses (1)	Number of analyses exceeding State standard: Maximum contaminant level (2)	Secondary maximum contaminant level (3)	Secondary preferred standard (4)
Primary standards				
Arsenic	276	4	--	--
Barium	80	0	--	--
Cadmium	30	0	--	--
Chromium	30	0	--	--
Fluoride	302	10	42	--
Lead	30	0	--	--
Mercury	30	0	--	--
Nitrate	265	3	--	--
Selenium	30	0	--	--
Silver	30	0	--	--
Secondary standards				
Chloride	335	--	0	1
Copper	107	--	--	1
Dissolved solids	308	--	4	23
Iron, filtered	29	--	3	3
Iron, unfiltered	240	--	17	41
Magnesium	314	--	0	0
Manganese	259	--	17	30
pH	333	--	--	23
Sulfate	333	--	8	23
Zinc	109	--	--	1
Totals[1]	343	15	73/77	99/103

[1]Total for column (1) is the number of separate sample locations. Total for column (2) is the number of locations where one or more constituents exceed the maximum contaminant level (MCL). Totals for column (3) consist of two values. The first is the number of locations where one or more constituents exceed the secondary maximum contaminant level (SMCL); the second is the number of locations where one or more constituents exceed either an MCL or SMCL. Totals for column (4) consist of two values. The first is the number of locations where one or more constituents exceed secondary preferred standards; the second is the number of locations where one or more constituents exceed either the MCL or the secondary preferred standard. The listed total exceedances incorporate analyses that do not include determinations for all the inorganic constituents for which drinking-water standards exist. Therefore, the totals may underestimate the number of sites that have an inorganic constituent at a concentration that is greater than the standard.

water discharges as springs. Nearly all fluoride values that exceed the MCL of 4.0 mg/L are from the north and west sides of the valley. Concentrations of iron and manganese that exceed standards are more widespread, but are somewhat more prevalent in the northern part of the valley.

Studies of other aspects of ground-water quality in Carson Valley have focused on radioactive and manmade organic constituents. Concentrations of radon, a radioactive gas, have been found to exceed 10,000 pCi/L (picoCuries per liter) in ground water in parts of the valley, especially on the west side (Lico and others, 1989). Although a standard has yet to be established for radon in drinking water, concern about the effects of radon on human health has led the U.S. Environmental Protection Agency to begin the process that leads to a standard (U.S. Environmental Protection Agency, 1986b).

Local ground-water quality has been affected by manmade organic compounds at an industrial facility adjacent to the Douglas County Airport, 3 mi north of Minden. Possible sources include existing waste-disposalfacilities (a percolation pond, septic tank, and leachfield) and facilities no longer in use (barrel-storage area and wastewater transfer tank). Samples were obtained during 1986 and 1987 from a network of 26 monitoring wells installed onsite and from domestic wells within a quarter-mile radius of the facility. Analytical results indicate that the predominant organic compounds are 1,1,1-trichloroethane (1,1,1-TCA) and trichloroethylene (TCE), and lesser amounts of cis-1,2-dichloroethylene, tetrachloroethylene, 1,2-dichloropropane, benzoic acid, and chloroform (Kennedy/Jenks/Chilton, 1987). The concentration of 1,1,1-TCA ranged from 0.2 to 3.5 mg/L at six of the monitoring wells (the MCL is 0.2 mg/L), and concentrations were near, but below, the standard at seven others. The concentration of TCE ranged from 0.013 to 0.32 mg/L at five of the monitoring wells and was 0.27 mg/L at a domestic well (the MCL is 0.005 mg/L). In an effort to remove the contamination and prevent further migration of contaminants, two ground-water extraction and air-stripping treatment systems have been installed, one onsite and one on an adjacent farm.

As part of a cooperative study with Douglas County during 1987, the Geological Survey collected water samples from 35 monitoring wells distributed valley-wide, and analyzed the samples for selected manmade organic compounds (Carl E. Thodal, U.S. Geological Survey, written commun., 1988). A sample taken from a well near the Douglas County Airport contained 0.0035 mg/L of chloroethane, 0.010 mg/L of 1,1-dichloroethane, and 0.0046 mg/L of trichloroethylene. Eleven other organic compounds also were detected at low concentrations in ground water at this site. Water from a monitoring well near the county landfill in the southeast part of the valley contained 0.0098 mg/L of tetrachloroethylene,

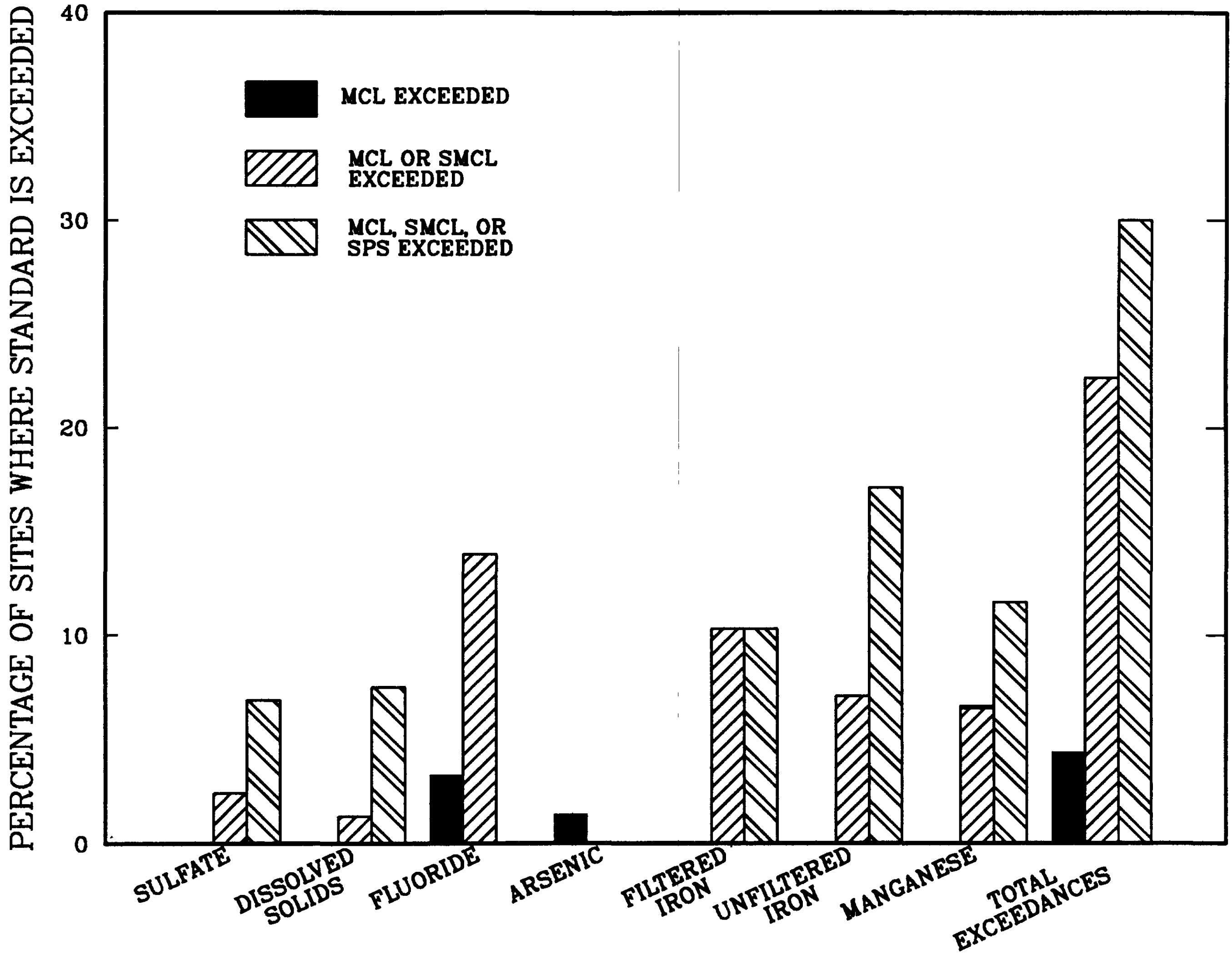

Figure 13.—Percentage of sites in the Carson Valley where concentrations of selected chemical constituents in sampled ground water exceeded maximum contaminant levels (MCL), secondary maximum contaminant levels (SMCL), or secondary preferred standards (SPS). Because some analyses do not include determinations for all the inorganic constituents having drinking-water standards, the percentages for the total-exceedances category may underestimate the number of sites having an exceedance.

0.0025 mg/L of methylene chloride, and 0.002 mg/L of dichlorodifluoromethane. Water from a well in the wetlands area on the east side of the valley contained 0.013 mg/L of bis(2-ethyl hexyl)-phthalate. Concentrations of vinyl chloride at two wells, one near Genoa and another near Johnson Lane, were 0.005 and 0.001 mg/L (the MCL is 0.0025 mg/L). Both of these are Geological Survey test wells cased with polyvinyl chloride (commonly called PVC) pipe, which is the probable source of vinyl chloride in the water. In addition, low concentrations of dichlorodifluoromethane, chloroform, TCE, and benzene were detected in five other wells at scattered locations in the valley. Organic compounds were not detected in the other 25 wells.

Two wells near an industrial park south of Gardnerville, were sampled by the Nevada Department of Environmental Protection during 1986. Analytical results revealed detectable levels of volatile organic compounds, although none exceeded drinking-water standards.

Potential sources of ground-water contamination in Carson Valley include the spreading of treated sewage, manufacturing activities, discharge from septic tanks, and a variety of sources located in urban and suburban areas such as underground gasoline-storage tanks and sewage pipelines.

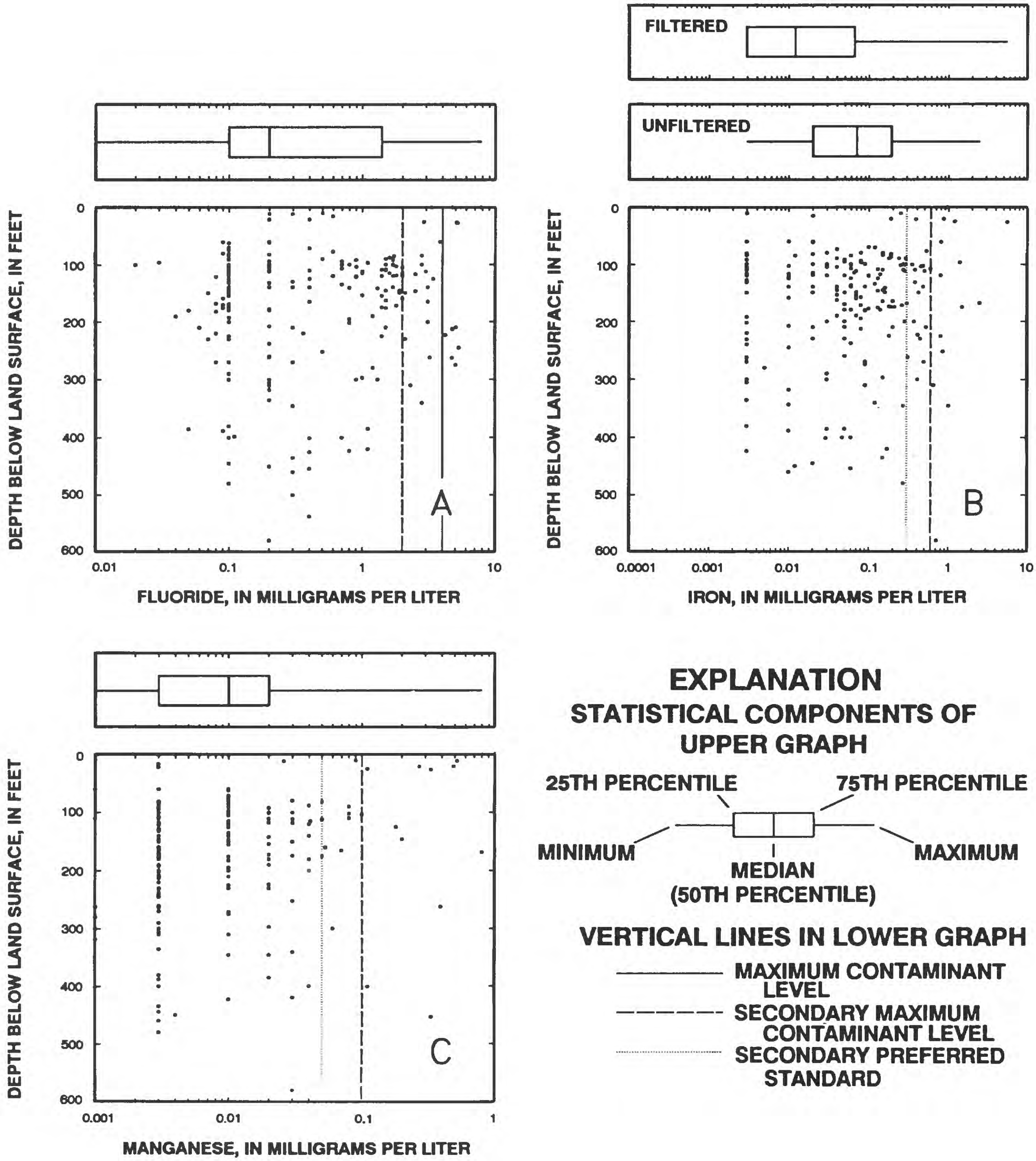

Figure 14.—Statistical distribution of concentrations (upper graph) and relation between concentration and well depth (lower graph) for (A) fluoride, (B) iron, and (C) manganese in sampled ground water of Carson Valley. In lower graphs, spring data are shown at land surface.

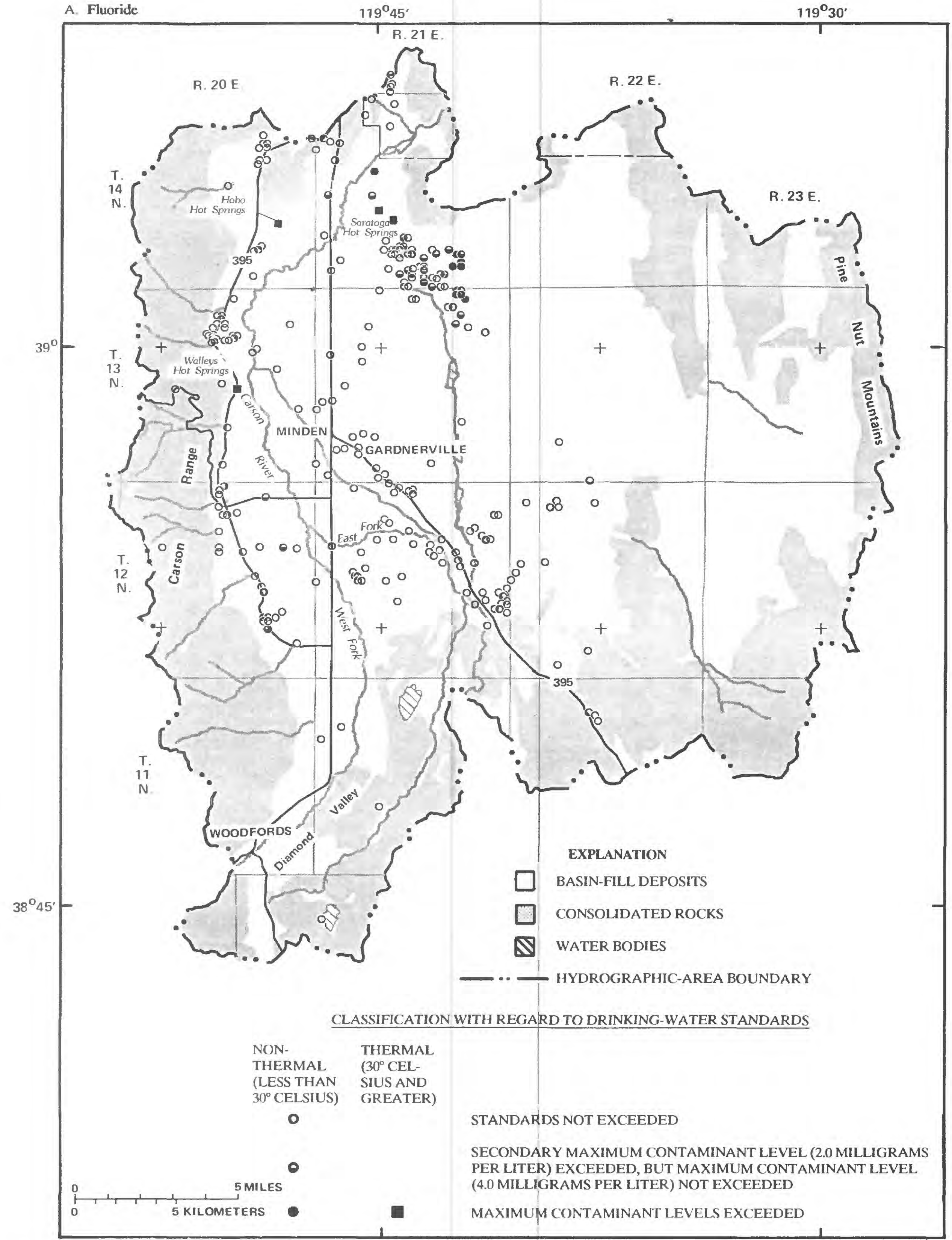

Figure 15A.—Sampling sites in the Carson Valley where (A) fluoride, (B), iron, and (C) manganese in ground water have exceeded and have not exceeded State drinking-water standards.

B. Iron

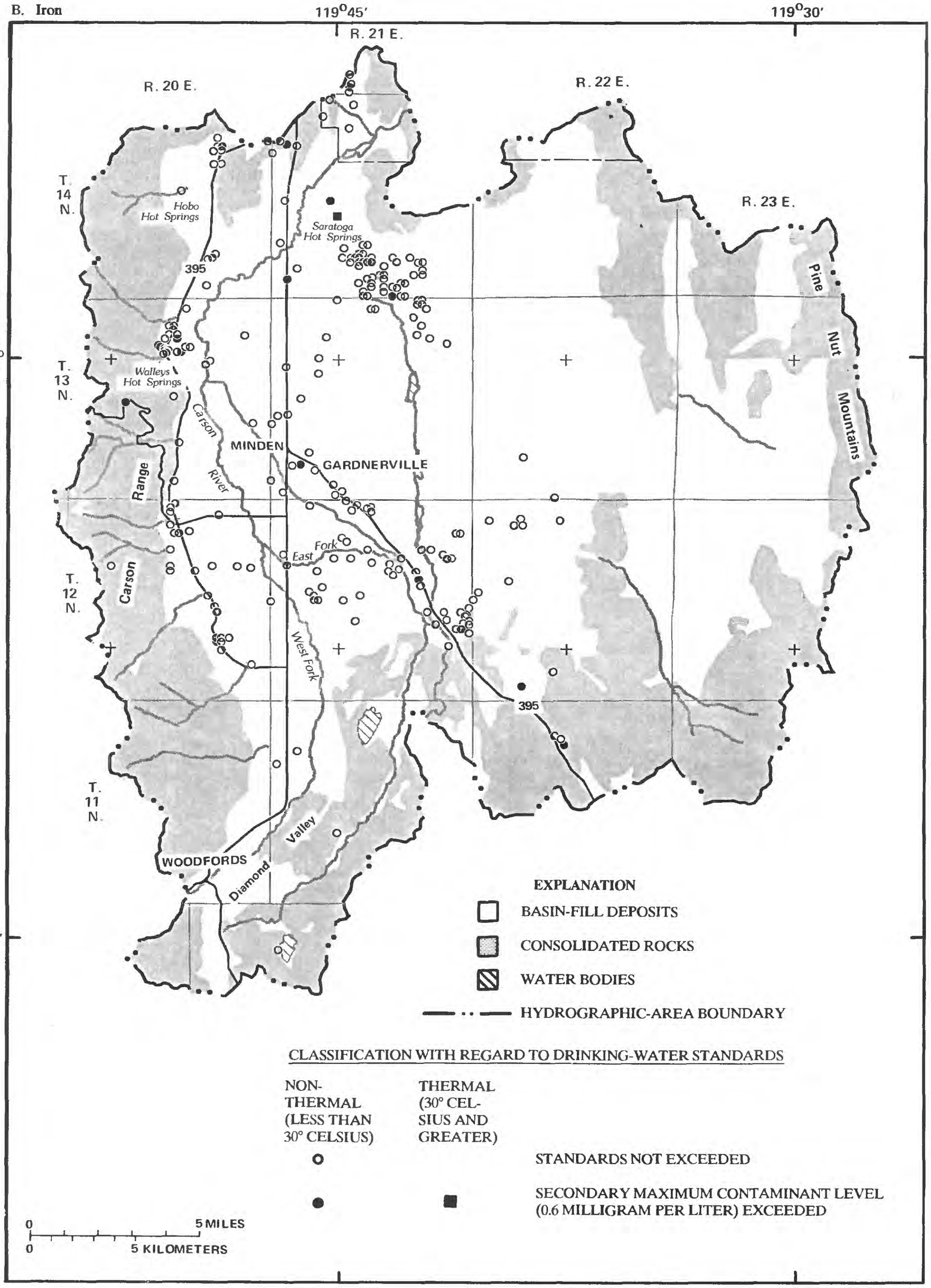

Figure 15B. – Continued.

C. Manganese

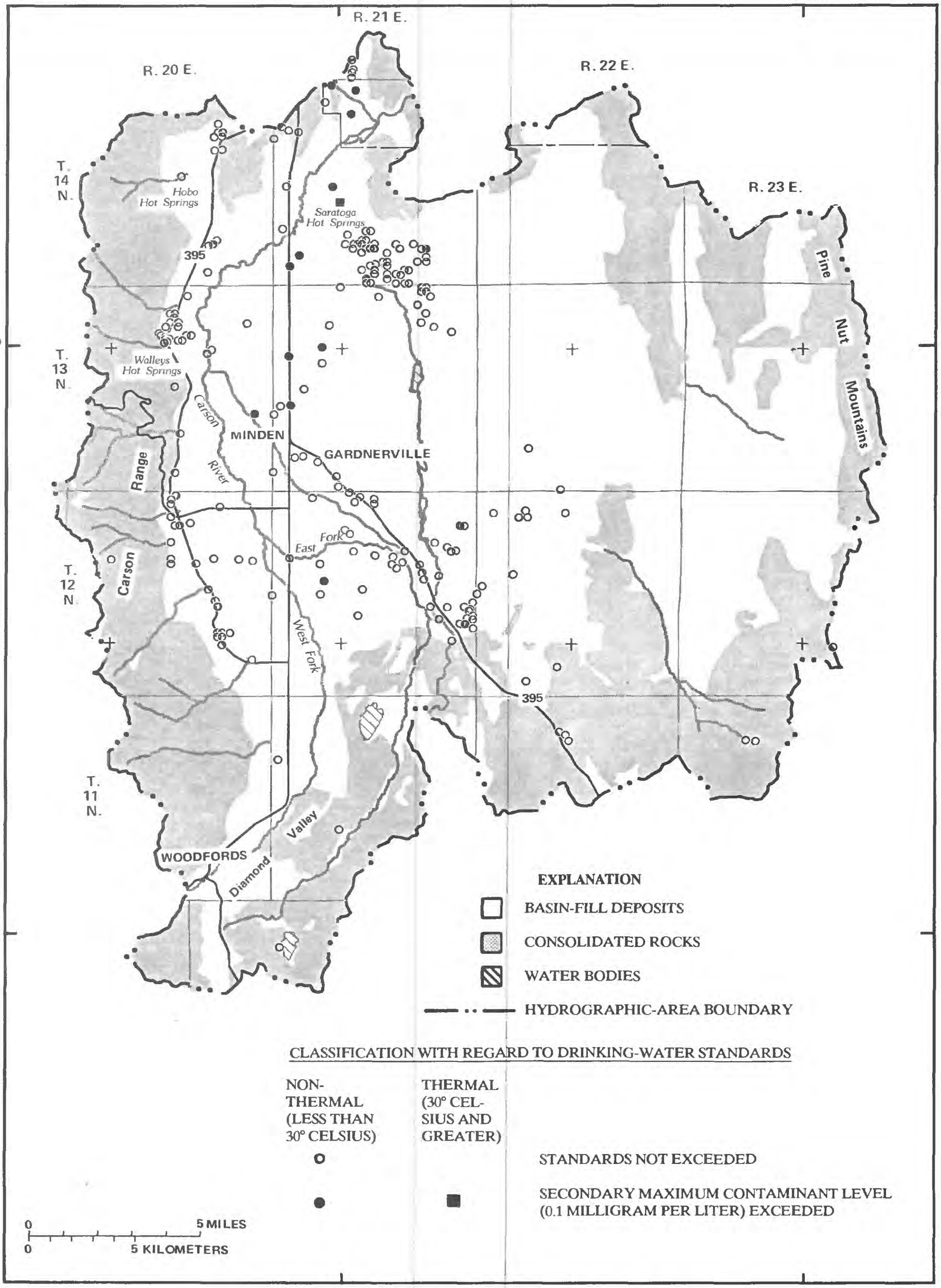

Figure 15C. – Continued.

Eagle Valley

The quality of ground water in Eagle Valley has been described in a study relating the stable isotopes of water to recharge sources (Szecsody and others, 1983), in a study of active geothermal systems (Trexler and others, 1980), and, much earlier, as part of a ground-water investigation of the basin (Worts and Malmberg, 1966).

Analyses of ground water compiled for this study were done by the Nevada State Health Laboratory (about 73 percent), the Desert Research Institute (about 16 percent), and the Geological Survey (11 percent). Sample locations consist of wells and a few springs that are distributed throughout most of the basin lowlands and in a few upland areas (pl. 1).

Both thermal and nonthermal ground water are present in Eagle Valley. Nonthermal ground water generally is alkaline and dilute, with dissolved-solids concentrations of 200 mg/L or less. Major cations are, in general order of abundance, calcium, sodium, plus potassium and magnesium; bicarbonate is the dominant anion with sulfate dominant in some water (fig. 16). Thermal water at Carson and Prison Hot Springs, and nearby nonthermal ground water, are dominated by sodium and sulfate.

Ground water in Eagle Valley is generally acceptable for irrigation (fig. 17). Sodium and salinity hazards and boron concentrations are low to medium for nonthermal water. Thermal water typically is higher in boron and also has a higher sodium hazard.

Samples of ground water that exceed one or more drinking-water standards are scattered fairly evenly throughout Eagle Valley (pl. 1). Fluoride and arsenic exceed the MCL's at about 3 percent of the sampled wells and iron and manganese most commonly exceed secondary standards (table 14). Others that also exceed standards, but less commonly, are copper, dissolved solids, pH, and sulfate (table 14 and fig. 18).

Concentrations of fluoride near or above the State MCL and SMCL appear to be limited to well depths of about 200 ft or less (fig. 19A), although water from a well deeper than 200 ft and near a hot spring would probably have concentrations that also exceed the standard. Locations where the fluoride standards are exceeded include Carson and Prison Hot Springs and one well in the eastern part of the valley (fig. 20A). High concentrations of iron and manganese are from a well with a total depth as great as 600 ft (figs. 19B, 19C); the highest value of each (about 6 mg/L) was from a 100-ft well. The high concentrations are most commonly found in wells in the southern part of the valley (sections 28, 29, 32, and 33, T. 15 N., R. 20 E.) and, to a lesser extent, in the east and north part of the valley and the lower part of Kings Canyon (figs. 20B, 20C).

Constituents other than iron and manganese with concentrations that exceed State drinking-water standards constitute only about 4 percent of the samples; however, data for some constituents are limited (only 6-8 analyses are included in the compilation for cadmium, chromium, lead, mercury, selenium, and silver). Arsenic concentrations equal to or greater than the MCL (0.05 mg/L) are found only in samples of thermal water. Concentrations of barium, nitrate, and zinc are below all the State drinking-water standards.

Losses of manmade organic compounds in Eagle Valley had been identified at five sites at the time of this data compilation; these losses were related to malfunctions of equipment used to store petroleum products (written records in files of Nevada Division of Environmental Protection). However, shallow ground water at only one of the sites, a service station in east Carson City, has been sampled for the organic compounds that constitute gasoline. At this site, an unknown quantity of gasoline leaked from an underground supply line over an uncertain period of time. Seven monitoring and sampling wells were installed at the site. Sample results indicated small quantities of gasoline components present at two of the wells (J.H. Kleinfelder & Associates, 1985). Gasoline floating on top of water was noted in another well, but no samples were collected. Two of the wells were resampled in 1987 by the Nevada Division of Environmental Protection. Water in one contained tetramethylbenzene, trimethylbenzene, xylene, toluene, and naphthalene at concentrations in the range from about 0.01 to about 0.1 mg/L. Tetramethylbenzene, trimethylbenzene, xylene, toluene, and benzene were present at concentrations between about 1 and 20 mg/L in water from the other well (analytical data from files of Nevada Division of Environmental Protection).

The Nevada Division of Environmental Protection has sampled 17 wells at a variety of water-use and water-disposal sites throughout the urban part of Carson City as part of a reconnaissance study to document contamination of ground water in areas of rapid growth. Traces of tetrachloroethylene were detected at two of eight wells sampled in areas of septic tanks and at one of two wells at the industrial sites (analytical data from files of Nevada Division of Environmental Protection).

Dayton Valley

The only study of ground-water quality in the Dayton Valley hydrographic area was made in

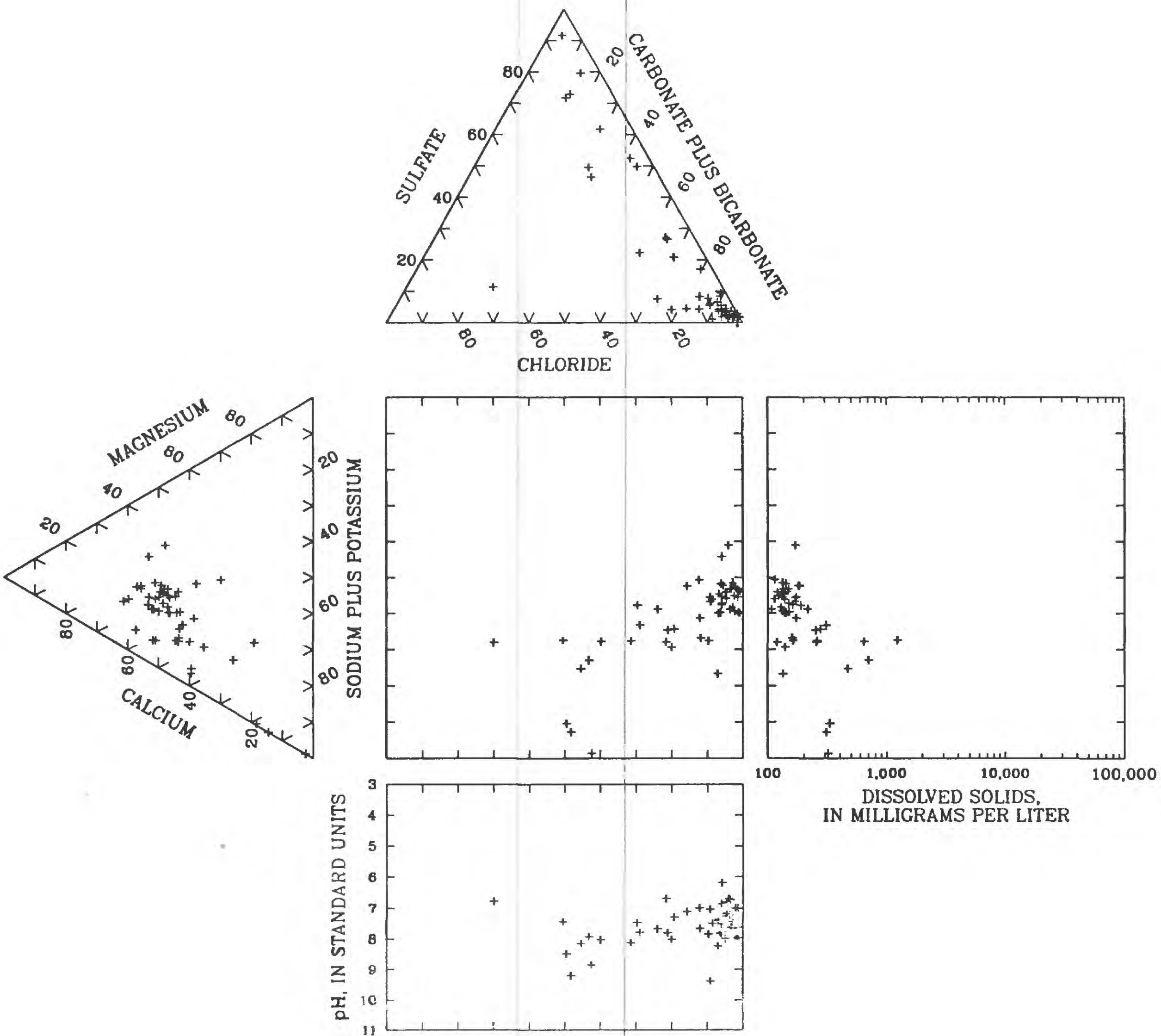

Figure 16.—General chemical character of sampled ground water in Eagle Valley.

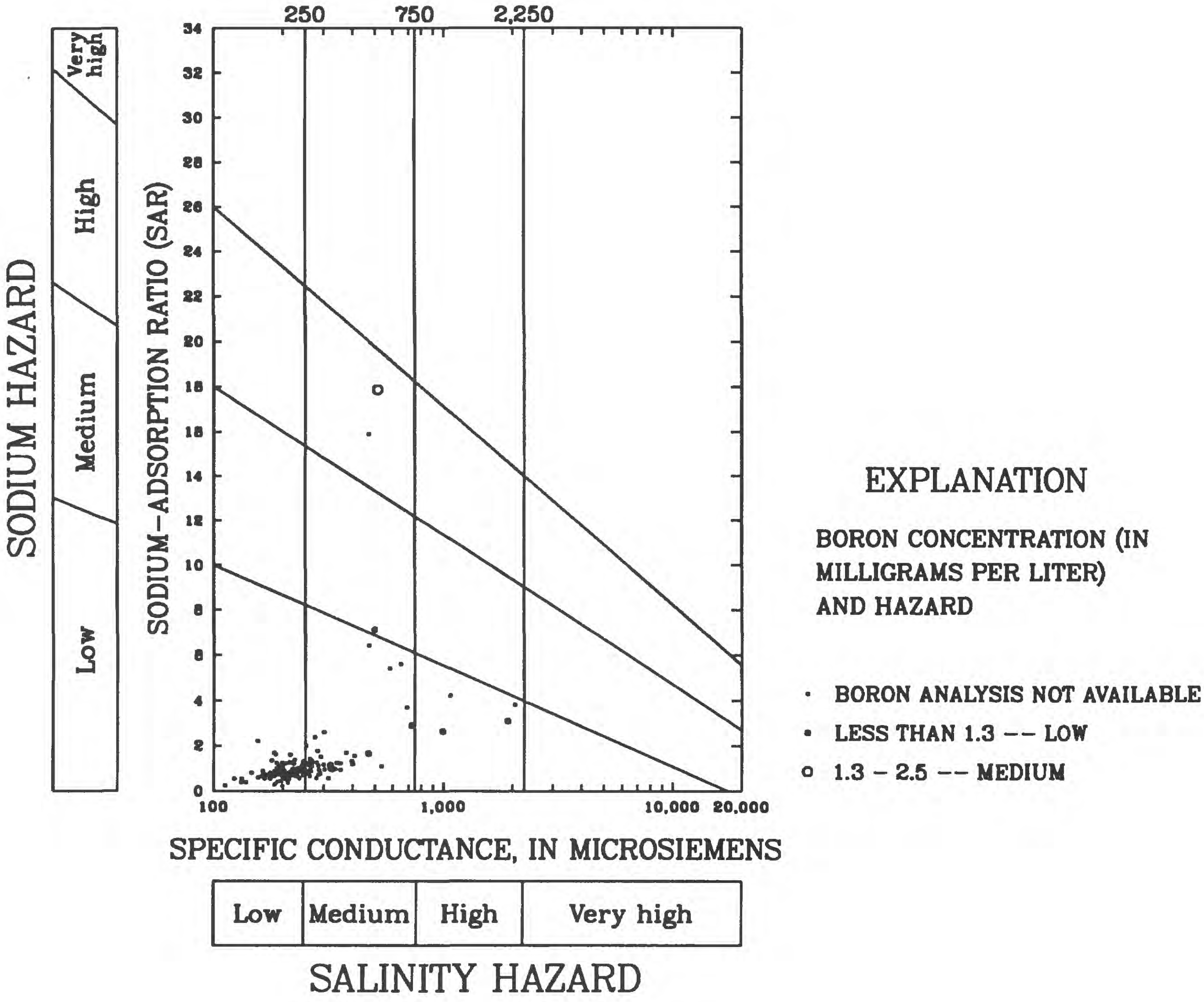

Figure 17.—General suitability of sampled ground water in Eagle Valley for irrigation. Information on boron hazard from Davis and DeWiest (1966, p. 122).

Stagecoach Valley (James R. Harrill, U.S. Geological Survey, written commun., 1988). Sources of data for the present study are the Nevada State Health Laboratory, the Geological Survey (mostly in Stagecoach Valley), and the Desert Research Institute. Ground water generally is not used for domestic purposes in the Virginia City area, so water-quality data are not available for that part of the hydrographic area. Otherwise, sample sites are located throughout much of the Dayton Valley hydrographic area, and data are available for each of the smaller ground-water basins in the area. Most sample locations are in lowland areas, although a few are in uplands (pl. 1).

Ground water in Dayton Valley is generally alkaline (most pH values range from 7.0 to 8.5) and concentrations of dissolved solids range from about 200 to as much as 2,000 mg/L (fig. 21). The dominant cations, in order of abundance, are calcium, sodium, magnesium, and potassium. Bicarbonate plus carbonate and, to a lesser extent, sulfate and chloride are the dominant anions. The water generally is acceptable for irrigation use (fig. 22). Except for a few samples, the sodium hazards and boron concentrations are low. Salinity hazards generally range from medium to very high.

Table 14.—*Summary of inorganic constituents and properties exceeding Nevada State drinking-water standards in Eagle Valley*

[See table 10 and text for explanation of standards, --, standard does not exist for indicated constituent or property]

Constituent or property	Number of analyses (1)	Number of analyses exceeding State standard: Maximum contaminant level (2)	Secondary maximum contaminant level (3)	Secondary preferred standard (4)
Primary standards				
Arsenic	99	3	--	--
Barium	38	0	--	--
Cadmium	6	0	--	--
Chromium	6	0	--	--
Fluoride	114	3	4	--
Lead	8	0	--	--
Mercury	7	0	--	--
Nitrate	120	0	--	--
Selenium	6	0	--	--
Silver	6	0	--	--
Secondary standards				
Chloride	154	--	0	0
Copper	42	--	--	3
Dissolved solids	141	--	1	3
Iron, unfiltered	126	--	22	35
Magnesium	156	--	0	0
Manganese	102	--	22	32
pH	155	--	--	6
Sulfate	154	--	0	4
Zinc	42	--	--	0
Totals[1]	163	3	38/38	59/60

[1]Total for column (1) is the number of separate sample locations. Total for column (2) is the number of locations where one or more constituents exceed the maximum contaminant level (MCL). Total for column (3) is a pair of numbers. The first is the number of locations where one or more constituents exceed the secondary maximum contaminant level (SMCL); the second is the number of locations where one or more constituents exceed either an MCL or SMCL. Total for column (4) is a pair of numbers. The first is the number of locations where one or more constituents exceed secondary preferred standards; the second is the number of locations where one or more constituents exceed either the MCL or the secondary preferred standard. The total exceedances reflect analyses that do not include all the inorganic constituents that have established drinking-water standards. Therefore, the totals may underestimate the number of sites that have an inorganic constituent at a concentration that is greater than the standard.

One or more State drinking-water standards are exceeded at sample sites throughout the Dayton Valley hydrographic area (table 15 and pl. 1). Fluoride most commonly exceeds the MCL and SMCL, and sulfate, dissolved solids, iron, and manganese, most commonly exceed the SMCL's and SPS's (fig. 23). With one exception, the analytical data are for wells with depths less than about 300 ft deep (fig. 24); the exception is a 450-ft well. Sulfate exceeds standards most commonly along the Carson River in the Riverview area, in the Mound House area, and in the west part of the Carson Plains (fig. 25A). The high values in the Mound House area most likely are related to gypsum (calcium sulfate) that is interbedded with Triassic and Jurassic metamorphic rocks, and to gypsite deposits in Quaternary and Tertiary basin fill. High sulfate concentrations in ground water in the Riverview area also may be related to gypsum deposits in metasedimentary rocks of Jurassic age although the presence of gypsum in this area has not been reported. Much of the ground water in the Riverview area is thermal. Some of the sites shown as nonthermal on figures 25A to E probably are thermal but temperatures were not measured or recorded at the time of sampling. High values of fluoride are mostly in the Riverview area and in the west part of the Carson Plains (fig. 25C).

High values of dissolved solids, iron, and manganese all show areal distributions similar to those of sulfate and fluoride. Samples that exceeded standards are particularly concentrated in three areas: along the Carson River in the Riverview area; the Mound House area; and western part of the Carson Plains (figs. 25B, 25D, 25E). Farther east, these constituents exceed standards at scattered sites.

Cyanide concentrations greater than 30 mg/L have been reported for two wells in the vicinity of Silver City (written records in files of the Nevada Division of Environmental Protection). No data are available concerning other manmade organic compounds.

Churchill Valley

Previous studies of ground-water quality in Churchill Valley are limited to water-supply investigations made in the vicinity of Fort Churchill Historic State Park (Hess and Mifflin, 1976; Hess and Jacobson, 1980), Lahontan State Recreation Area (Wateresource Consulting Engineers, 1974), and a brief discussion by Glancy and Katzer (1976) accompanied by 11 analyses. Nearly all the analyses of ground water compiled for the present study came from Nevada State Health Laboratory, with a few from Desert Research Institute. Large parts of Churchill Valley are undeveloped or only recently developed, so ground-water quality conditions as of 1988 probably were mostly a result of natural geochemical reactions. Local contamination resulting from septic systems may be present, but data are not sufficient to assess the effects. Data are not available for manmade organic compounds in the ground water in Churchill Valley.

Sampled sites are confined to an area in the western part of the basin, except for three sites in the eastern part (pl. 1). Sample sites are mostly in areas of basin fill, although a few are in upland areas. Most of the wells drilled in the valley draw water, at least in part, from

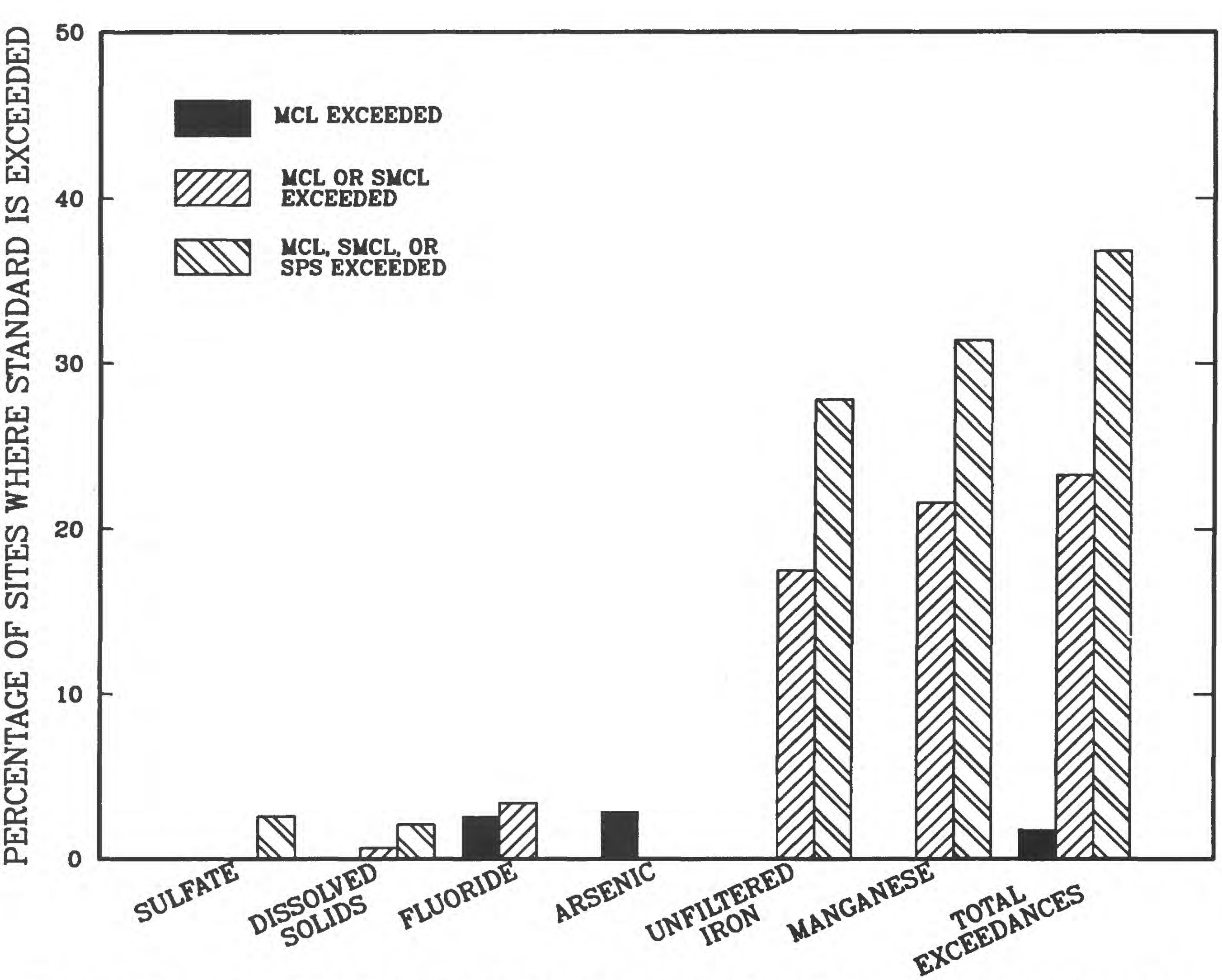

Figure 18.—Percentage of sites in the Eagle Valley where concentrations of selected chemical constituents in sampled ground water exceeded maximum contaminant levels (MCL), secondary maximum contaminant levels (SMCL), or secondary preferred standards (SPS). Because some analyses do not include determinations for all the inorganic constituents having drinking-water standards, the percentages for the total-exceedances category may underestimate the number of sites having an exceedance.

sediments that were deposited in ancient Lake Lahontan.

Ground water in Churchill Valley is neutral to alkaline and dissolved-solids contents generally range from 200 to 1,000 mg/L (fig. 26). Dominant cations are, in general order of abundance, calcium, sodium plus potassium, and magnesium; and bicarbonate is the dominant anion with sulfate dominant in some water.

Ground water in Churchill Valley generally is suitable for irrigation use (fig. 27). Sodium hazards are low for most samples, although four range from medium to very high. Salinity hazards range from low to high, and boron concentrations are low.

Ground water in Churchill Valley exceeds State drinking-water standards for one or more constituents at more than half of the 76 wells that were sampled (table 16 and pl. 1). The constituent that most commonly exceeds the MCL's is arsenic; those that commonly exceed SMCL's and SPS's are dissolved solids, iron, manganese, and sulfate (fig. 28). Sulfate concentrations exceeding the SMCL (500 mg/L) are from water in wells less than about 200 ft deep, whereas concentrations that exceed the SPS (250 mg/L) are from wells having a greater depth range (fig. 29A). Wells having water with the high sulfate concentrations are scattered in the north-central part of the basin (fig 30A). Wells having water with dissolved-solids concentrations exceeding the SMCL are scattered throughout the area sampled (fig. 30B). The SMCL for dissolved solids (1,000 mg/L) is exceeded in 10 percent of the samples. Water having higher concentrations generally are present in wells with depths shallower than about 200 ft below land surface (fig. 29B).

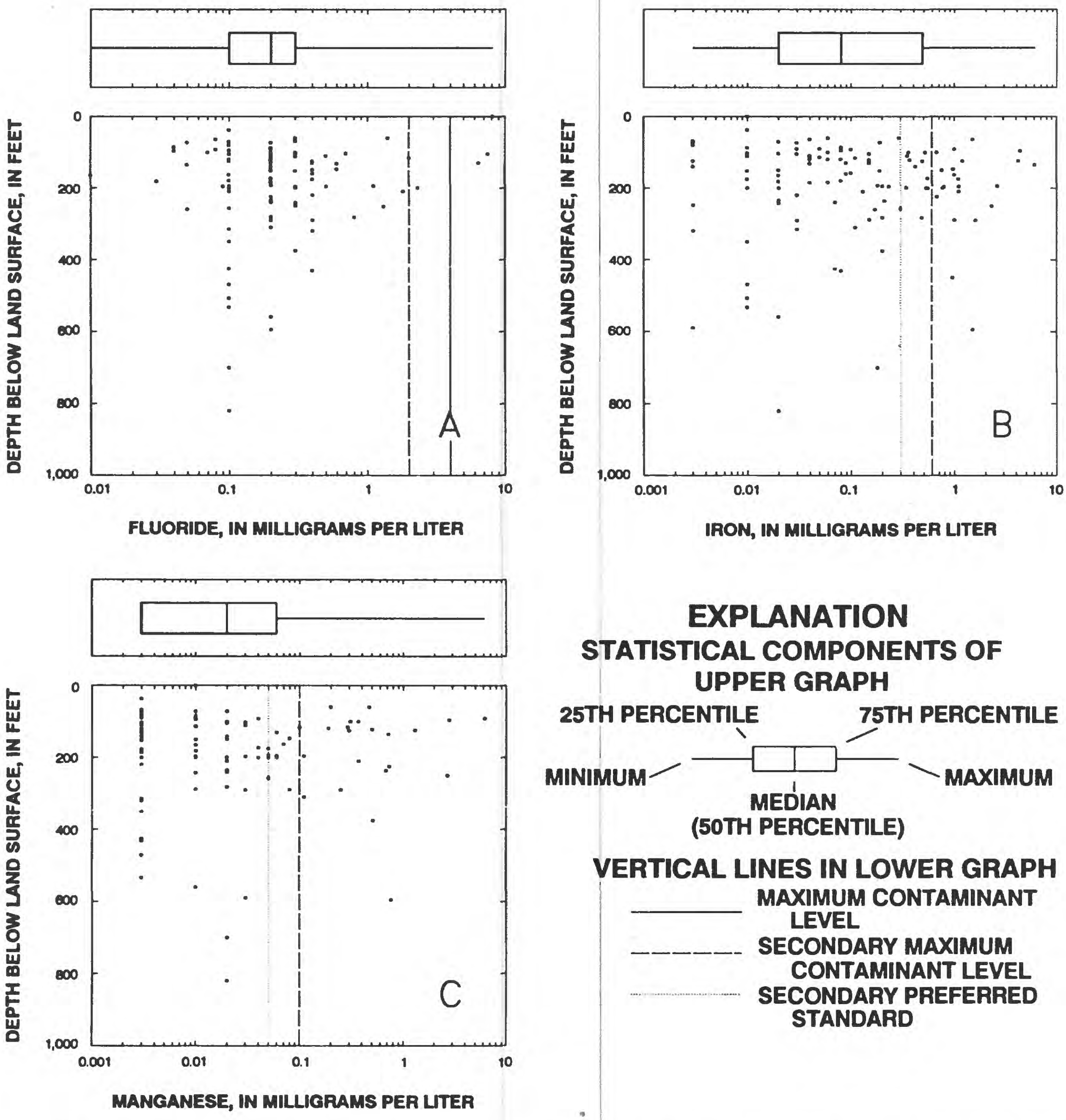

Figure 19.—Statistical distribution of concentrations (upper graph) and relation between concentration and well depth (lower graph) for (A) fluoride, (B) iron, and (C) manganese in sampled ground water of Eagle Valley. In lower graphs, spring data are shown at land surface.

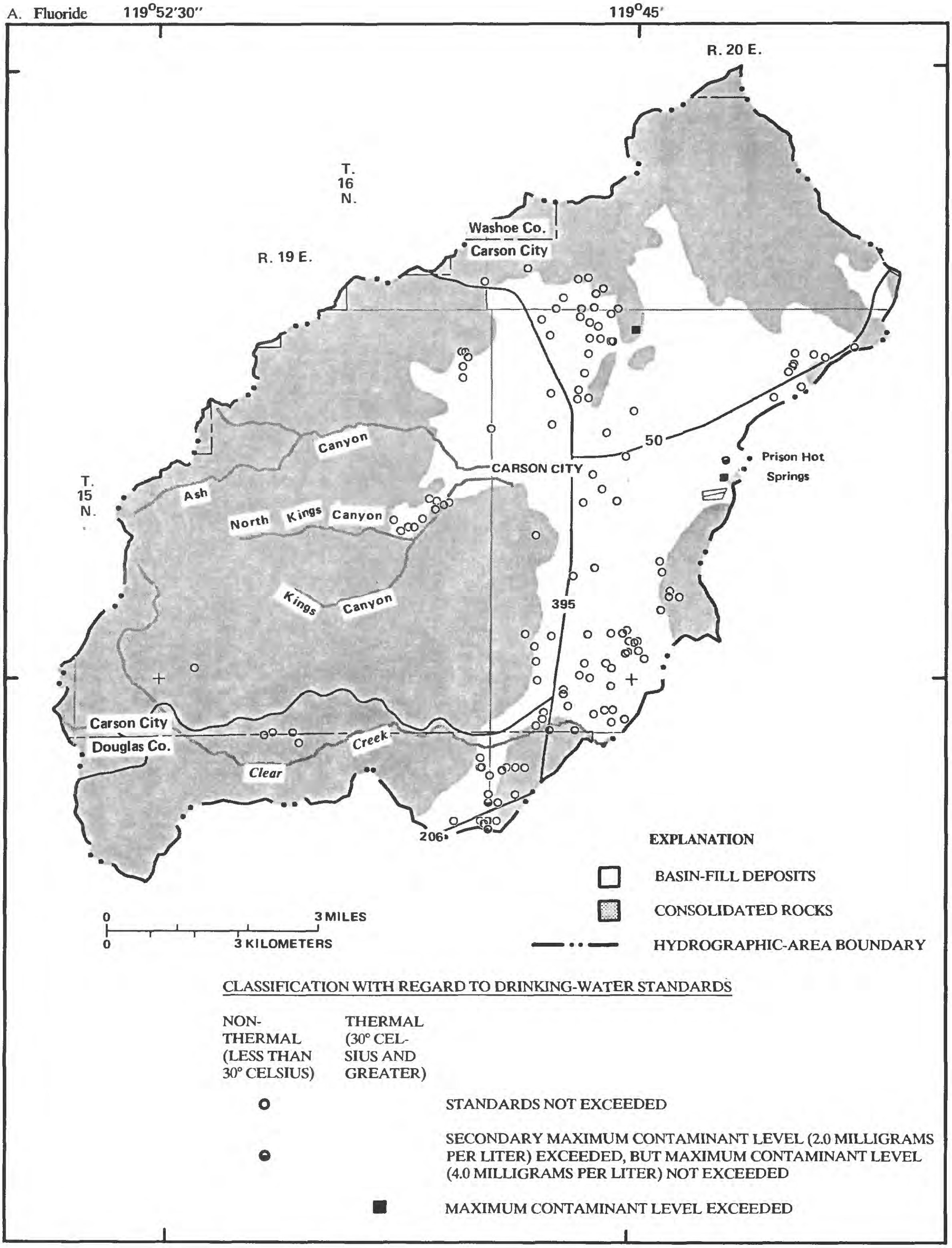

Figure 20A.—Sampling sites in the Eagle Valley where (A) fluoride, (B) iron, and (C) manganese in ground water have exceeded and have not exceeded State drinking-water standards.

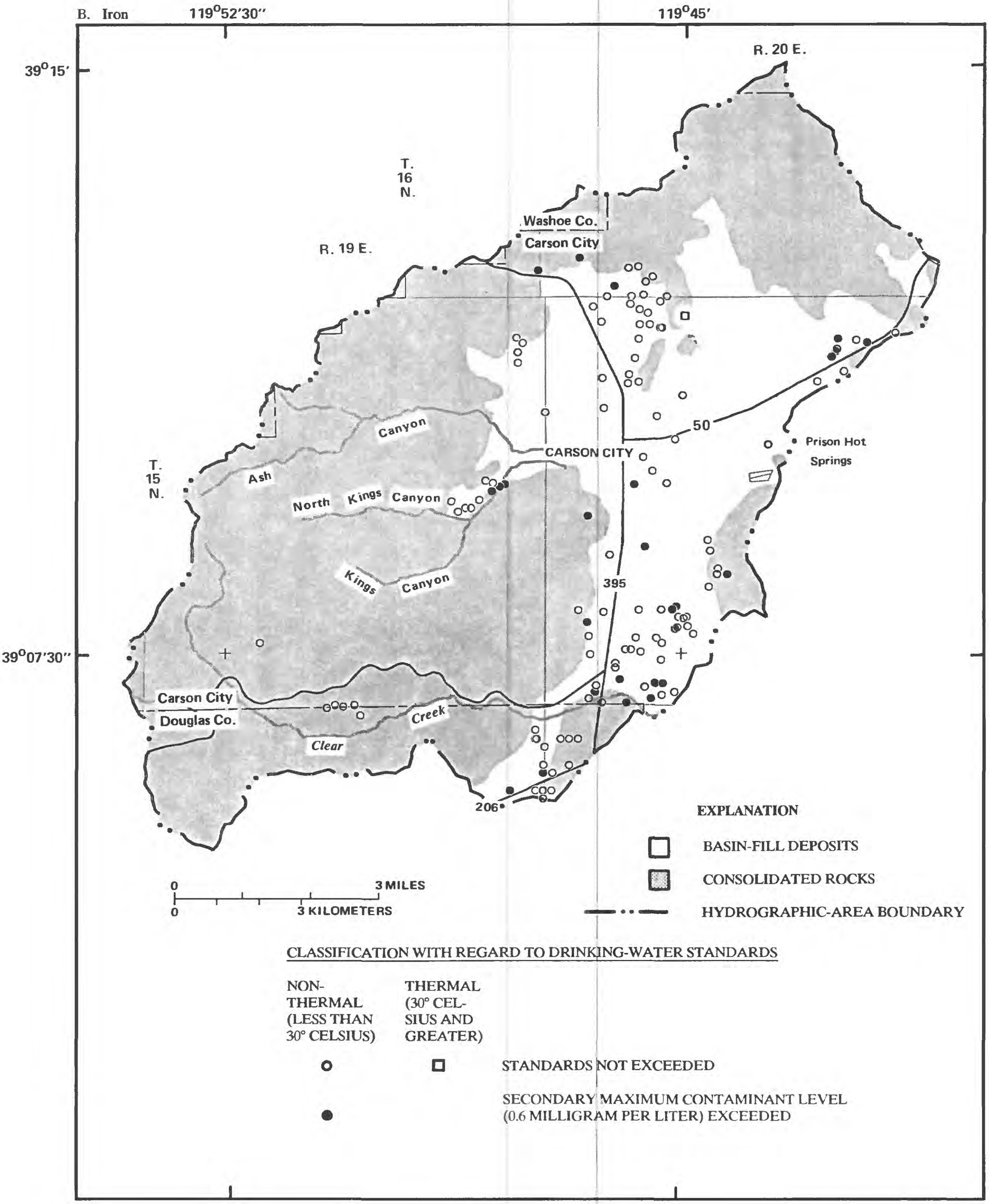

Figure 20B. – Continued.

C. Manganese

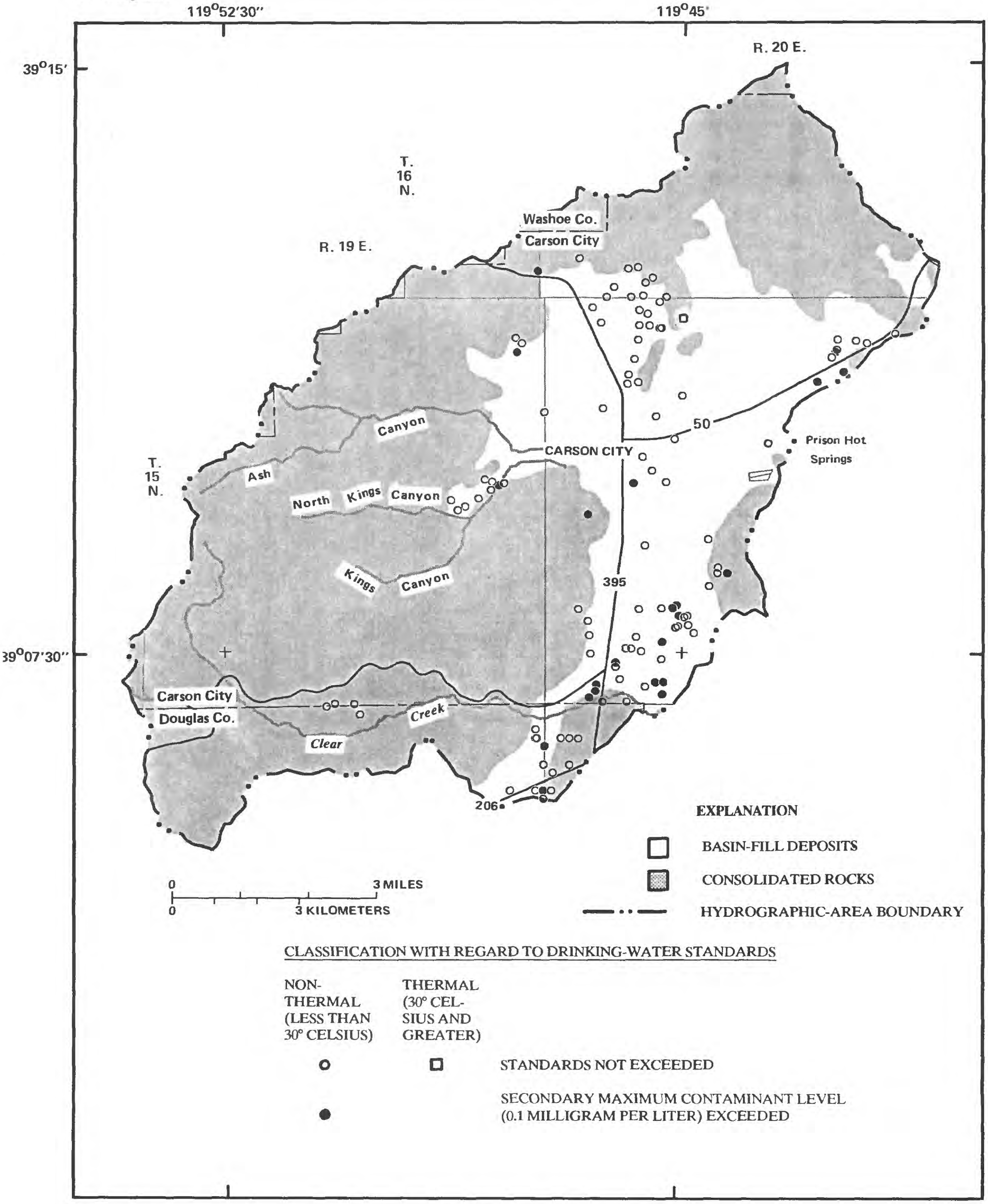

Figure 20C. – Continued.

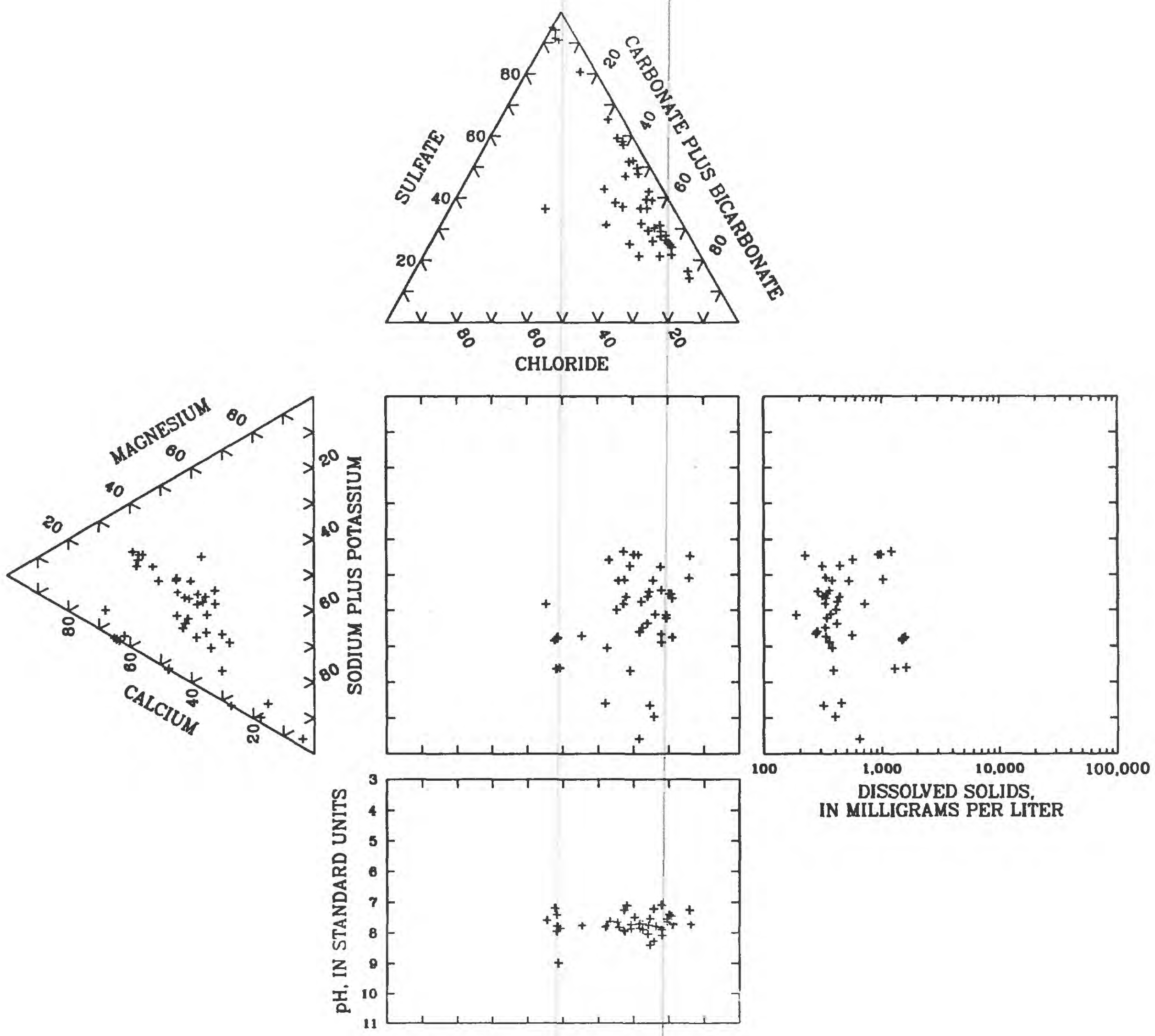

Figure 21.—General chemical character of sampled ground water in Dayton Valley.

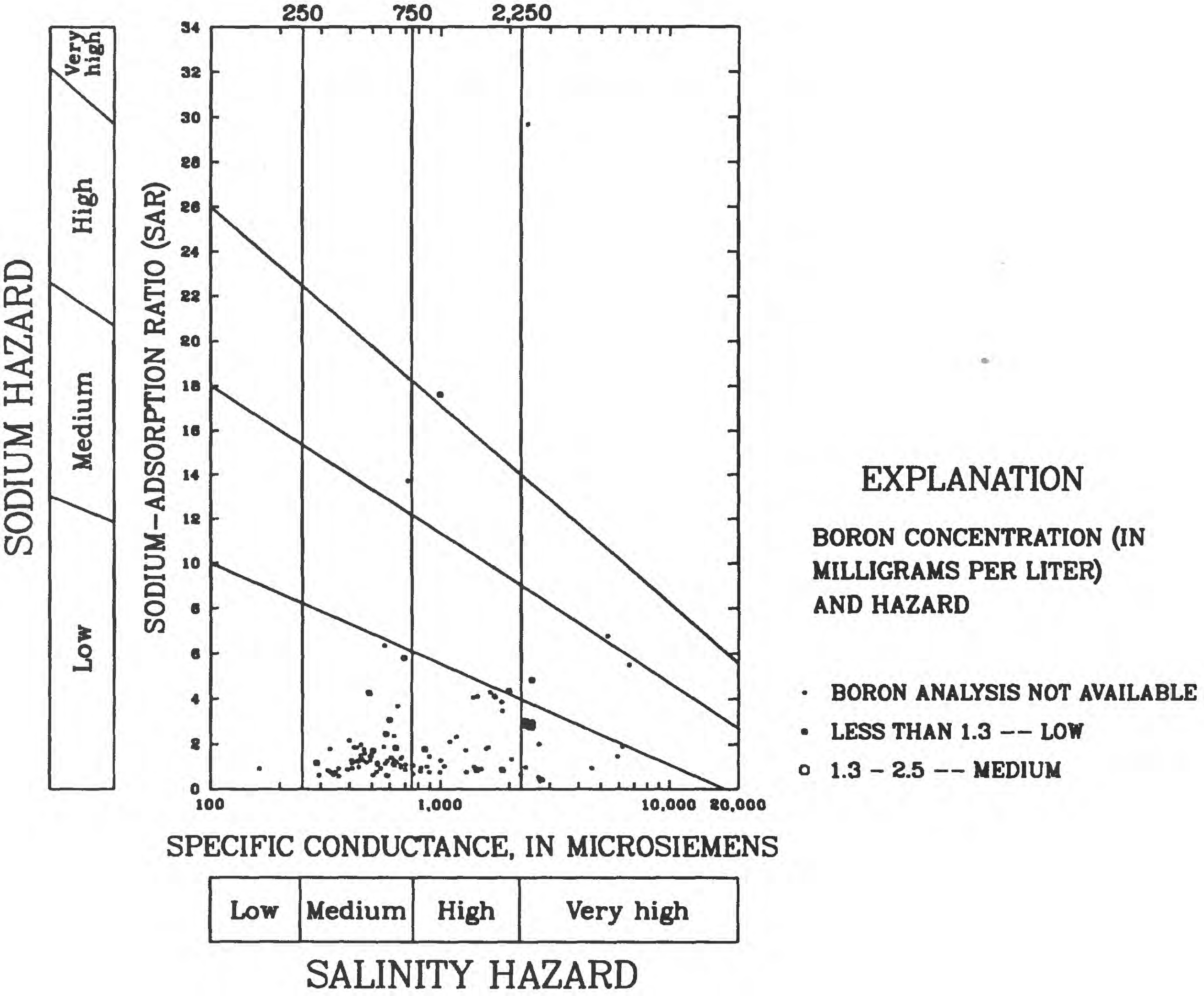

Figure 22.—General suitability of sampled ground water in Dayton Valley for irrigation. Information on boron hazard from Davis and DeWiest (1966, p. 122). Two of the 128 samples from Dayton Valley plot off the graph because their SAR values (44 and 70) exceed 34. Boron values are not available for these two samples.

Table 15.—*Summary of inorganic constituents and properties exceeding Nevada State drinking-water standards in Dayton Valley*

[See table 10 and text for explanation of standards, --, standard does not exist for indicated constituent or property]

		Number of analyses exceeding State standard		
Constituent or property	Number of analyses (1)	Maximum contaminant level (2)	Secondary maximum contaminant level (3)	Secondary preferred standard (4)
Primary standards				
Arsenic	113	4	--	--
Barium	45	0	--	--
Cadmium	22	0	--	--
Chromium	0	0	--	--
Fluoride	158	15	27	--
Lead	22	0	--	--
Mercury	22	0	--	--
Nitrate	156	1	--	--
Selenium	0	0	--	--
Silver	0	0	--	--
Secondary standards				
Chloride	193	--	0	0
Copper	54	--	--	1
Dissolved solids	184	--	58	91
Iron, filtered	22	--	0	2
Iron, unfiltered	141	--	29	48
Magnesium	179	--	3	3
Manganese	138	--	35	45
pH	199	--	--	7
Sulfate	194	--	53	74
Zinc	54	--	--	0
Totals[1]	206	20	100/102	125/127

[1]Total for column (1) is the number of separate sample locations. Total for column (2) is the number of locations where one or more constituents exceed the maximum contaminant level (MCL). Total for column (3) is a pair of numbers. The first is the number of locations where one or more constituents exceed the secondary maximum contaminant level (SMCL); the second is the number of locations where one or more constituents exceed either an MCL or SMCL. Total for column (4) is a pair of numbers. The first is the number of locations where one or more constituents exceed secondary preferred standards; the second is the number of locations where one or more constituents exceed either the MCL or the secondary preferred standard. The total exceedances reflect analyses that do not include all the inorganic constituents that have established drinking-water standards. Therefore, the totals may underestimate the number of sites that have an inorganic constituent at a concentration that is greater than the standard.

Arsenic concentrations that exceed the MCL in ground water are in the north-central and northeastern parts of the sampled area (fig. 30C), and appear to have come from wells having depths of 300 ft or less (fig. 29C). Concentrations of iron and manganese that exceed the SMCL are widely distributed throughout the sampled area (figs. 30D, 30E) and are from wells with depths generally less than 300 ft (figs. 29D, 29E). Wells along the western and northeastern shores of Lahontan Reservoir, in particular, yield water having high concentrations of iron and manganese. Constituents with concentrations that do not commonly exceed State drinking-water standards are nitrate, chloride, and pH.

Investigations of ground-water availability and quality at Fort Churchill Historic State Park (Hess and Mifflin, 1976; Hess and Jacobson, 1980) and at Lahontan State Recreation Area (Wateresource Consulting Engineers, 1974) indicate several water-quality problems including concentrations of arsenic, chloride, dissolved solids, iron, manganese, nitrate, and sulfate which exceed State standards. Dissolved sulfide has also been detected but not quantified (Wateresource Consulting Engineers, 1974). The investigators postulate that sediments deposited during the different stands of Lake Lahontan are the primary source of these constituents.

Carson Desert

Previous studies of ground-water quality in the Carson Desert have been made with regard to arsenic (Lico and others, 1986, 1987; Welch and others, 1988) or geothermal systems (southern Carson Desert, Bruce, 1980; Stillwater area, Morgan, 1982; and Soda Lakes-Upsal Hogback area, Olmsted and others, 1984). In addition, ground-water quality in the southern Carson Desert has been described by Glancy (1986) as part of an investigation of the ground-water system in the area.

Water-quality data used for the present study are about evenly divided between analyses done by the Nevada State Health Laboratory and the U.S. Geological Survey (fig. 9). In addition to the present study, the Geological Survey is also involved in a study of the effects of irrigation on the quality of ground water and surface water in the Fallon area. This study is part of a Department of the Interior program for investigating the effects of irrigation drainage on water quality (Hoffman and others, 1990).

The ground-water system in the southern Carson Desert consists of four hydraulically connected aquifers that were categorized by Glancy (1986) as the shallow-, intermediate-, and deep-alluvial aquifers and the basalt aquifer. These aquifers were briefly described in an earlier section of this report. The basalt aquifer is the most productive in the southern Carson Desert. This aquifer has been used since the 1940's and is the major source of municipal and industrial water supply for Fallon and the Fallon Naval Air Station. The shallow- and intermediate-alluvial aquifers are the principal

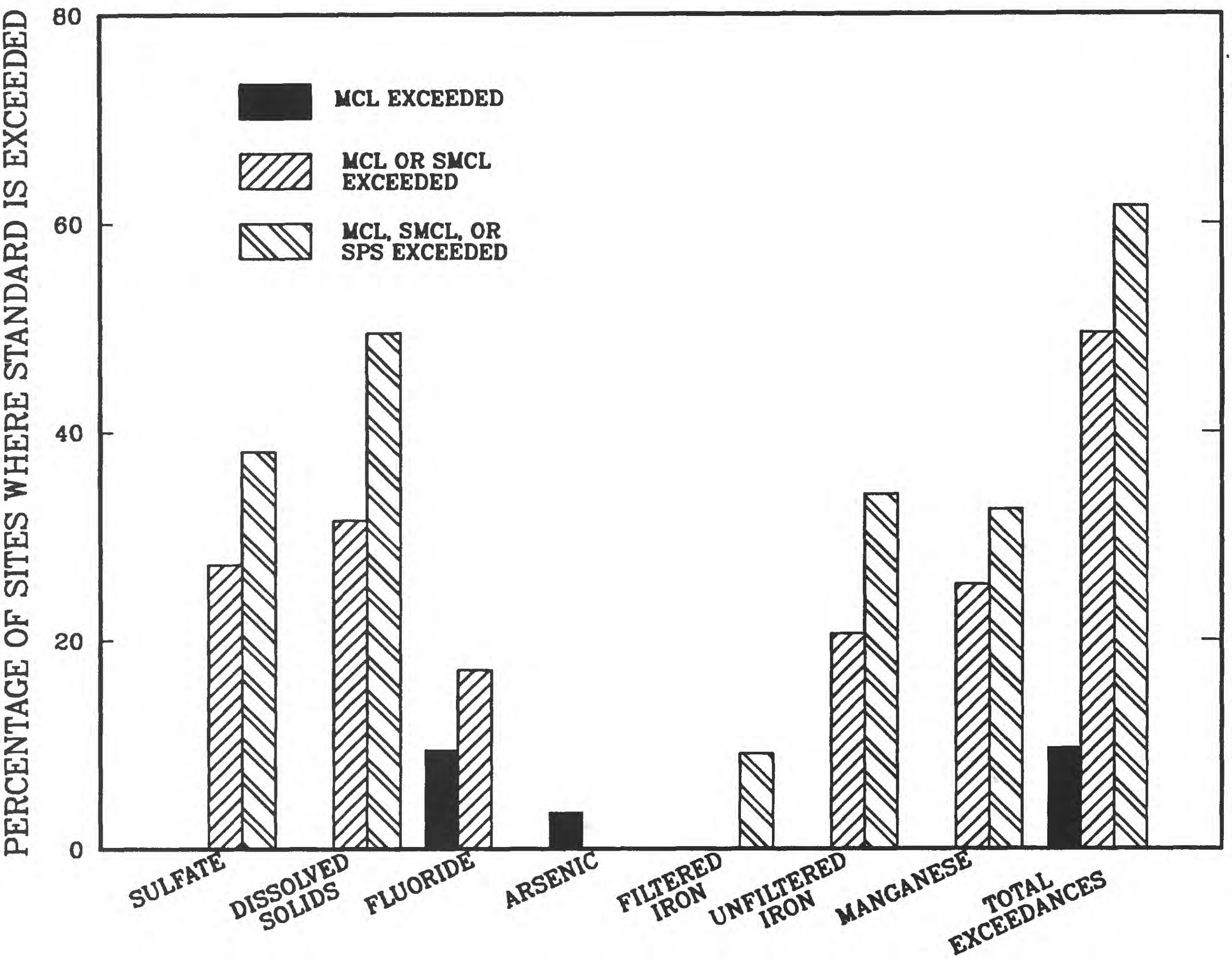

Figure 23.—Percentage of sites in the Dayton Valley where concentrations of selected chemical constituents in sampled ground water exceeded maximum contaminant levels (MCL), secondary maximum contaminant levels (SMCL), or secondary preferred standards (SPS). Because some analyses do not include determinations for all the inorganic constituents having drinking-water standards, the percentages for the total-exceedances category may underestimate the number of sites having an exceedance.

sources of water for domestic use in rural areas and for limited agricultural use. Geothermal systems in the Carson Desert do not constitute a hydrologically isolated aquifer; instead, they are connected to and part of flow systems in the aquifers described above. As a result, the geothermal systems can affect nearby water quality in these aquifers.

The various wells in the southern Carson Desert tap one or more of the aquifers described above. Most produce from the shallow- and intermediate-alluvial aquifers and about 20 produce from the basalt aquifer (Glancy, 1986, p. 8). Few wells are deeper than about 320 ft except for some deep exploration holes and the wells that tap the basalt aquifer (Glancy, 1986, p. 50). Thus, most of the sample sites shown in plate 1 represent wells that tap: (1) The shallow-alluvial aquifer at depths of 50 ft or less; (2) the intermediate-alluvial aquifer at depths of 50 to about 320 ft; and (3) the basalt aquifer at depths that range from near land surface just west of Rattlesnake Hill to more than 500 ft elsewhere (Glancy, 1986, p. 8). Some of these wells, however, probably produce water from more than one aquifer.

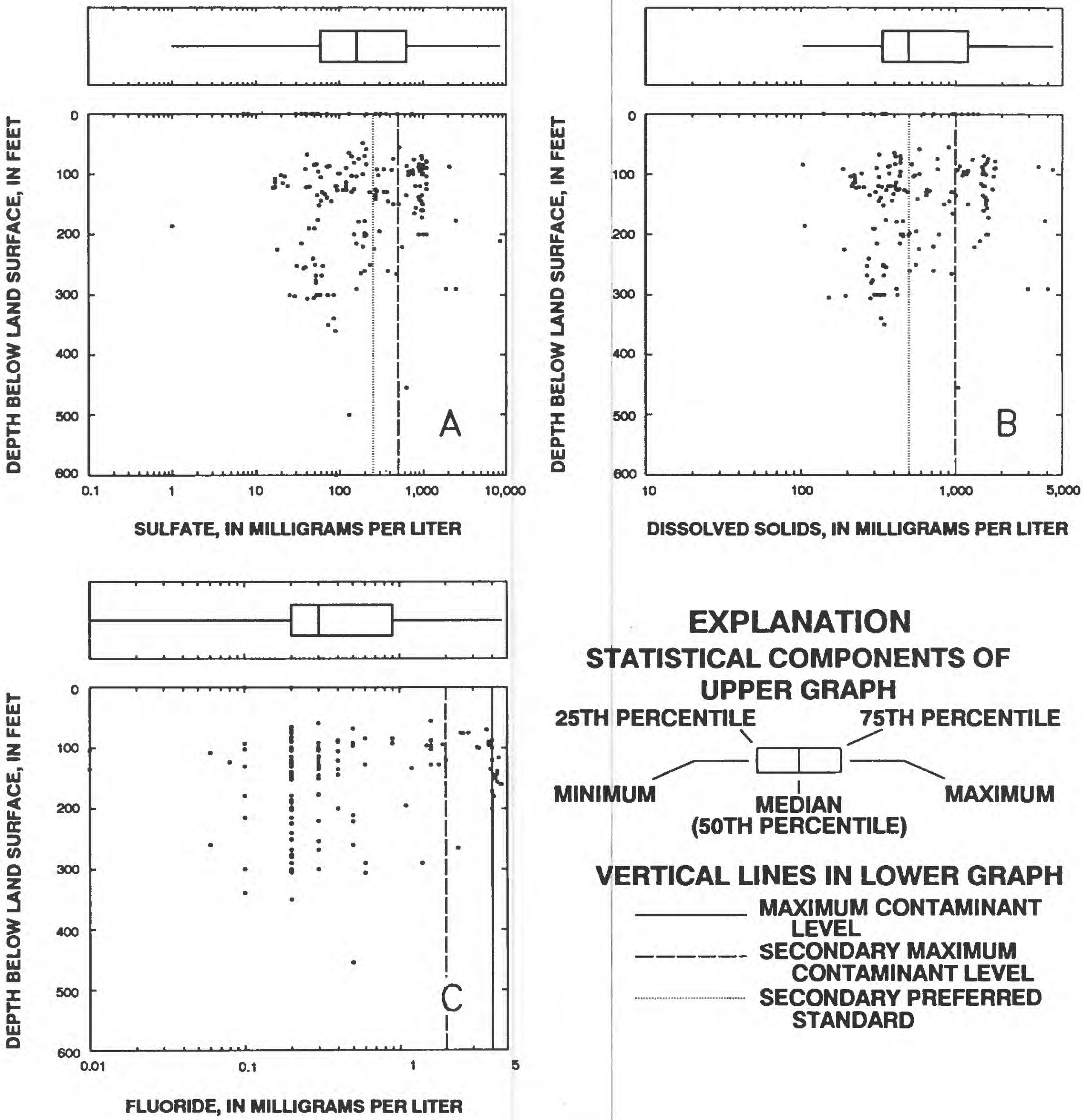

Figure 24.—Statistical distribution of concentrations (upper graph) and relation between concentration and well depth (lower graph) for (A) sulfate, (B) dissolved solids, (C) fluoride, (D) iron, and (E) manganese in sampled ground water of Dayton Valley. In lower graphs, spring data are shown at land surface.

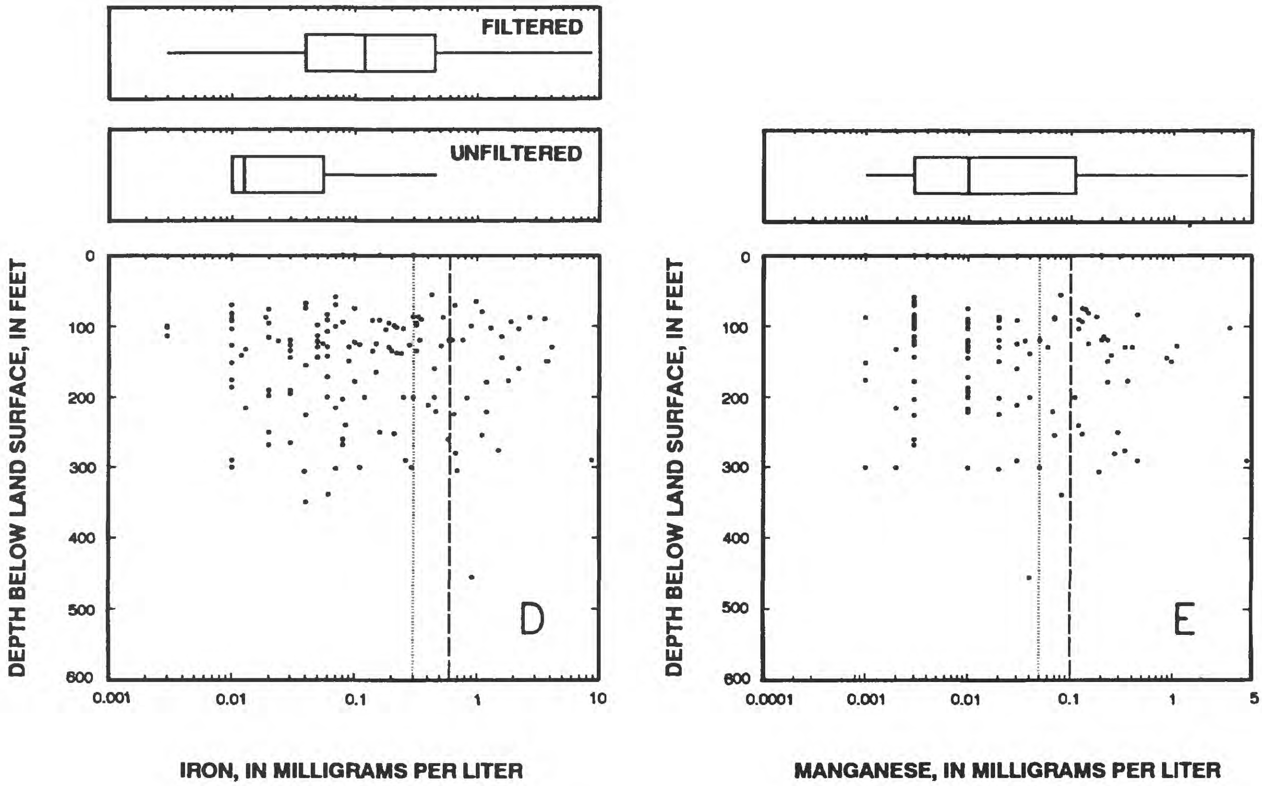

Figure 24. – Continued.

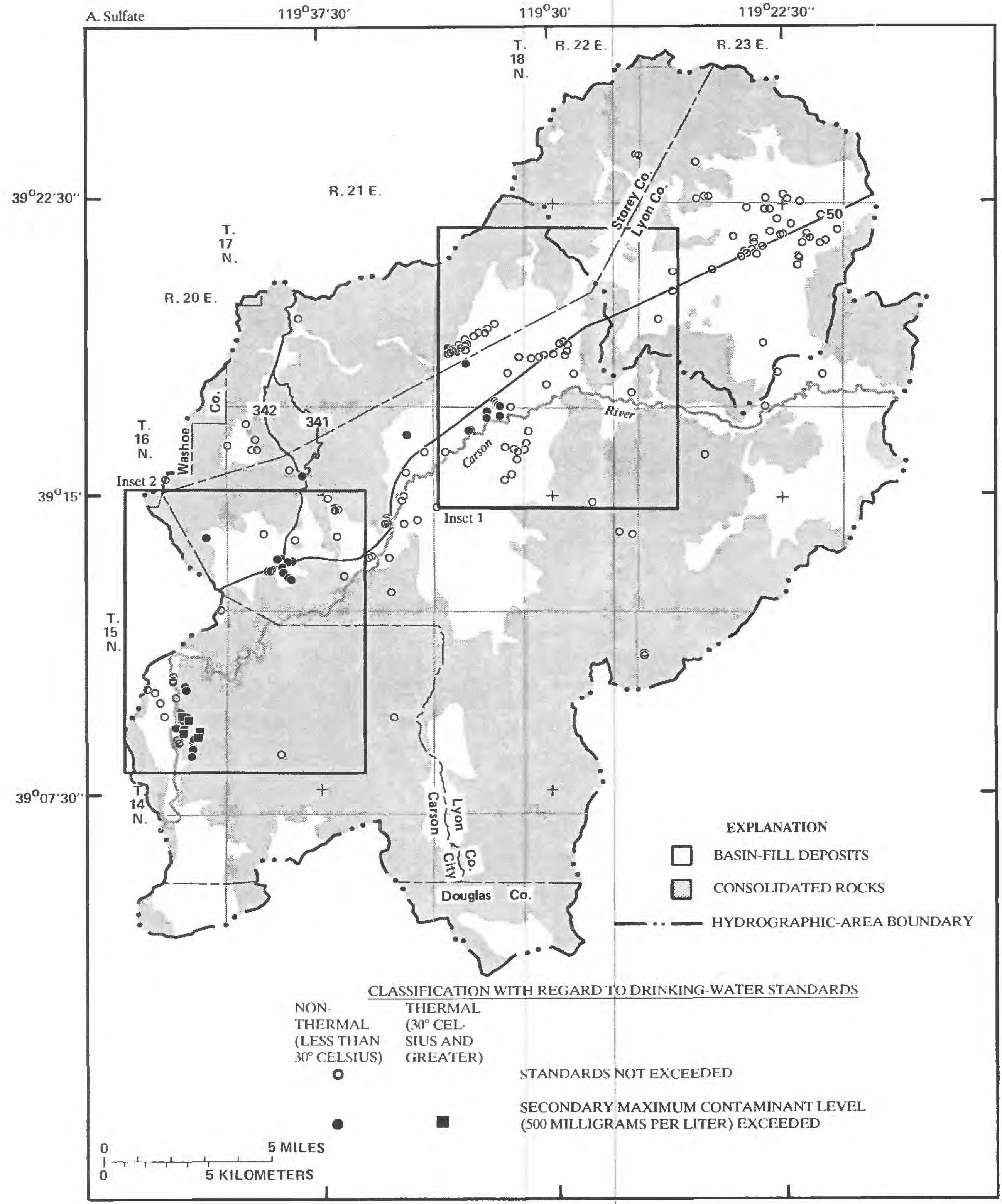

Figure 25A.—Sampling sites in the Dayton Valley where (A) sulfate, (B) dissolved solids, (C) fluoride, (D) iron, and (E) manganese in ground water have exceeded and have not exceeded State drinking-water standards.

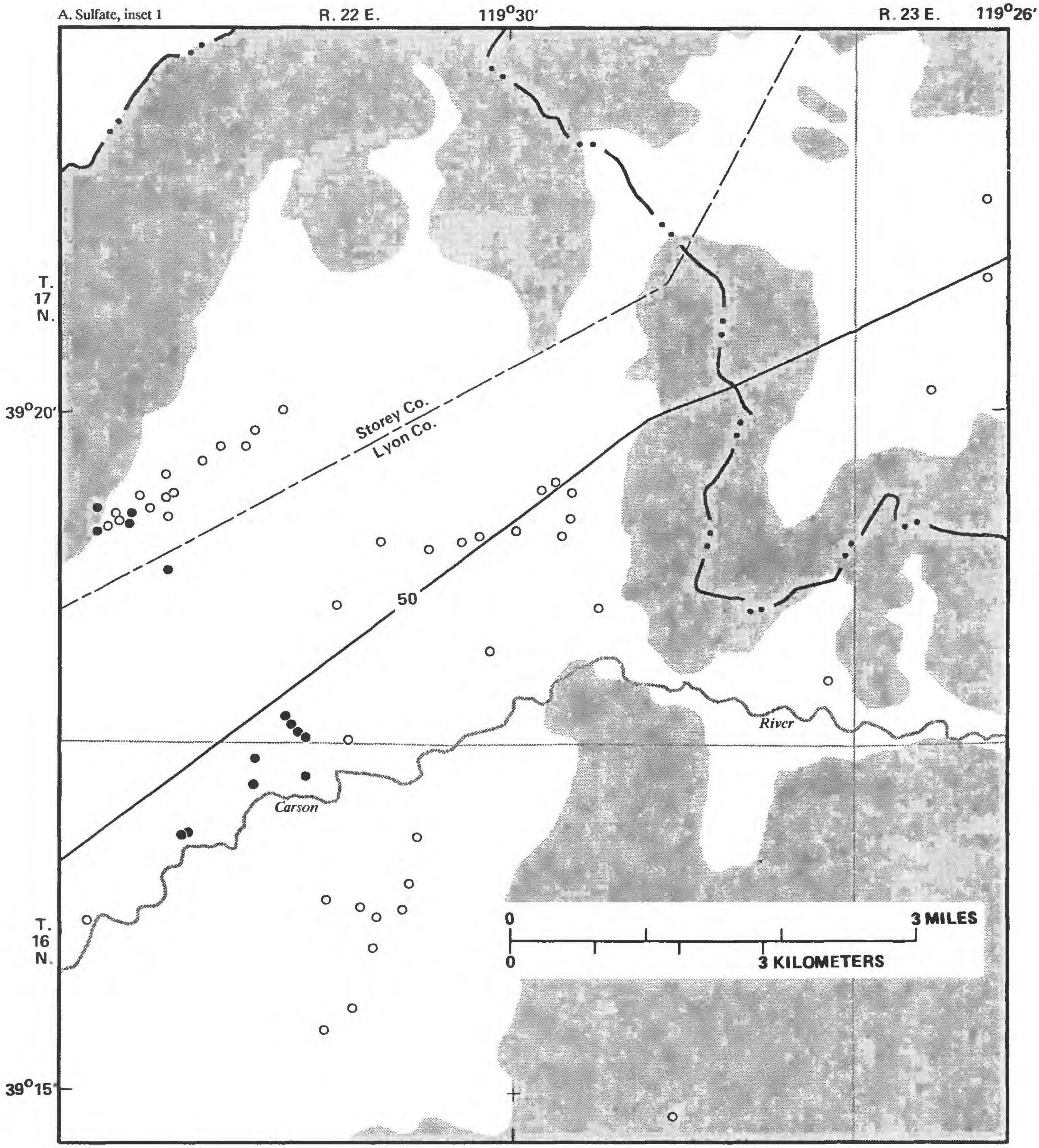

Figure 25A – Continued.

A. Sulfate, inset 2

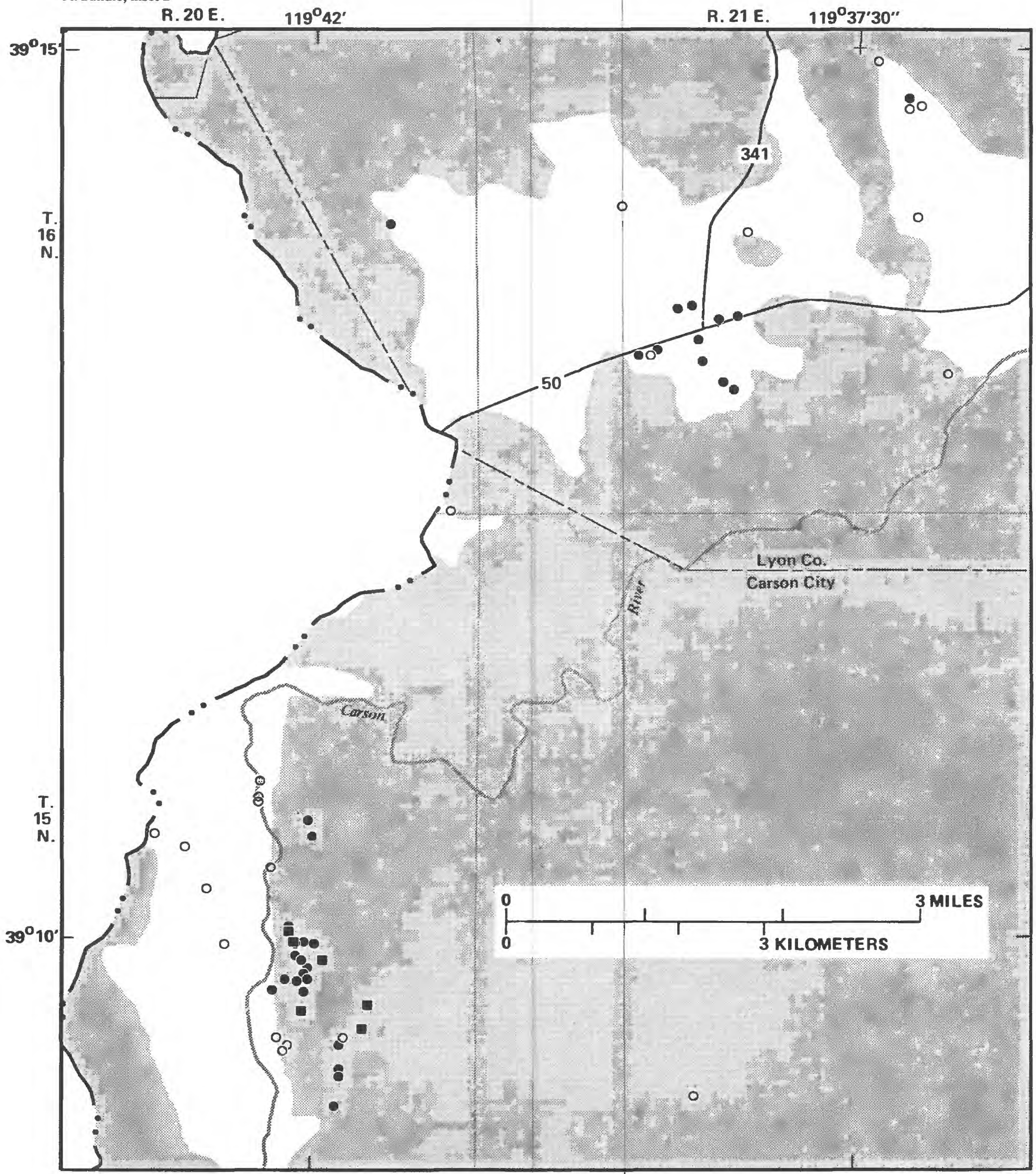

Figure 25A.—Continued.

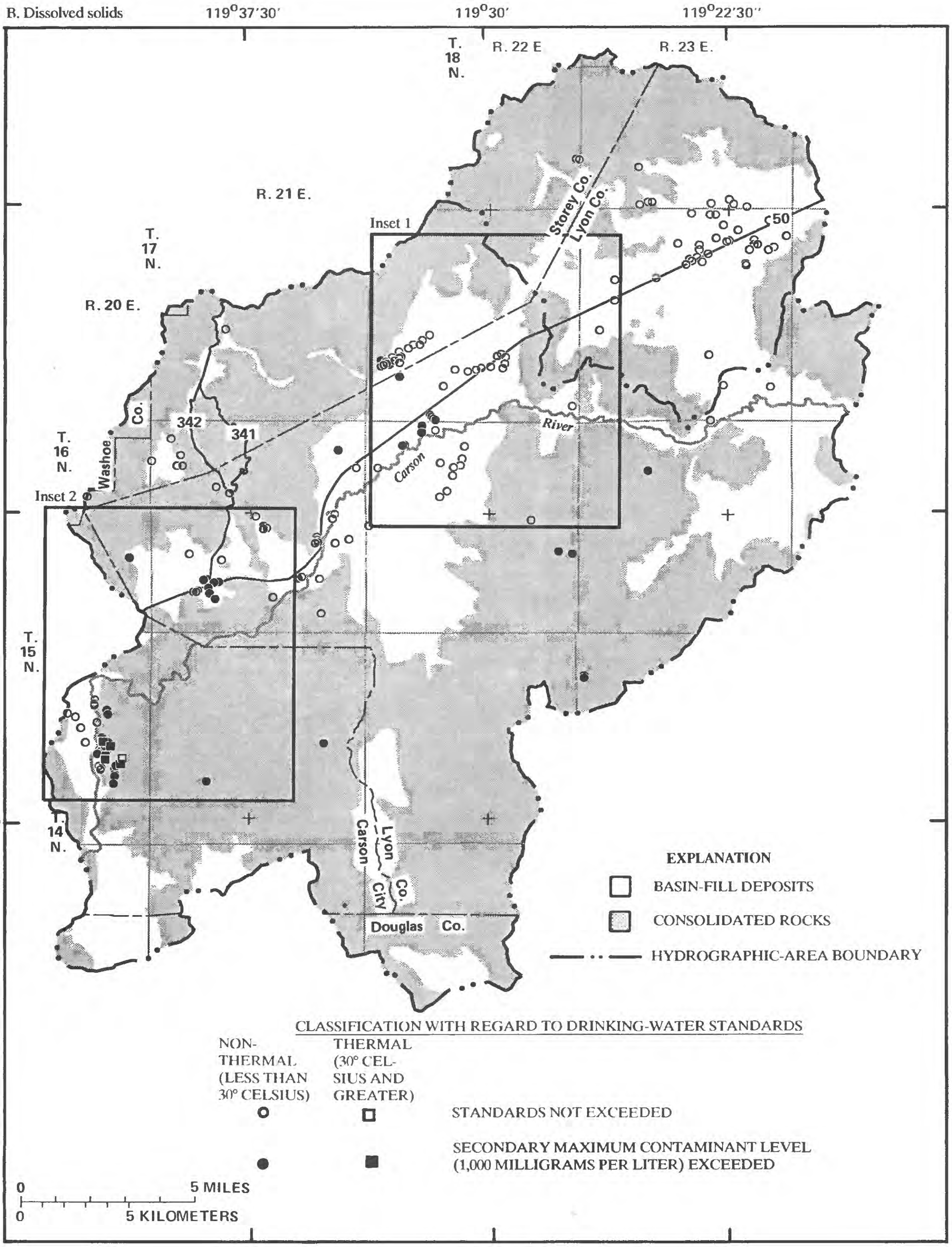

Figure 25B. – Continued.

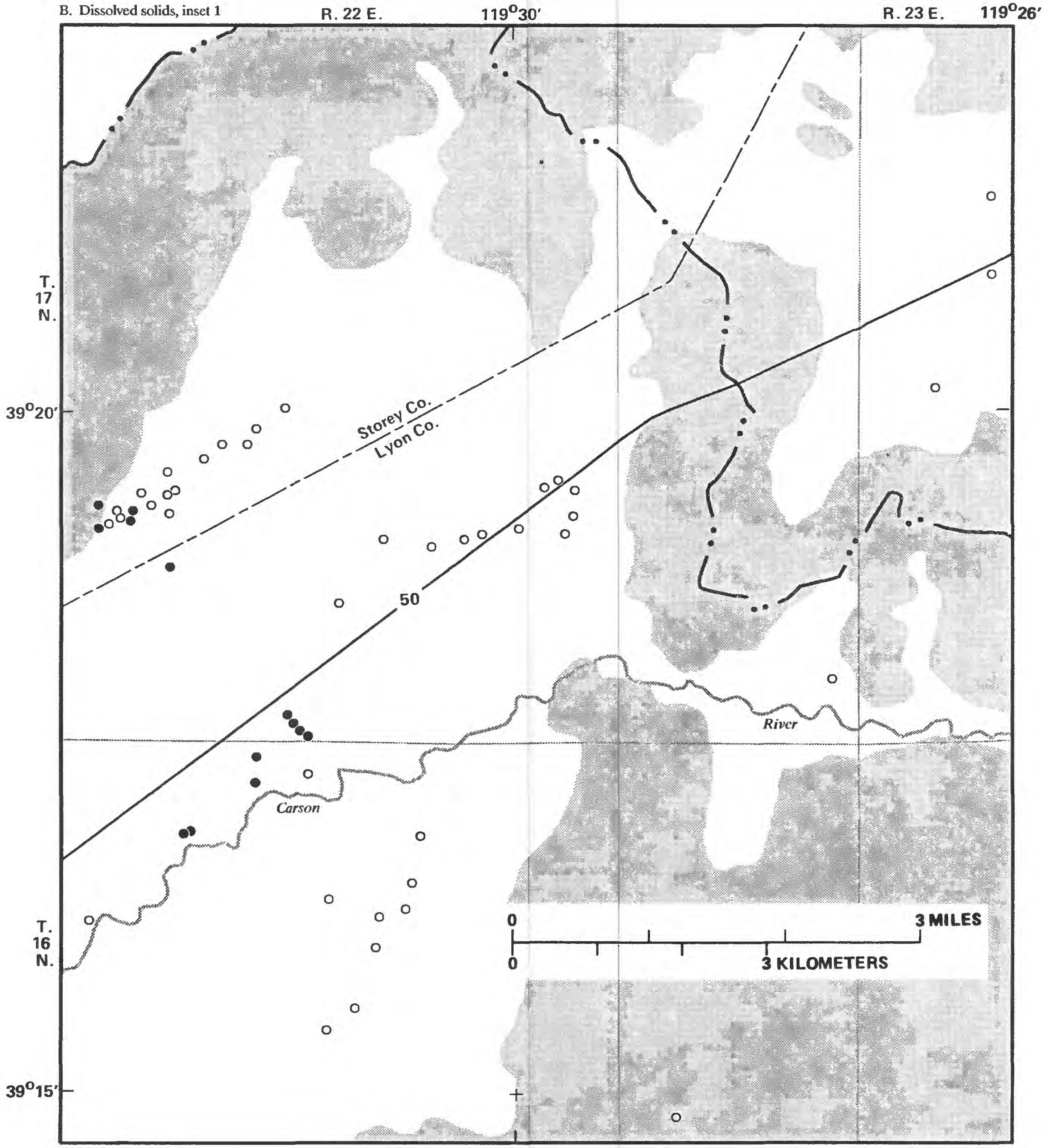

Figure 25B. – Continued.

B. Dissolved solids, inset 2

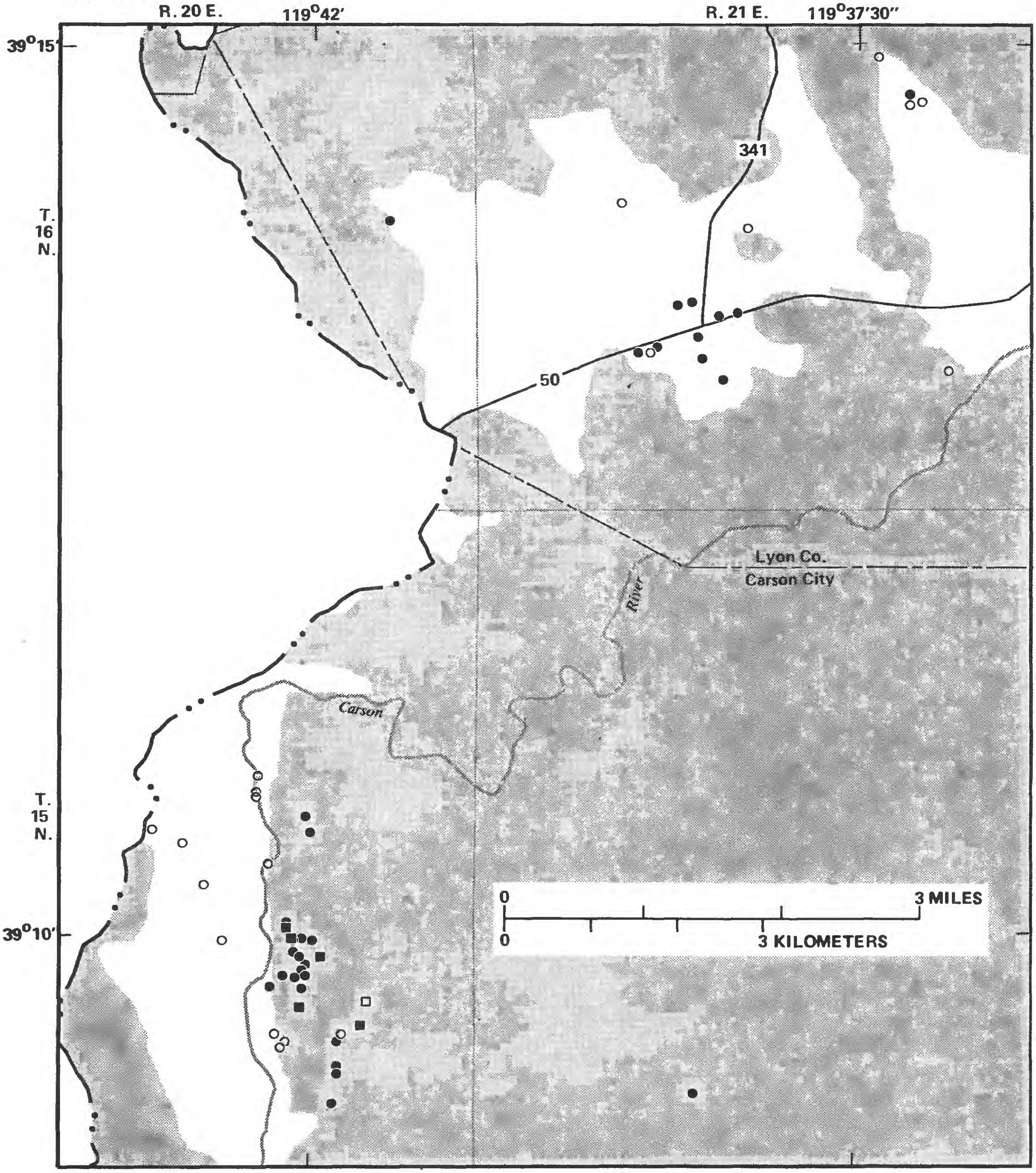

Figure 25B. – Continued.

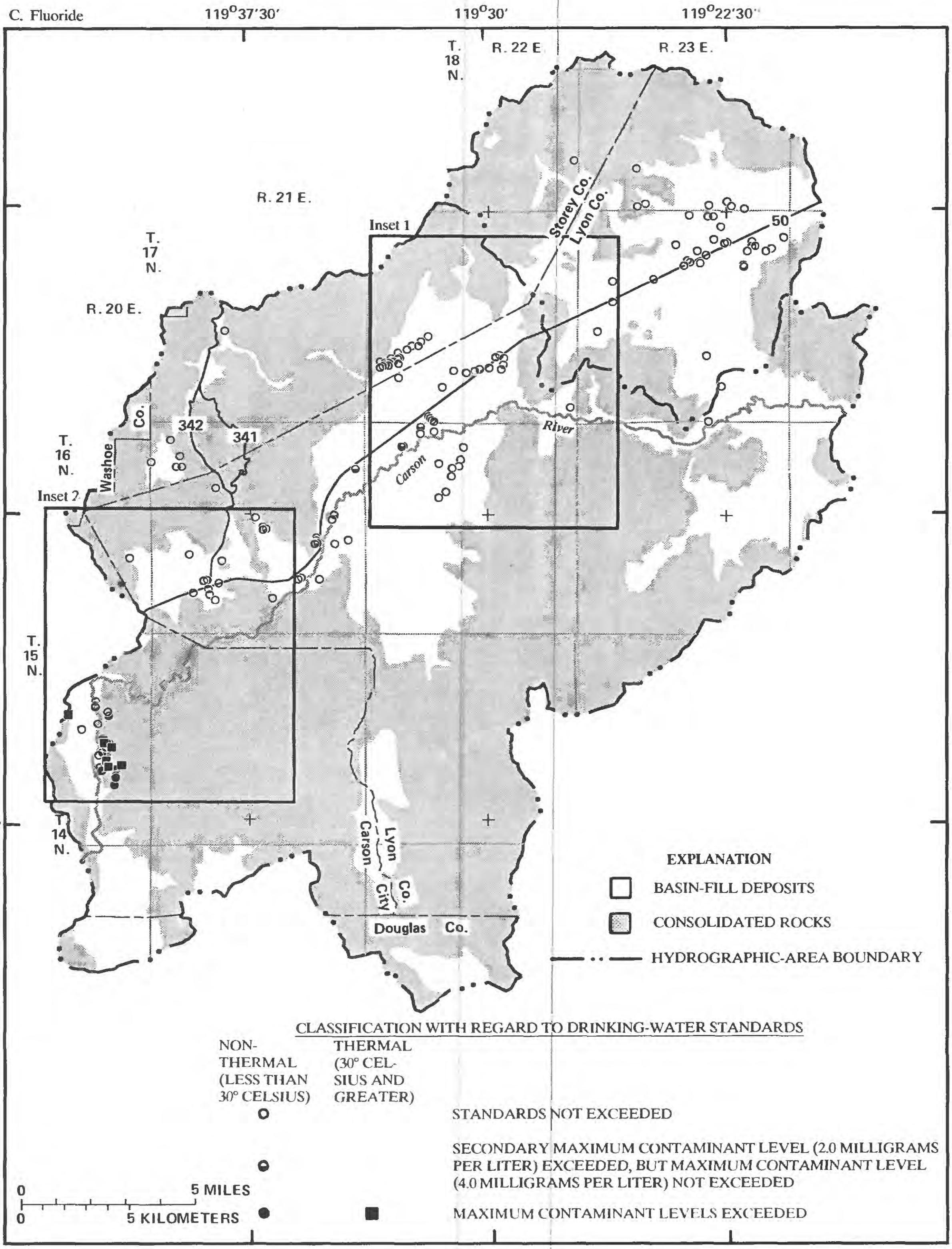

Figure 25C. – Continued.

C. Fluoride, inset 1

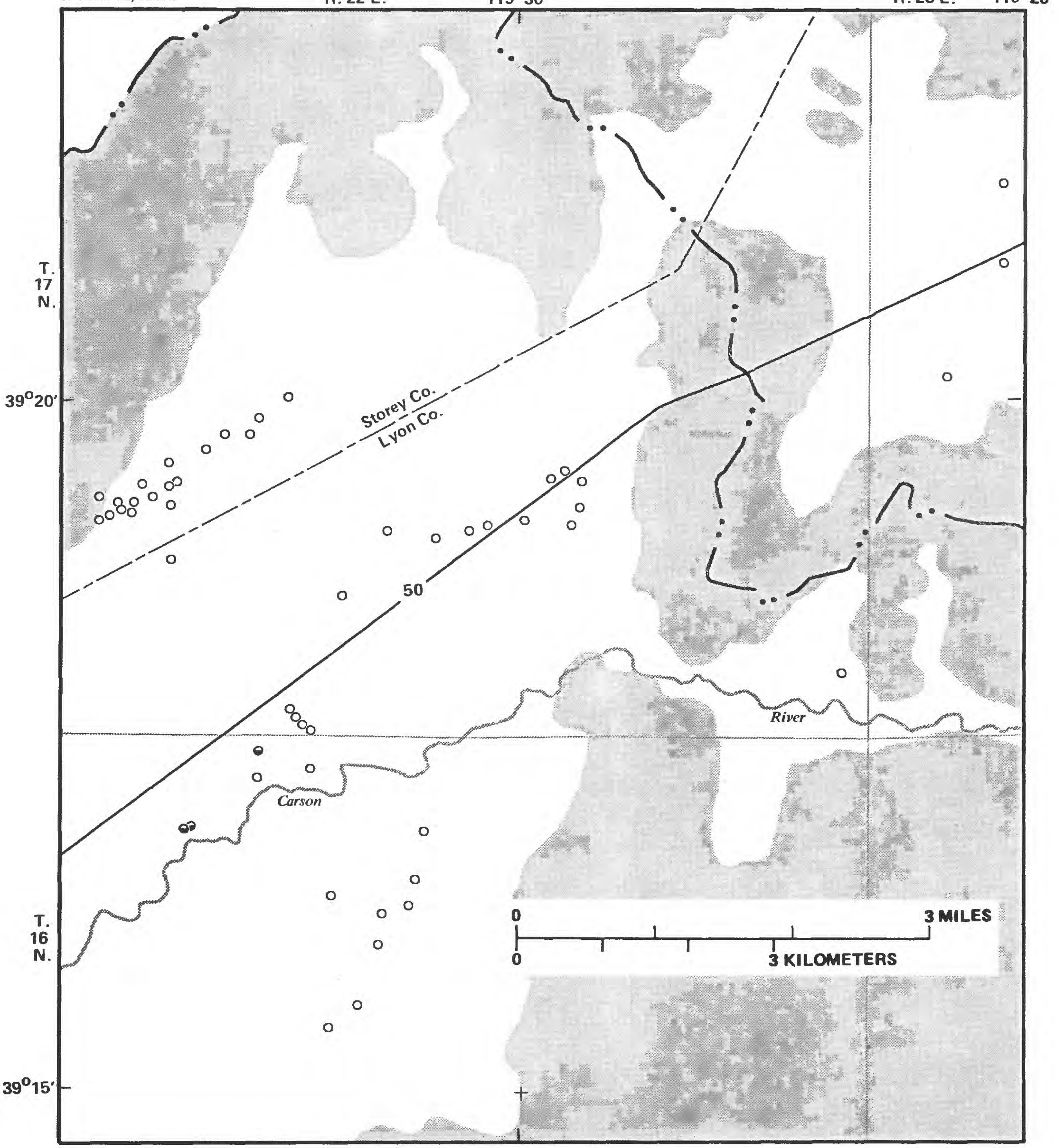

Figure 25C. – Continued.

C. Fluoride, inset 2

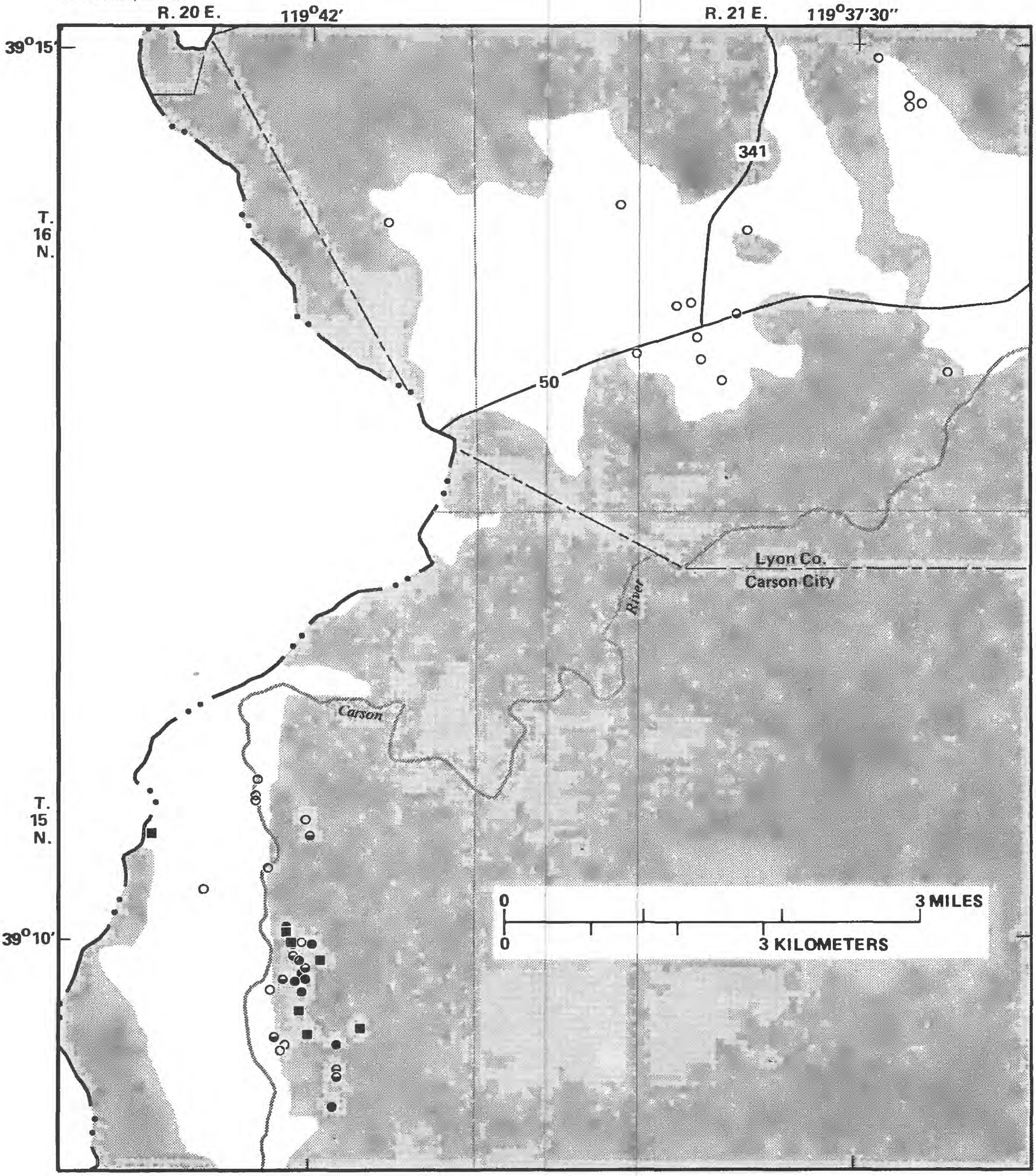

Figure 25C.—Continued.

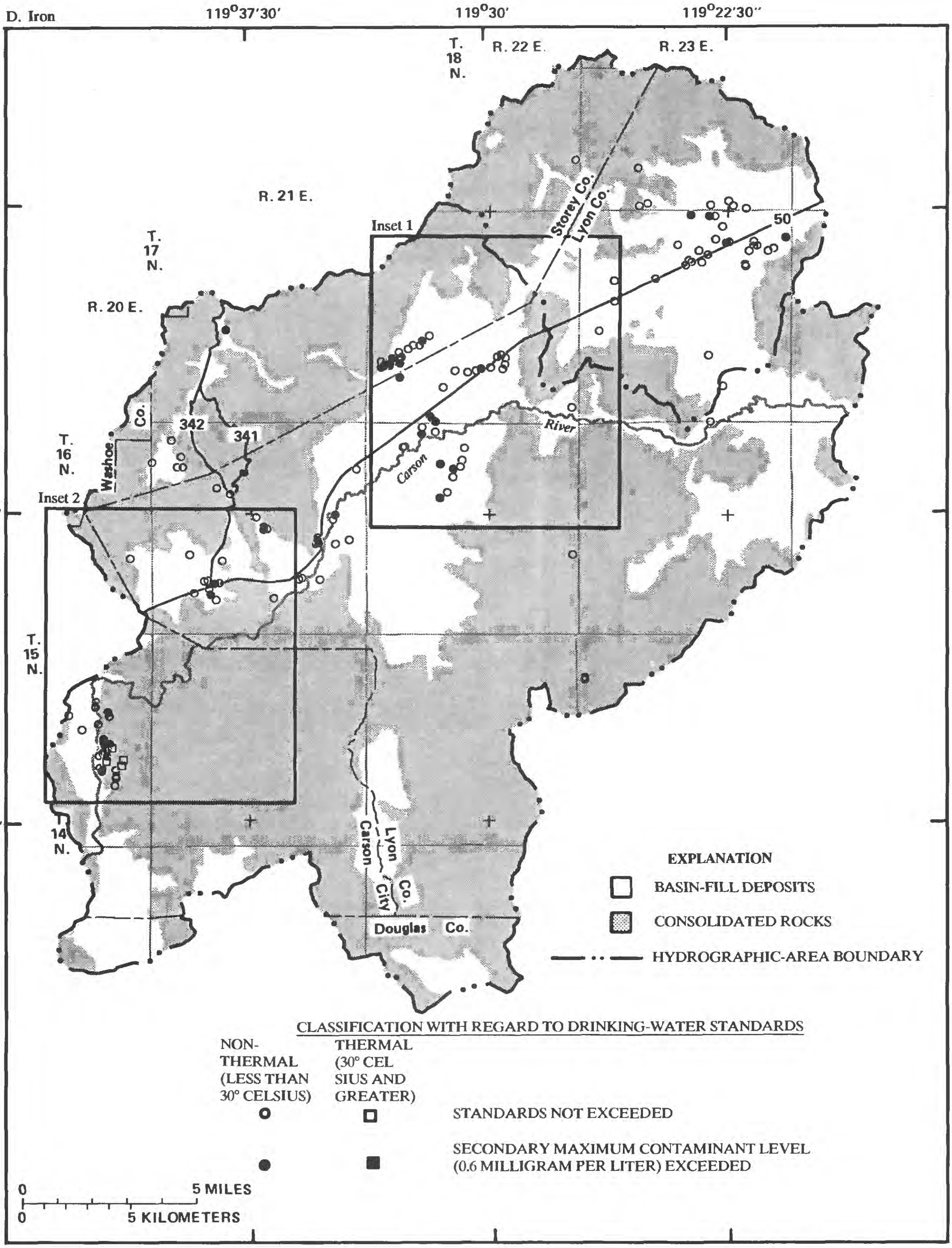

Figure 25D.—Continued.

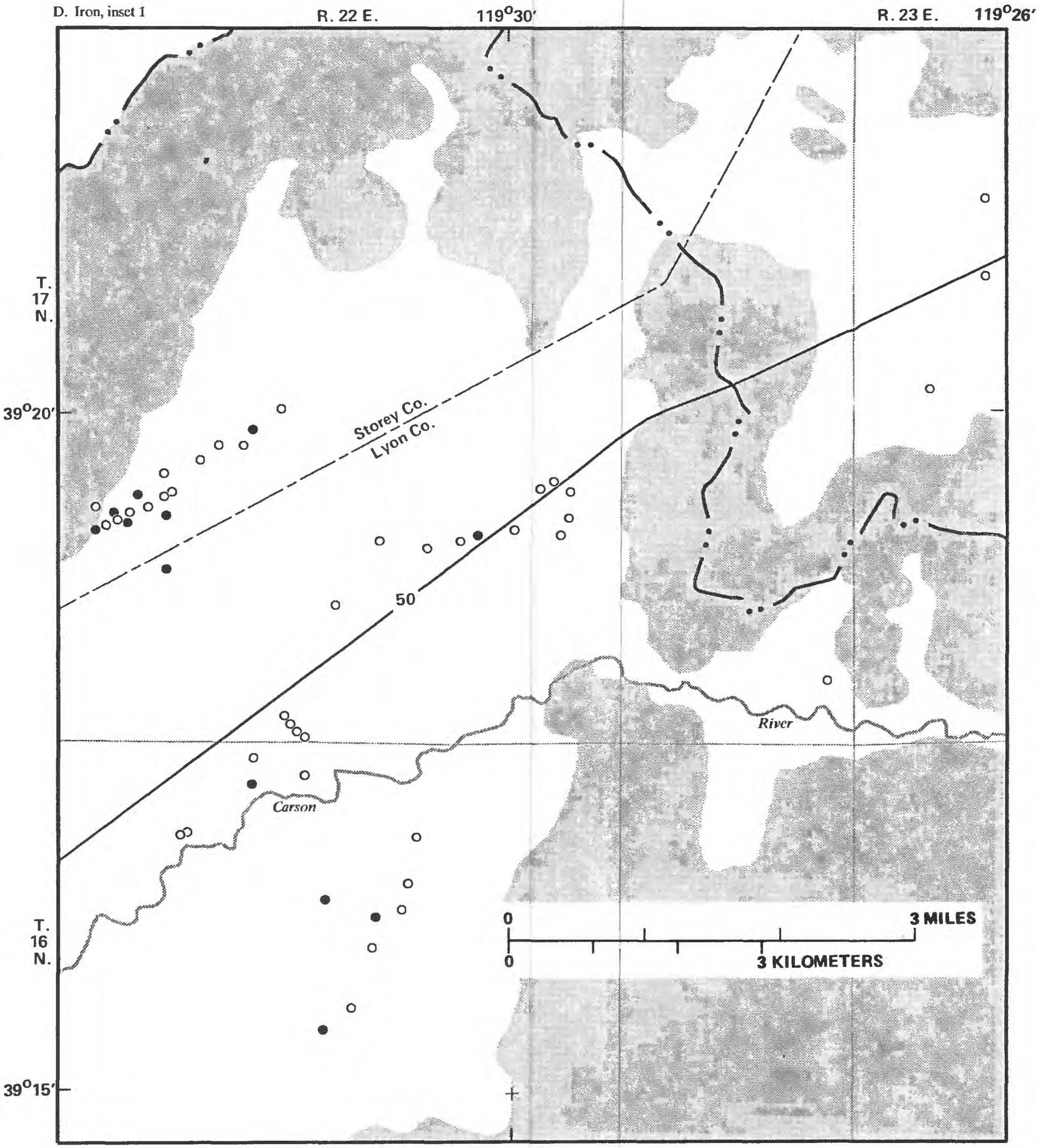

Figure 25D. – Continued.

D. Iron, inset 2

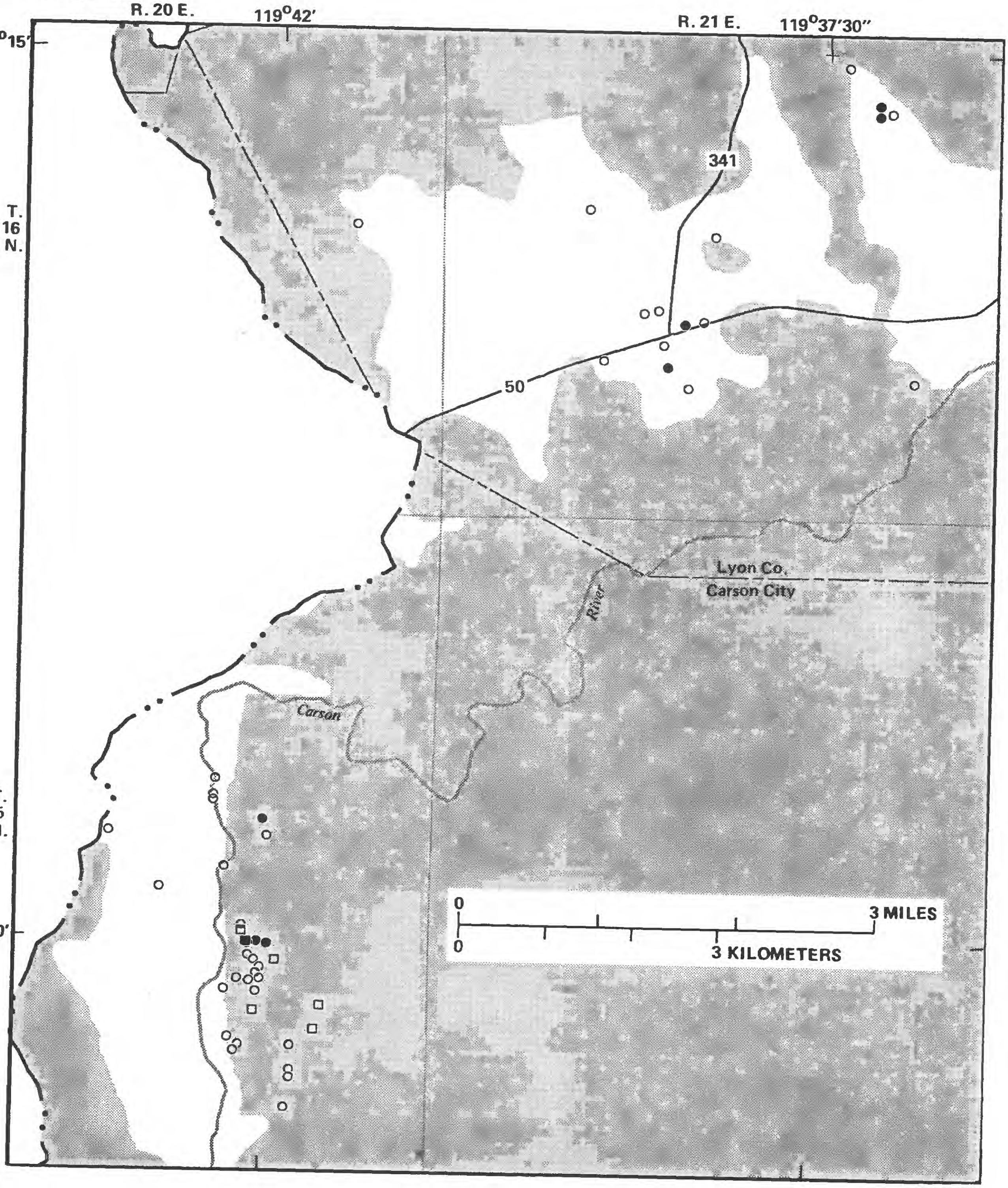

Figure 25D.—Continued.

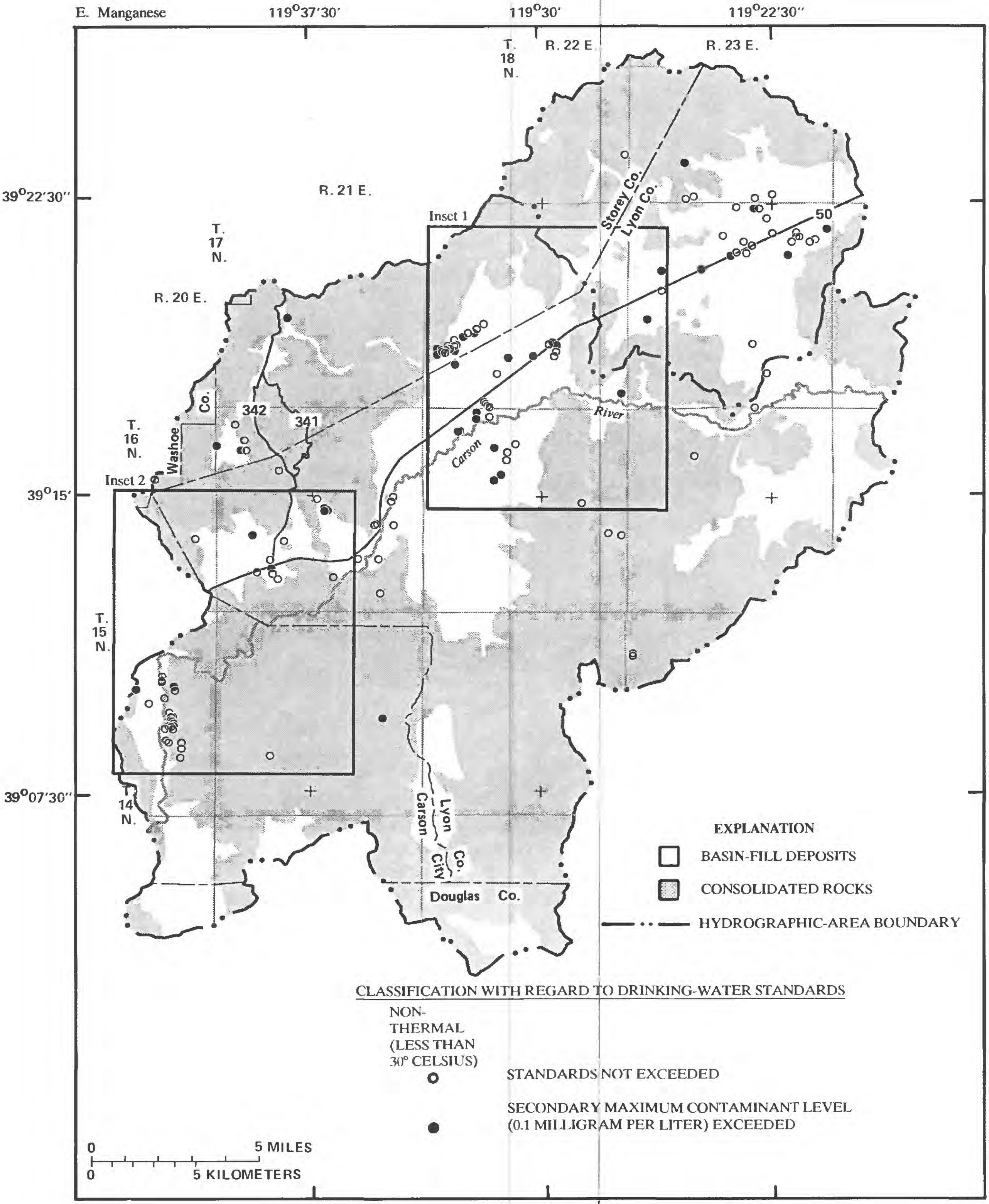

Figure 25E.—Continued.

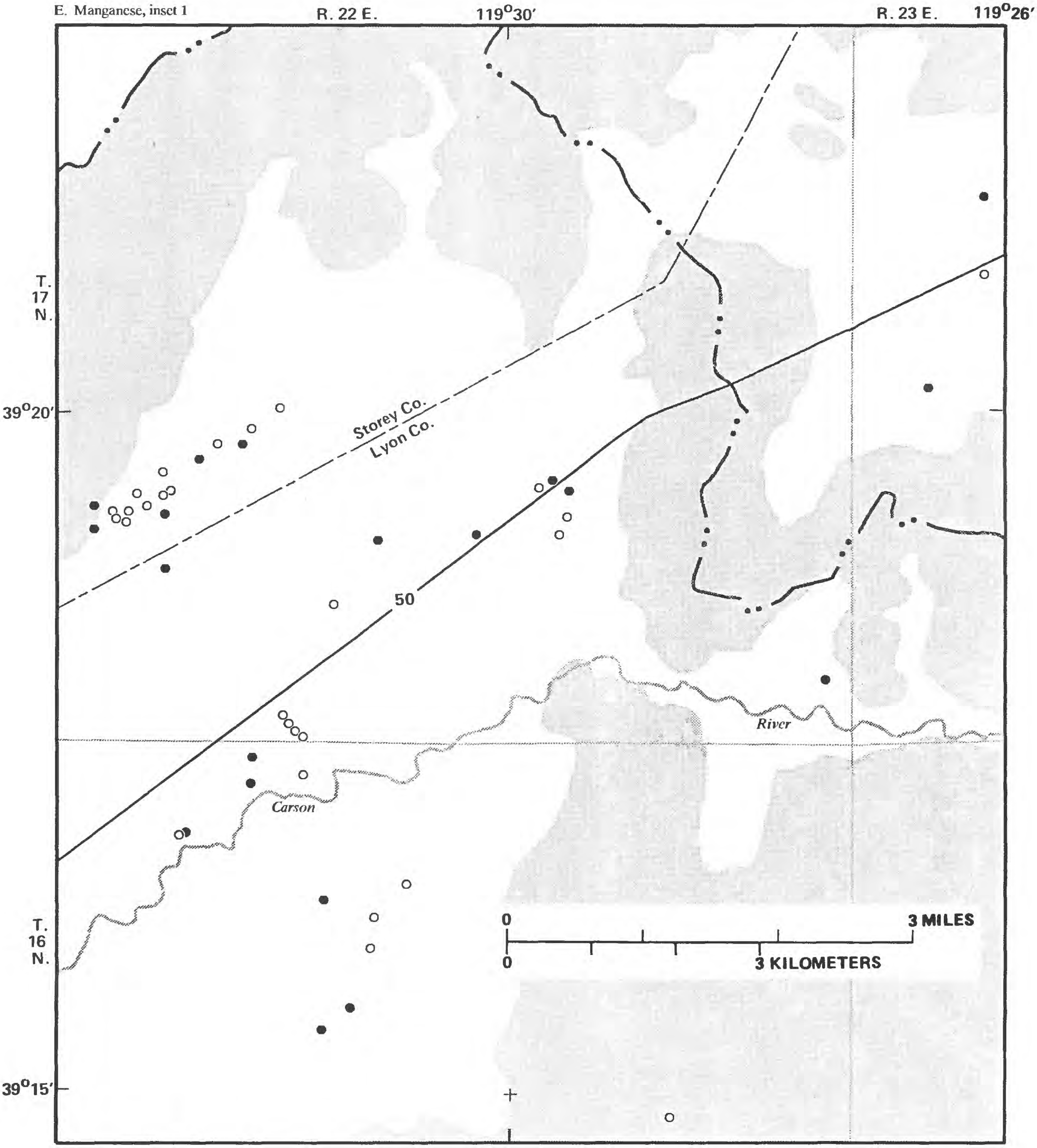

Figure 25E.—Continued.

E. Manganese, inset 2

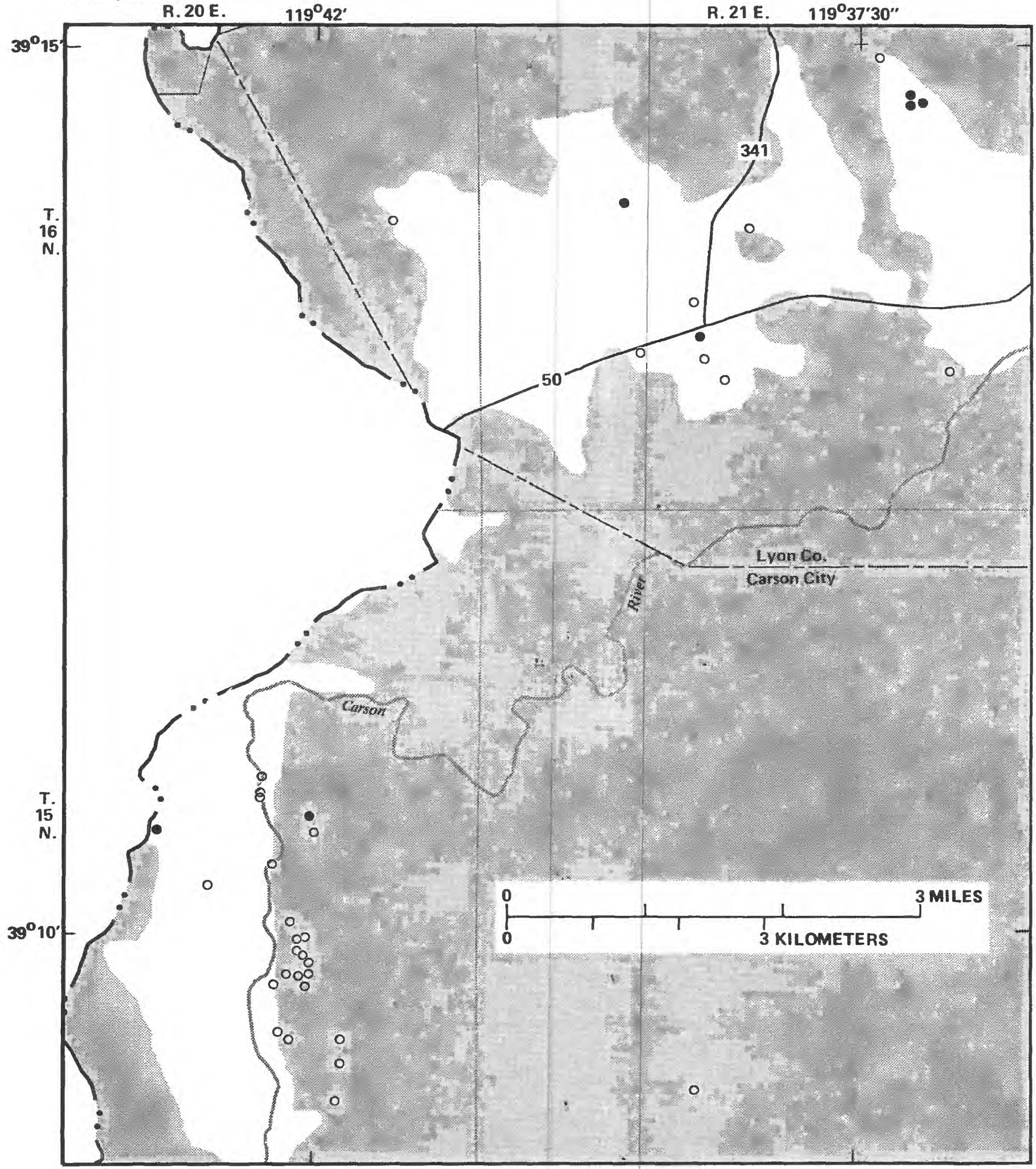

Figure 25E. – Continued.

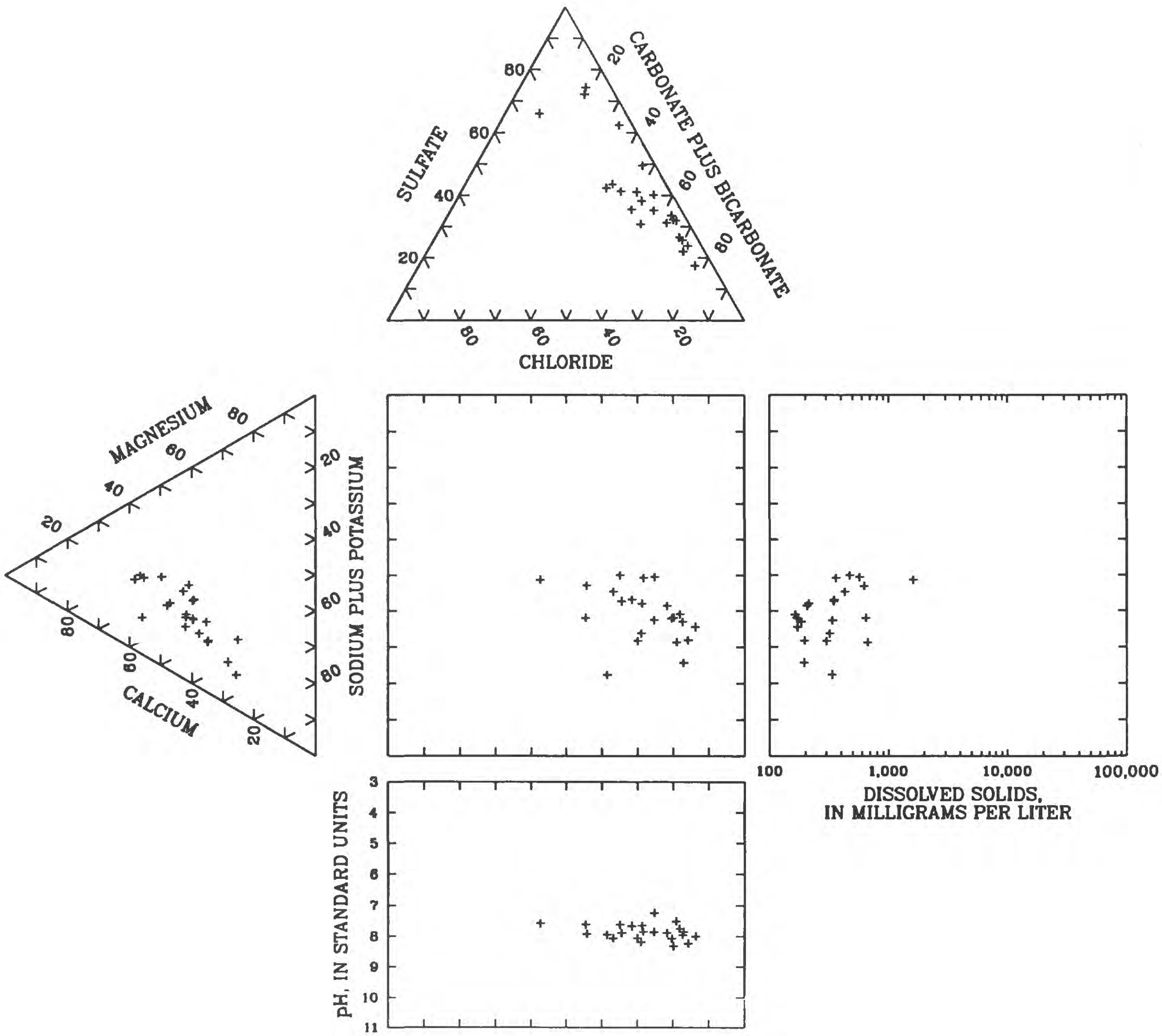

Figure 26. — General chemical character of sampled ground water in Churchill Valley.

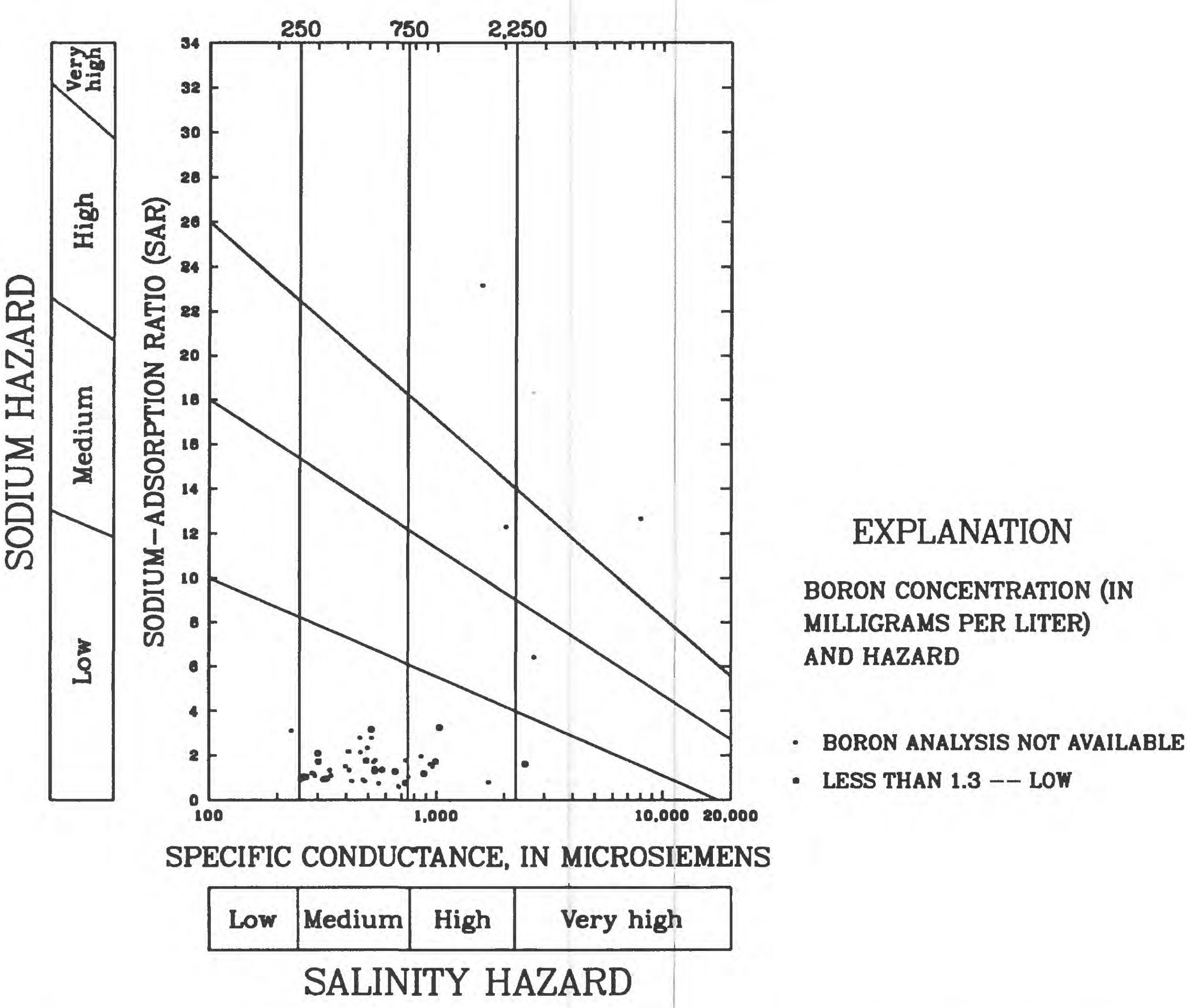

Figure 27.—General suitability of sampled ground water in Churchill Valley for irrigation. Information on boron hazard from Davis and DeWiest (1966, p. 122).

Sample sites are distributed throughout most of the southern Carson Desert and in an area extending northeastward from the Soda Lakes to and beyond Upsal Hogback (pl. 1). Most wells in the Carson Desert at depths greater than 500 ft, except for those that penetrate the basalt aquifer, produce thermal water unsuitable for domestic use. Thus, few chemical analyses are available for ground water deeper than about 500 ft.

The major-constituent chemistry of ground water in the Carson Desert has a greater compositional range than ground water from other parts of the Carson River basin. Figure 31 indicates that much of the sampled water is near neutral to alkaline (pH values generally range from 6.8 to 9.0) and dominated by sodium and chloride; concentrations of dissolved solids range from near 1,000 to 10,000 mg/L or more. Some ground water contains greater proportions of calcium, sulfate, and bicarbonate plus carbonate rather than just sodium and chloride. The Carson Desert has been the terminal sink for the Carson River for at least the past few tens of thousands of years, and for the Humboldt River north of the study area as well during years of abnormally high precipitation. The region has, at times, been covered with hundreds of feet of water, and at other times has been dry. Dissolved solids carried by both rivers and other streams

Table 16.—*Summary of inorganic constituents and properties exceeding Nevada State drinking-water standards in Churchill Valley*

[See table 10 and text for explanation of standards), --, standard does not exist for indicated constituent or property]

Constituent or property	Number of analyses (1)	Number of analyses exceeding State standard: Maximum contaminant level (2)	Secondary maximum contaminant level (3)	Secondary preferred standard (4)
Primary standards				
Arsenic	55	6	--	--
Barium	25	0	--	--
Cadmium	0	0	--	--
Chromium	0	0	--	--
Fluoride	62	1	2	—
Lead	0	0	--	--
Mercury	0	0	--	--
Nitrate	71	1	--	--
Selenium	0	0	--	--
Silver	0	0	--	—
Secondary standards				
Chloride	72	--	1	3
Copper	28	--	--	0
Dissolved solids	70	--	7	15
Iron, unfiltered	61	--	12	24
Magnesium	72	--	0	0
Manganese	53	--	28	29
pH	73	--	--	2
Sulfate	72	--	6	12
Zinc	28	--	--	1
Totals[1]	76	7	38/40	43/44

[1]Total for column (1) is the number of separate sample locations. Total for column (2) is the number of locations where one or more constituents exceed the maximum contaminant level (MCL). Total for column (3) is a pair of numbers. The first is the number of locations where one or more constituents exceed the secondary maximum contaminant level (SMCL); the second is the number of locations where one or more constituents exceed either an MCL or SMCL. Total for column (4) is a pair of numbers. The first is the number of locations where one or more constituents exceed secondary preferred standards; the second is the number of locations where one or more constituents exceed either the MCL or the secondary preferred standard. The total exceedances reflect analyses that do not include all the inorganic constituents that have established drinking-water standards. Therefore, the totals may underestimate the number of sites that have an inorganic constituent at a concentration that is greater than the standard.

to the Carson Desert thus have accumulated in sediments over tens of thousands of years. Many different solutes have accumulated in the basin, but sodium and chloride, being highly soluble, are the ones that seem to dominate the chemistry of much of the ground water in the southern Carson Desert.

Some ground water in the southern Carson Desert is suitable for irrigation purposes. Sodium hazards and boron concentrations range from low to very high and salinity hazards from medium to very high (fig. 32). The analyses with the highest hazards are not from a single aquifer or area, but are distributed among wells tapping the shallow- and intermediate-alluvial aquifers.

Ground water in the Carson Desert exceeds drinking-water standards much more commonly than ground water in other parts of the Carson River basin (table 17 and pl. 1). One or more MCL or SMCL is exceeded at 73 percent of the sample sites used for this study (fig. 33). Constituents that most commonly exceed MCL's are arsenic and fluoride and those that most commonly exceed the SMCL are chloride, sulfate, dissolved solids, iron, and manganese (fig. 33). The frequency with which concentrations of these six constituents and the dissolved-solids concentration exceed the MCL or SMCL standards ranges from less than 5 percent for iron (unfiltered) to 56 percent for arsenic.

Sulfate concentrations greater than the SMCL (500 mg/L) occur primarily in wells with depths less than 100 feet (fig. 34A). The intermediate-depth wells in the vicinity of Fallon commonly yield water with dissolved-solids concentrations less than 500 mg/L, although greater concentrations are fairly common.

Chloride and sulfate concentrations exceed SMCL's in thermal water and in scattered wells tapping the alluvial aquifers (figs. 35A, 35B). Alluvial wells near Stillwater and northeast of the Soda Lakes have ground water with concentrations of these two constituents that exceed the standards. Sulfate and chloride concentrations in ground water of the basalt aquifer do not exceed standards. Concentrations of dissolved solids in excess of 500 mg/L are in water from the basalt aquifer, in thermal and nonthermal water in the Stillwater and Soda Lakes-Upsal Hogback areas, and in some of the wells tapping the alluvial aquifers throughout much of the southern Carson Desert (fig. 35C).

Fluoride concentrations exceed the Nevada MCL in about 5 percent of the ground-water samples. Some nonthermal ground water in the vicinity of Stillwater and south of Fallon has fluoride concentrations that exceed the SMCL (fig. 35D), and some fluoride concentrations (about 5 percent) exceed the MCL of 4 mg/L. These high concentrations generally are in ground water from wells less than 250 ft deep (fig. 34D). Water from the basalt aquifer and most water from intermediate-depth wells in the vicinity of Fallon has fluoride concentrations that do not exceed either standard.

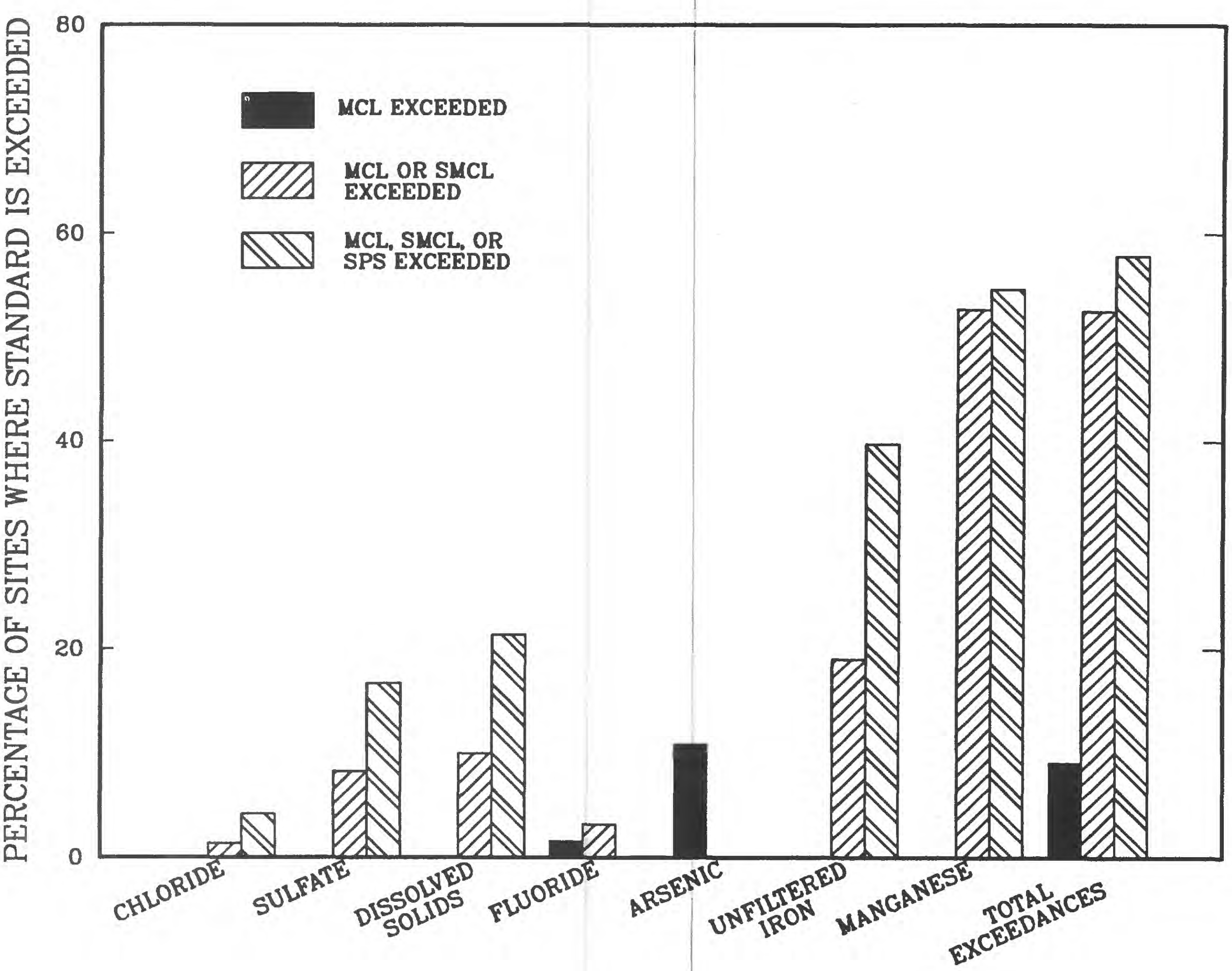

Figure 28.—Percentage of sites in the Churchill Valley where concentrations of selected chemical constituents in sampled ground water exceeded maximum contaminant levels (MCL), secondary maximum contaminant levels (SMCL), or secondary preferred standards (SPS). Because some analyses do not include determinations for all the inorganic constituents having drinking-water standards, the percentages for the total-exceedances category may underestimate the number of sites having an exceedance.

Arsenic concentrations exceeding the MCL (0.05 mg/L) are found throughout most of the southern Carson Desert (fig. 35E). In fact, concentrations exceed 0.5 mg/L in several shallow wells (depths less than about 50 ft; fig. 34E). In deeper ground water, including that from the basalt aquifer, arsenic concentrations are less than 0.5 mg/L, but many of the reported analyses still exceed the MCL.

Iron and manganese concentrations exceed the SMCL in water from wells throughout much of the southern Carson Desert (figs. 35F, 35G). Manganese (except for one well southeast of Fallon) and iron concentrations in the basalt aquifer are below the SMCL.

Other constituents that may affect or limit ground-water uses, but for which few data are available, include sulfide, lithium, and uranium. Maximum reported concentrations of uranium in shallow ground water exceed 0.5 mg/L, those of lithium exceed 30 μg/L (milligrams per liter), and those for sulfide are about 0.05 mg/L or less (U.S. Geological Survey, Carson City, Nev., unpublished data).

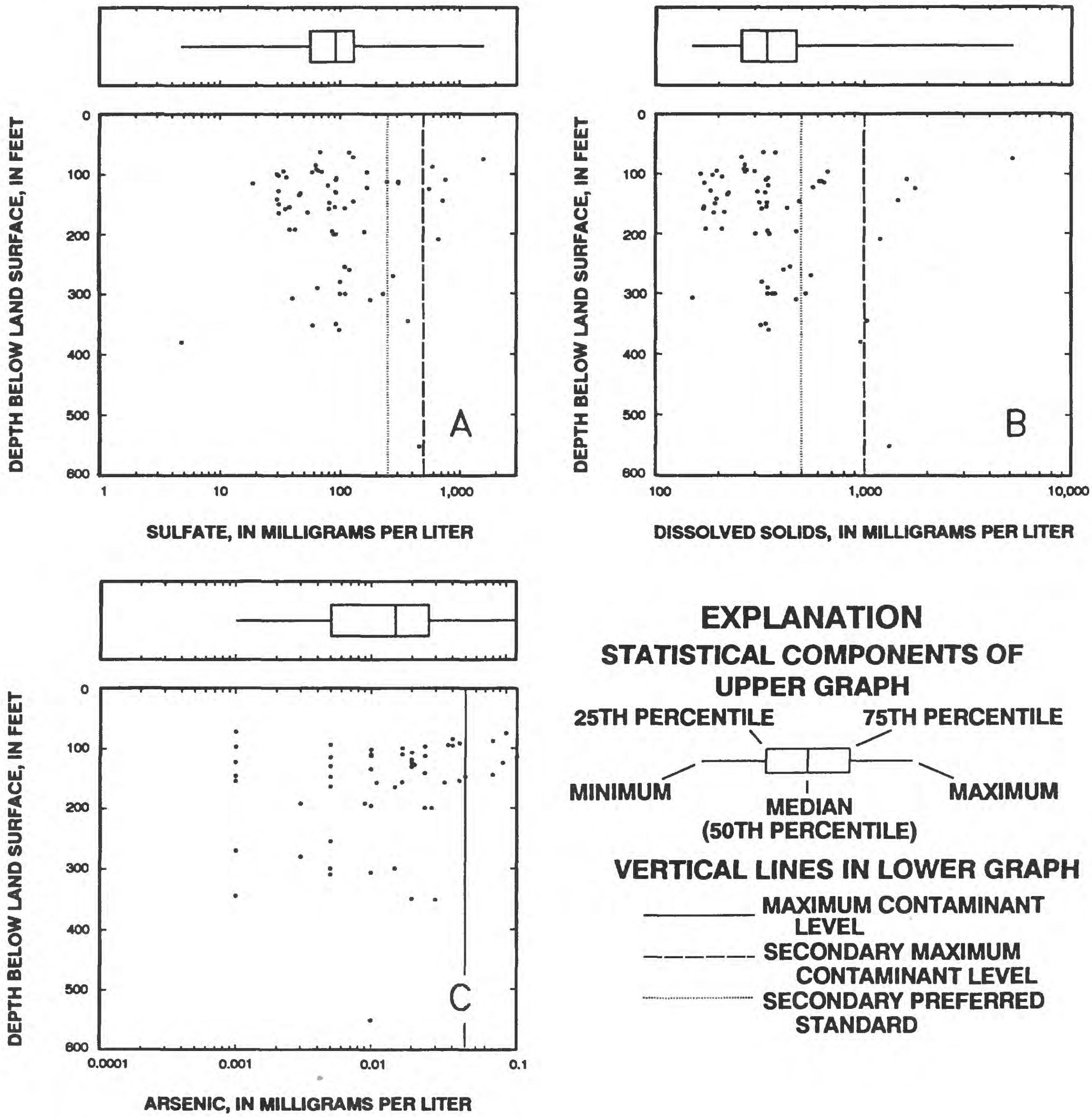

Figure 29.—Statistical distribution of concentrations (upper graph) and relation between concentration and well depth (lower graph) for (A) sulfate, (B) dissolved solids, (C) arsenic, (D) iron, and (E) manganese in sampled ground water of Churchill Valley.

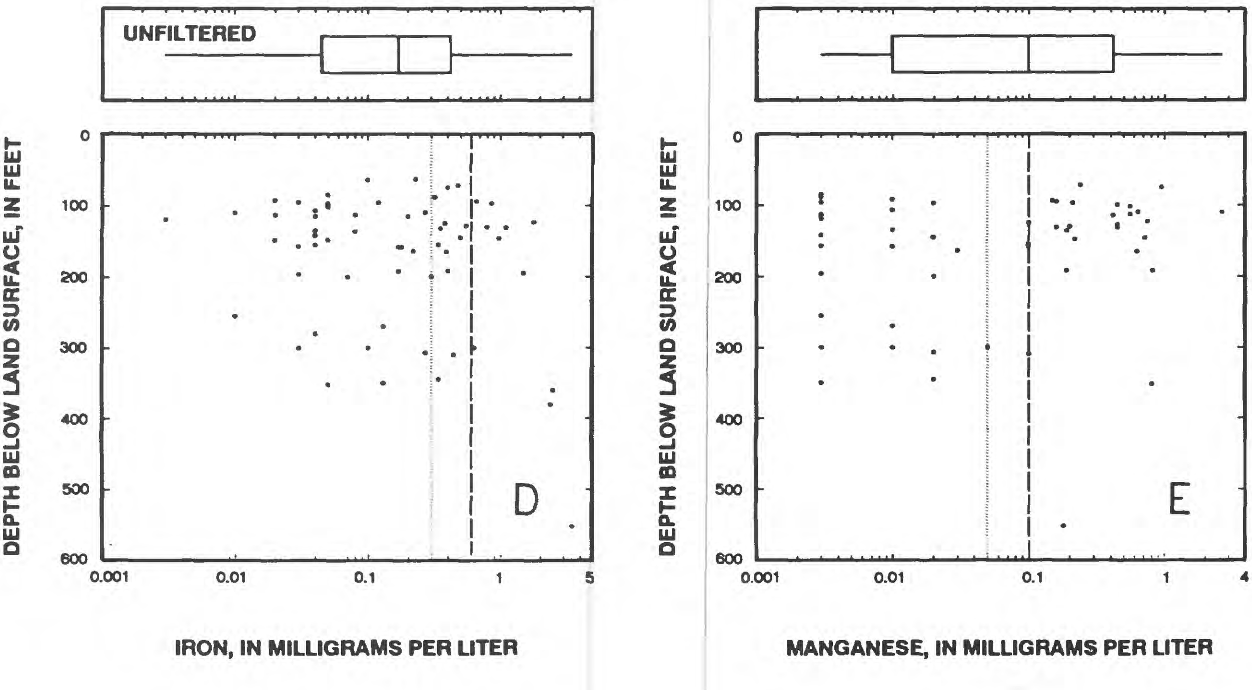

Figure 29.—Continued.

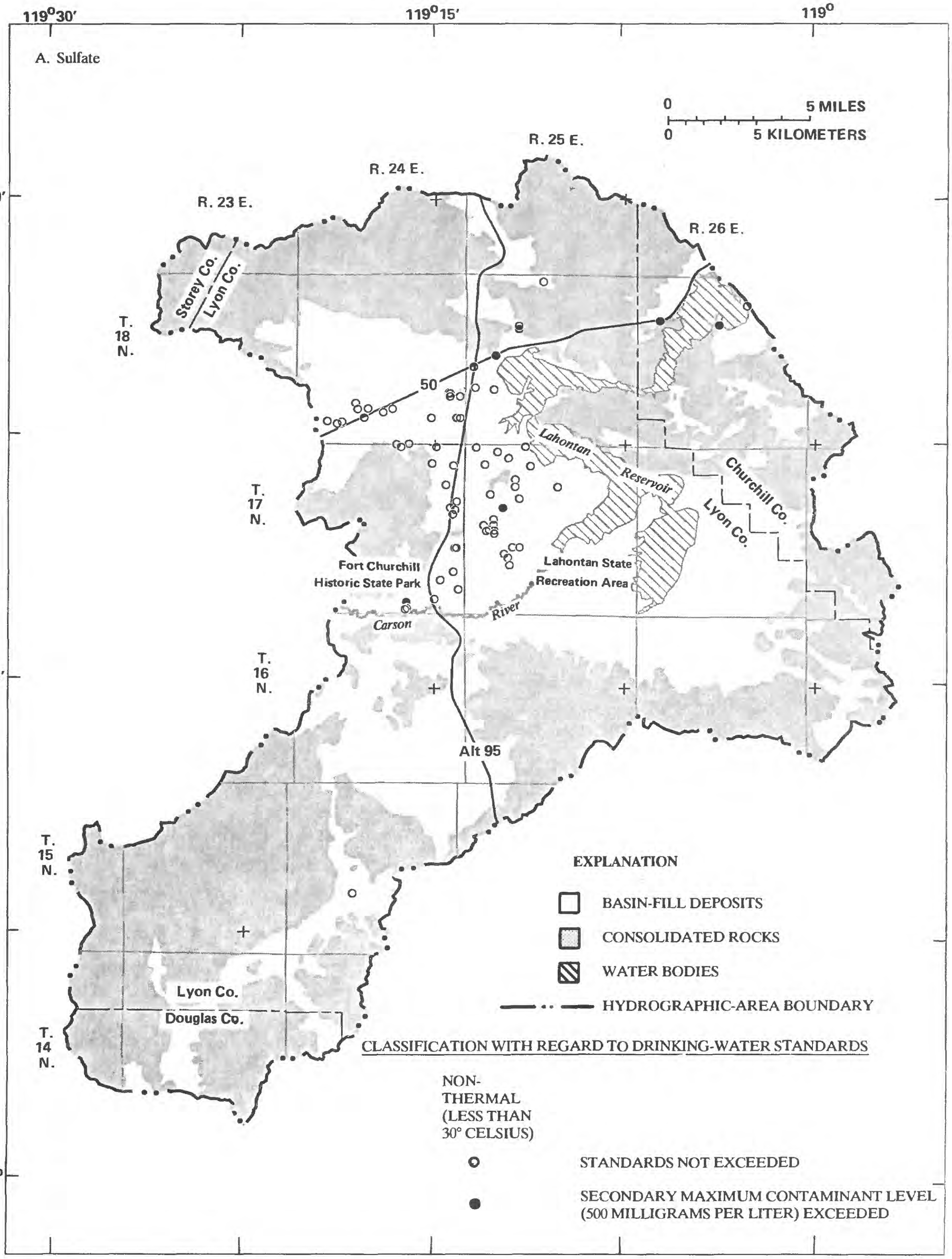

Figure 30A.—Sampling sites in the Churchill Valley where (A) sulfate, (B) dissolved solids, (C) arsenic, (D) iron, and (E) manganese in ground water have exceeded and have not exceeded State drinking-water standards.

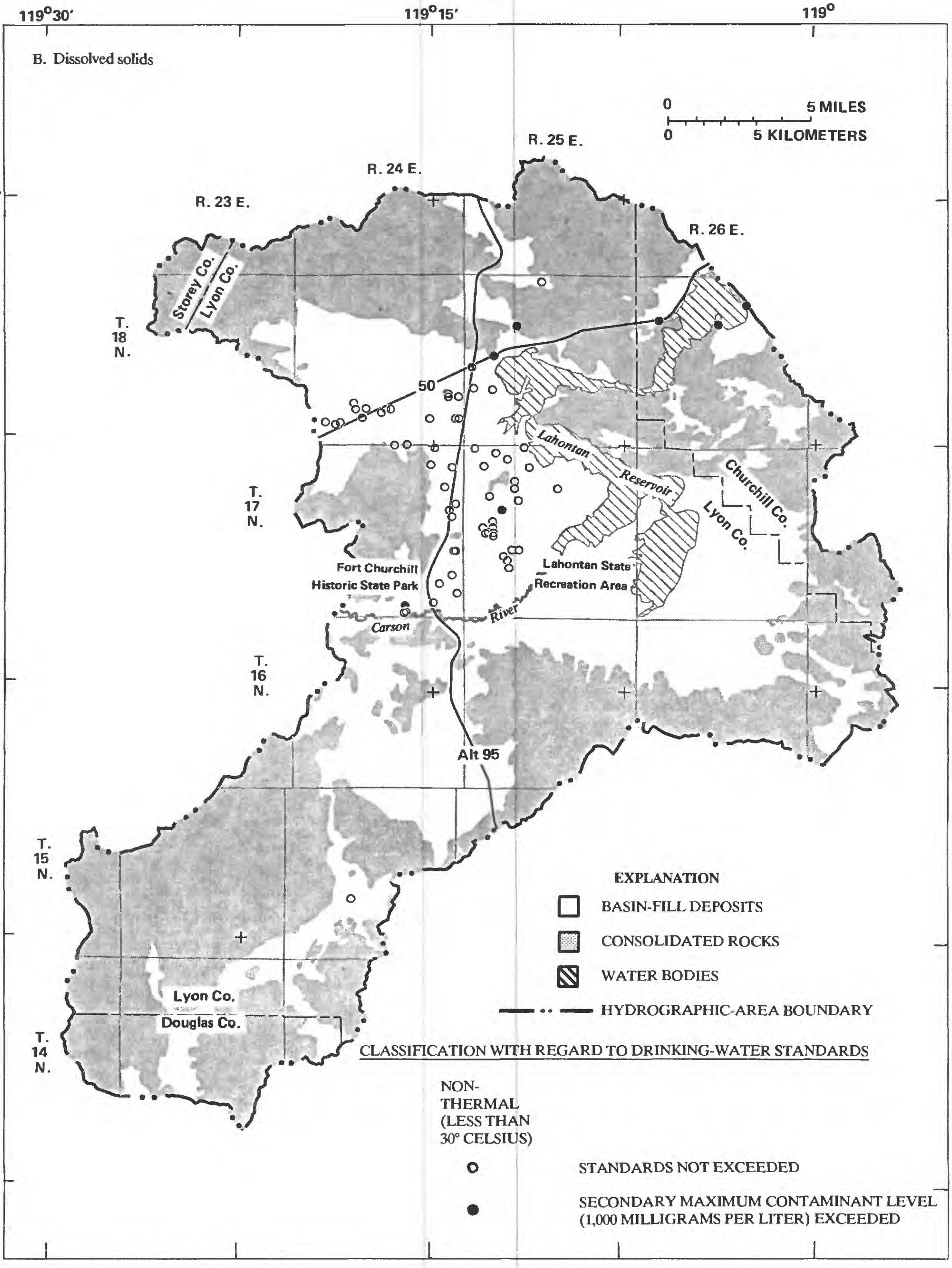

Figure 30B.—Continued.

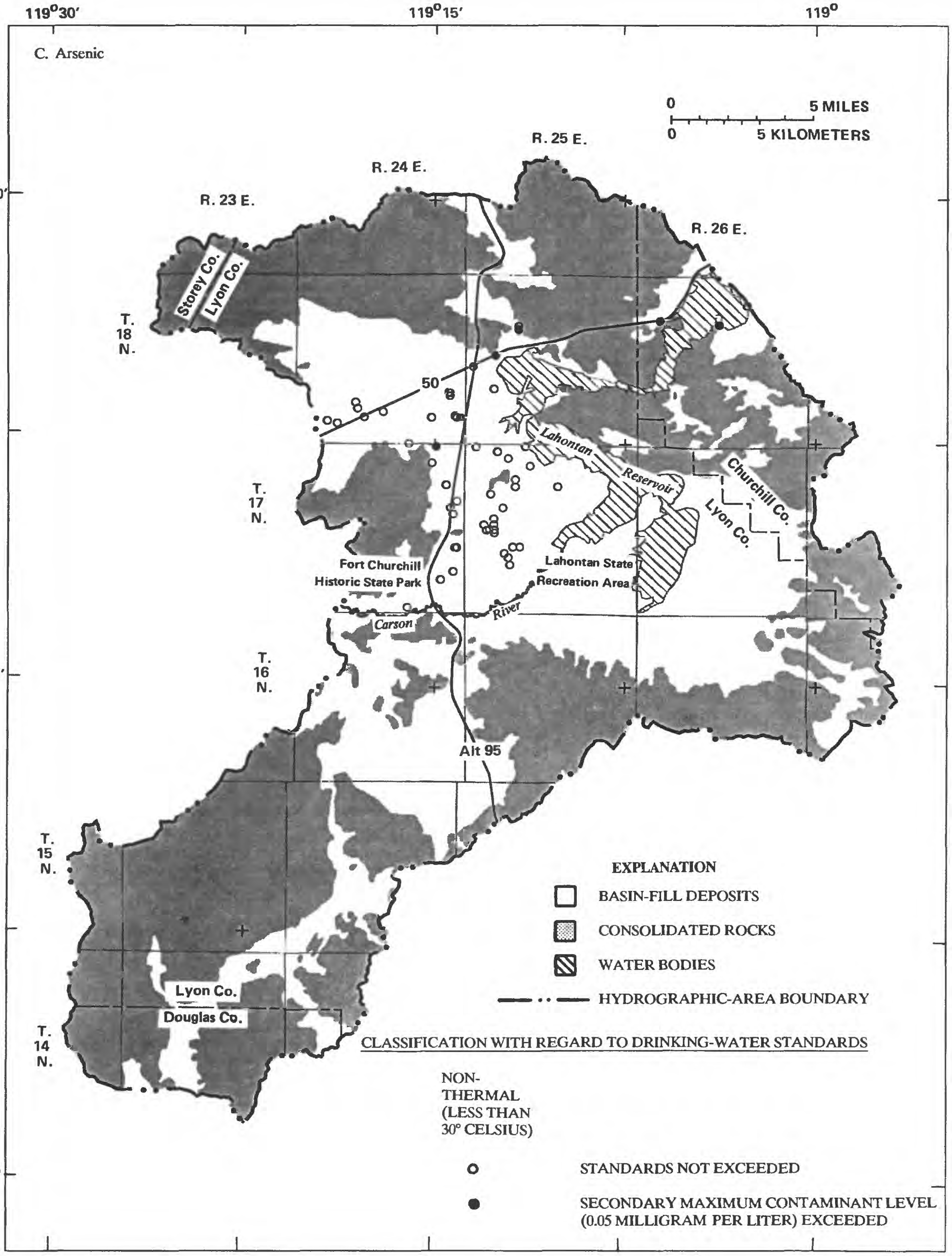

Figure 30C. – Continued.

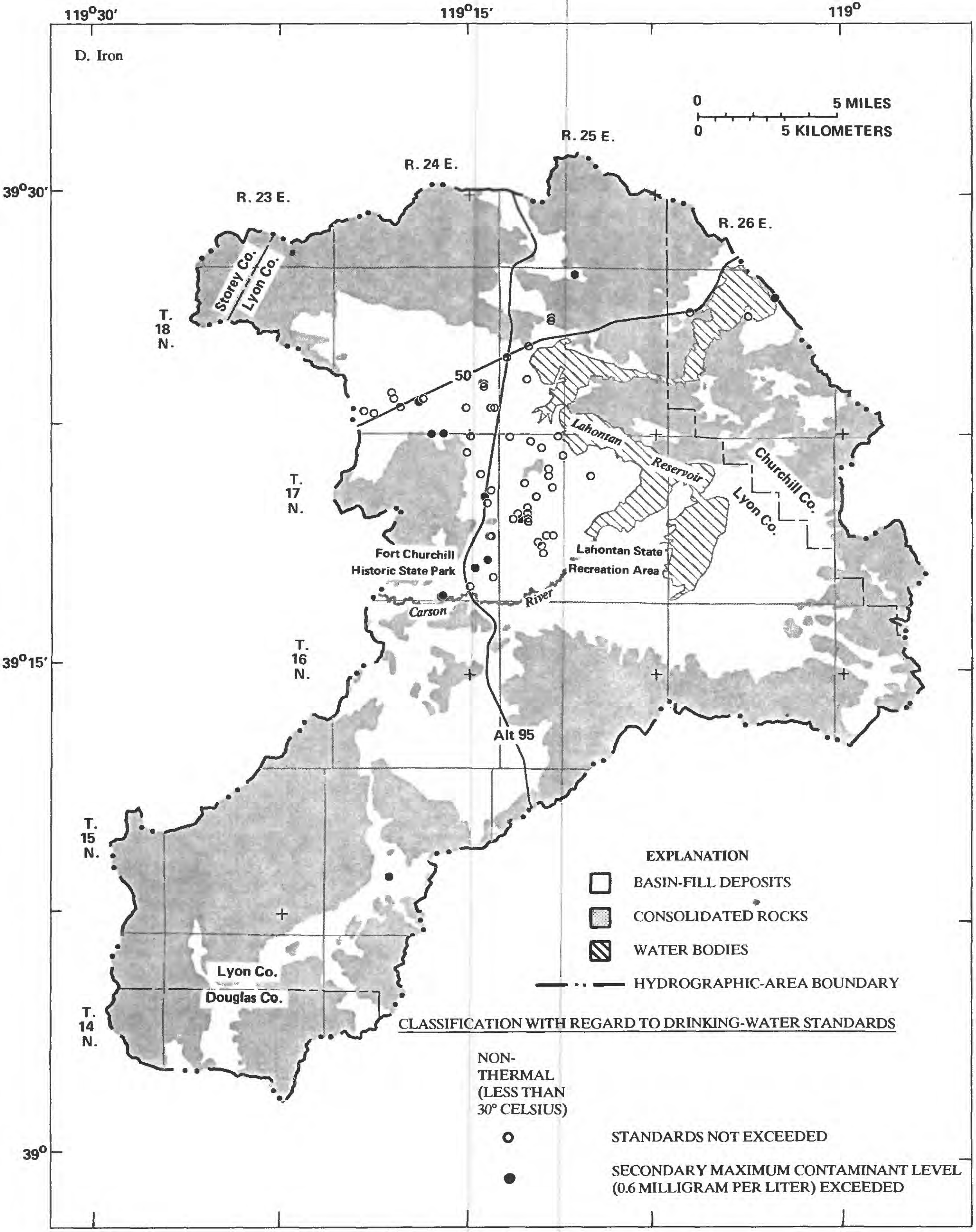

Figure 30D. – Continued.

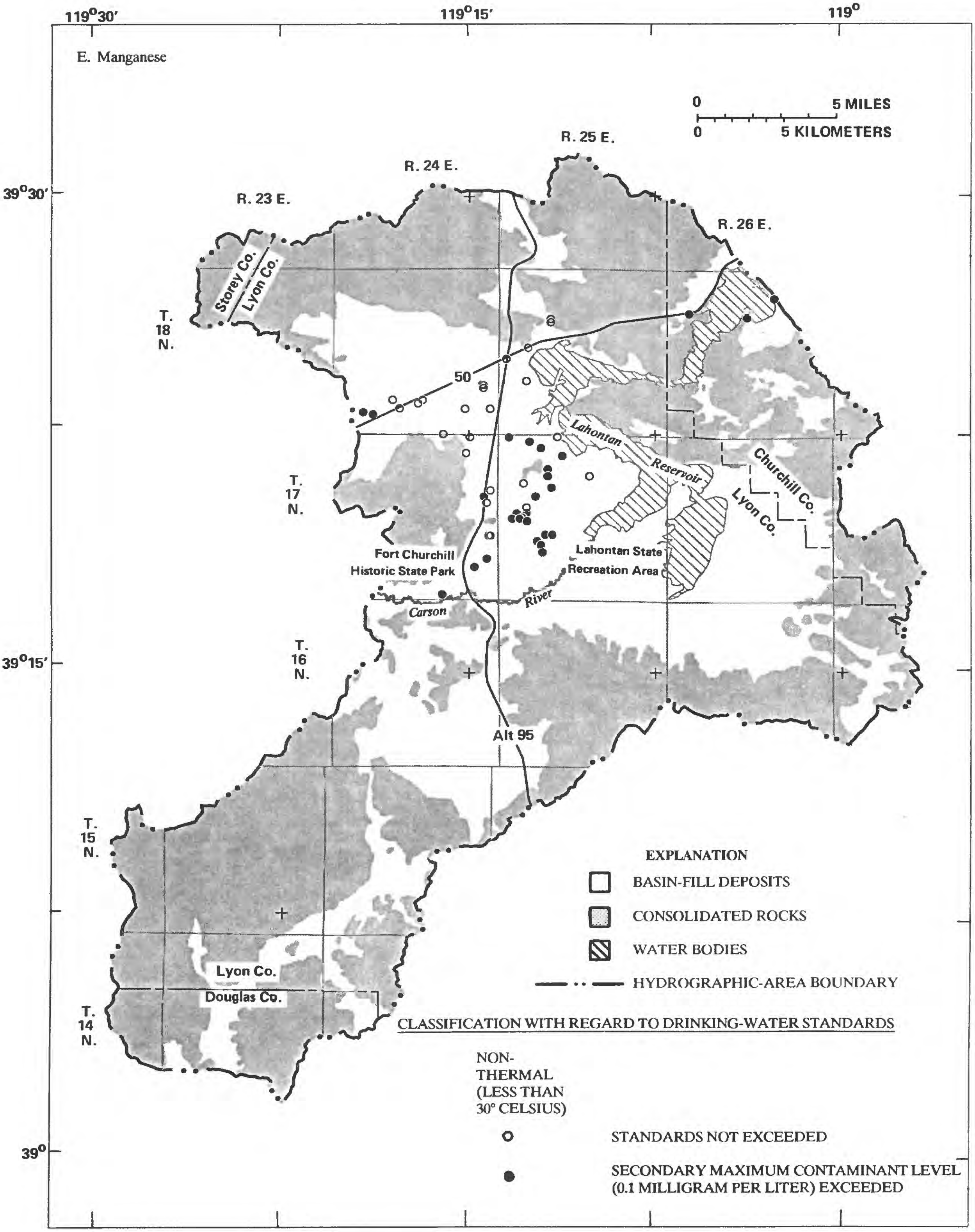

Figure 30E. – Continued.

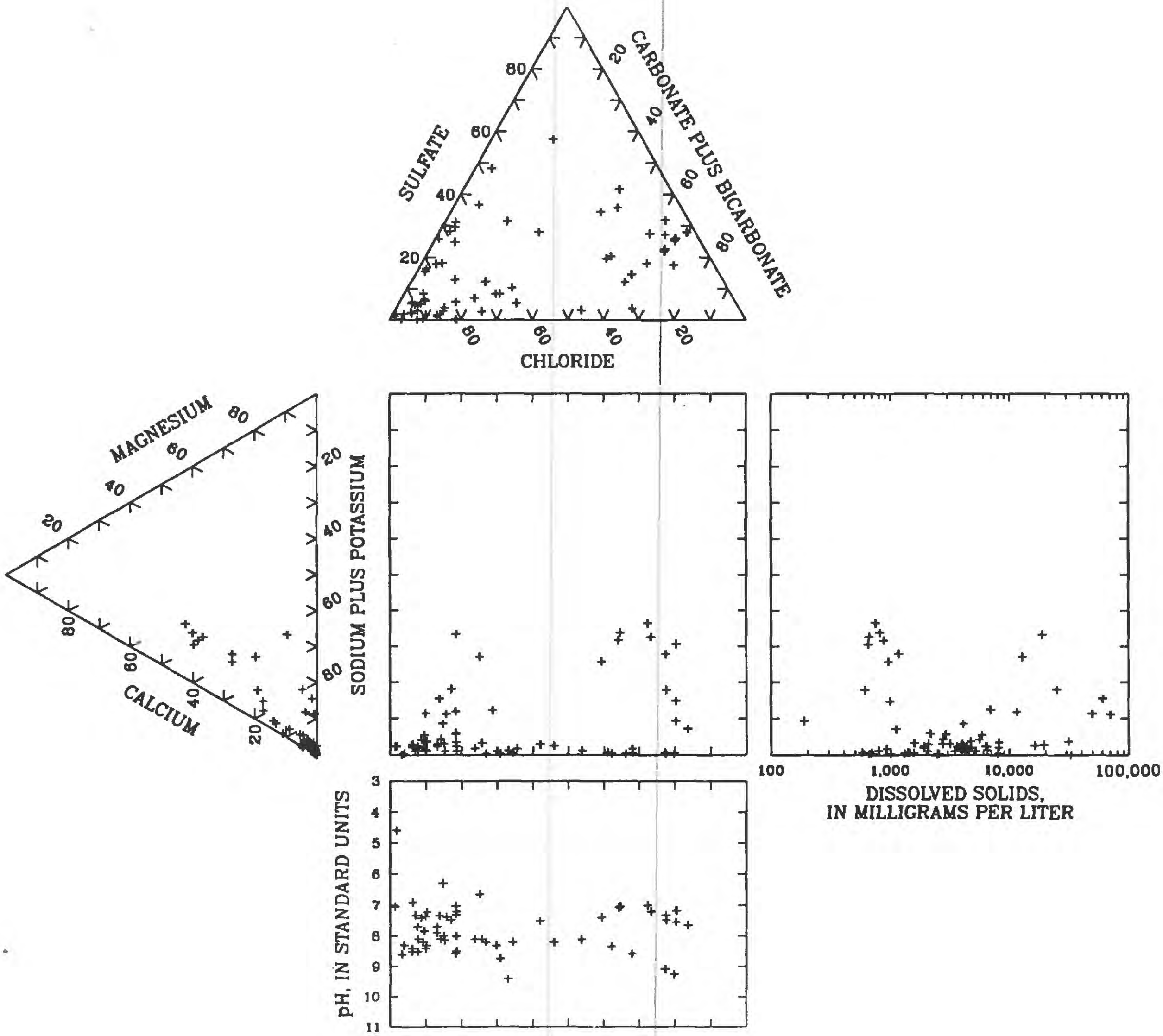

Figure 31. – General chemical character of sampled ground water in Carson Desert.

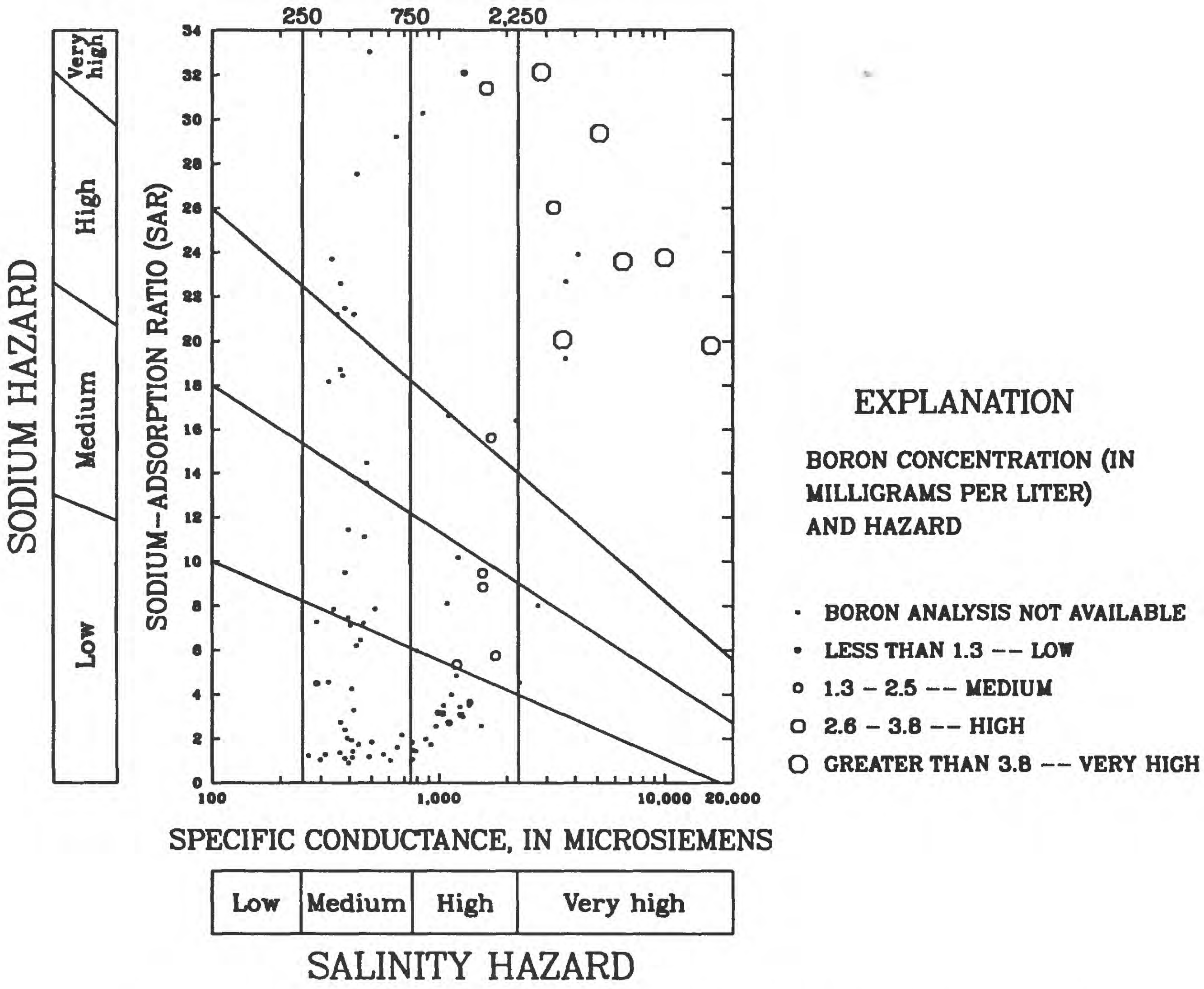

Figure 32.—General suitability of sampled ground water in Carson Desert for irrigation. Information on boron hazard from Davis and DeWiest (1966, p. 122). Sixty-eight of the 164 samples from Carson Desert plot off the graph because their SAR values exceed 34 (57 samples), or their specific-conductance values exceed 20,000 microsiemens (2 samples), or both (9 samples). Most available boron values for these samples exceed 3.8 mg/L.

Manmade organic compounds were detected in ground water in the southern Carson Desert at the U.S. Naval Air Station south of Fallon (industrial; records in files of Nevada Division of Environmental Protection). Two spills of naphtha (a volatile hydrocarbon mixture used as a solvent) are documented at a refinery 11 mi north of Fallon. The first (in August 1984) totaled 4,700 gallons, and the second spill 1 month later totaled about 1,000 gallons (records in files of Nevada Division of Environmental Protection). Observation wells were drilled around the periphery of the site and the odor of naphtha was apparent in some wells, although samples were not collected for analysis. About half of the total spill has been recovered.

Several spills of petroleum products have been documented at the Fallon Naval Air Station (records in files of Nevada Division of Environmental Protection). Most involved small amounts (100 gallons or less) of JP-5 jet fuel, although one spill involved an unknown amount of the fuel that leaked from a fuel-water separator for an unknown period of time. Samples of ground water collected near a runway construction site contained concentrations of total petroleum hydrocarbons that ranged from 1.5 to

Table 17.—*Summary of inorganic constituents and properties exceeding Nevada State drinking-water standards in Carson Desert*

[See table 10 and text for explanation of standards, --, standard does not exist for indicated constituent or property]

Constituent or property	Number of analyses (1)	Number of analyses exceeding State standard: Maximum contaminant level (2)	Secondary maximum contaminant level (3)	Secondary preferred standard (4)
Primary standards				
Arsenic	190	107	--	--
Barium	8	0	--	--
Cadmium	14	0	--	--
Chromium	9	2	--	--
Fluoride	186	10	37	--
Lead	16	0	--	--
Mercury	11	0	--	--
Nitrate	130	5	--	--
Selenium	9	0	--	--
Silver	6	0	--	--
Secondary standards				
Chloride	209	--	69	75
Copper	14	--	--	0
Dissolved solids	190	--	72	114
Iron, filtered	29	--	1	3
Iron, unfiltered	110	--	15	33
Magnesium	203	--	9	10
Manganese	130	--	45	60
pH	226	--	--	68
Sulfate	203	--	28	47
Zinc	11	--	--	0
Totals[1]	263	116	129/189	192/215

[1]Total for column (1) is the number of separate sample locations. Total for column (2) is the number of locations where one or more constituents exceed the maximum contaminant level (MCL). Total for column (3) is a pair of numbers. The first is the number of locations where one or more constituents exceed the secondary maximum contaminant level (SMCL); the second is the number of locations where one or more constituents exceed either an MCL or SMCL. Total for column (4) is a pair of numbers. The first is the number of locations where one or more constituents exceed secondary preferred standards; the second is the number of locations where one or more constituents exceed either the MCL or the secondary preferred standard. The total exceedances reflect analyses that do not include all the inorganic constituents that have established drinking-water standards. Therefore, the totals may underestimate the number of sites that have an inorganic constituent at a concentration that is greater than the standard.

2.3 mg/L (records in files of Nevada Division of Environmental Protection).

Pesticide containers were discarded at a State-licensed toxic-waste landfill 7.5 mi north of Fallon over an uncertain period of time; the dump was closed in 1985. Samples from a shallow monitoring well at the site have yielded no detectable concentrations of pesticides (Sertic and others, 1988, p. 56).

Other potential sources of ground-water contamination include septic-tank effluent in rural areas and an underground nuclear detonation triggered in 1963 in a remote, southeastern part of the Carson Desert hydrographic area (Desert Research Institute, 1964).

Area-to-Area Comparison of Water Quality

Ground-water quality in the Carson River basin differs among hydrographic areas, although on the basis of the compiled data, only a few inorganic constituents consistently exceed State drinking-water standards. These constituents are arsenic, chloride, dissolved solids, fluoride, iron, manganese, and sulfate (table 2; fig. 3). The geology and hydrology of the basin are sufficiently understood to permit some preliminary conclusions regarding possible controls they exert on the concentrations of these constituents in ground water. Comparison of the overall inorganic chemistry of ground water in upper parts of the Carson River basin with that in lower parts indicates some differences. Both the number of constituents that exceed State drinking-water standards and the frequencies with which they exceed those standards increase in areas downstream from Carson and Eagle Valleys. A contributing factor is the presence of sediments deposited during high levels of Pleistocene Lake Lahontan which, at its highest levels, extended as far west as Carson Plains and covered virtually all the lowlands of this valley, Stagecoach and Churchill Valleys, and the Carson Desert (fig. 2). The lake had no outlet, and dissolved-solids concentrations in water flushed from the upper parts of the basin by the Carson River and other streams accumulated in sediments as the lake receded, and became the source of arsenic, sulfate, chloride, and other constituents of present-day ground water. These constituents can redissolve and enter ground water when soils and shallow sediments are flushed by irrigation water and, especially in the Carson Desert, when ground-water levels rise as a result of irrigation.

Arsenic concentrations exceed the MCL (0.05 mg/L) in the five hydrographic basins of the Carson basin, but with the greatest frequency in the lower parts of the basin (fig. 3). In the Carson Desert over half of the ground-water sites sampled for arsenic have concentrations greater than the MCL. Some wells in the Carson Desert with depths less than 50 feet yield water with arsenic concentrations greater than 0.5 mg/L, or greater than 10 times the MCL.

Gypsum in metasedimentary rocks of Jurassic age and related gypsite deposits are a probable cause of high concentrations of sulfate in ground water in the Mound House area of the Dayton Valley hydrographic area. These rocks could also be sources of sulfate in

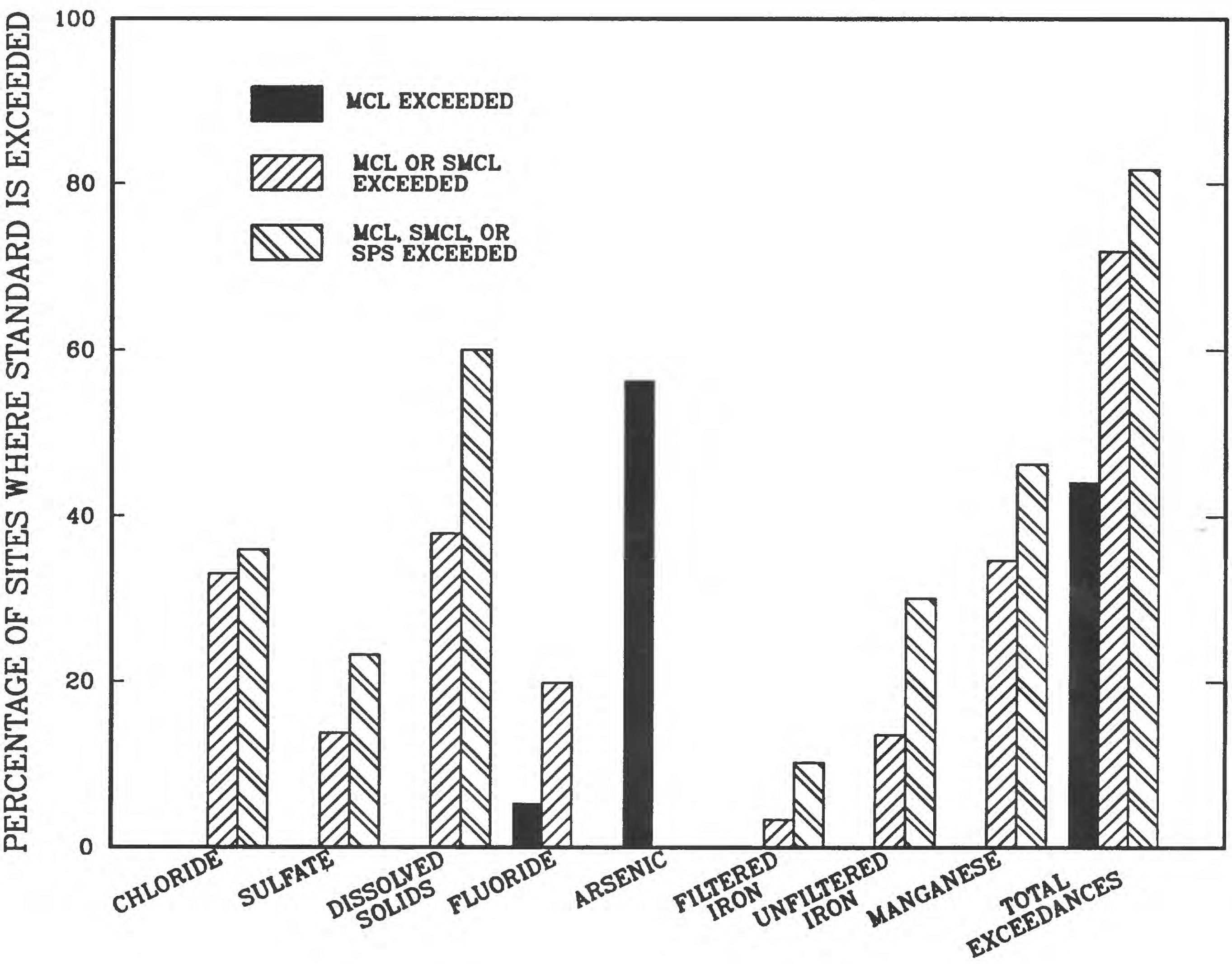

Figure 33.—Percentage of sites in the Carson Desert where concentrations of selected chemical constituents in sampled ground water exceeded maximum contaminant levels (MCL), secondary maximum contaminant levels (SMCL), or secondary preferred standards (SPS). Because some analyses do not include determinations for all the inorganic constituents having drinking-water standards, the percentages for the total-exceedances category may underestimate the number of sites having an exceedance.

other parts of the Carson River basin, although extensive gypsum deposits have not been found elsewhere. Another possible source of high sulfate concentrations might be oxidation of sulfide minerals in Jurassic metasedimentary and metavolcanic rocks. High concentrations of sulfate do not appear to be spatially related to areas of granitic rocks.

Ground water in thermal areas generally contains greater concentrations of dissolved constituents than in nonthermal areas. In addition, thermal water in one area commonly differs in its chemistry from thermal water in another area. However, fluoride seems to be present at high concentrations (greater than 2 mg/L) in most thermal areas.

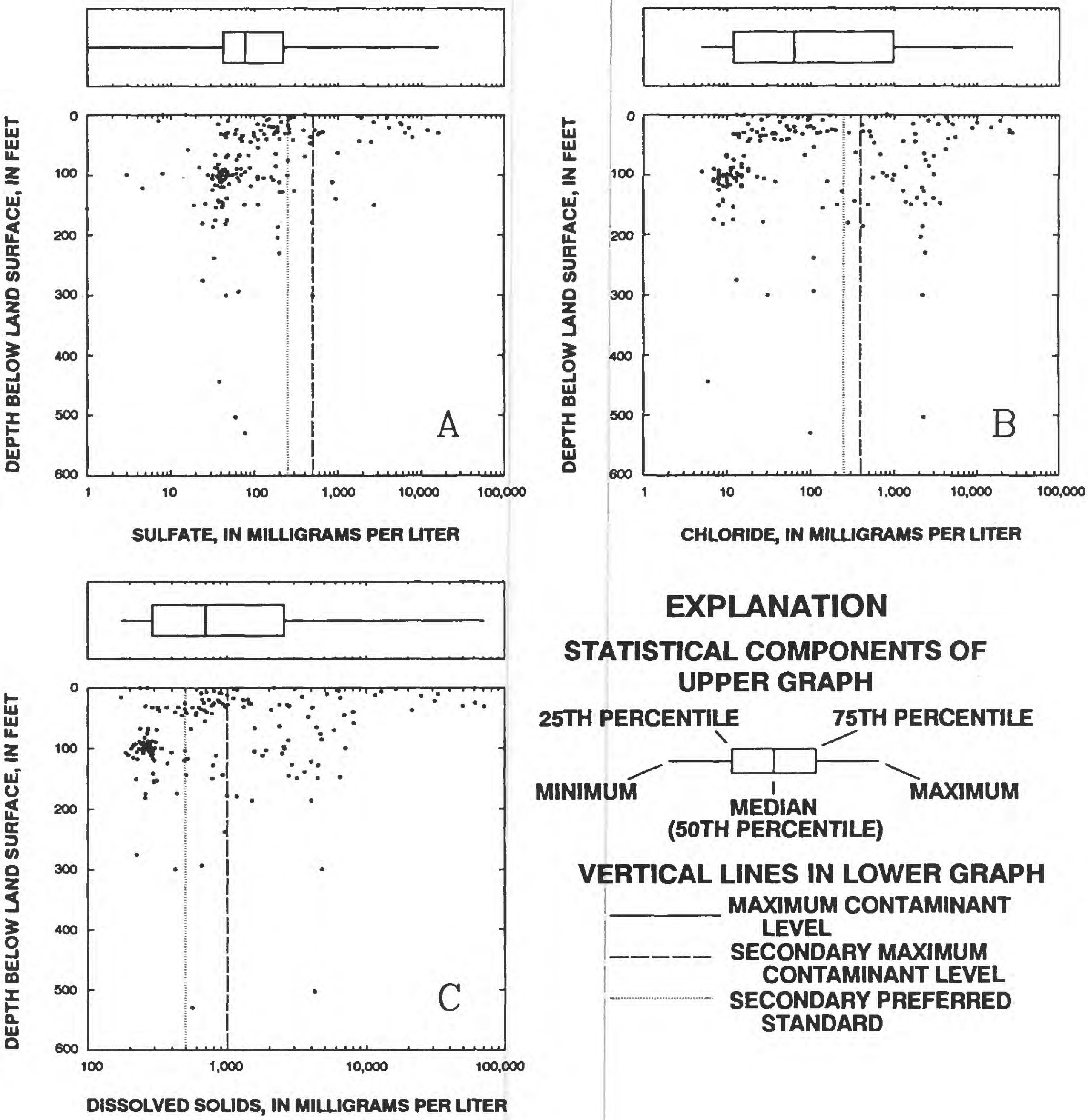

Figure 34.—Statistical distribution of concentrations (upper graph) and relation between concentration and well depth (lower graph) for (A) sulfate, (B) chloride, (C) dissolved solids, (D) fluoride, (E) arsenic, (F) iron, and (G) manganese in sampled ground water of Carson Desert. In lower graphs, spring data are shown at land surface.

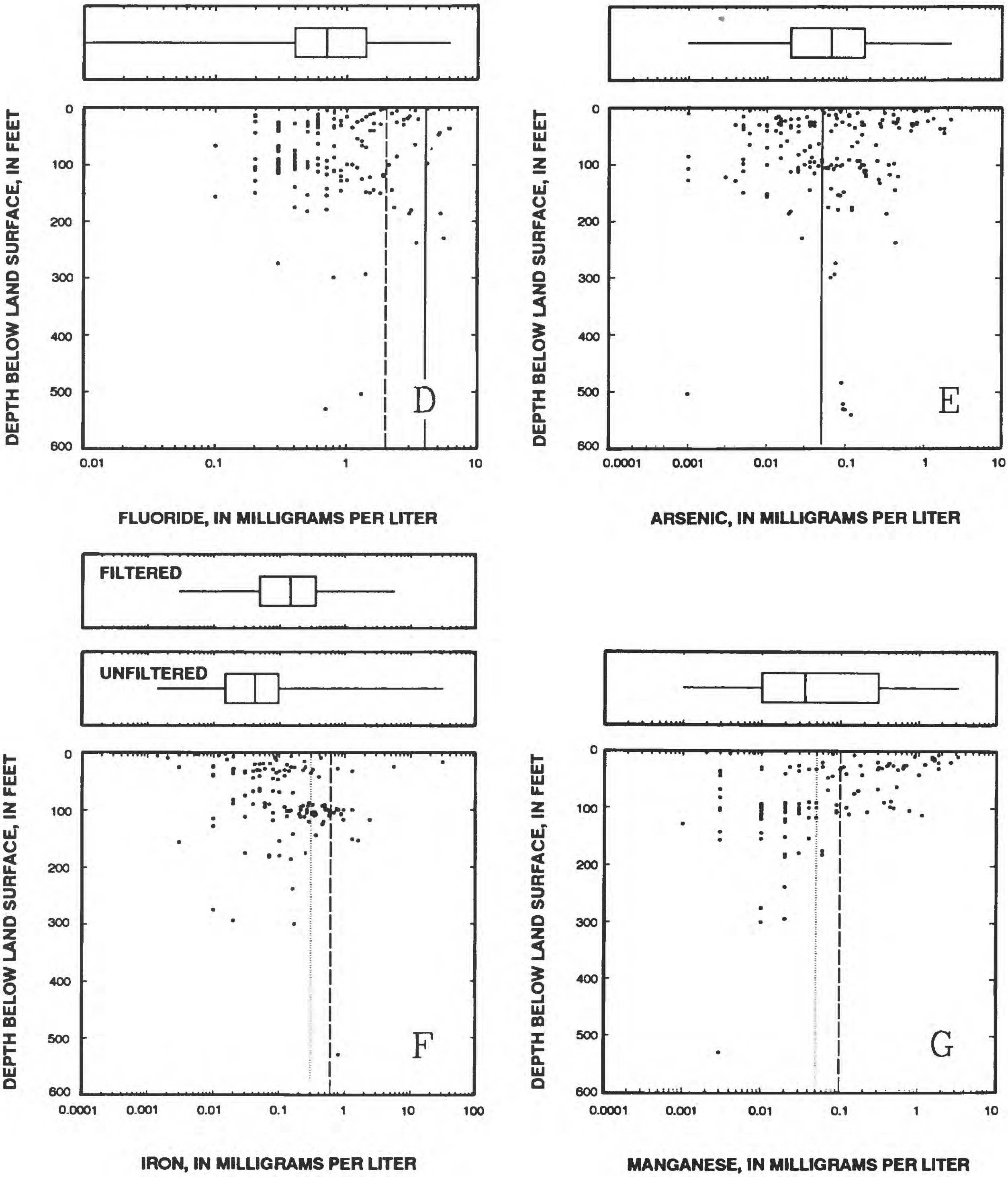

Figure 34.—Continued.

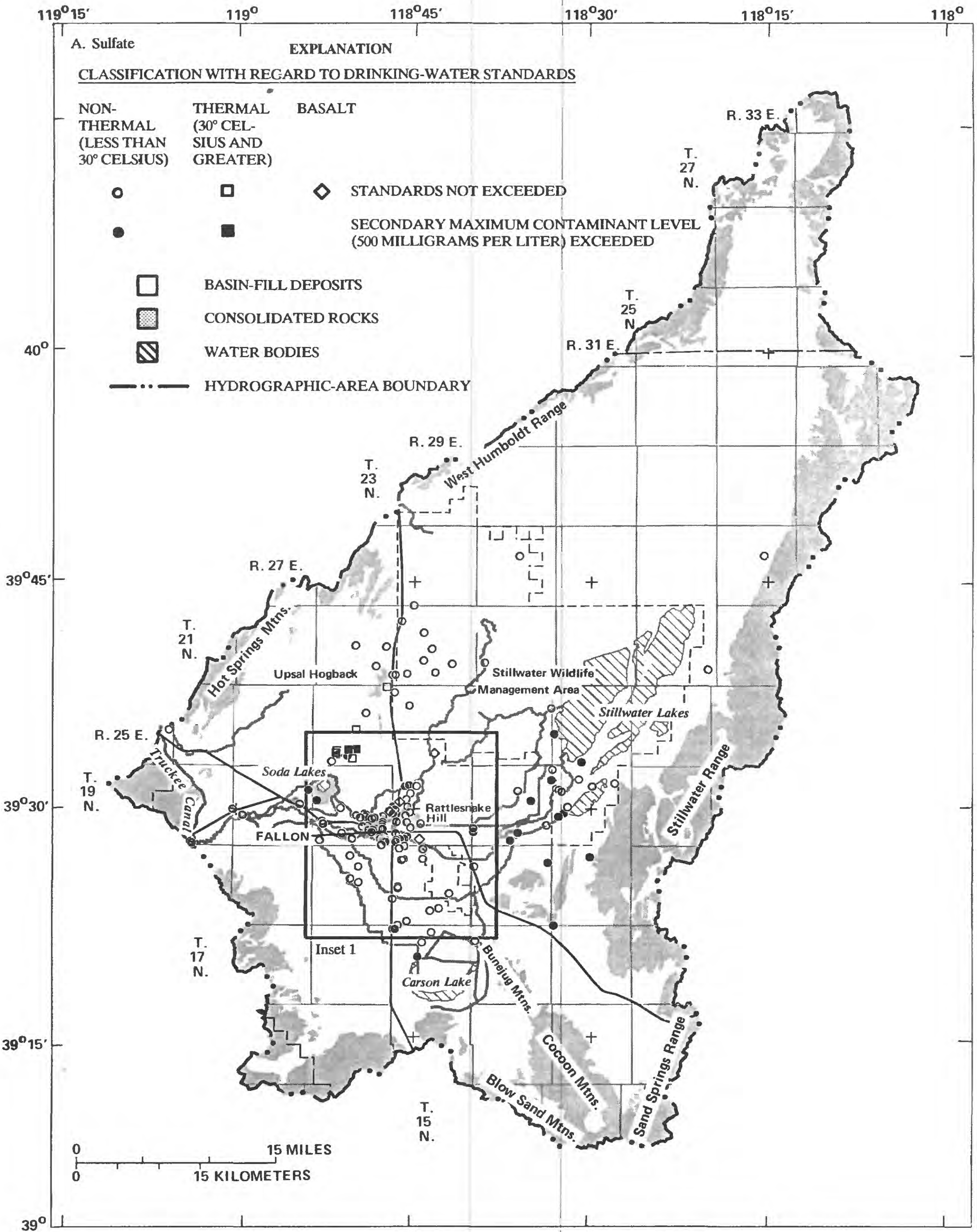

Figure 35A.—Sampling sites in the Carson Desert where (A) sulfate, (B) chloride, (C) dissolved solids, (D) fluoride, (E) arsenic, (F) iron, and (G) manganese in ground water have exceeded and have not exceeded State drinking water standards.

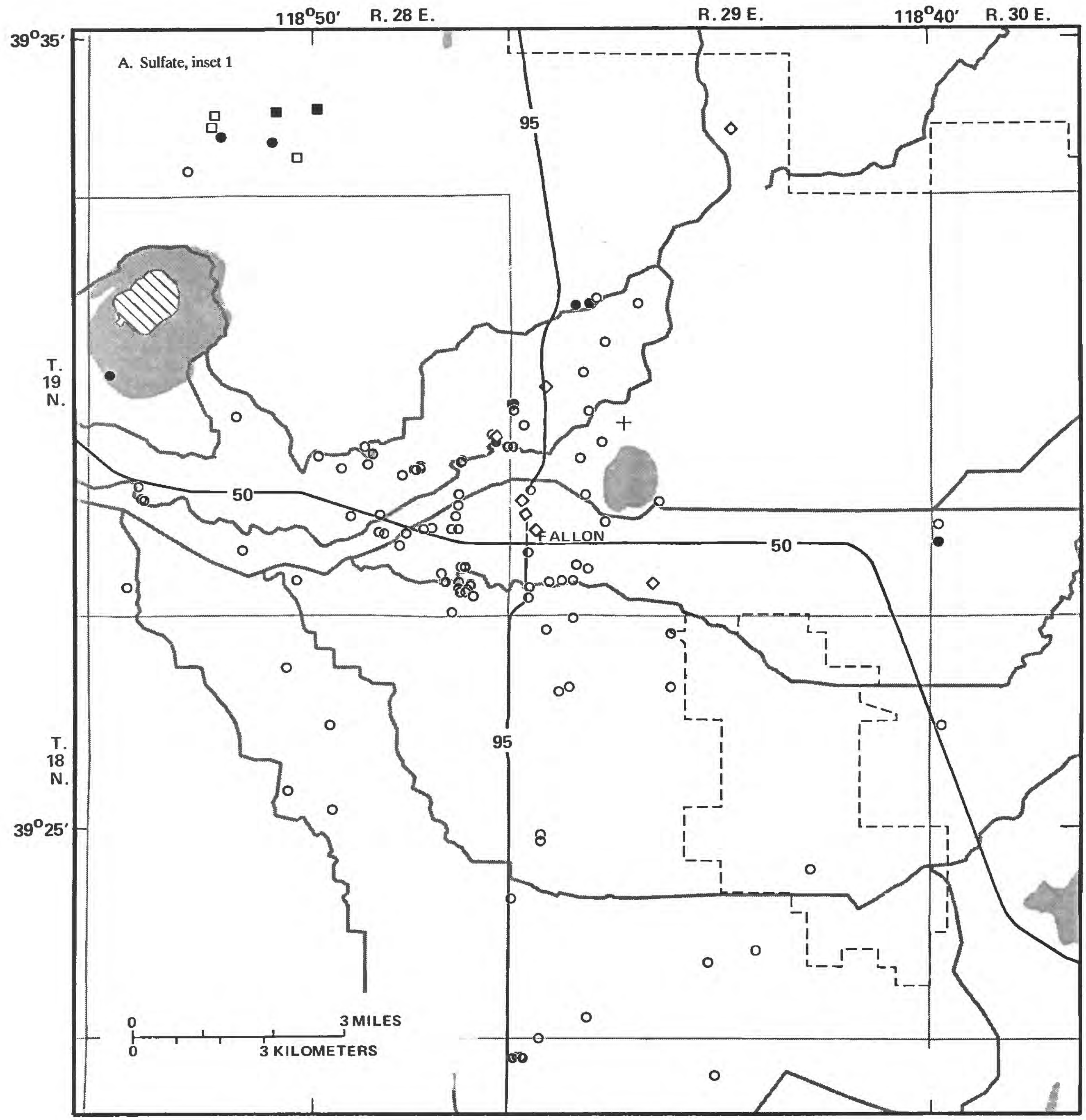

Figure 35A.—Continued.

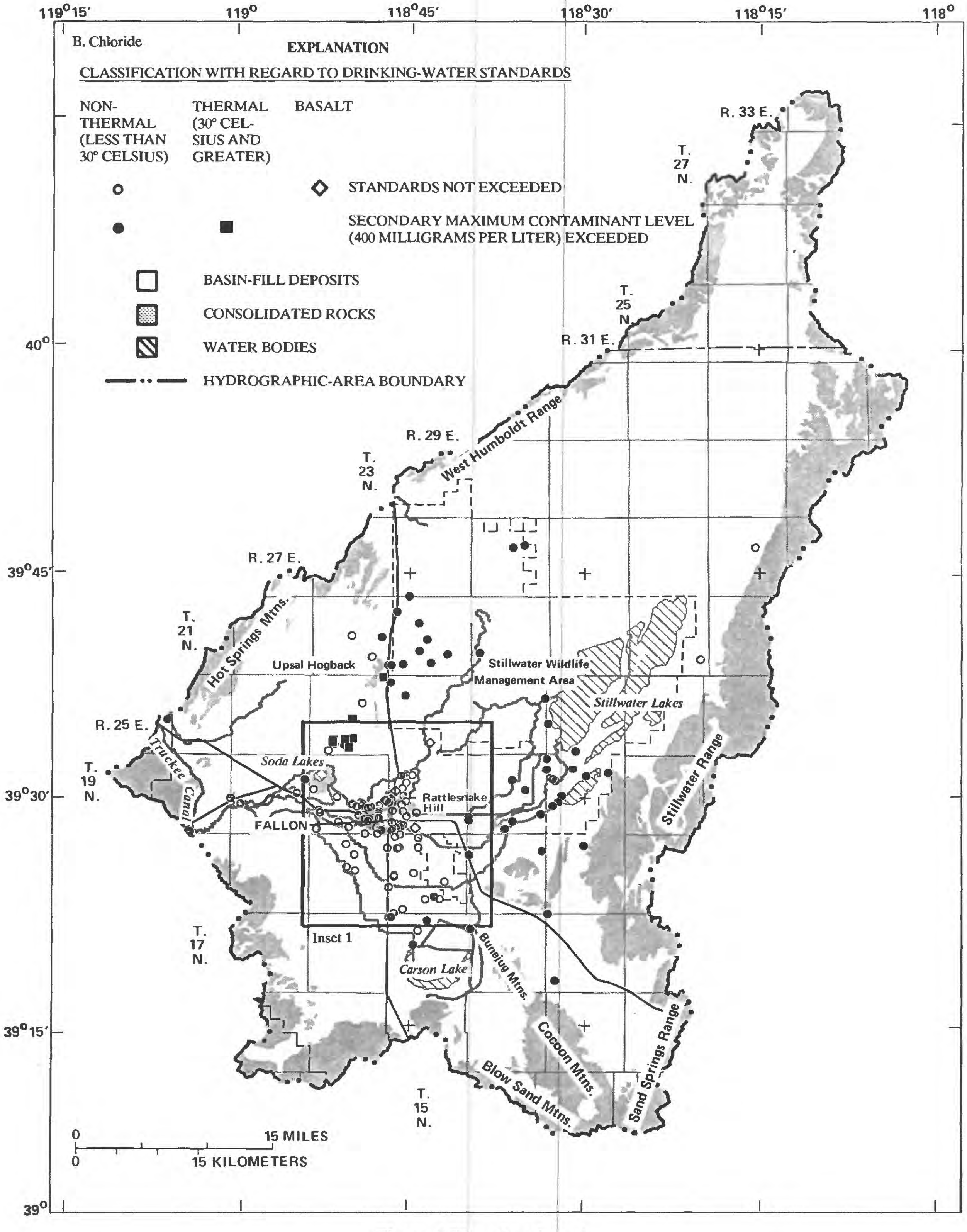

Figure 35B. – Continued.

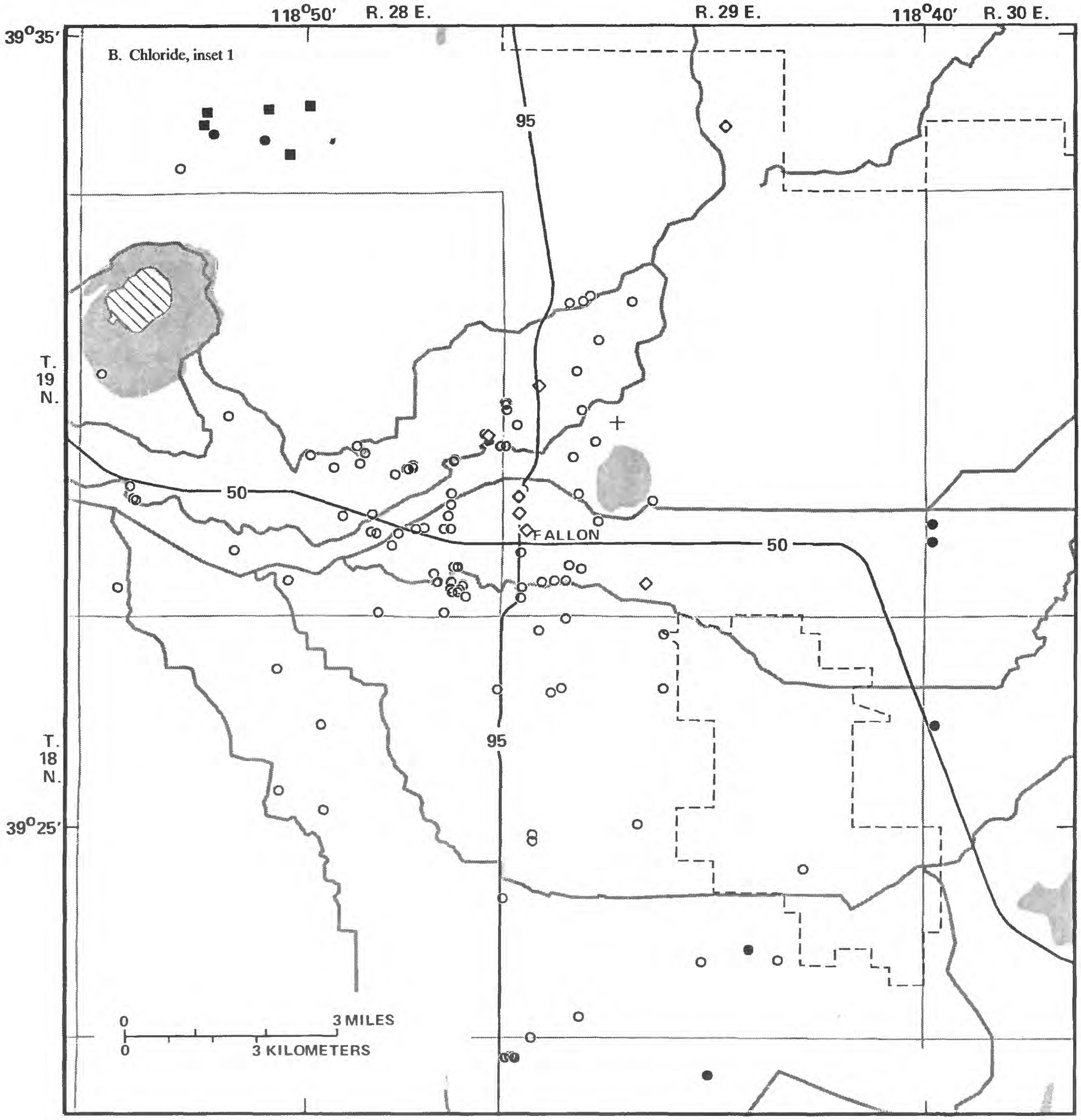

Figure 35B.—Continued.

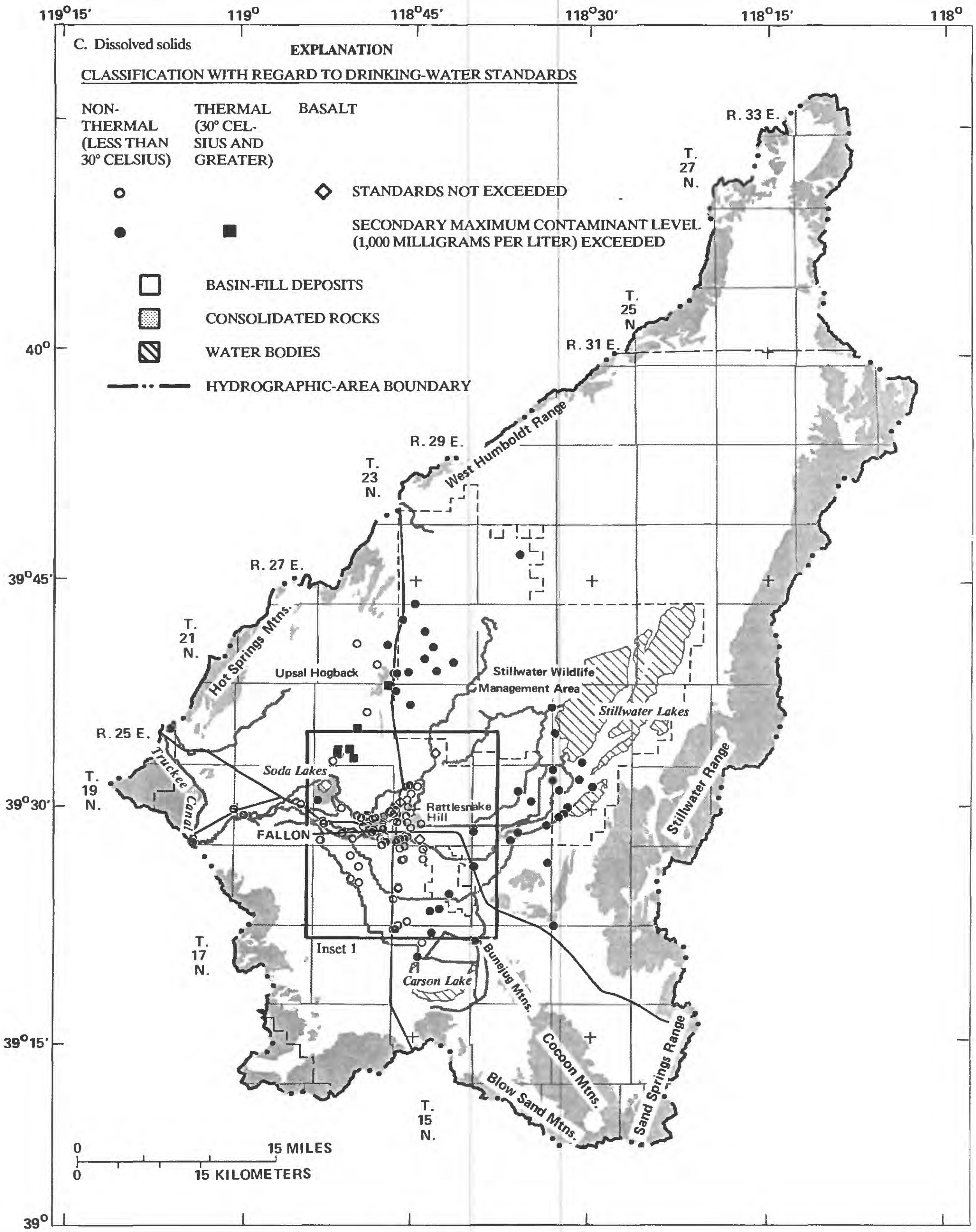

Figure 35C.—Continued.

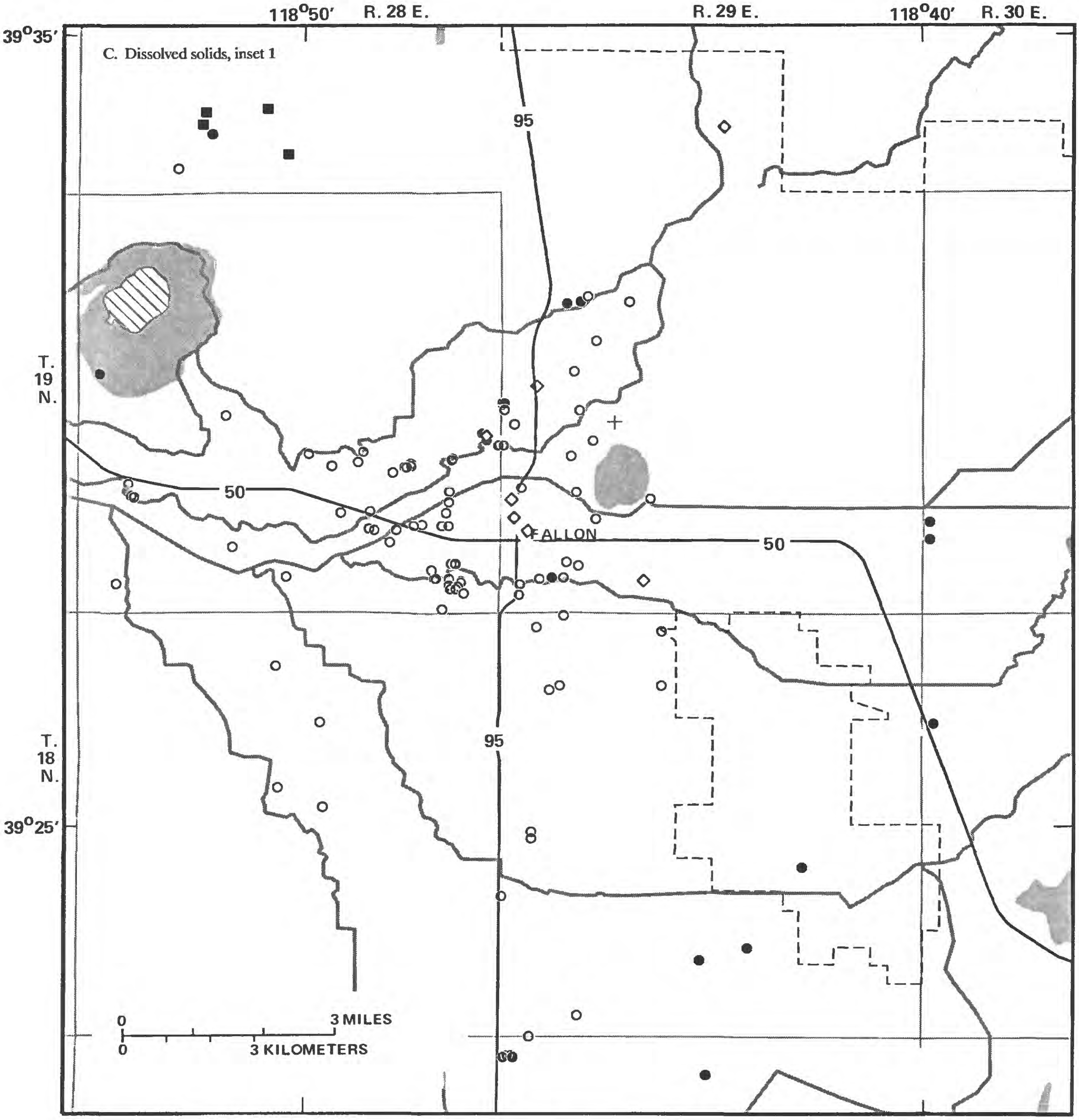

Figure 35C.—Continued.

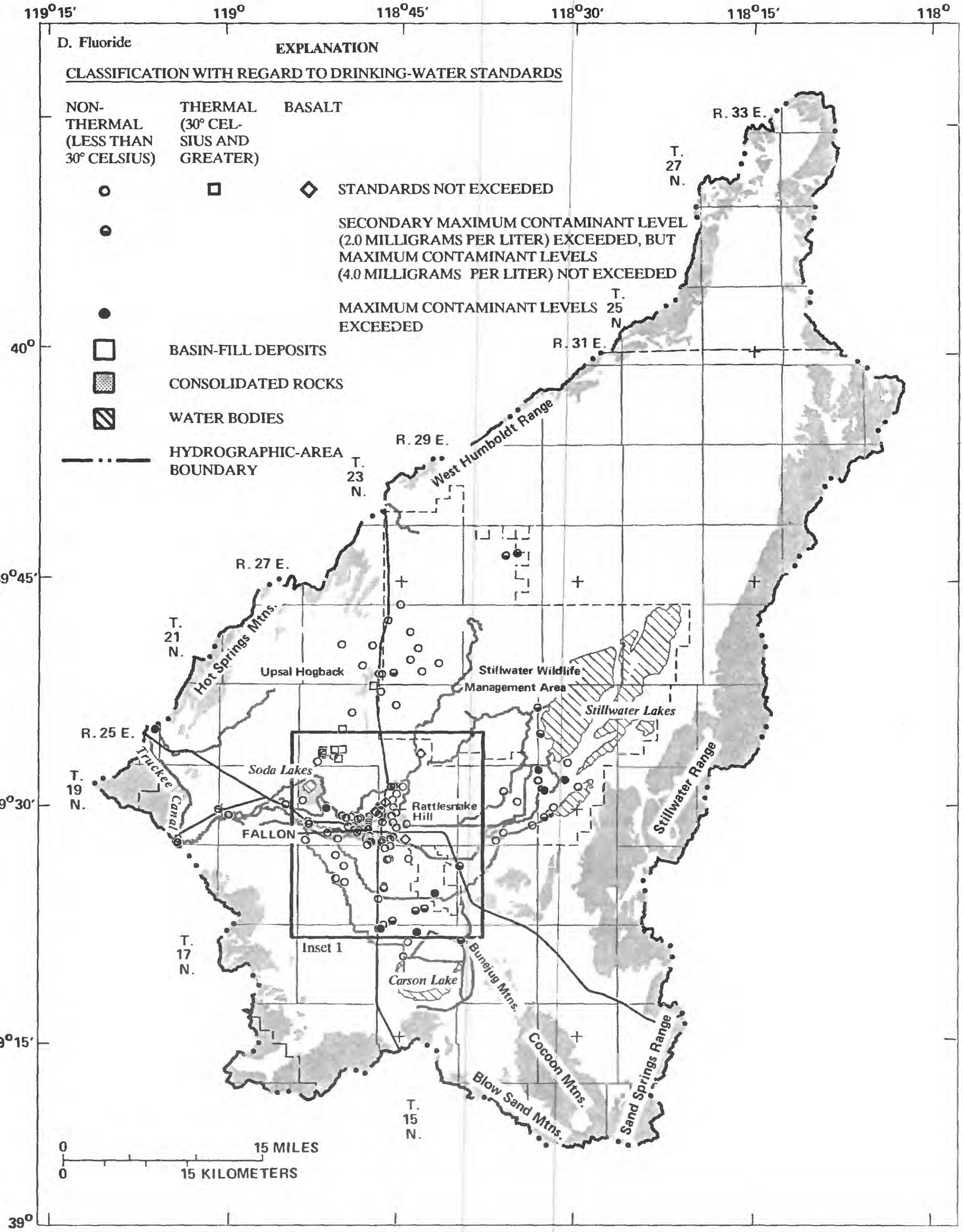

Figure 35D. – Continued.

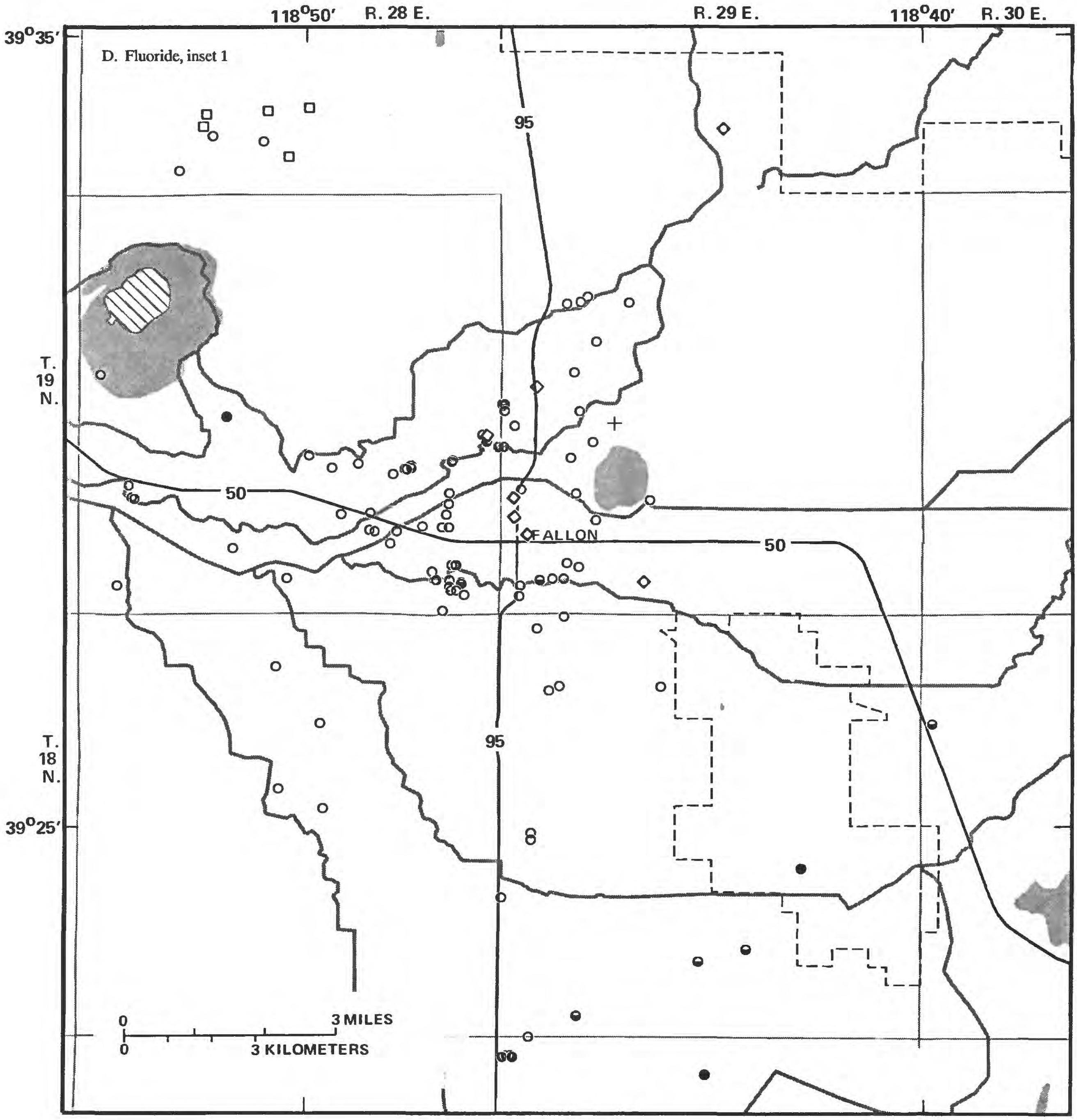

Figure 35D.—Continued.

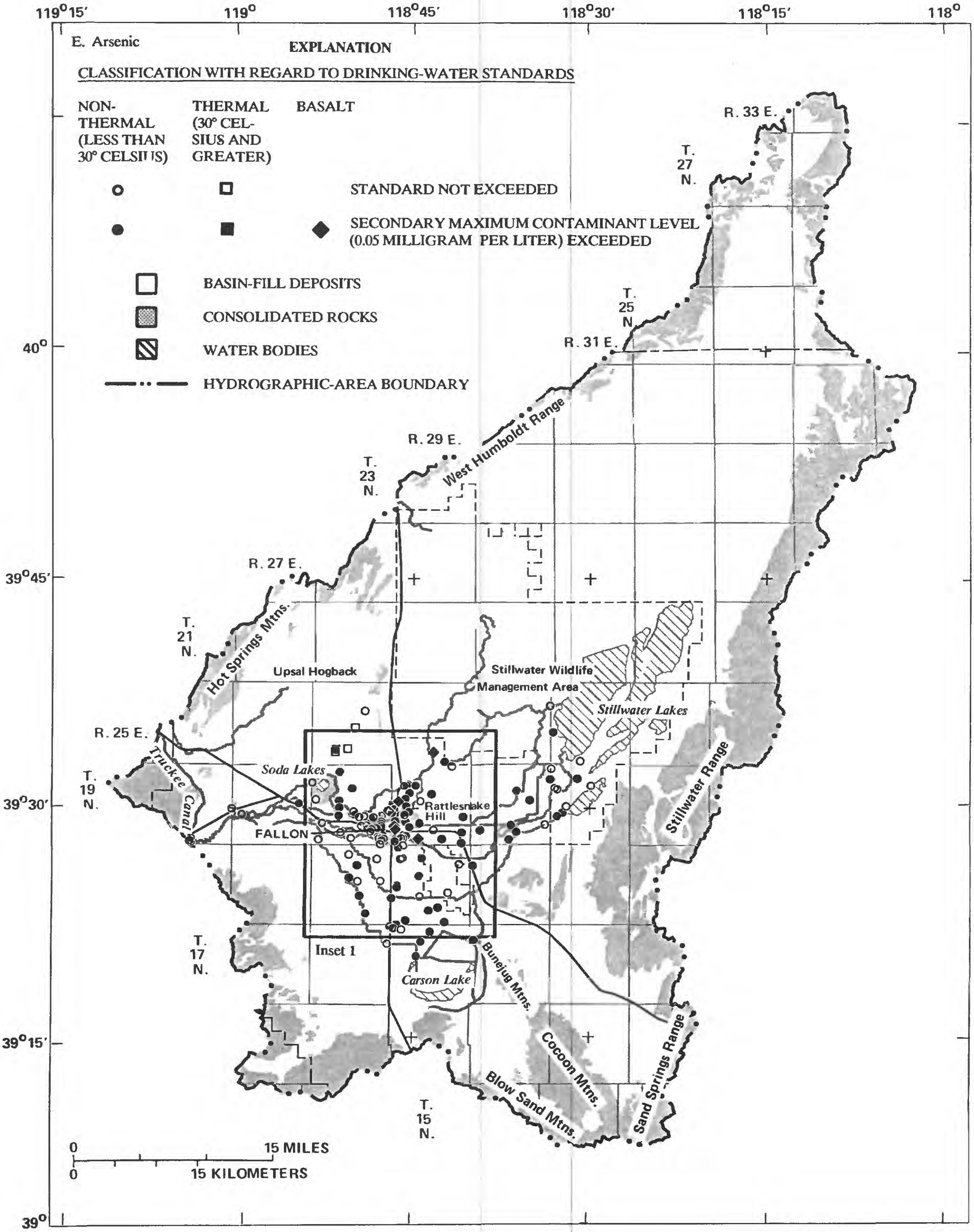

Figure 35E. – Continued.

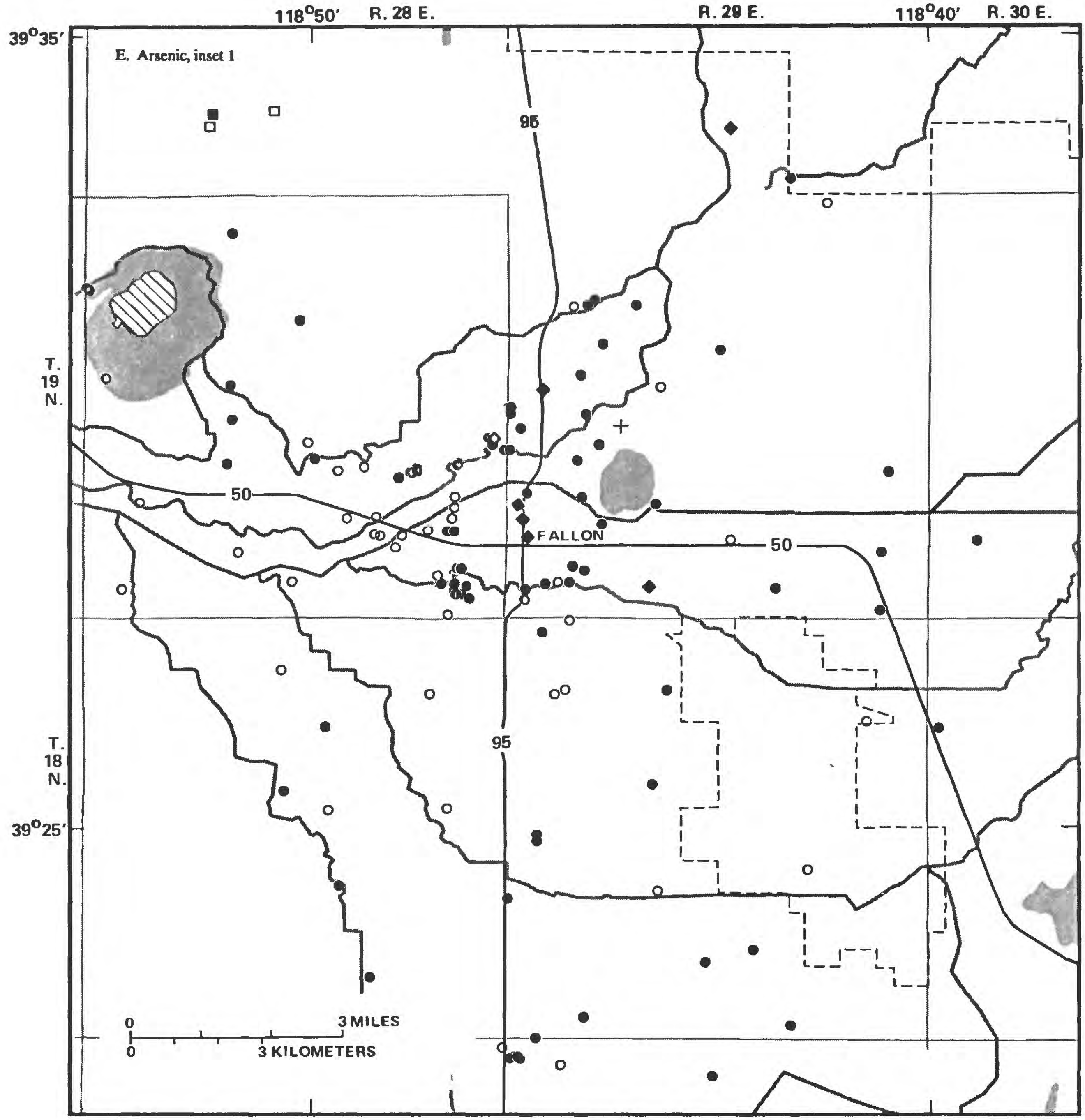

Figure 35E.—Continued.

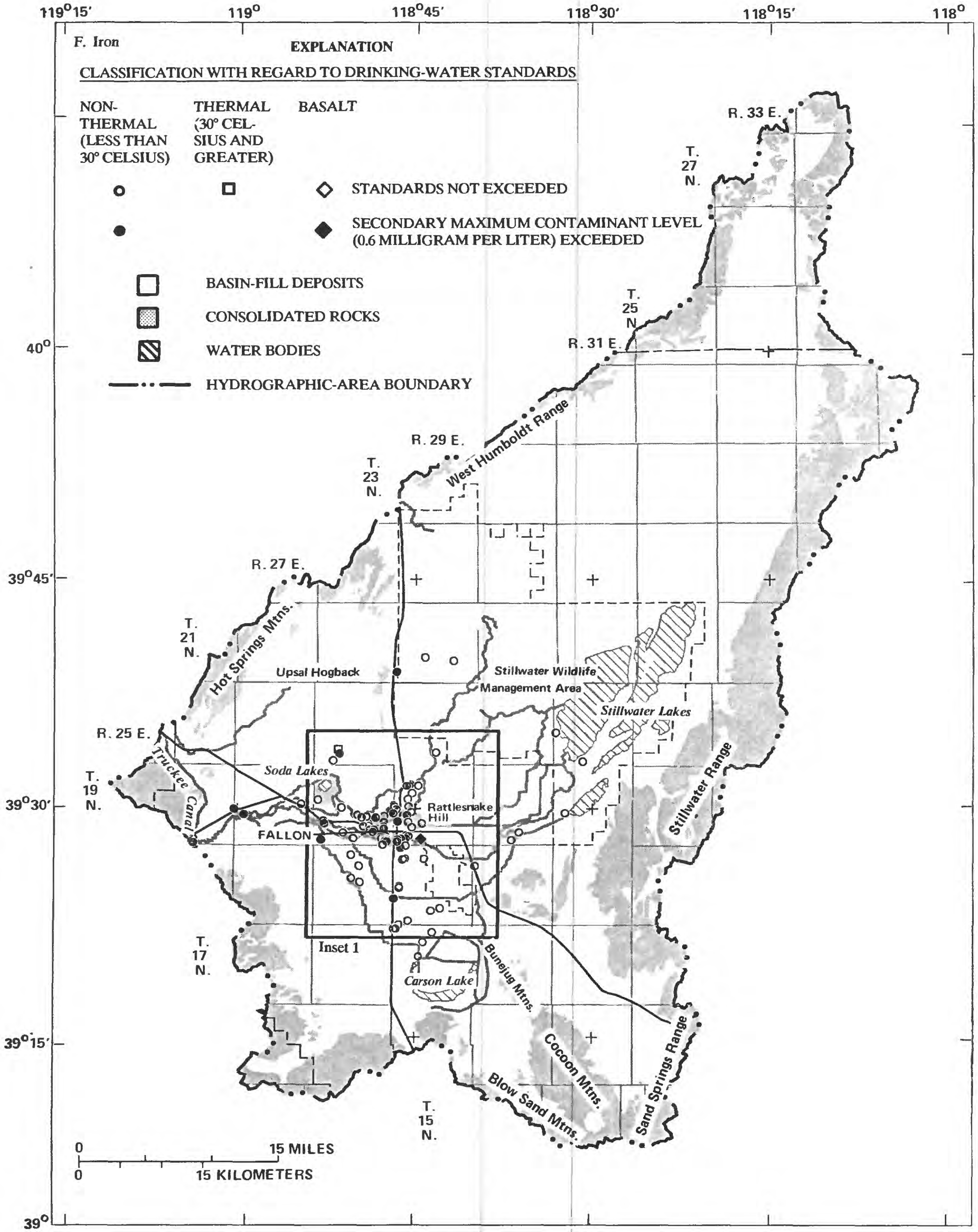

Figure 35F.—Continued.

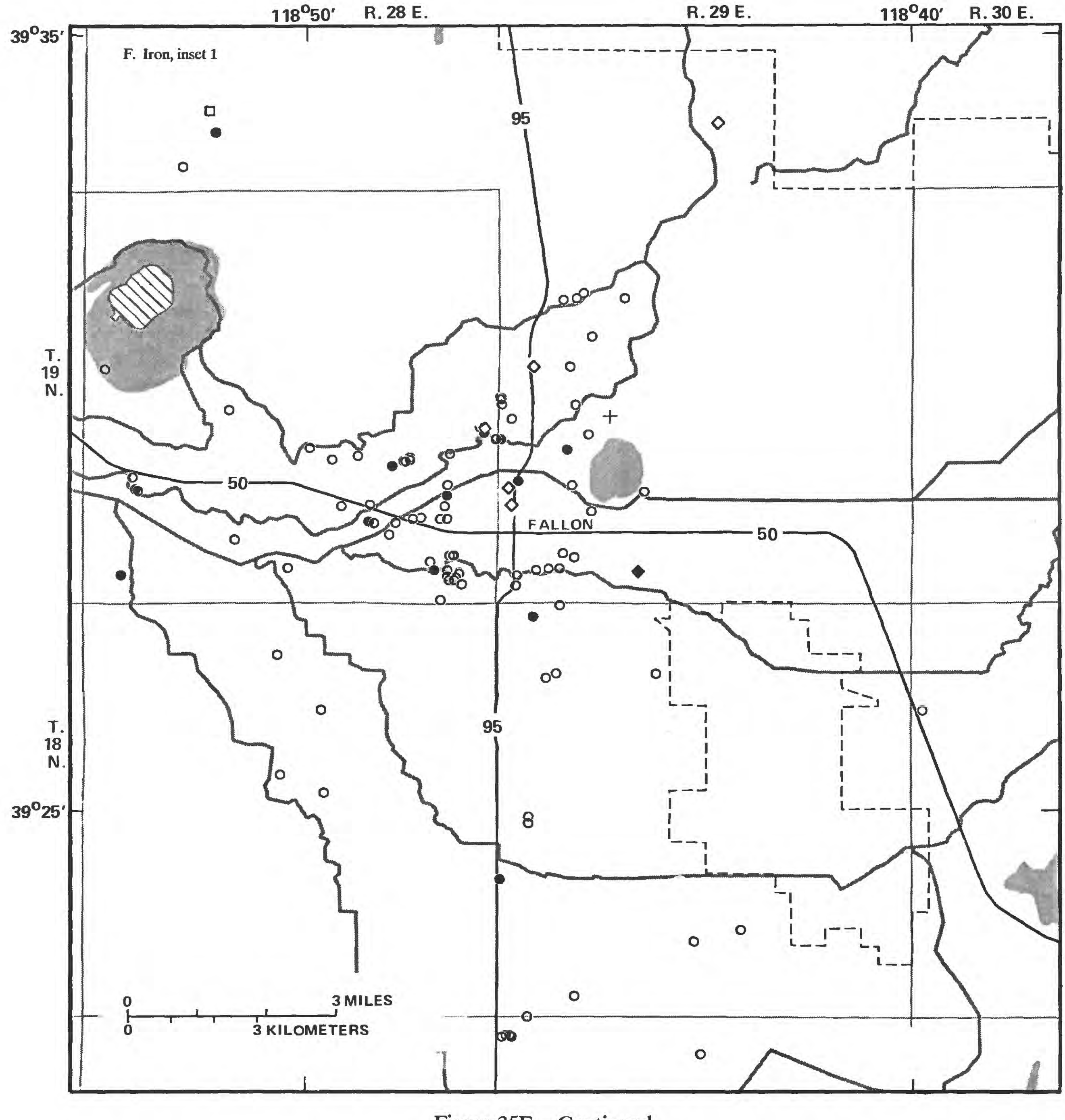

Figure 35F.—Continued.

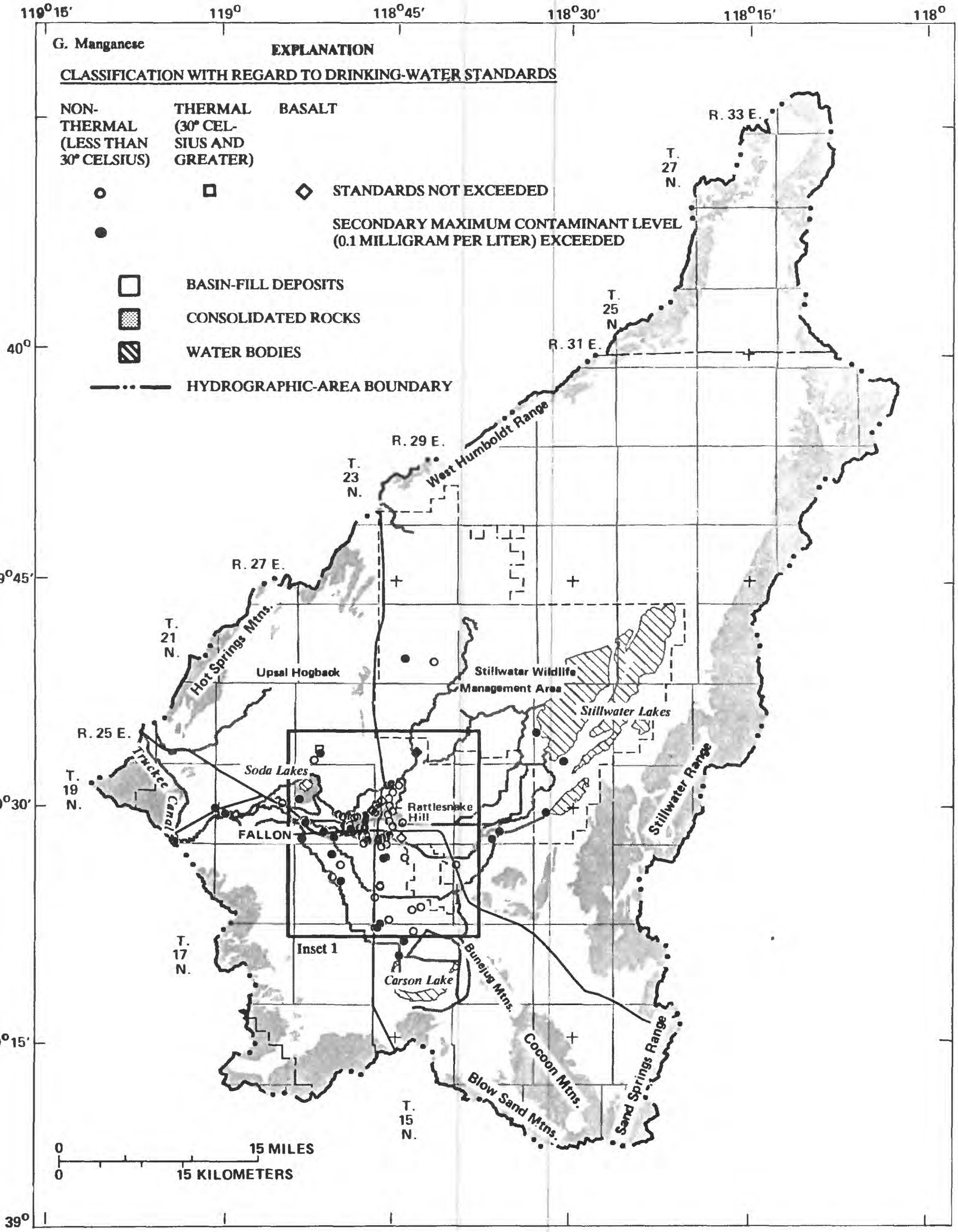

Figure 35G. – Continued.

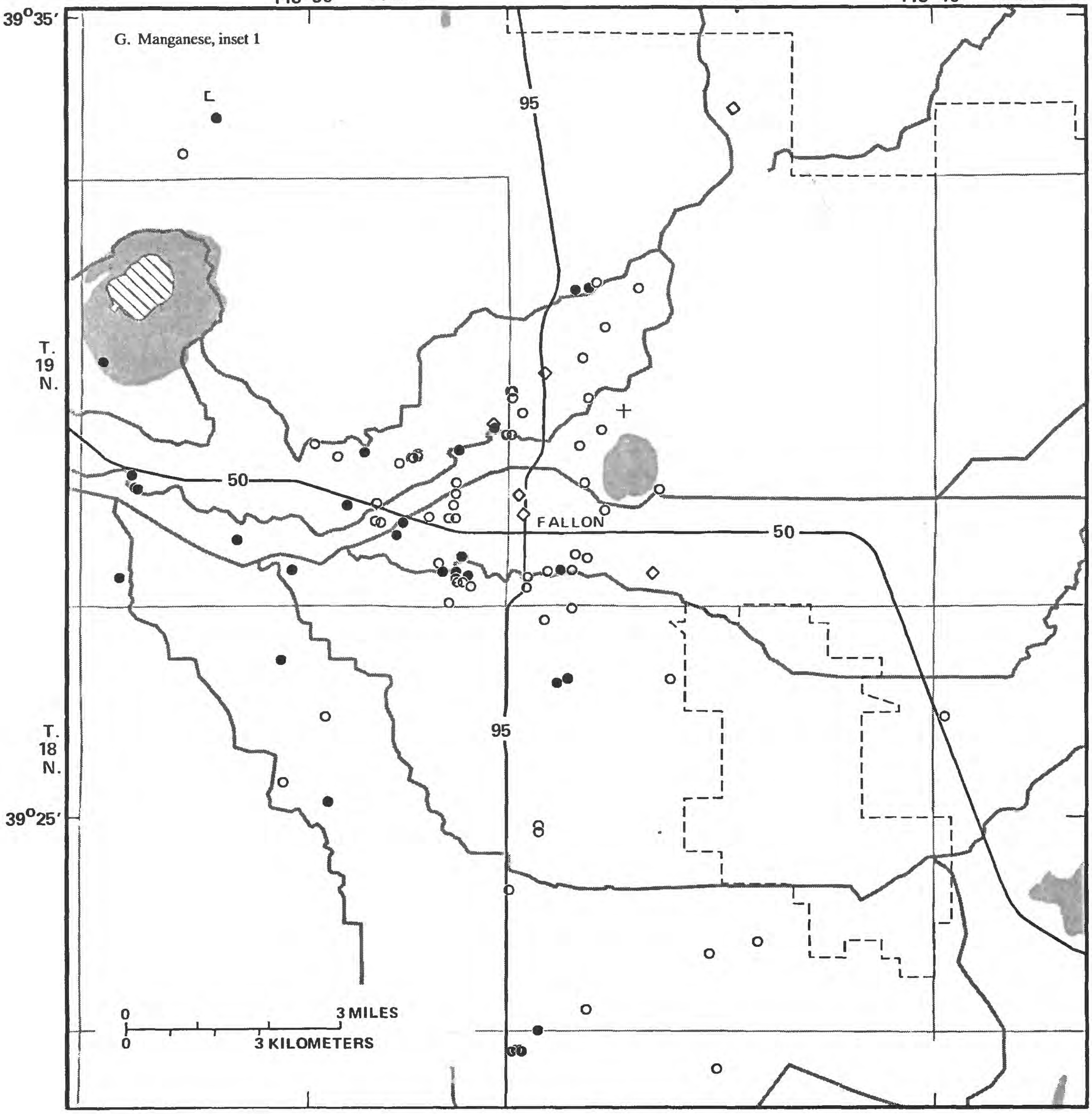

Figure 35G.—Continued.

In the Carson River basin, iron and manganese concentrations exceed State SMCL's more frequently than do any other chemical constituents in ground water. Both iron and manganese are most readily dissolved under reducing conditions, which can exist in aquifers for more than one reason. However, a common source for reducing conditions is decomposing organic matter that was incorporated with the sedimentary deposits as they accumulated. Organic matter can accumulate in basin-fill sediments, especially as riparian vegetation in valley lowlands and flood plains where vegetation is fairly dense.

Data for manmade organic compounds in ground water of the Carson River basin are sparse and have been collected mostly in response to suspected problems. The available data indicates that some of these compounds, particularly solvents and petroleum fuels, may be present in ground water at differing concentrations in the following types of areas: (1) Industrial areas, especially where solvents are routinely used, (2) any areas where petroleum products are stored in underground tanks, and perhaps (3) landfills.

Despite several limitations, the data compiled for this part of the Carson River basin pilot project provide an overview of ground-water quality in the basin with respect to physical properties, inorganic constituents, including some trace elements, and, in a few areas, manmade organic compounds. The compiled data do not include sample sites that permit a description of many constituents with established MCL's and SMCL's. In particular, determination of the concentrations of many of the trace inorganic constituents, radionuclides, gross measures of radioactivity, and manmade organic compounds are few or are not available for many of the basins in the Carson basin. The lack of data indicates a need for a data base on ground-water quality that is internally consistent with regard to water-quality constituents and sample-collection and preservation methods, and that has an adequate areal and vertical distribution of sampling sites.

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