U.S. DEPARTMENT OF THE INTERIOR
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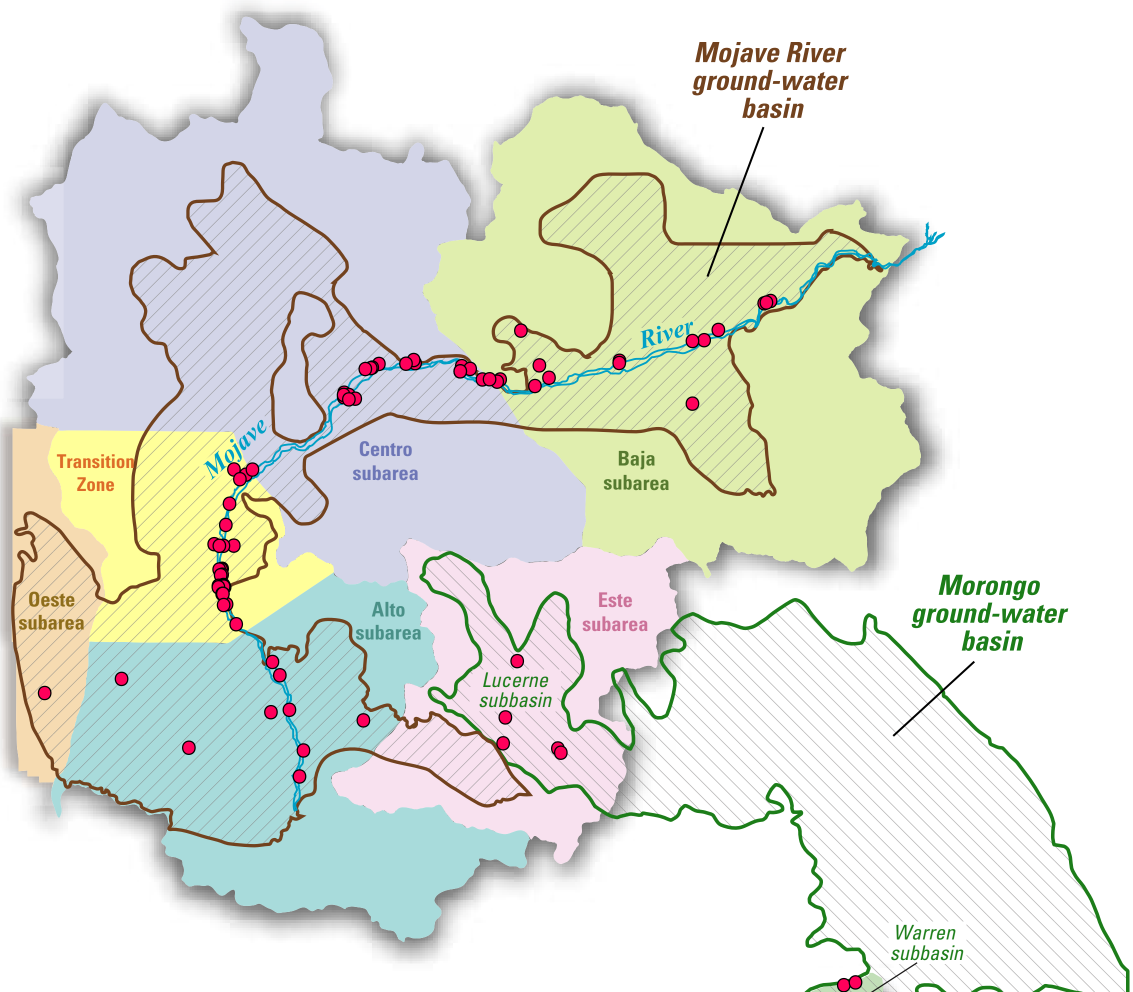
Lithologic and Ground-Water Data for Monitoring Sites in the Mojave River and Morongo Ground-Water Basins, San Bernardino County, California, 1992–98

Open File Report 02-354



Prepared in Cooperation with the **Mojave Water Agency**

USGS

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By Julia A. Huff, Dennis A. Clark, *and* Peter Martin

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MOJAVE WATER AGENCY

Sacramento, California
2002

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Multiply	By	To obtain
acre	0.4047	hectare
foot (ft)	0.3048	meter
inch (in.)	2.54	centimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

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

$$°F = (1.8 \times °C) + 32$$

Vertical Datum

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

Altitude, as used in this report, refers to distance above or below sea level.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 ˚C).

Water Quality Units

Concentrations of constituents in water samples are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is equivalent to "parts per million" and micrograms per liter is equivalent to "parts per billion."

Acronyms

MWA Mojave Water Agency

NWIS Web National Water Information System Web page

ODEX overburden drilling by the excenter method

PES polyethersulfone

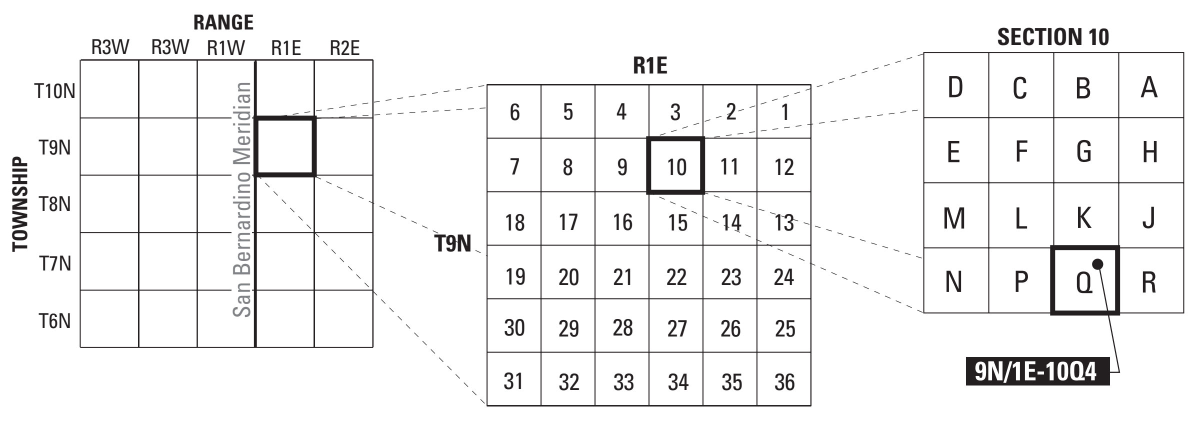
PVC polyvinyl chloride

RASA California Regional Aquifer-System Analysis

USGS U.S. Geological Survey

Well-Numbering System

Wells are identified and numbered according to their location in the rectangular system for the subdivision of public lands. Identification consists of the township number, north or south; the range number, east or west; and the section number. Each section is divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with "A" in the northeast corner of the section and progressing in a sinusoidal manner to "R" in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians; Humboldt (H), Mount Diablo (M), and San Bernardino (S). Well numbers consist of 15 characters and follow the format 009N001E10Q004S. In this report, well numbers may be abbreviated and written 9N/1E-10Q4. The following diagram shows how the number for well 9N/1WE-10Q4 is derived.



Well-numbering diagram (Note: maps in this report use abbreviated well numbers such as **"10Q4"**)

Lithologic and Ground-Water Data for Monitoring Sites in the Mojave River and Morongo Ground-Water Basins, San Bernardino County, California, 1992–98

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ABSTRACT

Lithologic and ground-water data were collected at 85 monitoring sites constructed in the Mojave Water Agency Management area in San Bernardino County, California, as part of a series of cooperative studies between the U.S. Geological Survey and the Mojave Water Agency. The data are being used to evaluate and address water-supply and water-quality issues. This report presents a compilation of the data collected at these sites from 1992 through 1998, including location and design of the monitoring sites, lithologic data, geophysical logs, ground-water-level measurements, and water-quality analyses.

One to five small (generally 2-inch) diameter wells were installed at each of the 85 monitoring sites to collect depth-dependent hydrologic data. Lithologic logs were compiled from descriptions of drill cuttings collected at each site and from observations recorded during the drilling of the borehole. Generalized stratigraphic columns were compiled by grouping similar lithologic units. Geophysical logs provide information on the character of the lithologic units and on the presence of ground water and the chemical characteristics of that water. Water-level and water-quality data were collected periodically from the sites during 1992 through 1998.

INTRODUCTION

The Mojave River and the Morongo ground-water basins are in the southwestern part of the Mojave Desert in southern California (fig. 1). The proximity of the area to the highly urbanized Los Angeles area has stimulated population growth and associated water use since the 1960s. Ground water is the primary source of water supply in most of the study area because surface water is unreliable for direct water supply. Water managers in the region are faced with many water-supply and water-quality issues, including ground-water overdraft, conjunctive use of ground water and surface water, quantity and quality of natural and artificial recharge, and anthropogenic and naturally occurring chemical constituents at concentrations exceeding drinking-water standards. In 1992, the U.S. Geological Survey (USGS) in cooperation with the Mojave Water Agency (MWA) began a series of studies to address these issues in the Mojave River and Morongo ground-water basins. The Mojave River basin studies were part of the U.S. Geological Survey Southern California Regional Aquifer-System Analysis (RASA) study. The objective of the RASA study was to analyze the major problems and issues that affect the use of ground water in southern California (Martin, 1986).

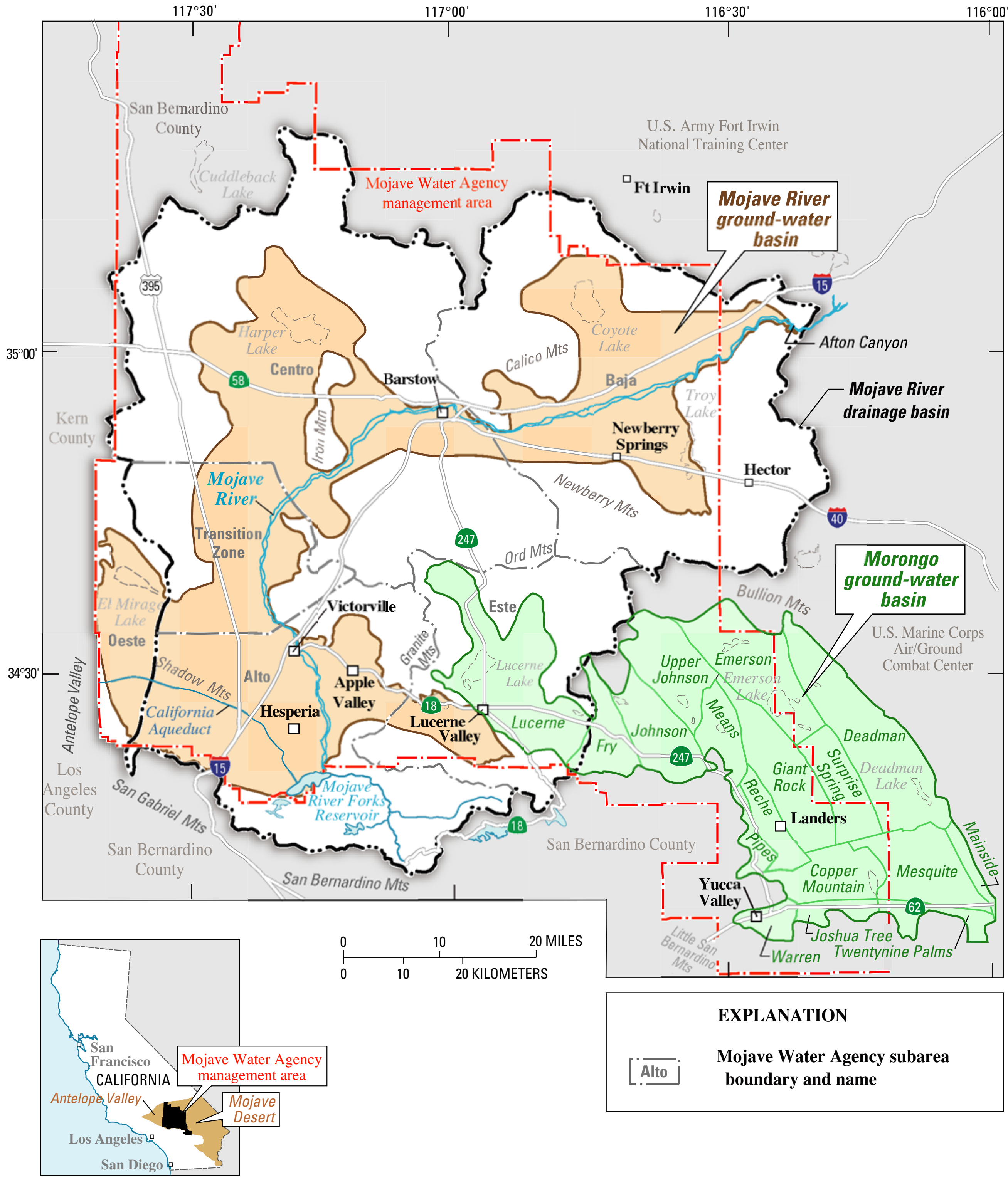

Figure 1. Mojave River and Morongo ground-water basins, San Bernardino County, California.

Purpose and Scope

To help evaluate and address water-supply and water-quality issues in the Mojave River and Morongo ground-water basin, the USGS and MWA cooperatively constructed 85 ground-water monitoring sites within the MWA management area (fig. 2). Construction of these monitoring sites provided data on lithology, water levels, ground-water quality, and aquifer properties at multiple depths in the aquifer systems within the Mojave River and Morongo ground-water basins. Most of the monitoring sites consist of multiple wells completed at different depths in the aquifer system. Prior to the construction of these monitoring sites, most geohydrologic data were collected from long-screened production wells or from shallow monitoring wells.

The purpose of this report is to present a compilation of the data collected at the monitoring sites from 1992 (when the first site was constructed) through 1998 (when data collection for the RASA study was completed). The data presented in this report include location and design of the monitoring sites, lithologic data, geophysical logs, ground-water levels, and water-quality analyses.

Description of Study Area

The climate of the area is typical of the Mojave Desert region of southern California; it is characterized by low precipitation, low humidity, and high summer temperatures. Most areas of the basin floor receive less than 6 in/yr of precipitation, although annual precipitation can be greater than 40 in. in the southern and eastern San Bernardino and San Gabriel Mountains (Lines, 1996). Most of the area is undeveloped; however, many of the desert communities increased in population in the 1980’s as growth in the Los Angeles area spread into the high desert (Umari and others, 1995). Agriculture is concentrated in the areas along the Mojave River, near El Mirage Lake (dry), near Harper Lake (dry), near Newberry Springs, and in Lucerne Valley.

The Mojave River ground-water basin is bounded by the San Bernardino and San Gabriel Mountains to the south, Afton Canyon to the northeast, the Lucerne Valley to the southeast, and Antelope Valley to the west (fig. 1). The ground-water basin encompasses about 1,400 mi^2 and is divided into six management subareas; Oeste, Este, Alto, Transition zone of the Alto (referred to in this report as the Transition Zone subarea), Centro, and Baja (fig. 2).

The Morongo ground-water basin covers about 1,000 mi^2 and is surrounded by the Ord and the Granite Mountains to the north, the Bullion Mountains to the east, the San Bernardino Mountains to the southwest, and the Pinto and Little San Bernardino Mountains to the south (fig. 2). The basin consists of 17 subbasins; Copper Mountain, Deadman, Emerson, Fry, Giant Rock, Johnson, Joshua Tree, Lucerne, Mainside, Means, Mesquite, Pipes, Reche, Surprise Spring, Twentynine Palms, Upper Johnson, and Warren (fig. 1). The Lucerne subbasin lies within the Este subarea of the Mojave River ground-water basin; however, ground water east of the Helendale Fault (fig. 2) is considered part of the Morongo ground-water basin (fig. 1).

Acknowledgments

The authors thank the personnel from the Mojave Water Agency, the U.S. Marine Corps, Victor Valley Water Reclamation Authority, Baldy Mesa Water District, the city of Barstow, Apple Valley Ranchos Water District, Jess Ranch, and the Hi Desert Water District for providing data, access to property, and permission to drill the monitoring sites. The authors also thank the many private well owners that provided information and allowed access to their property for construction of the monitoring sites. Funding for construction of the monitoring sites was provided by the Mojave Water Agency, the U.S. Marine Corps, and the city of Barstow. This report was completed with the help and suggestions of Callie Mack and Phil Contreras, both Scientific Illustrators with the U.S. Geological Survey, San Diego, California. William D. Littschwager compiled the lithologic logs for many of the monitoring sites presented in this report.

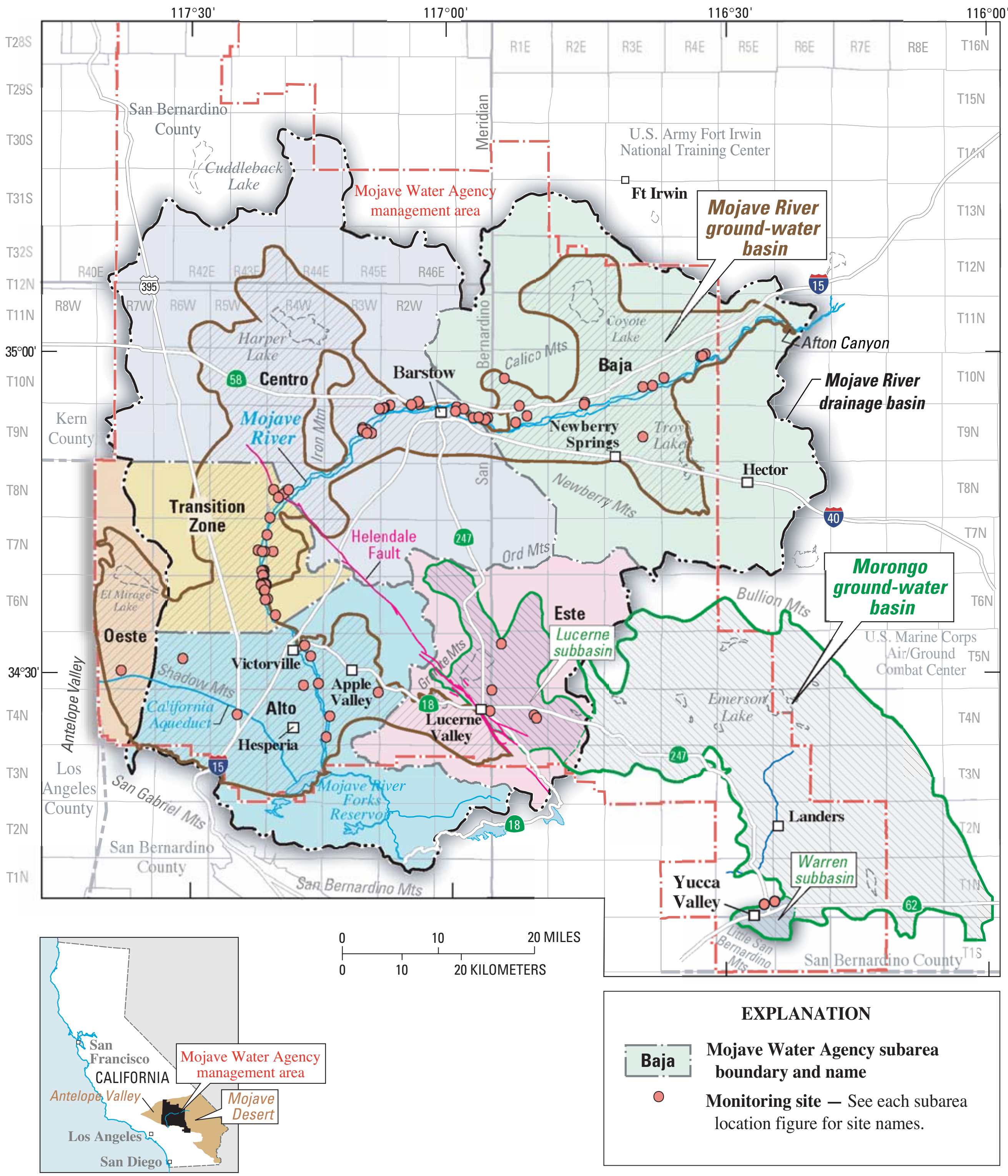

Figure 2. Location of monitoring sites within the Mojave River and Morongo ground-water basins, southern California.

LOCATION AND DESIGN OF MONITORING SITES

Between 1992 and 1998, 210 monitoring wells were installed at 85 sites in the Mojave Water Agency Management area, San Bernardino County, California. Most of the monitoring sites consist of more than one well; sites with more than one well are referred to as multiple-well monitoring sites. The multiple-well monitoring sites typically consist of three to five small (generally 2-in.) diameter wells installed at different depths in the same borehole. Each well in the borehole is screened over a specific interval (generally 20 ft) and is isolated from the other wells by a low-permeability bentonite grout seal. The construction of these wells enables the collection of depth-specific water-level, water-quality, and aquifer-property data. The common site name, state well number, site identification number, and the subarea or subbasin location of the 85 individual and multiple-well monitoring sites constructed for this study are presented in table 1.

The boreholes at the monitoring sites were drilled using mud rotary, air rotary, and auger methods; and ODEX (overburden drilling by the excenter method), also referred to as the reamer method. After total hole depth was attained, geophysical logs were made for most of the uncased boreholes; the logs, as well as the cuttings collected from each borehole, were used to design each monitoring site. The monitoring wells were constructed using 2-inch-diameter polyvinyl chloride (PVC) casing. The screened interval of each monitoring well typically consists of a 20-foot section of slotted PVC (slot size is 0.020-in.) at the bottom. Once the well was set to the desired depth, a filter pack was placed around the screened interval using Monterey #3 sand. A low-permeability bentonite grout then was placed to seal the borehole and effectively isolate the monitoring well. This process was repeated for each successive well. A well-construction diagram for a typical multiple-well monitoring site is presented in figure 3.

After completion, drilling fluid was evacuated from each monitoring well using compressed air. Extensive airlifting and a surging technique with compressed air were employed to break down the mudcake that had developed between the borehole and the surrounding formation during drilling. Specific conductance, pH, temperature, apparent color, and turbidity, along with the discharge rate and total volume, were recorded during this process. Development was continuous until no discernible drilling mud was present and field measurements had stabilized.

DATA COLLECTION

Geologic Data

Geologic information was collected at each site to characterize and correlate stratigraphic units and boundaries associated with the regional aquifer systems. The geologic information includes lithologic descriptions of the drill cuttings and a suite of geophysical logs. Selected core, or drill cutting samples, were analyzed at some of the monitoring sites for physical properties and mineralogy.

Lithologic Descriptions

Detailed lithologic logs were compiled from descriptions of drill cuttings collected at each borehole site and from observations recorded during drilling. For monitoring sites constructed using the mud-rotary method, cutting samples were collected at 20-foot drill intervals using a #120 sieve. At most sites, additional cutting samples were collected at intervals showing distinguishable changes in lithology. For the monitoring sites constructed using the ODEX and auger methods, cutting samples were collected at 1-foot intervals.

Table 1. Summary of individual and multiple-well monitoring sites in the Mojave River and Morongo ground-water basins, San Bernardino County, California

Common name	State well No.	Site identification No.	Subarea or subbasin
Mojave Ground-Water Basin Sites			
A1-1	6N/4W-18N2–3	343604117204501–2	Transition Zone subarea
A2	6N/5W-24A2–3	343559117210101–2	Transition Zone subarea
B1	6N/5W-12H2–3	343723117205401–2	Transition Zone subarea
B-1	7N/4W-6F4	344334117202501	Transition Zone subarea
B2	6N/5W-12H4–5	343723117205601–2	Transition Zone subarea
B-2	7N/4W-6F5	344334117202701	Transition Zone subarea
B3	6N/5W-12K4–5	343723117210401–2	Transition Zone subarea
B-3	7N/4W-6F6	344334117203001	Transition Zone subarea
B-4	9N/3W-23D3	345147117101201	Centro subarea
B-6	9N/3W-23D2	345136117101201	Centro subarea
B-7	9N/3W-14N1	345157117101201	Centro subarea
Barstow-1	9N/1W-4M4–7	345351116593301–4	Centro subarea
Barstow-2	9N/1W-4R2–4	345339116584501–3	Centro subarea
Barstow-3	9N/1W-9D5–7	345328116594301–3	Centro subarea
C1-1	6N/5W-1B4–5	343842117210501–2	Transition Zone subarea
C2-1	6N/5W-1B6–7	343842117211101–2	Transition Zone subarea
C3-1	6N/5W-1B8–9	343842117211801–2	Transition Zone subarea
C4-1	6N/5W-1C1–2	343840117212701–2	Transition Zone subarea
CALFAN	10N/1E-20M1–2	345631116541401–2	Baja subarea
Calico East	9N/2E-3G6–9	345416116451601–4	Baja subarea
Calico West	9N/2E-3K5–9	345404116451801–5	Baja subarea
CAMP CADY NO 1	10N/3E-26H1	345549116373701	Baja subarea
CAMP CADY NO 2	10N/4E-19M4	345630116362101	Baja subarea
CHERIES	8N/4W-20Q12	344546117185901	Transition Zone subarea
Daily	7N/4W-19Q5–7	344030117201101–3	Transition Zone subarea
Deep Creek	4N/3W-31L6–9	342318117141101–4	Alto subarea
Del Oro 1	4N/3W-12A1–3	342726117082401–3	Alto subarea
EPA I	6N/5W-13B1–2	343655117210701–2	Transition Zone subarea
EPA II	6N/5W-12G2–3	343733117210801–2	Transition Zone subarea
EPA III	6N/5W-12G4	343730117210401	Transition Zone subarea
EPA IV-A	6N/5W-1L1–2	343815117211901–2	Transition Zone subarea
EPA IV-B	6N/5W-1K1	343815117211101	Transition Zone subarea
EPA V-A	7N/5W-13H1–2	344159117205701–2	Transition Zone subarea
EPA V-B	7N/5W-13H3	344200117205001	Transition Zone subarea
EPA VI	6N/5W-12F1	343726117213001	Transition Zone subarea
EPA VII	6N/5W-12L5	343721117213001	Transition Zone subarea
F-1	9N/2W-3A1–2	345421117035301–2	Centro subarea
F-2	9N/2W-2E1	345407117034701	Centro subarea
F-3	9N/2W-3E1–3	345406117044001–3	Centro subarea
Helendale 1	8N/4W-21M1–4	344609117182901–4	Centro subarea
Helendale 2	8N/4W-20Q7–11	344546117190101–5	Transition Zone subarea
Helendale 3	8N/4W-29E-3–6	344524117193401–4	Transition Zone subarea
Helendale 4	8N/4W-19G1–4	344611117200801–4	Transition Zone subarea

Table 1. Summary of individual and multiple-well monitoring sites in the Mojave River and Morongo ground-water basins, San Bernardino County, California—Continued

Common name	State well No.	Site identification No.	Subarea or subbasin
Hodge-1	9N/3W-23F1–4	345124117094301–4	Centro subarea
Hodge-2	9N/3W-23C1	345146117094301	Centro subarea
Hodge-3	9N/3W-23H1	345126117091101	Centro subarea
Hodge-4	9N/3W-23L1	345123117094301	Centro subarea
JR-1	4N/4W-1C2–5	342814117150501–4	Alto subarea
Lenwood 1	9N/2W-6L11–14	345350117074001–4	Centro subarea
Lenwood 2	9N/2W-6M7	345448117075101	Centro subarea
Lenwood 3	9N/2W-6P1	345347117074101	Centro subarea
Lenwood 4	9N/2W-6P2	345345117074901	Centro subarea
Lenwood 5	9N/2W-6H6	345402117070401	Centro subarea
Lower Narrows	6N/4W-30J5	343435117195501	Transition Zone subarea
MANIX-1	10N/4E-11E1–2	345828116321101–2	Baja subarea
MANIX-2	10N/4E-11C1–2	345841116313801–2	Baja subarea
MANIX-3	10N/4E-11E3–4	345833116315901–2	Baja subarea
MC-1	9N/1W-10J12–15	345251116574201–4	Centro subarea
MC2	9N/1W-12L2–5	345251116560601–4	Baja subarea
MC3	9N/1W-12N4–7	345242116562101–4	Baja subarea
MC-4	9N/1W-11K12–15	345254116570401–4	Centro subarea
MOGW	4N/5W-21H1	342519117240701	Alto subarea
MSCW	5N/7W-28L1	342923117370601	Oeste subarea
NS-1	10N/3E-27J1–5	345542116383901–5	Baja subarea
NS-2	9N/3E-22R4–7	345104116384001–4	Baja subarea
Older-1	7N/5W-24R5–8	344028117210601–4	Transition Zone subarea
Older-2	7N/5W-23R1–4	344036117215201–4	Transition Zone subarea
Palisades No 1	7N/5W-25C2	344028117212401	Transition Zone subarea
Phelan-1	5N/6W-22E1–3	343030117300901–3	Alto subarea
Regional Park	5N/4W-23B1	343046117155801	Alto subarea
RS-1	4N/3W-19G2–6	342514117134801–5	Alto subarea
SF-1	4N/4W-3A2–5	342805117164501–4	Alto subarea
UN-1	5N/4W-14D1–4	343145117163501–4	Alto subarea
Vernola 1	9N/3W-1R5–7	345341117082101–3	Centro subarea
YEMBB	9N/1E-4K1–3	345356116523001–3	Baja subarea
YEMRIV	9N/1E-16F1–4	345224116525701–4	Baja subarea
YEMRR	9N/1E-10Q2–4	345259116514201–3	Baja subarea
Morongo Ground-Water Basin Sites			
LUV-1	4N/1E-23K1–2	342518116505401–2	Lucerne subbasin
LUV-2	4N/1E-23R1–2	342504116503801–2	Lucerne subbasin
North Side Rd 1	5N/1E-8N3–4	343155116543401–2	Lucerne subbasin
Pipeline 1	4N/1W-13R1–4	342544116555001–4	Lucerne subbasin
RL-1	4N/1W-1R4–7	342738116553901–4	Lucerne subbasin
RL-2	4N/1W-1R8–9	342738116553905–6	Lucerne subbasin
YV-1	1N/5E-36G1–4	340746116244201–4	Warren subbasin
YV-2	1N/5E-36M1–3	340737116250801–3	Warren subbasin

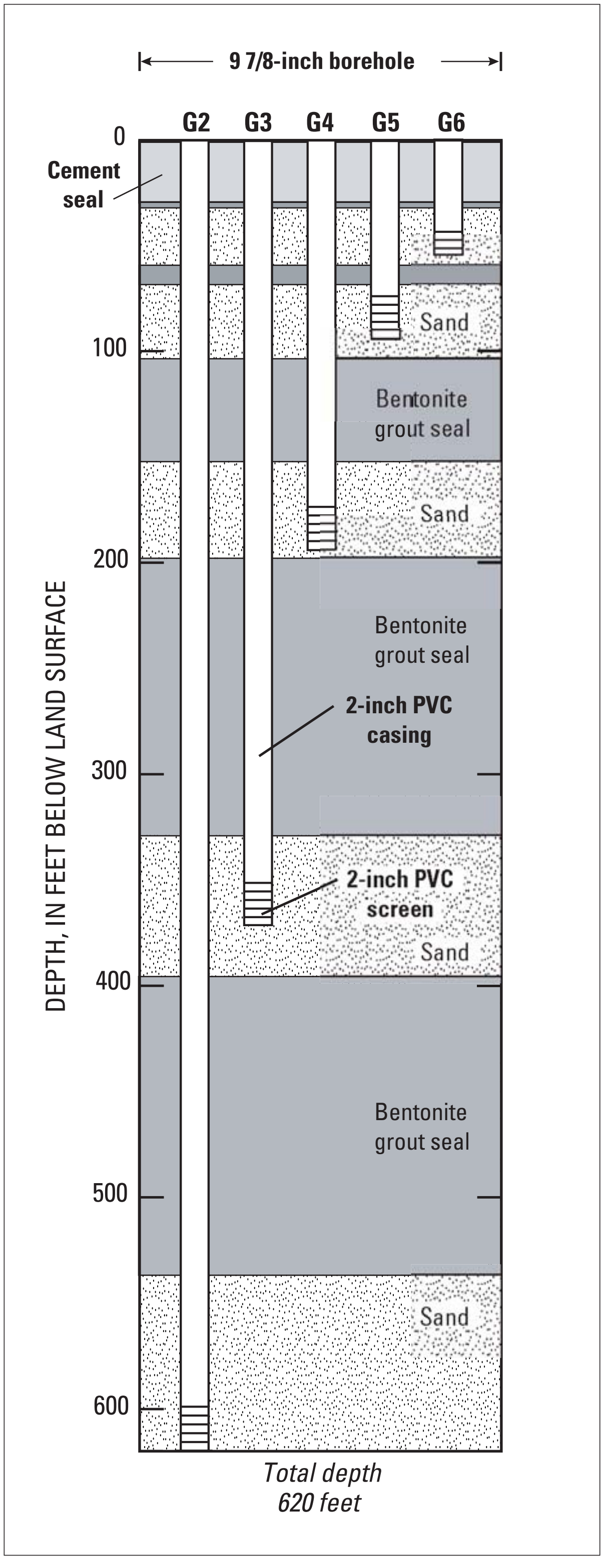

Figure 3. Example of well construction at multiple-well monitoring site RS-1 (4N/3W-19G2–6), San Bernardino County, California.

Drill cuttings were examined in the office (where they were described in greater detail) by grain size, texture, sorting, rounding, color, and any other noticeable features, such as wood or shell fragments. Texture (fig. 4) was determined on all cuttings using a method developed by Folk (1954), and particle-size description follow the National Research Council (1947) classification. This classification allows for correlation of grain-sized terms (such as "sand") to size limits in millimeters or inches. For samples containing fine-graned matieral, the terms "silt" and (or) "clay" are used in lieu of "mud." Color, determined on moist samples, follows the numerical color designations in Munsell Soil Color Charts (Munsell Color, 1994). Lithologic information for each monitoring site is presented graphically in the appendixes of this report; raw data are available at back of report.

Generalized stratigraphic columns were prepared for each monitoring site by grouping similar lithologic units as determined from detailed lithologic descriptions. The lithologic units were categorized into textural groups, such as gravels or sands (fig. 4)—based on estimated percentages of gravel and (or) sand, and the ratios of sand, silt, and clay present—following the nomenclature of Folk (1954). The information collected from the borehole geophysical logs also was used to help identify contact depths between major lithologic units.

Geophysical Logs

Borehole geophysical surveys were conducted at each site to provide information on the nature of the lithologic units and on the chemical character of ground water. Geophysical logs were made shortly after attaining total hole depth in the uncased, fluid-filled borehole. These surveys generally include caliper, natural gamma ray, spontaneous potential, 16-inch and 64-inch normal resistivity, and electromagnetic induction logs. Sonic, single-point, and guard- resistivity logs were made at some of the monitoring sites. Geophysical logs for selected monitoring sites are referenced in the "Data Presentation" section and presented graphically in the appendixes; raw data can be obtained at back of report.

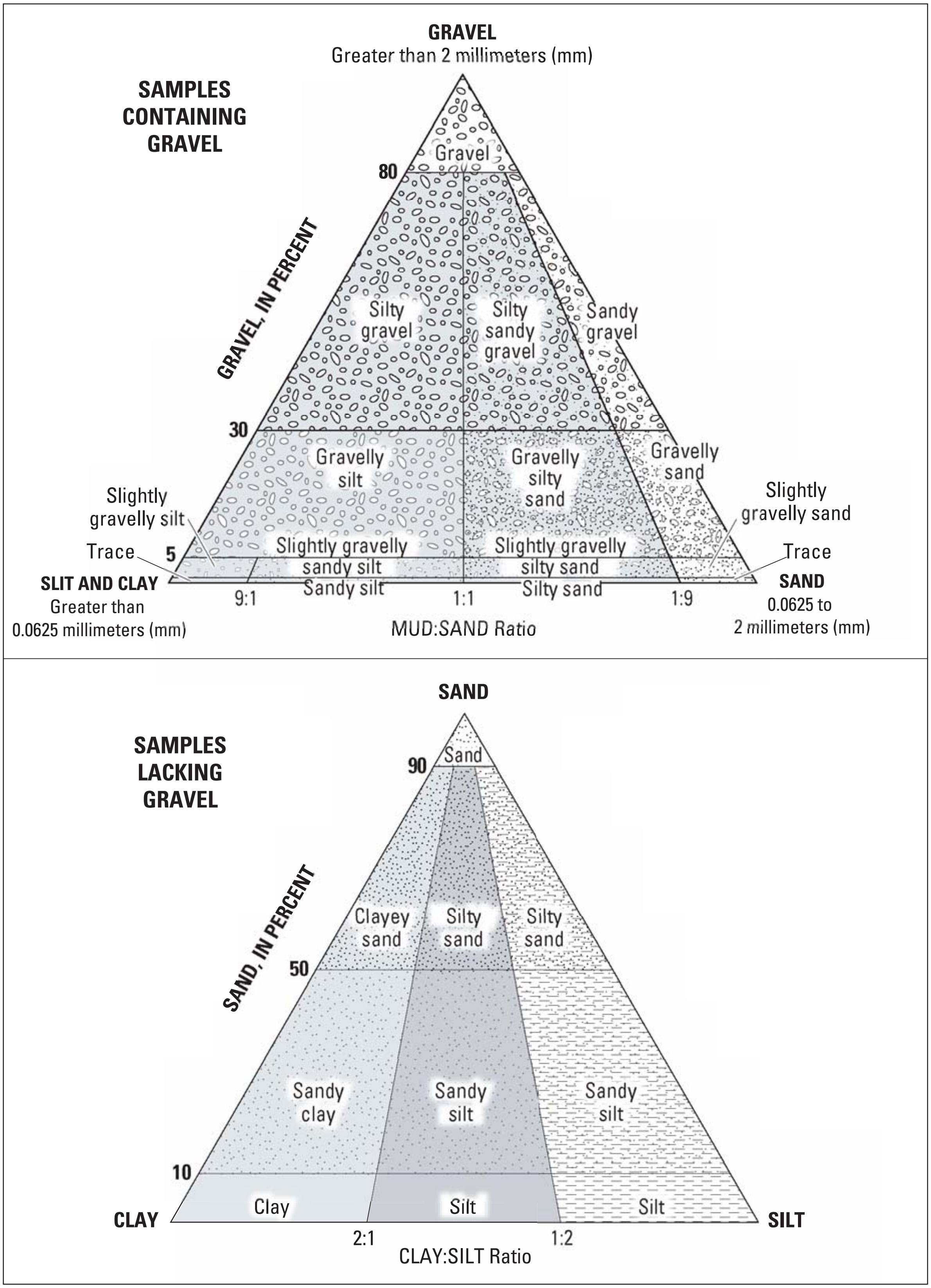

Figure 4. Nomenclature used to describe texture. (From Folk, 1954, fig. 1.)

Caliper devices measure the diameter of the borehole. The caliper log can be used to show the existence of unconsolidated cave-in sand or the presence of swelling clay. The caliper log can also be used to calculate the volume of filter pack and sealing materials needed to fill the annulus of the borehole.

Natural gamma-ray logs measure the intensities of gamma-ray emissions resulting from the natural decay of potassium-40 and of the daughter products of uranium and thorium (Schlumberger, 1972). Gamma-ray logs are used primarily to define lithology indicators and for geologic correlation. Clay, feldspar-rich gravel, and granite generally emit higher intensity gamma rays.

Spontaneous potential (SP) devices measure voltage differences that exist between non-porous and porous beds. An SP log usually has a baseline that corresponds to impermeable beds such as clay or shale. Deflections to the left of this baseline correspond to the positions of permeable strata if the formation water is less resistive (more saline) than the drilling mud. Deflections to the right of the baseline correspond to the positions of permeable strata if the formation water is more resistive (less saline) than the drilling mud.

Resistance devices, such as the single-point device, measure the resistance of the earth materials lying between an in-hole electrode and a surface electrode. The main uses of single-point resistance logs are for geologic correlation (for example, determining bed boundaries and changes in lithology) and fracture identification in resistive rocks (Keys and MacCary, 1985).

Resistivity devices also were used for the resistivity surveys; they measure the apparent resistivity of a volume of rock under the direct application of an electric current (Keys and MacCary, 1983). These logs are used to determine formation and fluid resistivity and to estimate formation porosity. In an alluvial aquifer system, low resistivity generally indicates water higher in dissolved solids and (or) fine-grained deposits such as silt, clay, and shale, whereas high resistivity indicates water lower in dissolved solids and (or) coarser material, such as sand or gravel. Therefore, resistivity can be used as an indicator of water quality—as dissolved-solids concentration increases, resistivity decreases. For example, the presence of high-dissolved-solids water in a formation would result in a low value of apparent resistivity. For this study, short (16-in.) normal and long (64-in.) normal devices were routinely used. In some boreholes, guard-resistivity devices also were used. The short-normal device records the apparent resistivity of the zone invaded by drilling fluid and the long-normal device records the apparent resistivity beyond the invaded zone. Guard devices are designed to define the boundaries of thin beds, particularly resistive ones, and to measure their resistivity (Doll, 1951).

Electromagnetic induction logs yield detailed information on the vertical electrical conductivity of a formation and of pore water (McNeill, 1986). These logs can be used to identify water-bearing units of different electrical conductivity through both PVC casing and screen, and in open boreholes. Because the electromagnetic induction tool responds to changes in the dissolved-solids concentration of ground water, it is possible to repeatedly track and map electrical anomalies associated with changes in dissolved-solids concentration of ground water over time (Williams and others, 1993).

Sonic logs, also known as acoustic and acoustic-velocity logs, are designed to measure the time it takes for a pulsed compressional sound wave to travel 1 ft. In unconsolidated material, sonic logs are principally used to measure porosity of the aquifer materials. Variations in porosity, and therefore in transit time, can help to identify contacts between lithologic units throughout the borehole. Transit time also can indicate cementation of geologic materials. Faster transit times indicate more cementation within the pore spaces.

Core Measurements

Core samples were collected at various depths at selected monitoring sites (table 2). Whole-core sections (approximately 6 in. in length) were subsampled from a limited number of cores to measure the physical properties of the soil material from monitoring sites MSCW in the Oeste subarea (figure A1) and MOGW in the Alto subarea (figure B1) of the Mojave River ground-water basin. Physical properties, such as water content, bulk density, porosity, water potential, particle size, water retention, and chemical composition of leachate were measured at the Desert Research Institute, University of Nevada, Reno, and the USGS laboratory in San Diego, California, following procedures defined by Soeder (1996). The results of the physical-property determinations are presented in Izbicki and others (2000). Selected drill-cutting samples were submitted to the USGS, Geologic Division, Branch of Geochemistry, in Denver, Colorado, to determine bulk mineralogy, using x-ray diffraction described in Klug and Alexander (1974).

Water-Level Data Collection

Ground-water levels were measured periodically at the monitoring sites, and also prior to water-quality sample collection. Water levels were measured to an accuracy of 0.01 ft using a calibrated steel tape or a calibrated electric tape.

Water-Quality Data Collection

Water-quality samples were collected periodically at each monitoring site after they were adequately developed. Sampling was conducted by USGS personnel; all samples were collected, handled, and preserved following written USGS field procedures by Sylvester and others (written commun., 1990). Purge logs, field measurements, and other information related to sample collection are on file at the USGS office in San Diego, California.

Table 2. List of individual and multiple-well monitoring sites in the Mojave River and Morongo ground-water basins, San Bernardino County, California, for which core samples are available

[Core-sample data available at the U.S. Geological Survey, Water Resources Discipline office, San Diego, California]

Common name	State well No.	Subarea or subbasin
Mojave Ground-Water Basin sites		
EPA I	6N/5W-13B1–2	Transition Zone subarea
EPA II	6N/5W-12G2–3	Transition Zone subarea
EPA III	6N/5W-12G4	Transition Zone subarea
EPA IV-A	6N/5W-1L1–2	Transition Zone aubarea
EPA IV-B	6N/5W-1K1	Transition Zone subarea
EPA V-A	7N/5W-13H1–2	Transition Zone subarea
EPA V-B	7N/5W-13H3	Transition Zone subarea
EPA VI	6N/5W-12F1	Transition Zone subarea
MANIX-1	10N/4E-11E1–2	Baja subarea
MANIX-2	10N/4E-11C1–2	Baja subarea
MC2	9N/1W-12L2–5	Baja subarea
MOGW	4N/5W-21H1	Alto subarea
MSCW	5N/7W-28L1	Oeste subarea
NS-1	10N/3E-27J1–5	Baja subarea
UN-1	5N/4W-14D1–4	Alto subarea
YEMRIV	9N/1E-16F1–4	Baja subarea
Morongo Ground-Water Basin sites		
Pipeline 1	4N/1W-13R1–4	Lucerne subbasin
YV-2	1N/5E-36M1–3	Warren subbasin

Prior to each sampling, water-level measurements were made and at least three well-casing volumes were purged from the well using a portable submersible pump. Specific conductance, pH, and water temperature were monitored during the purging process. Samples were collected only after these parameters had stabilized. Stability was attained when three successive measurements taken at intervals of 5 minutes or more differed by less than 5 percent for specific conductance, 0.1 units for pH, and 0.2°C for water temperature.

Portable meters were used to make the field measurements for specific conductance, pH, and alkalinity; the measurements were made using methods outlined by Wilde and Radtke (1998). All instruments were calibrated in the field prior to sample collection. Dissolved-oxygen measurements were made by Winkler titration. Water temperature was measured using a hand-held alcohol-filled thermometer that had a full-scale accuracy of 0.5°C or using a built-in thermistor attached to the conductivity probe (which had an accuracy of plus or minus 0.1°C). Both measuring devices were frequently checked against an American Standard Laboratory and Materials standard mercury thermometer and were within 0.5°C. Instrument log and calibration data are on file at the USGS office in San Diego, California.

Most water samples intended for routine analyses (major ions, nutrients, and trace elements) were pressure filtered in the field using a membrane polyethersulfone (PES) filter capsule that has a pore size of 0.45 µm. Laboratory samples intended for the analysis of pH, specific conductance, and acid-neutralizing capacity were not filtered. Polyethylene bottles were used to contain most of the samples and were rinsed three times using sample site water prior to filling. Samples collected for nutrient determinations were contained in a dark, opaque polyethylene bottles, and preserved on ice to inhibit bacterial growth. Samples for cation and selected trace element determinations were collected in acid-rinsed polyethylene bottles and preserved by acidifying the sample to a pH less than 2 using a small volume of concentrated nitric acid. Samples were shipped to the USGS National Water Quality Laboratory (NWQL) in Arvada, Colorado, for analysis following standard methods outlined by Fishman (1993), Faires (1993), and Struzeski and others (1996).

Water samples for analysis of the stable isotopes deuterium and oxygen-18 were collected in 60-milliliter glass bottles. The samples were not filtered. The bottles were not rinsed, but were sealed with a polyseal (conical) cap to minimize exchange with the atmosphere. These samples were shipped to the USGS Stable Isotope laboratory in Reston, Virginia, for analysis according to methods outlined by Coplen and others (1991). The result of these analyses are expressed in terms of per mil relative to Vienna Standard Mean Ocean Water (Gonfiantini, 1984). The estimate of precision (two sigma) for deuterium and oxygen-18 is 2 per mil and 0.2 per mil, respectively.

Water samples intended for the analysis of tritium were collected in 1-liter polyethylene bottles. The samples were not filtered. Bottles were not rinsed, and care was taken not to aerate the sample during collection. Samples were sealed with a polyseal (conical) cap to minimize exchange with the atmosphere. These samples were analyzed by USGS laboratories or by laboratories under contract arrangements with the USGS. The activity of tritium is reported in terms of tritium units (TU) with a two-sigma estimate of precision. Each tritium unit equals 1 atom of ^{3}H in 10^{18} atoms of hydrogen.

Water samples for analysis of carbon-13 and carbon-14 isotopes were collected in 1-liter amber glass bottles. Samples were filtered in the field using a membrane (PES) filter capsule with a 0.45-µm pore size. The bottle was bottom-filled and allowed to overflow an amount several times the bottle volume, then sealed with a Teflon-septa cap and held on ice. Carbon-13 and carbon-14 isotopes of the dissolved inorganic carbon were analyzed by contract laboratories approved by the USGS. Results of the carbon-13 analyses are reported in per mil relative to the Vienna PeeDee belemnite standard (Coplen, 1994). The activity of carbon-14 is reported with a one-sigma estimate of precision relative to the 1950 National Bureau of Standards for oxalic acid standard (Stuiver and Polach, 1977; Wigley and Muller, 1981).

DATA PRESENTATION

Mojave River Ground-Water Basin

Seventy-seven monitoring sites were constructed in the Oeste, Alto, Transition Zone, Centro, and Baja subareas of the Mojave River ground-water basin (fig. 2). Data for these monitoring sites are presented by subarea in appendixes A through E in graphic (figs. A1–E11) and tabular (tables A1–E13) format.

Oeste Subarea

One monitoring site (a single well) was constructed within the Oeste subarea; the location of the subarea and of this monitoring site is shown in figure A1. Well-construction data are given in table A1, and a detailed lithologic log is shown in table A2. The gamma-ray log for this site, the generalized stratigraphic column, and the well diagram are shown in figure A2. Water-level and water-quality data are presented in tables A3 and A4, respectively.

Alto Subarea

Nine monitoring sites were constructed within the Alto subarea; the location of the subarea and of the monitoring sites is shown in figure B1. Well-construction data are given in table B1, and detailed lithologic logs, for those wells with logs, are given in tables B2 through B9. Any geophysical logs of the boreholes, generalized stratigraphic columns, and well diagrams are shown in figures B2 through B9. Water-level and water-quality data are given in tables B10 and B11, respectively.

Transition Zone Subarea

Thirty monitoring sites were constructed within the Transition Zone subarea; the location of the subarea and of the monitoring sites is shown in figure C1. Well-construction data are given in table C1, and detailed lithologic logs, for those wells with logs, are given in tables C2 through C18. Any geophysical logs made of the boreholes, generalized stratigraphic columns, and well diagrams are shown in figures C2 through C18. Water-level and water-quality data are given in tables C19 and C20, respectively.

Centro Subarea

Twenty-two monitoring sites were constructed within the Centro subarea; the location of the subarea and of the monitoring sites is shown in figure D1. Well-construction data are given in table D1, and detailed lithologic logs are given in tables D2 through D23. Geophysical logs made of the boreholes, generalized stratigraphic columns, and well diagrams are shown in figures D2 through D23. Water-level and water-quality data are given in tables D24 and D25, respectively.

Baja Subarea

Fifteen monitoring sites were constructed within the Baja subarea; the location of the subarea and of the monitoring sites is shown in figure E1. Well-construction data are given in table E1, and detailed lithologic logs, for those wells with logs, are given in tables E2 through E11. Any geophysical logs made of the boreholes, generalized stratigraphic columns, and well diagrams are shown in figures E2 through E11. Water-level and water-quality data are given in tables E12 and E13, respectively.

Morongo Ground-Water Basin

Eight monitoring sites were constructed within the Lucerne and Warren subbasins of the Morongo ground-water basin (fig.2). Data for these sites are presented by subbasin in appendixes F and G in graphic (figs. F1–F6 and G1–G3, respectively) and tabular (tables F1–F8 and G1–G5, respectively) format.

Lucerne Subbasin

Six monitoring sites were constructed within the Lucerne subbasin; the location of the subbasin and of the monitoring sites is shown in figure F1. Well-construction data are given in table F1, and detailed lithologic logs are given in tables F2 through F6. Geophysical logs of the boreholes, generalized stratigraphic columns, and well diagrams are shown in figures F2 through F6. Water-level and water-quality data are given in tables F7 and F8, respectively.

Warren Subbasin

Two monitoring sites were constructed within the Warren subbasin; the location of the subbasin and of the monitoring sites is shown in figure G1. Well-construction data are given in table G1, and detailed lithologic logs are given in tables G2 and G3. Geophysical logs of the boreholes, generalized stratigraphic columns, and well diagrams are shown in figures G2 and G3. Water-level and water-quality data are given in tables G4 and G5, respectively.

ACCESSING DATA

Users of the data presented in this report are encouraged to access information through the USGS National Water Information System Web page (NWISWeb) located at http://waterdata.usgs.gov/nwis/

NWISWeb serves as an interface to a database network of site information, real-time, ground-water, surface-water, and water-quality data collected from locations throughout the 50 states and elsewhere. Data are updated from the database network on a regularly scheduled basis.

Data are retrieved by category and geographic area and can be selectively refined by specific location or parameter field. NWISWeb can output water-level and water-quality graphs, site maps, data tables (in HTML and ASCII format) and develop site-selection lists.

Updates to data presented in this report after publication are made to the U.S. Geological Survey's NWIS. Additional geophysical logs, sample collection notes, and other information not contained in NWIS are kept on file at the USGS office in San Diego, California. Formal requests for specific data should be directed to the U.S. Geological Survey, California District Office, Hydrologic Data Center located in Sacramento, California.

SUMMARY

Eighty-five ground-water monitoring sites were constructed in the Mojave River and Morongo ground-water basins of San Bernardino County, California, as part of a series of cooperative studies between the U.S. Geological Survey and the Mojave Water Agency to help evaluate and address water-supply and water-quality issues. One to five small (generally 2-in.) diameter wells were installed at each of the monitoring sites to collect depth-dependent hydrologic data. Lithologic logs were compiled from descriptions of drill cuttings and cores collected during the drilling at each site and from observations recorded during the drilling of the boreholes. Generalized stratigraphic columns were compiled by grouping similar lithologic units. Geophysical logs provide information on the character of the lithologic units and the presence and chemical characteristics of ground water. Water-level and water-quality data were collected periodically at the sites from 1992 through 1998.

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