Regional Water Table (2004) and Water-Level Changes in the Mojave River and Morongo Ground-Water Basins, Southwestern Mojave Desert, California

By Christina L. Stamos, Julia A. Huff, Steven K. Predmore, and Dennis A. Clark

In cooperation with the
MOJAVE WATER AGENCY

Scientific Investigations Report 2004-5187

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Geological Survey, Reston, Virginia: 2004
For sale by U.S. Geological Survey, Information Services
Box 25286, Denver Federal Center
Denver, CO 80225-0286

For more information about the USGS and its products:
Telephone: 1-888-ASK-USGS
World Wide Web: http://www.usgs.gov/

Suggested citation:
Stamos, C.L., Huff, J.A., Predmore, S.K., and Clark, D.A., 2004, Regional Water Table (2004) and Water-Level Changes in the Mojave River and Morongo Ground-Water Basins, Southwestern Mojave Desert, California: U.S. Geological Survey Scientific Investigations Report 2004–5187, 7 p.

Contents

Plate

Figures

Conversion Factors, Datum, and Abbreviations

CONVERSION FACTORS

Multiply	By	To obtain
feet (ft)	0.3048	meter
inch (in.)	2.54	centimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometers
square miles (mi^2)	12.590	square kilometers

DATUM

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

ABBREVIATIONS

SWP California State Water Project

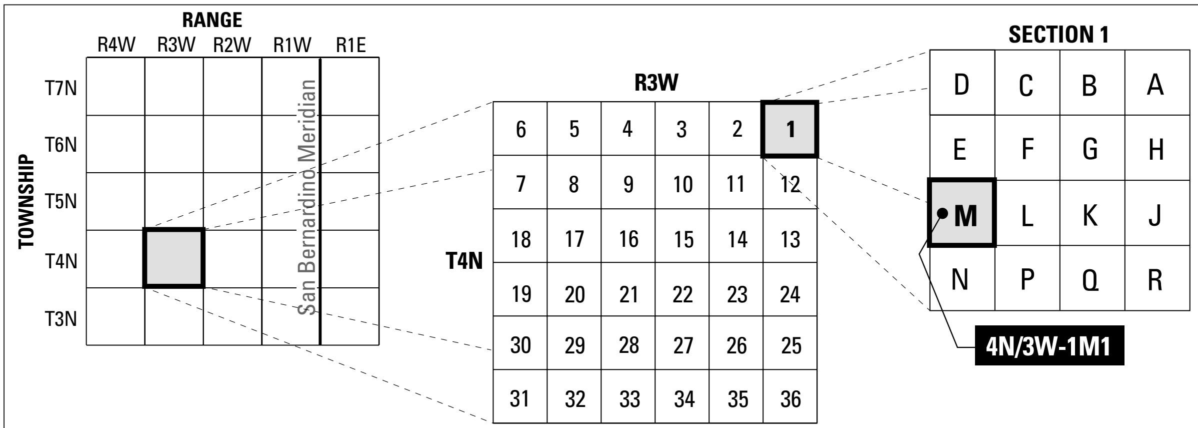
Organizations

MWA Mojave Water Agency

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). All wells in the study area are referenced to the San Bernardino base line and meridian (S). Well numbers consist of 15 characters and follow the format 004N003W01M001S. In this report, well numbers are abbreviated and written 4N/3W-1M1. Wells in the same township and range are referred to only by their section designation, 1M1. The following diagram shows how the number for well 4N/3W-1M1 is derived.



Well-numbering diagram (Note: maps in this report use abbreviated well numbers such as **"1M1"**)

Regional Water Table (2004) and Water-Level Changes in the Mojave River and the Morongo Ground-Water Basins, Southwestern Mojave Desert, California

By Christina L. Stamos, Julia A. Huff, Steven K. Predmore, and Dennis A. Clark

Abstract

The Mojave River and Morongo ground-water basins are in the southwestern part of the Mojave Desert in southern California. Ground water from these basins supplies a major part of the water requirements for the region. The continuous population growth in this area has resulted in ever-increasing demands on local ground-water resources. The collection and interpretation of ground-water data helps local water districts, military bases, and private citizens gain a better understanding of the ground-water flow systems, and consequently, water availability.

During March and April 2004, the U.S. Geological Survey and other agencies made almost 900 water-level measurements in about 740 wells in the Mojave River and Morongo ground-water basins. These data document recent conditions and, when compared with historical data, changes in ground-water levels. A water-level contour map was drawn using data from 500 wells, providing coverage for most of the basins. In addition, 26 long-term (as much as 74 years) hydrographs were constructed which show water-level conditions throughout the basins, 9 short-term (1992 to 2004) hydrographs were constructed which show the effects of recharge and discharge along the Mojave River, and a water-level-change map was compiled to compare 2002 and 2004 water levels throughout the basins.

The water-level change data from 334 wells show that more than one half (102) of the wells in the Mojave River ground-water basin had water-level declines of 0.5 ft or more, and almost one fifth (32) of the wells had declines greater than 5 ft. between 2002 and 2004. The water-level change data also show that about one tenth (17) of the wells compared in the Mojave River ground-water basin had water level increases of 0.5 ft or more. Most of the water-level increases were the result of stormflow in the Mojave River during March 2004, which resulted in recharge to wells in the floodplain aquifer mainly along the river in the Alto subarea and the Transition zone, and along the river east of Barstow. In the Morongo ground-water basin, nearly one half (55) of the wells had water-level declines of 0.5 ft or more, and about one tenth (13) of the wells had declines greater than 5 ft. The Warren subbasin, where artificial-recharge operations in Yucca Valley (pl. 1) have caused water levels to rise, had water-level increases of as much as about 97 ft since 2002.

Introduction

The Mojave River and Morongo ground-water basins are in the southwestern part of the Mojave Desert in southern California, approximately 80 and 40 mi northeast, respectively, of Los Angeles (fig. 1, pl. 1). Surface water in these basins is minimal and normally is limited to ephemeral flow during winter and spring storms and discharge from perennial springs in some areas of the Morongo ground-water basin. The major source of surface water is the Mojave River; however, its flow is unpredictable and not a dependable source for water supply because most of the river's 100-mile channel usually is dry. The lack of significant surface-water resources has resulted in the use of ground water as the primary source for private, agricultural, and municipal supply. Because of increasing urbanization, demands on local water supplies have created overdraft conditions in some areas of the desert basins. Periodic monitoring of ground-water levels aids in the management of the Mojave River and Morongo ground-water basins.

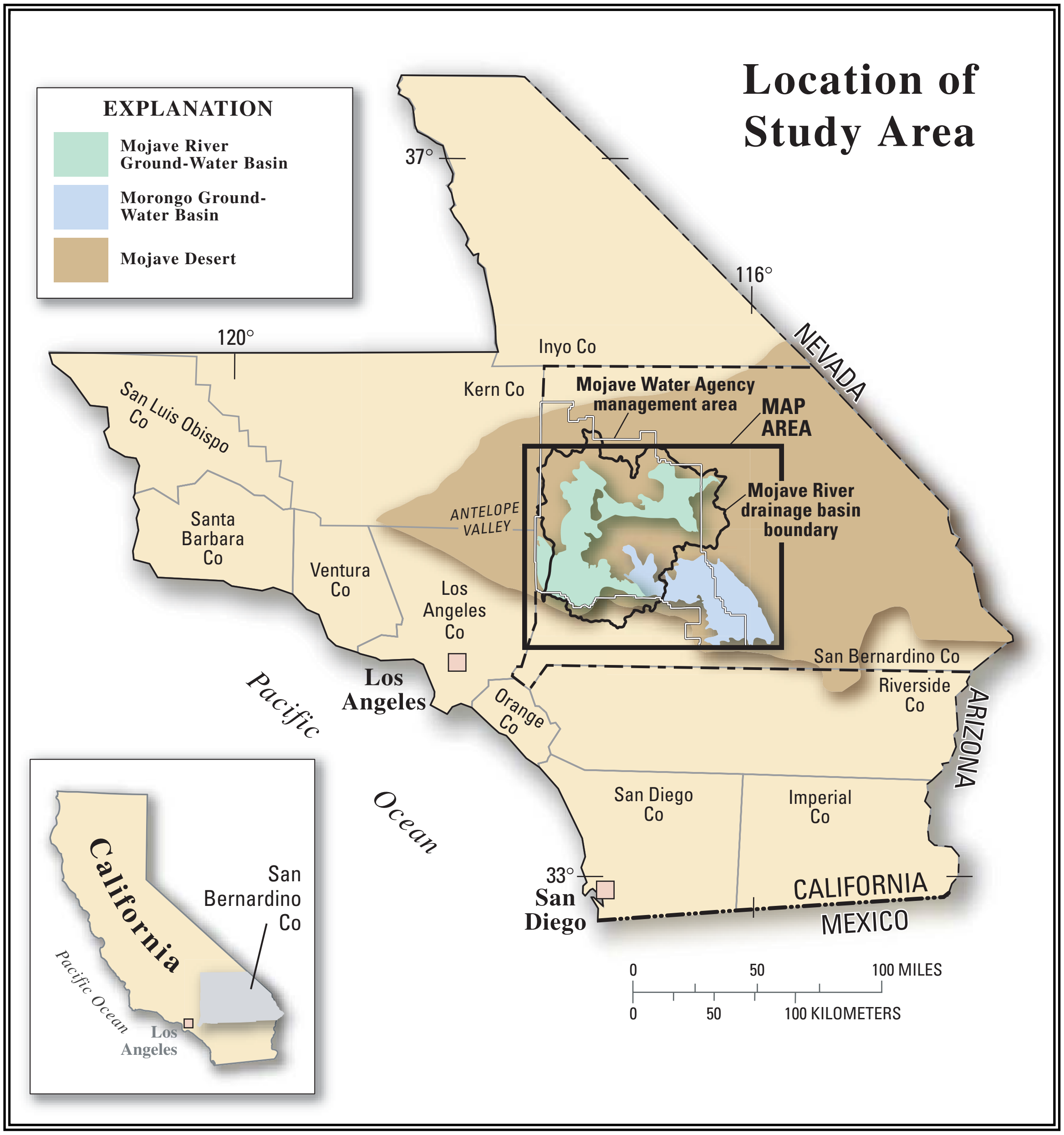


Figure 1. Location of the Mojave River and Morongo ground-water basins in the southwestern Mojave Desert, California.

Purpose and Scope

The U.S. Geological Survey (USGS), in cooperation with the Mojave Water Agency (MWA), constructed a water-table map describing the ground-water conditions in the spring (March and April) of 2004 in a continuing effort to monitor ground-water conditions in the Mojave River and Morongo ground-water basins. Almost 900 water-level measurements were collected by the USGS, the MWA, and local water districts in about 740 wells during March and April 2004. Water-level data collected from 500 of the wells were used to construct the map, which shows the altitude of the water table and general direction of ground-water movement. Historical water-level data were used in conjunction with data collected from this study to construct water-level hydrographs to show both long-term (1930–2004) and short-term (1992–2004) water-level changes in the Mojave River and Morongo ground-water basins. Water-level changes between spring 2002 and spring 2004 were determined by comparing water levels measured in the same well during both periods. Data presented in this report are referenced to the North American Vertical Datum of 1988 (NAVD 88). This report is a continuation of a series of previously published USGS reports and maps (Stamos and Predmore, 1995; Trayler and Koczot, 1995; Mendez and Christensen, 1997, Smith and Pimentel, 2000; Smith, 2002; and Smith and others, 2004).

Description of Study Area

The Mojave River and Morongo ground-water basins together encompass about 2,400 mi^2. The climate of these basins is typical of the Mojave Desert region of southern California. Most areas of the basin floor receive 4 to 6 in/yr of precipitation, although annual precipitation can be greater than 40 in. in the southern and eastern San Bernardino and the San Gabriel Mountains (Lines, 1996). Recharge to the ground-water system from direct infiltration of precipitation is minimal.

The Mojave River ground-water basin (fig. 1) is approximately 1,400 mi^2 and extends from the San Bernardino and the San Gabriel Mountains in the south to north of Harper and Coyote Lakes (dry) (pl. 1). The ground-water basin is bordered on the west by Antelope Valley and shares its southeastern boundary with the Morongo ground-water basin. For water-management purposes, the Mojave River ground-water basin was divided into five subareas, partially based on the Mojave River drainage basin boundary: Alto (including the Transition zone), Baja, Centro, Este, and Oeste (fig. 2).

The primary source of ground-water recharge in the Mojave River ground-water basin is intermittent streamflow in the Mojave River, which usually occurs during January through March, and from sporadic releases of imported water from the California State Water Project (SWP) at the Rock Springs, Hodge, and Lenwood recharge sites (pl. 1). Since July 1994, the basin has received SWP water at the Rock Springs Outlet (near well 4N/3W-31L9) southeast of Hesperia (Mojave Water Agency, 1996); the basin has also received SWP water at the Lenwood recharge site (near well 9N/3W-1R7) and at the Hodge recharge site (near well 9N/3W-23D2) (pl. 1) since 1999 (Stamos and others, 2001).

The Morongo ground-water basin is about 1,000 mi^2 and is surrounded by the Ord and Granite Mountains to the north, the Bullion Mountains to the east, the San Bernardino Mountains to the southwest, and (not shown on pl. 1) the Pinto and Little San Bernardino Mountains to the south. The Morongo ground-water basin is separated into 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. 2). The Morongo ground-water basin is recharged by infiltration from flow in ephemeral stream channels and, since 1995, from SWP water recharged to ponds at the Hi-Desert recharge site (near well 1N/5E-36M5) in the Warren subbasin.

Acknowledgments

This report could not have been completed without the assistance provided by the city of Adelanto, the Apple Valley Ranchos Water Company, the Baldy Mesa Water District, the County of San Bernardino, the Hesperia Water District, the Bighorn-Desert View Water Agency, the Hi-Desert Water District, the Joshua Basin Water District, the Lockheed Martin Corporation, the Sheep Creek Water Company, the Southern California Water Company, the Twentynine Palms Water District, and the Victor Valley Water District. Appreciation is also expressed to the private well owners who provided access to their wells, to staff members from the MWA for collecting and providing data, and to the many USGS personnel that contributed to this project.

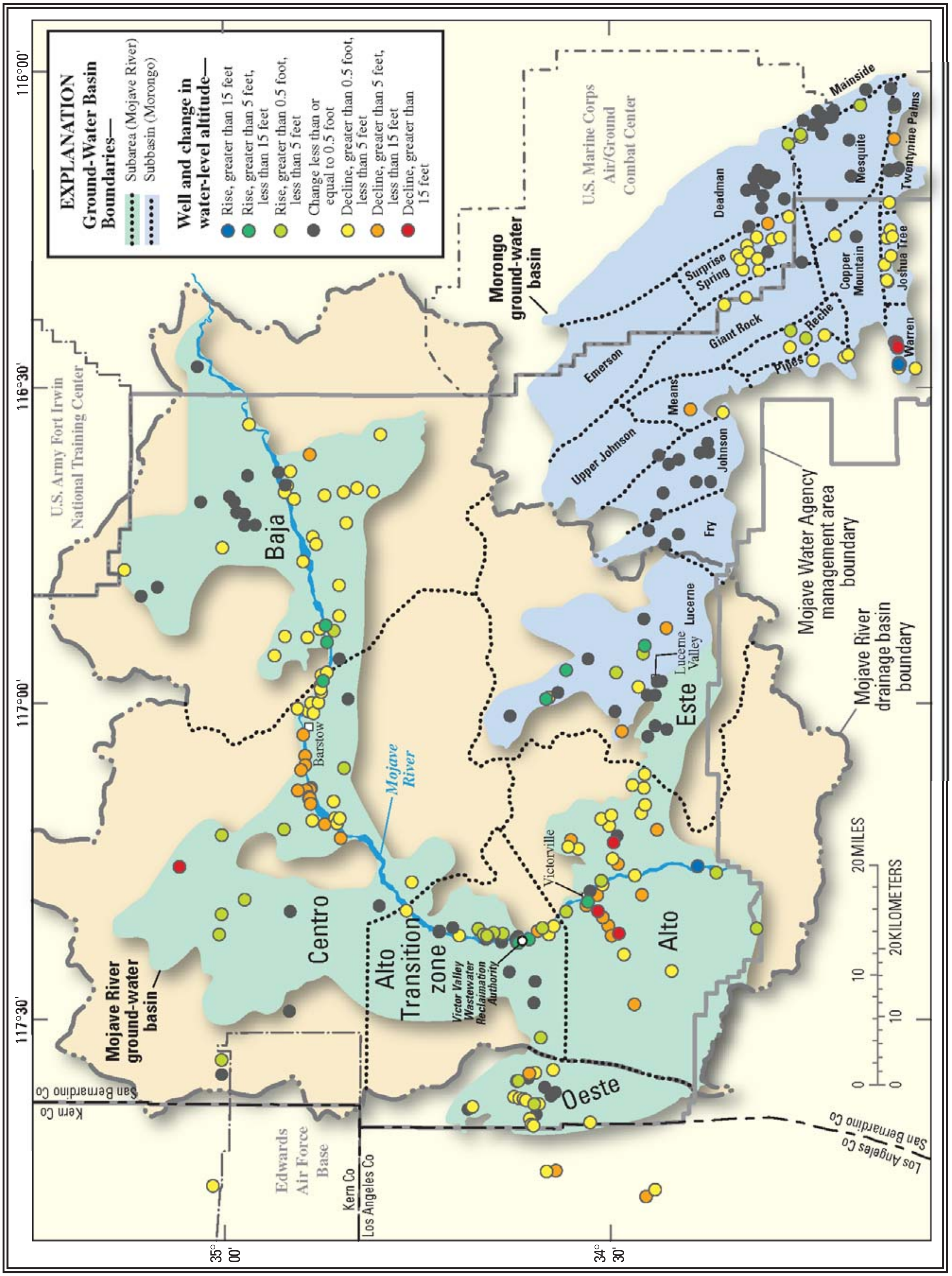


Figure 2. Water-level changes between spring 2002 and spring 2004 in the Mojave River and Morongo ground-water basins in the southwestern Mojave Desert, California.

Geohydrology

The boundaries of the Mojave River and the Morongo ground-water basins generally are defined by the contact between the water-bearing unconsolidated deposits and the surrounding and underlying non-water-bearing consolidated igneous and metamorphic rocks. The ground-water system in the Mojave River Basin consists of two unconfined aquifers, which are part of the Basin and Range aquifers in southern California (Planert and Williams, 1995). The most productive aquifer is the floodplain aquifer, which is composed of permeable young river deposits of Holocene age and older river deposits of Pleistocene age. This aquifer is as much as 200 ft thick and yields most of the ground water pumped from the Mojave River Basin (Stamos and others, 2001). The most widespread aquifer in the area is the regional aquifer; it is composed of unconsolidated older alluvium and fan deposits of Pleistocene to Tertiary age. In some places, the regional aquifer also consists of partly consolidated to consolidated sedimentary deposits of Tertiary age. The regional aquifer is as much as 1,000 ft thick. Other geologic units, such as bedrock and lake deposits, commonly contain ground water, but they are not considered reliable sources of ground water in the study area.

The Mojave River and Morongo ground-water basins are separated by the Helendale Fault, which acts as a barrier to ground-water flow near Lucerne Valley (pl. 1). The regional aquifer in the Morongo ground-water basin consists of continental deposits of Quaternary and Tertiary age that extend to as much as 10,000 ft deep (Moyle, 1984). For a more comprehensive description of the geohydrology of the ground-water basins, the reader is referred to Stamos and others (2001), Smith and Pimentel (2000), and Mendez and Christensen (1997).

Perched ground water has been identified in three areas of the Mojave River and Morongo ground-water basins. Perched ground water is unconfined ground water separated from an underlying body of ground water by an unsaturated zone (Lohman, 1972). The approximate areas of perched ground water are near El Mirage Lake (dry), Lucerne Valley (Jill Densmore, U.S. Geological Survey, written commun., 1999) and Mesquite Lake (dry) (Mendez and Christensen, 1997) (pl. 1).

Ground-Water Levels and Flow

In March and April 2004, water-level measurements were attempted in about 740 wells in the Mojave River and Morongo ground-water basins to measure the altitude of the water table and to determine the direction of ground-water flow (pl. 1). It was not possible to obtain accurate water-level measurements in wells that were being pumped, had nearby pumping, or had obstructions; therefore, static water-level data were collected from 500 wells. The water-level data from these wells were used to construct the map, which shows the altitude of the water table and general direction of ground-water movement. To download a file containing the USGS site and California State well numbers for the wells used to construct the maps in this report, go to http://pubs.water.usgs.gov/sir2004-5187/. This file can be used to retrieve water-level and water-quality data from the USGS National database by going to http://waterdata.usgs.gov/ca/nwis.

The water table is the surface on which the fluid pressure in the pores of a porous medium is exactly atmospheric (Freeze and Cherry, 1979). The water table is defined by the levels at which water stands in wells that just penetrate the top of the water body (Lohman, 1972). The water-level measurements used for plate 1 are from wells with various perforated intervals in the saturated zone (ground-water body). Although these wells may have different perforated zones, the measured water levels from the zones are within about 10 ft and, therefore, reasonably represent the water-table altitude. In addition, the measured water levels can be used to infer the general direction of ground-water flow.

Ground water flows from areas of higher hydraulic head to areas of lower hydraulic head (downgradient), and perpendicular to the water-level contours (pl. 1). Water-level contours from the 2002 water-level map (Smith and others, 2004) were used as a guide to interpret the 2004 water-level contours in areas where 2004 water-level data were not available. In some areas of the map, water-levels were affected by recent pumping, or nearby wells that were pumping, which resulted in steep water-level gradients and water-level contours that bend abruptly around wells.

As part of a ground-water observation network, the USGS, in cooperation with local water agencies, water districts, the military, and private landowners, has constructed many multiple-well monitoring sites. These sites consist of a cluster of two or more observation wells completed at different depths within a single borehole, each typically screened across a 20-foot interval. Data from the shallowest well of a multiple-well site were used for the regional water-table map. In areas of a perched water table, both the perched and regional water levels are shown on the water-level map (pl. 1). The 2004 water levels were measured using a steel tape or a calibrated electric tape; when neither of these methods was possible, an airline was used. Water-level data collected by other agencies for this report were validated and deemed to adhere to USGS guidelines (noted as "reported" in the USGS National database). The water-level altitude was determined by subtracting the water-level measurement (depth to water, in feet below land surface) from the established land-surface referenced to the North American Vertical Datum 1988 (NAVD 88).

Water-Level Changes

Historical water-level data were used in conjunction with data collected during this study to determine both long-term (1930–2004) and short-term (1992–2004) water-level changes in the Mojave River and Morongo ground-water basins. Long-term water-level changes are depicted by 26 water-level hydrographs (pl. 1). Some hydrographs combine data from more than one well to show water-level changes over a greater period of time for a particular area. The long-term hydrographs for the Mojave River ground-water basin show that water levels have declined between 50 and 75 ft in the Alto subarea (pl. 1, fig. 2) since the mid-1940s (well 5N/5W-22E1, -22E2, -22E6), about 75 ft in the Harper Lake region of the Centro subarea since the 1960s (well 11N/4W-29R1), and more than 100 ft in the Baja subarea since the early 1950s (well 9N/1E-10L1, -4K3). The long-term hydrographs for the Morongo ground-water basin show little or no change in most of the subbasins, but there have been significant water-level declines in five of the subbasins due to pumping. Water levels have declined about 40 ft in the Joshua Tree subbasin since the early 1960s (well 1N/7E-32C1), about 50 ft in the Reche subbasin since the early 1960s (well 2N/6E-18B1), about 100 ft in the Lucerne subbasin since the mid 1950s (well 5N/1W-25G1), about 150 ft in the Surprise Spring subbasin since the early 1950s (well 2N/7E-2C1), and more than 300 ft in the Warren subbasin between the mid 1940s and 1995 (well 1N/5W-36K1, -36K2) (pl. 1, fig. 2). The rapid decline in some wells in the Warren subbasin has been reversed since 1995 because of artificial recharge to ponds at the Hi-Desert recharge sites (pl. 1).

Nine short-term hydrographs were constructed from data collected between 1992 and 2004 in the Mojave River ground-water basin (pl. 1) to record the effects of seasonal recharge and discharge along the river and the effects of evapotranspiration of riparian vegetation, which is minimal during winter. These short-term hydrographs show that, since 1992, there has been some recharge to the floodplain aquifer from stormflows in the Mojave River in the Alto and Centro subareas, but that there has been minimal recharge from stormflows in the Baja subarea. In the Transition zone, the ground-water levels in the vicinity of well 7N/5W-23R3 (pl. 1) remained stable owing to recharge from treated wastewater that is discharged about 4 mi upstream by the Victor Valley Wastewater Reclamation Authority (fig. 2).

A water-level change map (fig. 2) was prepared by comparing water levels from the same wells during spring 2002 and spring 2004; 334 wells had water-level data for both years in the study area. About one third (119) of the water levels in 2004 were within 0.5 ft of the water levels in 2002. One half (167) of the wells had water-level declines of 0.5 ft or more and about one tenth (48) of the wells had declines greater than 5 ft. Of the 179 wells compared within the Mojave River ground-water basin, more than one half (102) of the wells had water-level declines of 0.5 ft or more and almost one fifth (32) of the wells had declines greater than 5 ft. The water-level change data also show that about one tenth (17) of the wells compared in the Mojave River ground-water basin had water level increases of 0.5 ft or more. Most of these increases were the result of stormflow in the Mojave River during March 2004 which resulted in recharge to wells in the floodplain aquifer mainly along the river in the Alto subarea and the Transition zone and along the river east of Barstow (fig. 2). Some increases also occurred near Harper Lake (dry) (pl. 1) where there has been a significant reduction in pumpage during the last decade (Stamos and others, 2001), resulting in steadily increasing water levels since the early 1990s.

Of the 138 wells compared within the Morongo ground-water basin, nearly one half (55) of the wells had water-level declines of 0.5 ft or more, and about one tenth (13) of the wells had declines greater than 5 ft. The water-level change data also show that about one tenth (13) of the wells compared had water level increases of 0.5 ft or more. These increases occurred mainly in the Warren subbasin, where artificial-recharge operations in Yucca Valley have caused water levels to rise as much as 97 ft since 2002. (pl. 1).

References Cited

Bortugno, E.J., 1986, Map showing recency of faulting, San Bernardino Quadrangle, California Division of Mines and Geology Regional Geologic Map Series, San Bernardino Quadrangle-map no. 3A, scale 1:250,000.

Cox, B.F., and Wilshire, H.G., 1993, Geologic map of the area around the Nebo Annex, Marine Corps Logistics Base, Barstow, California: U.S. Geological Survey Open-File Report 93-568, 36 p., 1 map sheet, scale 1:12,000.

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

Lines, G.C., 1996, Ground-water and surface-water relations along the Mojave River, Southern California: U.S. Geological Survey Water-Resources Investigations Report 95-4189, 43 p.

Lohman, S.W., 1972, Definitions of selected ground-water terms—Revisions and conceptual refinements: U.S. Geological Survey Water-Supply Paper 1988, 21 p.

Londquist, C.J., and Martin, Peter, 1991, Geohydrology and ground-water-flow simulation of the Surprise Spring Basin aquifer system, San Bernardino County, California, U.S. Geological Survey Water-Resources Investigations Report 89-4099, 41 p.

Mendez, G.O., and Christensen, A.H., 1997, Regional water table (1996) and water-level changes in the Mojave River, Morongo, and Fort Irwin ground-water basins, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations Report 97-4160, 34 p., map in pocket.

Mojave Water Agency, 1996, First annual engineer's report on water supply for water year 1994-95: Victorville, California, 55 p.

Moyle, W.R., 1984, Bouguer gravity anomaly map of the Twentynine Palms Marine Corps Base and vicinity, California: U.S. Geological Survey Water-Resources Investigations Report 84-4005, scale 1:65,500, 1 sheet.

Planert, Michael, and Williams, J.S., 1995, Ground water atlas of the United States: Segment 1, California, Nevada: U.S. Geological Survey Hydrologic Investigations Atlas 730-B.

Schaefer, D.H., 1979, Ground-water conditions and potential for artificial recharge in Lucerne Valley, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations Report 78-118, 37 p.

Smith, G.A., Stamos, C.L., and Predmore, S.K., 2004, Regional water table (2002) and water-level changes in the Mojave River and Morongo ground-water basins, Southwestern Mojave Desert, California: U.S. Geological Survey Scientific Investigations Report 04-5081, http://water.usgs.gov/pubs/sir/2004/5081/.

Smith, G.A., 2002, Regional water table (2000) and ground-water-level changes in the Mojave River and the Morongo ground-water basins, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations Report 02-4277, http://water.usgs.gov/pubs/wri/wri024277/.

Smith, G.A., and Pimentel, M.I., 2000, Regional water table (1998) and ground-water-level changes in the Mojave River and the Morongo ground-water basins, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations Report 00-4090, 107 p., map in pocket.

Stamos, C.L., Martin, Peter, Nishikawa, Tracy, and Cox, B.F., 2001, Simulation of ground-water flow in the Mojave River ground-water basin, California: U.S. Geological Survey Water-Resources Investigations Report 01-4002, 129 p.

Stamos, C.L., and Predmore, S.K., 1995, Data and water-table map the of the Mojave River ground-water basin, San Bernardino County, California, November 1992: U.S. Geological Survey Water-Resources Investigations Report 95-4148, scale 1:125,000, 1 sheet.

Trayler, C.R., and Koczot, K.M., 1995, Regional water table (1994) and water-level changes in the Morongo Basin, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations Report 95-4209, scale 1:125,000, 1 sheet.