DEUTERIUM CONTENT OF WATER FROM WELLS AND PERENNIAL SPRINGS, SOUTHEASTERN CALIFORNIA

U.S. GEOLOGICAL SURVEY

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REGIONAL AQUIFER-SYSTEM ANALYSIS

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By Jim D. Gleason[1], Guida Veronda[2], George I. Smith[1], Irving Friedman[1], *and* Peter Martin[1]

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
meter (m)	3.281	foot
kilometer (km)	0.614	mile

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$\text{Temp. } ^\circ F = 1.8 (\text{temp. } ^\circ C) + 32.$$

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

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Abstract

The deuterium (D) content of about 300 ground-water samples from wells and perennial springs in southeastern California, and the oxygen-18 content of 101 of these samples are presented and evaluated. These stable-isotope data were compiled, as part of the southern California basins Regional Aquifer-System Analysis study, as an aid to determining the quantity and distribution of recharge and the flow between aquifer layers in the study area.

Values of delta D range from -130 per mil in the northern part of the study area to -60 per mil in the southern part. The observed distribution of delta-D values is the result of orographic and meteorologic processes. Differences between delta-D values of sampled ground water and those of precipitation indicate that recent recharge from local precipitation is relatively insignificant in many areas. Anomalously "heavy" or "light" delta-D values, relative to regional trends, are attributed to discharge and evaporation of ground water at playa lakes, recharge of river water, and interruption of ground-water flow in unconsolidated sediments by faults.

INTRODUCTION

The areal distribution of the concentrations of the stable isotopes deuterium and oxygen-18 in ground water in southeastern California is depicted and evaluated in this report. The deuterium content of about 300 ground-water samples and the oxygen-18 content of 101 of these samples are presented. Thirty-two of the samples were collected by the U.S. Geological Survey in 1977-78 as part of a study to determine the mineral and brine potential of playa lakes in selected basins in southeastern California. Most of the remaining samples were collected during the winters and springs of 1981 and 1982 as part of the Climate Change Program of the U.S. Geological Survey. Selected additional samples were collected through 1986. Stable-isotope data from three previous studies also have been included. These data are for 19 samples from the Coso thermal area east of the southern Sierra Nevada (Fournier and Thompson, 1980, tables 1 and 2); 5 samples from areas in

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Nevada just east of Death Valley (Winograd and Friedman, 1972, table 1); and 9 samples from the Imperial Valley (Coplen, 1971, table 1). Also presented, for comparison, are weighted averages of deuterium content of recent precipitation collected for the purposes of this report at 32 stations over the 7-year period April 1982 to April 1989 (Irving Friedman and G. I. Smith, U.S. Geological Survey, written commun., 1989).

The compilation of stable-isotope data presented here was done as part of the Regional Aquifer-System Analysis (RASA) program. The objectives of the southern California basins RASA study are to (1) determine the geohydrologic framework of the coastal and desert basins in southern California excluding the Central Valley, and (2) identify and analyze major issues and problems affecting the use of ground water in these basins (Martin, 1986). The quantity and distribution of recharge and the flow between aquifer layers are issues that have been selected for detailed investigation during this RASA study; the data on stable-isotope ratios of ground water presented in this report will be useful in addressing both issues.

Collection of the new (1981-86) samples included in this report required the assistance and cooperation of many persons--including landowners and employees of ranches and water districts who provided access to wells and well-construction and other data. Although it is not possible to cite all of them, the following people, acting on behalf of themselves as well as their organizations, deserve our special thanks: J.P. Calzia, E. Carlson, J.A. Crowley, R.D. Dockter, E. N. Eldridge, G.E. Ericksen, L. Lunk, J. McConaha, G.F. Moulton, L.L. Reise, A. Romspert, and G.T. Server.

STABLE-ISOTOPE CHEMISTRY

The ratios of the heavy isotopes of oxygen (oxygen-18 [^{18}O]) and hydrogen (deuterium [D, or ^{2}H]) in ground water, relative to the more abundant isotopes (^{16}O and ^{1}H), are indicators of its hydrologic history. The isotope ratios are expressed in delta notations (δ) as per mil (parts per thousand [‰]) differences relative to the standard known as Vienna Standard Mean Ocean Water (V-SMOW):

$$\delta^{18}O = \frac{(^{18}O^{16}O)\ sample - (^{18}O^{16}O)\ standard}{(^{18}O/^{16}O)\ standard} \times 1{,}000,\ and$$

$$\delta D = \frac{(^{2}H/^{1}H)\ sample - (^{2}H/^{1}H)\ standard}{(^{2}H/^{1}H)\ standard} \times 1{,}000.$$

Oxygen-isotope values have been normalized for 0 per mil V-SMOW and -55.5 per mil Standard Light Antarctic Precipitation (SLAP); hydrogen-isotope values have been normalized for 0 per mil V-SMOW and -428 per mil SLAP. Oxygen and hydrogen samples, run in duplicate, are considered precise to 0.1 and 0.8 per mil, respectively. The relation between δD and $\delta^{18}O$ of natural water was first proposed by Friedman (1953) and later was quantified by Craig (1961), who found that plots of $\delta^{18}O$ and δD in precipitation throughout the world are linearly correlated. This linear relation is referred to as the global meteoric water line (MWL) and is the result of the fact that seawater is the source of most precipitation.

The isotopic composition of seawater is relatively constant; therefore, the isotopic composition of vapor derived from ocean waters having the same temperature also is constant. However, as this water vapor condenses and precipitates, the proportion of heavier isotopes removed is greater than that of the lighter isotopes. This leaves the remaining vapor relatively depleted in oxygen-18 and deuterium. This process is known as isotopic fractionation. Isotopic fractionation is temperature dependent: the lower the temperature of condensation, the greater the fractionation. The net result of these processes is that precipitation from a given storm becomes progressively lighter isotopically as the storm moves inland, and precipitation that condenses at lower temperatures is lighter than precipitation condensing at higher temperatures (Dansgaard, 1964; Friedman and others, 1964).

Evaporation also causes fractionation. When water is evaporated, during the precipitation process or after precipitation reaches the ground, the lighter isotopes of oxygen and hydrogen are preferentially partitioned into the vapor phase, causing the remaining water to be isotopically heavy. After the water becomes recharge and migrates below the depth at which evaporation occurs, little further change in the isotopic composition occurs at the low temperatures of most ground-water systems, although exchange between the oxygen in water and some rocks can occur. Most changes in the isotopic composition of ground water along a flow line reflect primarily the mixing of waters within the aquifer system.

DATA-COLLECTION PROCEDURES AND MEASUREMENT TECHNIQUES

The collection plan and procedures for the 1981-86 samples were designed to provide water samples for analyses of hydrogen- and oxygen-isotope ratios from a representative selection of the perennial springs and deep wells within part of the Basin and Range province and adjacent regions in southeastern California. To avoid collecting samples whose isotope ratios were altered by evaporation while the water was standing in storage tanks or ponds, wells were sampled at the pump while it was operating, provided that the pump had operated long enough to evacuate all water in the well casing. In general, where several wells were available, the deepest well was sampled, although in some areas shallow wells also were sampled to test for any vertical gradients in isotope concentration. In addition, information about depths to the water table, pump or impeller, well casing, perforation zones, and so forth, was compiled. Springs that were sampled, most of which are shown on U.S. Geological Survey topographic maps, were flowing and were sampled at or close to their discharge points. For samples collected during 1977-78, field measurements of specific gravity, pH, and temperature were made. For those wells that have been assigned a State well number in table 1, corroborating and supplemental data are available in U.S. Geological Survey files[1].

Measurements of deuterium concentration were made using techniques described by Friedman (1953) and Friedman and Woodcock (1957). Oxygen-18 analyses were made by first equilibrating a small amount of each water sample with carbon dioxide. The carbon dioxide then was separated from the water and purified before being analyzed in a mass spectrometer for its oxygen-18/oxygen-16 ratio. All brine samples were distilled to dryness and the residue heated to above 250 degrees Celsius (°C) to remove salts before further treatment.

DEUTERIUM CONTENT OF WATER FROM WELLS AND SPRINGS

All stable-isotope data are given in table 1 (at back of report). In general, the listing is from north to south; the specific sequence is determined by the letter and number assigned by the California Department of Water Resources (1964) to the hydrologic units, which are outlined and labeled on the map, and by the sample number within each unit. The letter indicates the drainage province in which the hydrologic unit is located. Most of the data included in this study are from the Lahontan (W) and Colorado River (X) Drainage Provinces. The boundaries of hydrologic units are drawn on the basis of surface-drainage divides. Laboratory number, State well number (where applicable), altitude of land surface, location, water-table and well depths, and other data on the sample source also are given. All data points are plotted on plate 1. Where more than one sample was collected from the same spring or well, average δD values were plotted. Several samples were collected outside the western boundary of the study area; deuterium data from these samples are given in table 1 and are assigned to the hydrologic unit nearest the sample site.

To portray regional patterns in deuterium concentration in the water of deep wells, lines of equal δD values were drawn on plate 1 on the basis of plotted data points, using an interval of 10 per mil. A few individual data points (whose values are enclosed by parentheses) were ignored in drawing the lines because their values clearly are anomalous with respect to the range indicated by the enclosing lines. Deuterium content in water from springs was not considered in plotting these lines, but the δD values of water from springs can be compared with δD values of ground water from wells in nearby areas.

The δD values are negative because all waters are isotopically "lighter" (depleted in deuterium) than seawater. This results from the fact that the area is 75 km or more inland from the Pacific Ocean and the Gulf of California, which are the sources of virtually all atmospheric moisture that falls as precipitation in the area. Some of the deuterium originally in the airmasses that were in nominal equilibrium with seawater (δD = 0 per mil)

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was fractionated into the precipitation that condensed prior to reaching this area of study. This process alone produces a detectable easterly gradient in deuterium content, but the effect of mountains in the paths of storms is more pronounced. As airmasses are forced over high mountains, adiabatic cooling occurs in proportion to the altitude of the mountains. This cooling causes condensation and results in increased deuterium loss from easterly moving airmasses over short horizontal distances (see Smith and others, 1979, p. 173-175). The notably "light" (more negative) values, east of the highest segments of the Sierra Nevada and northeast of the high peaks in the San Bernardino Mountains, are attributed to this process. Conversely, "heavy" (less negative) values are noted inland from low passes in mountainous terrain, particularly in the westernmost part of the Antelope Hydrologic Unit (W26), which is rimmed along its western border by relatively low ranges; "heavy" values also are present along the west edge of the southernmost part of the Imperial Hydrologic Unit (X23), which is bounded by low mountains and is close to the Pacific Ocean and the Gulf of California. The trends of the lines of equal δD values are relatively uninfluenced by the position and trends of areally small or topographically low mountain ranges of the Lahontan and Colorado River Drainage Provinces. The lines of equal δD cross moderate-sized mountain masses, indicating that the mountains either had minimal influence on the deuterium content of moist airmasses, or that extensive interbasin ground-water leakage has occurred since recharge.

The δD values shown on plate 1 range from -130 per mil in the north to near -60 per mil in the south. Most of this range can be attributed to the effect of high mountains noted above. In addition, other north-south δD gradients are produced by the temperature gradients relative to latitude and the statistically greater likelihood of high-latitude storms bringing moisture to the northern areas and low-latitude storms bringing moisture to areas in the south. Both factors, therefore, combine to assure that the more northerly areas commonly receive precipitation that is condensed at lower temperatures than is precipitation falling in the southern areas, resulting in greater fractionation and isotopically "lighter" precipitation in the north than in the south.

Many of the δD values from deep wells and some springs shown on plate 1 are depleted 20 to 30 per mil relative to the weighted average of recent precipitation collected at 32 stations in the study area by Friedman and others (Irving Friedman and G.I. Smith, U.S. Geological Survey, written commun., 1989). The mean δD values (δD_m) for the precipitation-collection stations shown on plate 1 represent 14 semiannual samplings of precipitated rain and snow made during the 7 years between April 1982 and April 1989; the δD values are weighted by the amount of precipitation in each 6-month sample. These data suggest that the isotopically lighter ground-water samples were products of other climatic regimes or abnormal precipitation years, when the amounts of precipitation were well above present norms and the isotopic fractionation was more extreme than at present. Examples of these contrasts between ground water and recent precipitation values are found near the following precipitation stations:

Station	δD_m	Hydrologic unit	Enclosing δD lines
Darwin	-87	W20	-100 and -110
Death Valley	-75	W09	-100 and -110
Goldstone	-64	W17	-90 and -100
Twentynine Palms	-64	X09	-90 and -80
Chiriaco Summit	-58	X18	-80 and -90
Mt. San Jacinto	-84	X19	-60 and -70

Conversely, δD_m values at some stations are similar to δD values of surrounding ground water. Examples:

Station	δD_m	Hydrologic unit	Enclosing δD lines
Tehachapi Pass	-69	W25	-70 and -80
Borrego Springs	-57	X22	-60 and -70

Inspection of plate 1 shows several areas that are isotopically anomalous relative to the regional trends. Many of the anomalously "heavy" δD values for those areas represent samples that were collected from wells or springs associated with one of the many playa lakes found in southeastern California. Some of these playa lakes are regional discharge areas (Moyle, 1974), meaning that ground water flowing toward these areas has approached the surface and evaporated, becoming isotopically enriched in deuterium in comparison with the surrounding ground water in that region. The most extensively sampled of these discharge areas is Searles Lake (Hydrologic Unit W21). Samples collected from wells within the boundary of the dry lake have isotopic values that are at least 50 per mil heavier than those from the surrounding alluvial and bedrock areas. A more complete description of the isotopic character of the brines and salts beneath Searles Lake is included in Friedman and others (1982). Water samples from wells in Bristol, Cadiz, and Danby Lakes (Hydrologic Units X10, X11 and X12, respectively), which are discharge areas, also show the results of evaporation. A single isotopic data point from the playa lake in the middle of the Panamint Hydrologic Unit (W20) suggests that this lake also is a discharge area. In contrast, well samples from beneath the following eight dry lakes show no isotopic evidence of evaporative discharge: Superior (in Hydrologic Unit W19), Cuddeback (W27), El Mirage (W28), Lucerne (X01), Soggy and Melville (X02), Means (X04), and Emerson (X05).

Three other areas that contain anomalous δD values are in the Mojave, Imperial, and Coachella Hydrologic Units. The δD values of water samples from 8 of 11 wells within 5 km of the Mojave River (Mojave Hydrologic Unit W28) are in the -60 to -70 per mil range, whereas wells more than 5 km away from the river yield water with δD values that are 20 per mil, or more, lighter. Three samples of Mojave River water (collected in December 1984 and January and June 1985) have δD values of -57, -61, and -70 per mil. In most years, the Mojave River flows intermittently along this strip underlain by isotopically recent water and well beyond it in flood years (Woolfenden, 1984, p. 8-9). The similarities between the isotopic character of the river-water samples and samples from ground water underlying the river clearly show that the river is the major source of recharge to the alluvium along both sides of its flood plain. Thus, δD values can be helpful in ascertaining the extent of recent recharge and the relation between surface water and ground water.

The Imperial Hydrologic Unit (X13) also contains anomalous δD values in the area southeast of the Salton Sea. Most wells in the nonirrigated parts of the Imperial Hydrologic Unit (the areas west of the New River and east of East Highline Canal) yield water with δD values of -62 to -77 per mil. In the area that is irrigated with water from the Colorado River, δD values average about -90 per mil. In June 1984, river water near Yuma had a δD value of -108, and water samples collected from the All American and East Highline canals had δD values of -107 and -106 per mil. Wells adjacent to the Colorado River and All American Canal in the Yuma (X27) unit and the southern part of the Amos-Ogilby unit (X26) had δD values ranging from -104 to -114 per mil, indicating that these wells are deriving water predominantly from the modern Colorado River, from its prehistoric floodings of this area, or from leakage of the 20th-century irrigation canals. Coplen (1971, p. 115) concluded that recharge by partially evaporated Colorado River water explains the light δD values (average about -90 per mil) of most of the water underlying the below-sea-level southern Imperial Hydrologic Unit.

The Coachella Hydrologic Unit (X19) contains two distinct zones of δD values that appear to be separated by the San Andreas fault system. Water samples from wells northeast of the fault system have δD values that range from -84 to -94 per mil, whereas samples from southwest of the fault system range from -65 to -79 per mil. The δD data indicate that ground-water flow in the unconsolidated deposits of the area is interrupted by the San Andreas fault system, thus demonstrating how δD values can be used to identify barriers to the movement of ground water within an individual hydrologic unit.

OXYGEN-18 ANALYSES

The delta oxygen-18 ($\delta^{18}O$) analyses of samples from 73 wells and springs that were analyzed for this study, plus 28 $\delta^{18}O$ analyses from other studies, are given in table 1 and are plotted against δD in figure 1. The samples chosen for ^{18}O analysis were selected to represent the entire study area and possibly explain some anomalous values. Almost all the samples plot to the right of the meteoric water line in figure 1. Samples that plot the farthest from the meteoric water line are from geothermal wells (W22-03, W24-03, W24-04, X21-03, and X23-09) in which temperatures range from 57° to 232° C. The water from those wells apparently has reacted with the minerals in the enclosing rocks, resulting in an enrichment of oxygen-18.

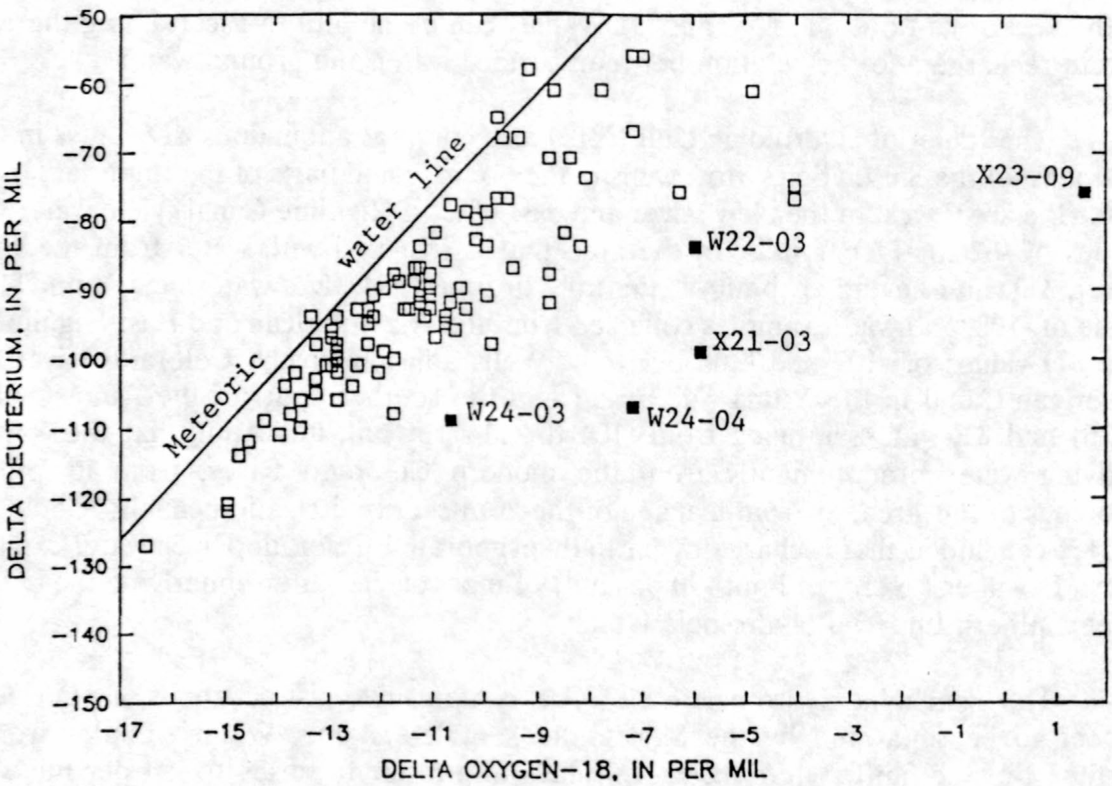

Figure 1. Relation between hydrogen- and oxygen-isotope ratios in water from selected wells and springs. Solid symbols represent samples from geothermal wells.

CONCLUSIONS

Values of δD in samples from wells and springs in southeastern California range from -130 per mil in the north to -60 per mil in the south. The observed distribution is the result of orographic and meteorologic processes. The high altitude of the Sierra Nevada in the northern part of the area causes the δD values in samples from east and southeast of the range to be much "lighter" (more negative) than would be produced from latitude effects alone. "Heavy" δD values in the south, with the exception of the Imperial Valley, are results of lower latitudes and the increasing amounts of precipitation derived from low-latitude storms.

In general, the trends of the δD lines do not change significantly as they cross the medium to low mountain regions of the Lahontan and Colorado River Drainage Provinces. This implies that those ranges, because of their low altitude, have little meteorological effect on the storms that pass through the regions,

In many areas, the δD values of sampled ground water are significantly different from the δD values of precipitation collected over a recent 7-year period. This difference suggests that recent recharge from local precipitation is relatively insignificant in these areas. More data and research are needed to determine the age and meteorological character of the climatic periods that recharged the ground water that is isotopically "light" in comparison with present precipitation.

Many of the δD values for samples collected from wells or springs associated with playa lakes in the study area are anomalously "heavy" relative to regional trends. Most of these playa lakes are regional discharge areas. Therefore, ground water in these areas has approached the surface and evaporated, becoming isotopically enriched in deuterium in comparison with the surrounding ground water in the region.

The δD values of water in some samples from the Mojave, Imperial, and Coachella Hydrologic Units also are anomalous relative to regional trends. The δD of samples from wells near the Mojave River (Mojave Hydrologic Unit) are 20 per mil, or more, lighter than samples 5 km away from the river. The δD values of samples from the Mojave River water are similar to those of the underlying ground water, indicating that the river is the major source of recharge to the alluvium along its flood plain. The Imperial Hydrologic Unit contains anomalous δD values in the area southeast of the Salton Sea. Wells in the irrigated parts of the hydrologic Unit are about 10 to 20 per mil lighter than wells in the unirrigated parts. Light δD values in the irrigated parts of the Imperial Hydrologic Unit have been attributed to recharge by partially evaporated Colorado River water. The Coachella Hydrologic Unit contains two distinct zones of dissimilar δD values that appear to be separated by the San Andreas fault system. Water samples from wells northeast of the fault system have δD values that are about 10 per mil "lighter" than samples from wells southwest of the fault system. The δD data indicate that ground-water flow in the unconsolidated deposits of the area is interrupted by the San Andreas fault system.

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Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*

[All depths in meters below land surface; --, no data]

Hydrologic unit: From a classification developed by the California Department of Water Resources (1964). Names of drainage provinces and hydrologic units were assigned by California Department of Water Resources (1964) except for Panamint, Searles, Fenner, Lanfair, and Coachella units. The State-assigned name for these units is indicated by parentheses.
Sample number: The initial letter and number indicate the hydrologic unit in which the sample was collected. The number after the dash is a serial number within that unit.
Laboratory number or reference: All data were collected and analyzed by the U.S. Geological Survey for this study except for those marked with A, B, C, or D. References for those samples are: A, Fournier and Thompson (1980); B, Coplen (1971); C, Winograd and Friedman (1972); D, Occidental Research Company, unpublished data, published here with permission.
State well number: For those wells and springs that are assigned a State well number (based on location within the rectangular system for the subdivision of public land), supplemental data are on file in U.S. Geological Survey files (5735 Kearny Villa Road, Suite O, San Diego, CA 92123).
δD and $\delta^{18}O$: Measures of the ratio of deuterium to hydrogen and of oxygen-18 to oxygen-16 (respectively), per mil, as explained in the text.
Notes: LADWP, Los Angeles Department of Water and Power; CT, cased (without perforations) to indicated depth; ORC, Occidental Research Corp.; PL, pump (or intake) level (depth of); PZ, perforated zone (depth of); SG, specific gravity of water; TD, total depth of completed well, listed in notes only when analyzed sample was collected during drilling, when well depth at the time was as listed under "Total well depth"; T, temperature, in degrees Celsius; pH, in standard units.

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
Lahontan Drainage Province												
Owens	W03-01	3452-38	06S/33E-14D01	37/25.1	118/19.6	1,271	119	29	-125	--	09/22/83	LADWP No. 365, PZ 44-59 & 77-110
	W03-02	3452-35		37/20.1	118/23.6	1,257	194	5	-127	-16.5	09/22/83	LADWP No. 141, PZ 9-188
	W03-03	3452-37		36/55.7	118/14.1	1,171	57	11	-123	--	09/22/83	LADWP No. 351, CT 12
	W03-04	3452-34		36/53.3	118/14.2	1,169	109	0	-122	--	09/22/83	LADWP No. 103, PZ 61-109
	W03-05	3452-33		36/47.8	118/09.6	1,160	96	0	-125	--	09/22/83	LADWP No. 1
	W03-06	3452-36	15S/36E-28F01	36/36.2	118/04.2	1,149	124	11	-126	--	09/22/83	LADWP No. 344, PZ 21-44 & 72-119
	W03-07	3445-06		36/44.3	117/52.2	1,097	--	3	-121	--	05/11/77	Keeler water well, brackish
	W03-08	A		36/19.8	117/56.9	1,094	--	--	-121	-14.9	00/00/74	Dirty Socks Spring; T=33
	W03-09	3445-07		36/16.8	118/00.4	1,112	--	2	-109	--	05/11/77	Olancha school-grounds
Deep Springs	W05-01	3185-13		37/15.6	118/02.0	1,508	--	--	-131	--	02/26/64	Buckhorn Springs
	W05-02	3185-11		37/16.5	118/01.3	1,508	--	--	-129	--	02/26/64	Spring feeding Deep Springs Lake
Eureka	W06-01	3446-40		37/06.6	117/42.2	878	102	--	-126	--	06/13/78	SG = 1.010, pH = 9.6, T = 29
Saline	W07-01	3453-42		36/48.3	117/46.3	427	--	0	-123	--	01/08/86	Lower Warm Springs
	W07-02	3453-43		36/48.8	117/45.9	445	--	0	-122	-14.9	07/02/86	Palm Spring

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
Amargosa	W09-01	3461-44	11S/42E-10BS01	37/01.2	117/23.2	741	--	--	-111	-13.9	01/17/85	Grapevine Springs, T = 26.5
	W09-02	3452-24	11S/42E-26	36/56.8	117/22.0	543			-110	--	04/08/81	Mesquite Spring
	W09-03	3461-42	14S/45E-30BS01	36/43.0	117/07.6	3	--	--	-91	--	12/20/84	Palm Tree Springs, T = 12
	W09-04	3455-13	15S/44E-36Q02	36/36.3	117/08.7	9	91	40	-110	-13.5	04/19/82	Stovepipe Wells
	W09-04	3452-25	15S/44E-36Q02	36/36.3	117/08.7	9	91	40	-109	--	04/08/81	Stovepipe Wells
	W09-04	3461-39	15S/44E-36Q02	36/36.3	117/08.7	9	91	40	-104	--	12/18/84	Stovepipe Wells
	W09-05	3452-22	28N/01E-36GS01	36/30.9	116/49.4	286	--	--	-101	--	04/07/81	Nevares Spring, T = 33
	W09-06	3455-16	17S/49E-27BS01	36/26.0	117/11.6	1,170	--	--	-103	-13.2	04/20/82	Emigrant Spring
	W09-06	3452-26	17S/49E-27BS01	36/26.0	117/11.6	1,170	--	--	-100	--	04/08/81	Emigrant Spring
	W09-07	3452-23	27N/01E-23BS01	36/27.4	116/50.2	116	--	--	-105	-13.2	04/07/81	Texas Spring
	W09-07	3461-43	27N/01E-23BS01	36/27.4	116/50.2	116	--	--	-105	-13.2	01/14/85	Texas Spring, T = 31
	W09-08	3452-21		36/26.8	116/47.9	301	--	--	-103	--	04/07/81	Travertine Spring
	W09-09	3461-41	26N/02E-13FS15	36/22.8	116/42.6	634	--	--	-79	-9.9	12/19/84	Navel Springs, T = 14
	W09-10	3440-23	25N/01E-33FS01	36/14.6	116/52.8	-80	--	--	-86	--	04/04/84	Tule Spring,
	W09-11	3446-38		36/15.2	116/22.1	611	102	--	-106	--	06/11/78	SG = 1.015, pH = 9.0, T = 23
	W09-12	3461-40	18N/05E-02ES02	34/40.9	116/25.3	66	--	--	-93	-10.3	12/13/84	Saratoga Springs, T = 28.5
	W09-12	3455-14	18N/05E-02ES02	34/40.9	116/25.3	66	--	--	-91	--	04/23/82	Saratoga Springs
	W09-13	3452-13		35/39.8	116/17.8	134	--	--	-86	--	04/06/81	
	W09-14	3452-19		35/46.6	115/53.4	1,494	--	--	-89	--	04/06/81	Horse Thief Spring
	W09-15	3452-06		35/26.8	115/39.9	1,158	122	--	-87	--	04/03/81	
	W09-16	3452-08	14N/13E-10D02	35/19.0	115/35.3	1,558	24	--	-81	--	04/03/81	
	W09-17	3318-21 C		36/44.3	116/21.6	953	--	--	-102	--	01/00/69	Well J-12, T = 26
	W09-18	3318-46 C	17S/50E-09	36/28.8	116/20.0	695	--	--	-107	--	03/00/70	Fairbanks Spring, T = 28
	W09-19	3318-37 C	18S/50E-03	36/27.1	116/18.9	671	--	--	-107	--	03/00/70	Crystal Pool, T = 32
	W09-20	3318-47 C	18S/51E-07	36/22.8	116/16.4	710	--	--	-107	--	03/00/70	Indian River Spring, T = 32
	W09-21	3318-38 C	18S/51E-19	36/21.5	116/16.5	683	--	--	-107	--	03/00/70	Big Spring, T = 28
Mesquite	W11-01	3452-14		35/45.8	115/40.2	808	183	30	-97	-12.9	04/06/81	
	W11-02	3452-15		35/49.4	115/43.1	823	71	55	-93	--	04/06/81	

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
Ivanpah	W12-01	3450-29		35/36.3	115/20.4	823	201	--	-75	--	03/21/81	
	W12-02	3450-31		35/28.0	115/15.4	945	165	--	-83	-10.1	03/21/81	
	W12-03	3450-30		35/27.8	115/20.6	838	18	--	-75	--	03/21/81	Saline water
	W12-04	3446-36		35/25.8	115/19.9	869	102	--	-83	--	07/10/78	SG = 1.005, pH = 8.4, T = 24.8
	W12-05	3450-27	15N/15E-13G03	35/23.5	115/19.5	892	251	--	-84	-11.2	03/21/81	T = 29
	W12-06	3450-32		35/28.0	115/15.4	945	262	--	-98	-12.2	03/21/81	
Leach	W14-01	3451-54		35/32.8	116/38.3	710	--	--	-101	-12.4	04/01/81	Two Springs
Bicycle	W16-01	3451-48		35/17.4	116/38.2	716	183	--	-97	--	03/31/81	Well No. B-2
Coyote	W18-01	3451-47	12N/02E-07MS12	35/08.7	116/49.0	731	--	--	-99	-11.9	03/31/81	Paradise Spring, T = 41
	W18-02	3451-42		35/06.0	116/47.8	564	49	--	-93	-11.0	03/30/81	T = 23
	W18-03	3446-18		35/03.8	116/45.3	519	139	--	-84	-8.1	06/21/78	SG = 1.010, pH = 7.9, T = 26
Superior	W19-01	3451-55		35/16.6	117/06.0	945	30	--	-101	-12.9	04/02/81	
	W19-02	3446-16		35/14.7	117/01.7	913	108	--	-100	--	06/19/78	SG = 1.010, pH = 8.4, T = 20
Panamint (Ballarat)	W20-01	3455-10		36/18.9	117/31.9	963	--	--	-108	-13.7	05/11/82	China Garden Spring
	W20-02	3440-22	19S/44E-23KS04	36/15.8	117/11.2	1,311	--	--	-98	-12.7	04/05/84	Wildrose Spring
	W20-02	3455-18	19S/44E-23KS04	36/15.8	117/11.2	1,311	--	--	-97	--	04/19/82	Wildrose Spring
	W20-02	3452-27	19S/44E-23KS04	36/15.8	117/11.2	1,308	--	--	-104	-13.3	04/08/81	Wildrose Spring
	W20-03	A		36/10.6	117/38.8	1,768	--	--	-99	-12.8	04/00/79	Flowing water, abandoned mine, T = 15
	W20-04	A		36/09.0	117/40.1	1,917	--	--	-98	-12.8	04/00/79	Coles Springs; T = 13
	W20-05	3455-05	20S/42E-32AS01	36/12.2	117/27.3	1,244	--	--	-95	--	02/11/82	Springs, unnamed, piped to quarry
	W20-06	3452-30		36/08.9	117/12.5	366	--	--	-101	--	04/07/81	Spring
	W20-07	A		36/06.0	117/30.3	1,829	--	--	-94	-13.3	04/00/79	Tennessee Spring, T = 16
	W20-08	A		36/05.1	117/29.6	1,969	--	--	-94	-12.8	04/00/79	Spring east of Junction Ranch, T = 14
	W20-09	3452-32		36/02.7	117/13.4	320	6	--	-93	--	04/07/81	
	W20-10	3467-29	21S/44E-13BS01	36/06.4	117/10.3	790	--	--	-97	--	03/31/85	Chris Wicht Camp Spring
	W20-11	3467-30	22S/44E-12MS01	36/02.0	117/11.1	732	--	--	-91	-12.1	03/31/85	Pleasant Canyon Spring

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	W20-12	3467-28	24S/45E-11MS01	35/51.4	117/05.5	972	--	--	-90	-11.9	03/31/85	Sourdough Spring
	W20-13	3453-29		35/26.7	117/05.3	1,073	--	--	-91	-11.0	03/04/86	Pink Hill Spring
	W20-14	3453-31		35/24.1	117/01.0	1,134	--	--	-84	--	02/20/86	Mesquite Spring
	W20-15	3467-53		35/59.0	117/19.8	625	305	--	-100	--	09/18/85	Test well, PZ 274-305
	W20-16	3441-50		35/57.8	117/13.9	315	73	--	-42	--	08/00/85	
Searles (Trona)	W21-01	3404-57		35/49.2	117/24.3	789	--	--	-94	-12.1	11/19/74	Spring
	W21-02	3404-50		35/49.7	117/19.2	538	--	--	-96		11/19/74	Well 36
	W21-03	3467-52		35/46.6	117/16.6	585	201	--	-61	-4.8	09/18/85	Well L-2, test, PZ 171-201
	W21-04	3404-46		35/44.4	117/19.7	494	109	0	-26	--	11/19/74	Mixed Layer, A-zone, pumping, CT 68
	W21-05	3467-36		35/40.4	117/22.7	502	43	11	-83	--	05/04/85	New well, PZ 5-43, pump test
	W21-06	D		35/40.3	117/18.1	494	100	--	-34	--	10/00/80	TD 150
	W21-07	3453-30		35/39.4	117/08.6	1,049	--	--	-91	-11.2	02/27/86	Amity Spring
	W21-08	3467-41		35/38.7	117/18.3	498	122	--	-54	--	09/18/85	Well U-19, pumping, CT 122
	W21-09	3467-45		35/37.4	117/16.3	536	182	--	-55	--	09/18/85	Well U-32, pumping, PZ 121-182
	W21-10	3467-48		35/36.6	117/18.3	550	143	--	-93	--	09/18/85	Well U-22, pumping, PZ 58-143
	W21-11	3467-49		35/36.1	117/18.8	561	119	--	-100	-11.7	09/18/85	Well U-24, pumping, PZ 86-119
	W21-12	3455-01		35/35.6	117/17.1	597	185	--	-95	-10.7	02/10/82	Well U-28, T = 31, pumping, PZ 110-185
	W21-13	3455-02	28S/44E-08C01	35/31.3	117/17.6	731	148	96	-102	-12.8	02/10/82	
	W21-14	3453-28		35/27.2	117/10.6	936	--	--	-92	--	03/04/86	Lead Pipe Spring
	W21-15	3453-32		35/23.6	117/14.8	1,256	--	--	-96	-10.5	04/23/86	Granite Wells Spring
	W21-16	3453-34		35/22.1	117/14.0	1,305	--	--	-92	--	04/23/86	Stone Corral Spring
	W21-17	3453-35		35/24.9	117/12.3	1,173	--	--	-100	--	04/23/86	Seep Spring
Coso	W22-01	A		36/07.0	117/45.3	1,445	--	--	-98	-13.2	04/00/79	Haiwee Spring, T = 17
	W22-02	A		36/07.7	117/41.6	1,868	--	--	-96	-12.9	04/00/79	Spring, town of Dead End, T = 12

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	W22-03	A		36/03.0	117/46.0	1,100	95	--	-99	-5.8	04/00/79	Coso No.1 Well, T = 140
	W22-04	A		35/56.9	117/33.9	1,305	--	--	-89	-11.6	04/00/79	Spring, Mountain Spring Canyon, T = 14
	W22-05	A	09S/12E-32H01	35/56.6	117/31.5	1,570	--	--	-93	-12.4	04/00/79	Spring, Wild Rose Mine, T = 12.5
Indian Wells	W24-01	A		36/05.0	117/57.1	1,050	206	--	-112	-14.5	04/00/79	Phil Hennis Ranch, T = 22.5
	W24-02	A		36/04.6	117/57.0	1,046	221	65	-109	-14.2	04/00/79	Rose Valley Ranch, T = 8
	W24-03	A		36/02.3	117/47.4	1,262	--	--	-109	-10.6	00/00/74	Steam condensate, fumarole, T = 97
	W24-04	A		36/03.2	117/48.2	1,195	--	--	-107	-7.1	12/00/74	CGEH No.1 Well, T = 70
	W24-05	3455-08	23S/38E-17D01	35/57.1	117/53.3	972	--	--	-96	--	02/11/82	Spring, domestic supply, Little Lake
	W24-06	3452-42		35/47.9	117/52.3	753	137	--	-83	--	02/00/84	
	W24-07	A		35/51.7	117/31.4	1,231	--	--	-89	-11.3	04/00/79	Spring in Wilson Canyon, T = 12
	W24-08	A	26S/39E-02C01	35/41.0	117/44.8	703	--	18	-95	-12.2	04/00/79	Well, SW region of Naval Base, "cold"
	W24-09	A	25S/40E-11K01	35/46.4	117/38.2	660	--	--	-94	-11.1	04/00/79	Artesian well, Center Line Rd., T = 20
	W24-10	3459-16	26S/30E-30K01	35/38.1	117/43.0	713	222	--	-101	--	03/25/82	Well 8, T = 34
	W24-11	3459-17	27S/38E-31D01	35/32.9	117/56.1	937	114	--	-108	-11.7	03/25/82	
	W24-12	A		35/59.3	118/05.9	1,920	--	--	-106	-13.5	04/00/79	Well, Grumpy Bear Restaurant, "cold"
	W24-13	A		35/56.8	118/04.8	2,216	--	--	-104	-13.8	04/00/79	Spring 3/4 mi. SW of Big Pine Mdw., T = 7
	W24-14	A		35/53.0	118/03.5	2,146	--	--	-102	-13.6	04/00/79	Chimney Peak Springs, Kennedy Meadow, T = 9
	W24-15	3455-09		35/39.6	118/01.2	1,338	19	--	-91	--	02/11/82	
	W24-16	3453-27	26S/39E-19P01	35/39.2	117/49.4	735	--	--	-93	--	09/17/85	
	W24-17	3453-25	27S/39E-01G01	35/37.1	117/50.3	777	--	--	-88	-11.0	09/17/85	

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	W24-18	3453-47		35/47.2	117/57.5	951	--	--	-93	--	01/24/86	Spring, Sand Canyon
Fremont	W25-01	3459-13	29S/40E-22D01	35/23.9	117/40.9	866	244	120	-100	-12.8	03/24/82	Canyon Springs
	W25-02	3455-03		35/23.8	117/38.9	695	--	--	-103	--	02/10/82	
	W25-03	3459-18		35/18.8	117/55.7	579	183	--	-85	--	03/25/82	Depth uncertain
	W25-04	3459-19		35/17.0	117/57.3	594	305	--	-84	--	03/25/82	Well No. 21, PL 122, T = 35?
	W25-05	3459-20		35/12.3	118/01.1	701	274	--	-81	--	03/25/82	T = 24, PL 122
	W25-06	3459-24		35/07.1	118/26.0	1,250	165	104	-77	--	03/26/82	
	W25-07	3459-27		35/07.6	118/20.3	1,234	130	--	-75	--	03/26/82	PL 114
Antelope	W26-01	3459-22		35/04.9	117/47.5	716	366	85	-93	-11.4	03/25/82	PL 122
	W26-02	3459-28	10N/13W-18P01	34/57.1	118/18.3	902	122	114	-77	-4.0	03/27/82	
	W26-03	3459-29		34/57.1	118/13.6	869	137	91	-79	--	03/27/82	
	W26-04	3459-31		34/57.1	118/09.5	777	91	79	-78		03/27/82	
	W26-05	3459-33		34/58.0	118/01.6	747	67	53	-84	--	03/27/82	
	W26-06	3459-35		34/53.8	118/18.9	823	213	79	-87	-11.2	03/27/82	
	W26-07	3459-24		34/54.4	117/44.1	762	111	52	-98	-9.8	03/26/82	
	W26-08	3459-47		34/52.0	117/49.2	701	122	--	-82	--	03/31/82	
	W26-09	3459-37	09N/13W-13K02	34/49.4	118/24.8	794	183	70	-73	--	03/27/82	
	W26-10	3459-41		34/49.5	118/12.4	716	107	46	-69	--	03/28/82	
	W26-11	3459-45		34/49.6	117/54.2	701	201	40	-80	--	03/31/82	AFB well No. 14
	W26-12	3459-39	08N/16W-20A01	34/46.3	118/35.9	933	64	--	-68	-9.6	03/27/82	Neehach No. 4
	W26-13	3459-38	08N/15W-22A02	34/46.2	118/27.0	837	130	50	-75	--	03/27/82	
	W26-14	3459-40		34/42.1	118/18.6	747	--	--	-64	--	03/28/82	T = 23
	W26-15	3459-42		34/44.7	118/01.7	716	85	--	-75	--	03/28/82	
	W26-16	3459-43	08N/10W-35N01	34/44.3	117/54.7	732	91	60	-82	--	03/28/82	
	W26-17	3450-02		34/39.7	117/49.0	777	87	--	-86	--	03/17/81	
	W26-18	3459-55	06N/11W-20A01	34/36.3	118/03.6	779	183	103	-74	--	03/01/82	
	W26-19	3450-02		34/36.7	117/46.1	847	79	--	-86	-10.7	03/17/81	
	W26-20	3450-01	06N/09W-33B02	34/33.8	117/51.0	861	198	43	-77	--	03/17/81	CT 55
	W26-21	3459-52		34/25.3	117/54.8	1,524	116	--	-84	--	04/01/82	
Cuddeback	W27-01	3446-13		35/18.4	117/28.1	778	123	--	-99	--	06/16/78	SG = 1.010, pH = 7.8, T = 25
Mojave	W28-01	3461-36	32S/43E-28K01	35/07.0	117/22.4	694	--	0	-97	-10.9	01/15/85	McDonald "well" (spring)
	W28-02	3451-52	13N/05E-10R01	35/13.9	116/25.6	412	--	--	-92	-10.6	04/01/81	Bitter Spring
	W28-03	3452-03		35/16.4	116/02.8	351	100	52	-88	--	04/03/81	
	W28-04	3446-35		35/10.6	116/03.5	282	122	--	-92	--	07/09/78	SG = 1.002, pH = 8.4, T = 28
	W28-05	3467-31	12N/8E-11E01	35/08.3	116/06.3	305	--	--	-75	--	03/30/85	
	W28-06	3452-02	12N/7E-14F01	35/07.9	116/12.5	447	238	127	-82	--	04/03/81	T = 35
	W28-07	3452-01		35/02.1	116/22.6	457	129	5	-87		04/03/81	

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	W28-08	3452-09	11N/12E-25G01	35/00.6	115/38.9	646	210	--	-88	-11.7	04/03/81	Depth uncertain
	W28-09	3451-57		34/56.1	116/51.9	640	183	73	-92	-11.2	04/02/81	Water supply for Calico, PL 137
	W28-10	3451-39	09N/01E-03P02	34/53.8	116/51.1	596	122	32	-66	--	03/30/81	USMC well No. 5
	W28-11	3451-38		34/53.0	116/51.7	594	107	35	-61	-8.6	03/30/81	USMC well No. 4
	W28-12	3450-15		34/52.9	116/39.0	579	55	--	-63	--	03/19/81	Saline water, T = 21
	W28-13	3459-09		34/51.0	115/35.9	1,280	--	--	-81	--	03/22/82	Arrowhead Spring
	W28-14	3451-36	09N/03W-34C02	34/49.7	117/11.1	707	26	19	-65	--	03/21/81	Brackish water
	W28-15	3451-35		34/46.1	117/19.3	732	67	7	-61	--	03/21/81	
	W28-16	3446-19		34/48.6	116/33.3	541	29	0	-78	--	06/23/78	Artesian, SG = 1.025, pH = 7.5, T = 22
	W28-17	3450-19		34/47.9	116/35.0	533	60	--	-66	--	03/19/81	
	W28-18	3450-20		34/47.3	116/23.2	640	213	--	-72		03/19/81	T = 32
	W28-19	3446-11		34/39.1	117/36.7	864	53	--	-95	--	06/14/78S	G = 1.010, pH = 7.5, T = 22, TD 81
	W28-20	3461-38	07N/04W-31M01	34/39.0	117/20.6	777	14	7	-60	--	01/15/85	
	W28-21	3451-33		34/38.1	117/21.2	777	122	18	-80	--	03/29/81	CT 61
	W28-22	3461-37	06N/04W-30N01	34/34.4	117/20.4	831	61	9	-77	--	01/15/85	
	W28-23	3459-53		34/30.9	117/34.1	1,021	183	134	-85	--	04/01/82	Well No. 2, S.B. Co., T = 27
	W28-24	3450-08	05N/04W-35J02	34/28.7	117/15.4	858	126	--	-66	--	03/18/81	Well No. 4, PL 30
	W28-25	3450-07		34/24.1	117/16.3	945	91	--	-64	--	03/18/81	
	W28-26	3448-43		34/59.6	117/32.5	754	152	58	-102	-12.0	07/06/85	Kramer Junction well, brackish
	W28-27	3459-10		34/59.6	117/15.8	640	137	--	-93	--	03/24/82	
Broadwell	W29-01	3446-33		34/51.6	116/11.3	395	154	--	-83	--	07/06/78	SG = 1.015, pH = 7.8, T = 29
						Colorado River Drainage Province						
Lucerne	X01-01	3446-20		34/30.7	116/56.7	869	35	--	-72	--	05/24/78	SG = 1.070, pH = 8.0, T = 19, TD 102
	X01-01	3446-21		34/30.7	116/56.7	869	102	--	-95	--	05/24/78	SG = 1.012, pH = 7.6, T = 21
	X01-02	3450-12		34/28.3	116/56.6	869	88	8	-89	--	03/18/81	
	X01-03	3451-28	04N/02E-17B01	34/26.0	116/47.9	945	61	50	-97	--	03/29/81	
Johnson	X02-01	3466-09		34/27.0	116/41.4	878	35	--	-96	--	04/24/84	SG = 1.007, pH = 8.5, T = 19, TD 49
	X02-01	3446-10		34/27.0	116/41.4	878	49	--	-96	--	05/23/78	SG = 1.000, pH = 8.9, T = 20

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	X02-02	3446-08		34/27.1	116/34.4	827	102	--	-92	--	05/17/78	SG = 1.010, pH = 9.0, T = 23
	X02-03	3451-27		34/23.0	116/42.4	998	--	--	-93	-12.2	03/28/81	Old Woman Spring
	X02-04	3451-23	03N/04E-17F01	34/21.1	116/34.9	981	148	136	-95	--	03/28/81	
Means	X04-01	3446-06		34/24.0	116/30.3	785	94	--	-97	--	05/15/78	SG = 1.010, pH = 9.0, T = 22.8
Emerson	X05-01	3446-02		34/25.9	116/25.2	699	102	--	-89	--	05/12/78	SG = 1.015, pH = 7.6, T = 26
	X05-02	3446-04		34/26.7	116/23.4	699	102	--	-97	--	05/13/78	SG = 1.010, pH = 7.8, T = 25
	X05-03	3455-23	04N/06E-18L01	34/25.7	116/23.3	699	16	12	-83	--		
	X05-04	3455-25	04N/06E-34E01	34/23.4	116/21.0	719	33	30	-94	--		
	X05-05	3451-20		34/17.0	116/24.6	914	125	41	-83	--	03/27/81	
	X05-06	3451-19	02N/05E-27K02	34/13.9	116/27.1	1,054	99	58	-82	--	03/27/81	
Deadman	X07-01	3451-11	02N/07E-03B01	34/17.8	116/21.5	792	210	--	-88	--	03/26/81	Well No. 2 A, PZ 79-210
	X07-02	3455-21		34/18.6	116/15.9	768	184	84	-86	--	06/21/82	PZ 119-177
	X07-03	3455-22		34/18.3	116/11.7	643	118	86	-86	--	--	PZ 117-122
Joshua Tree	X08-01	3451-05		34/10.0	116/14.2	701	125	44	-82	--	03/25/81	PL 111
	X08-02	3451-12		34/08.4	116/18.8	838	230	123	-82	--	02/27/81	County well No. 11
	X08-03	3451-14		34/07.6	116/25.0	975	244	107	-82	-10.9	03/27/81	Water district well No. 7
Dale	X09-01	3450-44	01N/12E-17P01	34/10.1	115/44.8	372	25	11	-90	-11.0	03/22/81	
	X09-02	3450-46		34/10.3	115/52.9	442	79	--	-90	-10.4	02/22/81	T = 54
	X09-03	3446-27		34/08.9	115/43.5	357	47	--	-76	-6.2	04/29/78	SG = 1.025, pH = 8.2, T = 22, TD 133
	X09-04	3451-01	01N/09E-31A01	34/07.4	116/04.3	639	104	35	-83	--	02/25/81	County well No. 3
Fenner (Route Sixtysix)	X10-01	3459-08	08N/13E-13P01	34/46.8	115/36.5	1,128	67	44	-76	--	03/22/82	
	X10-02	3450-21		34/44.0	115/14.7	518	183	103	-83	--	03/20/81	Highway Mountain Sta., T = 35
	X10-03	3446-29		34/29.4	115/45.4	183	154	--	-56	--	05/02/78	SG = 1.190, pH = 6.5, T = 26
	X10-04	3451-07		34/47.1	115/39.7	1,341	28	--	-76	--	03/25/81	
	X10-05	3446-31		34/28.0	115/41.5	183	248	--	-58	--	05/09/78	SG = 1.18, pH = 5.9, T = 29

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	X10-06	3457-47		34/25.5	115/33.4	238	75	--	-73	--	05/13/82	Geothermal test, in bedrock, TD 103
	X10-06	3457-48		34/25.5	115/33.4	238	81	--	-73	--	05/13/82	Geothermal test, in bedrock, TD 103
	X10-06	3457-49		34/25.5	115/33.4	238	103	--	-79	--	05/13/82	Geothermal test, in bedrock, TD 103
	X10-07	3450-23	10N/18E-35B03	34/54.8	115/04.2	792	274	183	-87	-11.3	03/20/81	
Cadiz	X11-01	3446-41	03N/15E-21K01	34/19.6	115/25.0	166	76	3	-63	--	04/26/78	SG = 1.100, pH = 6.8, T = 24
	X11-02	3446-42	03N/15E-33H01	34/18.1	115/24.3	166	55	19	-50	--	04/26/78	SG = 1.200, pH = 6.1, T = 24
	X11-03	3445-05		34/17.5	115/24.9	166	126	--	-47	--	03/00/80	
	X11-04	3446-43	02N/15E-11D02	34/16.7	115/23.0	166	58	8	-41	--	03/26/78	
	X11-05	3446-44		34/16.0	115/21.6	166	61	--	-46	--	04/26/78	
	X11-06	3446-45	02N/15E-13E01	34/15.4	115/20.9	166	66	9	-55	--	04/26/78	SG = 1.120, pH = 6.5, T = 24
Ward	X12-01	3459-04		34/50.4	114/57.6	625	213	175	-86	--	03/19/82	T = 27
	X12-02	3458-56		34/33.8	115/10.1	1,250	--	--	-82	-8.4	03/17/82	Spring
	X12-03	3458-54		34/31.8	115/07.5	1,006	24	--	-77	--	03/17/82	
	X12-04	3446-25		34/15.2	115/11.2	188	153	--	-66	--	04/25/78	SG = 1.135, pH = 7.8, T = 25
	X12-05	3446-23		34/11.7	115/03.7	188	154	--	-84	--	04/19/78	SG = 1.015, pH = 7.9, T = 31
Lanfair (Holmer)	X13-01	3450-33		35/29.4	115/02.3	1,204	280	--	-93	-11.5	03/21/81	T = 29, CT 244
	X13-02	3450-35		35/20.8	114/56.6	899	244	--	-71	-8.7	03/21/81	
	X13-03	3450-37		35/18.0	114/51.9	777	183	137	-77	--	03/21/81	
	X13-04	3450-24		35/09.6	115/09.4	1,234	183	--	-82	--	03/20/81	
	X13-05	3450-38		34/53.7	114/45.8	381	--	--	-80	-10.1	03/21/81	Klinefelter Spring
Chemehuevis	X14-01	3459-01		34/28.5	114/26.2	198	146	69	-72	--	03/19/82	T = 28
	X14-02	3459-06		34/26.6	114/28.7	229	5	0	-77	--	03/19/82	Artesian
Colorado	X15-01	3450-42	01N/23E-09E01	34/11.5	114/35.1	283	204	--	-68	--	03/22/81	
	X15-02	3458-24		33/13.1	114/51.7	262	12	--	-59	--	03/02/82	
Rice	X16-01	3450-43		34/05.0	114/51.0	274	122	107	-65	--	03/22/81	T = 26, CT 117
Chuckwalla	X17-01	3451-52		33/56.4	115/25.1	290	--	--	-82	--	04/01/81	
	X17-02	3450-49	04S/15E-11C01	33/51.4	115/23.0	226	174	--	-78	--	03/24/81	
	X17-03	3450-51		33/51.8	115/14.3	168	107	7	-84	-9.9	03/25/81	T = 28
	X17-04	3450-48	05S/15E-27H01	33/43.1	115/24.8	276	182	131	-74	--	03/24/81	T = 32

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	X17-05	3458-33	08S/17E-33C01	33/26.5	115/13.5	594	5	--	-61	-7.7	03/04/82	
Coachella (Whitewater)	X19-01	3451-16	01S/04E-28C01	34/03.4	116/34.6	802	52	22	-75	--	04/27/84	PZ 34-43
	X19-02	3467-01		33/59.0	116/39.3	488	53	--	-74	--	04/25/84	
	X19-03	3467-05		33/58.0	116/30.0	365	116	--	-87	--	04/26/84	T = 43
	X19-04	3467-14		33/57.0	116/47.8	792	--	--	-65	-9.7	04/26/84	Spring, T = 12
	X19-05	3467-02	02S/04E-36D01	33/57.2	116/32.1	335	238	--	-79	--	04/25/84	Well 22, T = 20, PZ 120-230
	X19-06	3467-07		33/55.1	116/25.3	332	81	--	-89	--	04/25/84	T = 61
	X19-07	3467-08		33/55.1	116/25.3	332	93	--	-94	-10.7	04/25/84	T = 41
	X19-08	3467-09		33/50.3	116/31.0	122	311	--	-68	-9.3	04/26/84	Well 28, PZ 180-304
	X19-09	3467-20		33/50.3	116/27.9	122	246	93	-74	--	04/27/84	Well 4562, PZ 121-246
	X19-10	3467-22		33/39.0	116/23.9	62	283	--	-74	--	04/27/84	Well 5624, PZ 198-280
	X19-11	3467-23	05S/07E-30J01	33/42.1	116/17.1	21	274	60	-79	-10.3	04/27/84	Well 574, PZ 152-274
	X19-12	3467-16		33/37.7	116/13.4	-34	205	--	-68	--	04/27/84	Well 6782, PZ 122-183
	X19-13	3467-19		33/34.0	116/04.1	-56	274	--	-70	--	04/27/84	Well 7991, PZ 121-274
	X19-14	3467-18	08S/09E-31Q01	33/25.8	116/04.9	-8	107	--	-70	--	04/27/84	Well 8993, PZ 70-107
	X19-15	3458-36		33/25.4	116/04.7	0	109	--	-68	--	04/27/84	Sampled from end of 1.5-km pipeline, PZ 71-106
	X19-16	3450-47		33/39.8	115/43.9	522	305	--	-84	--	03/24/81	T = 35
West Salton Sea	X21-01	3458-44	11S/10E-32R01	33/10.0	115/56.7	46	--	0	-75	-4.0	03/08/82	Artesian well
	X21-02	3458-38		33/23.1	116/01.4	-69	--	--	-78	-10.6	03/07/82	Spring, T = 37
	X21-03	3458-40		33/18.3	115/55.4	-70	549	518	-84	-5.9	03/07/82	T = 57
Anza Borrego	X22-01	3457-05		33/29.0	116/37.9	1,204	91	--	-65	--	02/20/82	PL 87
	X22-02	3457-08	10S/06E-05F01	33/19.9	116/23.7	247	215	84	-64	--	02/20/82	Borrego Water Co.
	X22-03	3457-07	10S/05E-36A01	33/16.3	116/24.4	219	116	75	-56	--	02/20/82	Well at park housing
	X22-04	3457-09	11S/06E-07K03	33/14.7	116/23.2	215	143	81	-70	--	02/20/82	Borrego Water Co.
	X22-05	3457-13	12S/08E-10Q02	33/08.2	116/08.0	47	66	31	-72	--	02/21/82	Warm
	X22-06	3457-14		33/07.3	116/07.7	46	112	--	-71	--	02/21/82	T = 36
	X22-07	3457-16		32/58.8	116/26.9	655	61	56	-55	--	02/21/82	
	X22-08	3457-22		32/57.0	116/19.2	610	--	--	-72	--	02/21/82	Spring, cold
	X22-08	3457-23		32/57.0	116/19.2	610	--	--	-74	--	02/21/82	Spring, cold

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	X22-08	3457-24		32/57.0	116/19.2	610	--	--	-75	--	02/21/82	Spring, cold
	X22-09	3457-26		32/52.4	116/11.5	183	--	19	-70	--	02/21/82	
	X22-10	3467-27		32/51.7	116/25.2	1,805	90	--	-65	--	11/02/84	Depth uncertain
	X22-11	3461-48		32/37.3	116/11.1	855	46	5	-47	--	11/22/85	Domestic water supply
	X22-12	3461-47		32/37.0	116/11.5	863	0	--	-58	-9.1	11/22/85	Jacumba Hot Spring, T = 40
Imperial	X23-01	B		33/25.1	115/43.6	-30	192	--	-71	-8.3	9/16/70	Youth Spa
	X23-02	3458-50		33/23.9	115/39.8	-15	192	0	-73	--	03/10/82	Artesian, T = 58
	X23-03	3458-49		33/22.2	115/39.0	0	91	0	-72	--	03/10/82	Artesian, T = 24
	X23-04	3458-48	09S/13E-20LS01	33/22.3	115/38.2	0	--	--	-72	--	03/10/82	Frink Spring
	X23-05	3458-16		33/15.2	115/15.3	427	18	--	-68	--	02/28/82	
	X23-06	B		33/13.4	115/36.1	-64	--	--	-67	-7.1	09/16/70	Flowing well near Niland
	X23-07	3457-39		33/11.2	115/22.3	46	52	--	-65	--	02/24/82	Well ED-13, PZ 30-49
	X23-08	3458-28		33/12.7	115/15.7	259	19	--	-62	--	04/03/82	
	X23-09	3458-46		33/09.9	115/28.1	-67	914	--	-76	+1.6	03/09/82	Geothermal well, T = 232
	X23-10	3458-47		33/07.7	115/36.7	-46	353	--	-71	--	03/09/82	T = 41
	X23-11	3458-13		33/04.5	115/21.3	-6	259	--	-92	-8.7	02/27/82	T = 41
	X23-12	3458-11		33/02.9	115/22.5	-15	--	--	-66	--	02/27/82	
	X23-13	B		32/58.5	115/29.3	-35	396		-91	-9.9	09/16/70	Magnolia Union School
	X23-14	B		32/55.9	115/29.0	-29	366	--	-90	-10.4	--	Kendalls' Plunge No.1, Hart Rd. & Hwy. 115
	X23-15	B		32/52.2	115/29.3	-27	168	--	-87	-9.4	09/17/70	Schnaffner Dairy
	X23-16	B		32/47.9	115/27.7	-2	335		-94	-11.1	11/29/70	Holtville Iceplant
	X23-17	3457-43		32/48.3	115/46.0	15	61	--	-74	-8.0	02/24/82	T = 32
	X23-18	3457-44		32/47.8	115/45.9	15	1,829	--	-101	--	02/24/82	Geothermal well, T = 174
	X23-19	3457-55		32/46.2	115/45.5	15	--	0	-88	-8.7	02/24/82	Artesian well
	X23-20	3457-27		32/45.4	115/57.4	91	569	15	-77	-9.7	02/22/82	
	X23-21	3457-28		32/43.8	115/59.3	91	170	--	-77	--	02/22/82	T = 29
	X23-22	3457-29		32/43.8	115/59.8	137	183	43	-77	--	02/22/82	T = 33
	X23-23	3457-30		32/43.1	115/57.2	91	88	--	-77	-9.5	02/22/82	
	X23-24	B		32/42.8	115/04.0	48	77		-106	-12.8	09/17/70	Gordon's well
Amos-Olgilby	X26-01	3458-09		33/05.8	115/15.2	91	98	--	-62	--	02/26/82	Well No. 6-RC, PZ 42-48 & 60-72
	X26-02	3457-34		33/05.3	115/14.4	91	93	--	-58	--	02/24/82	Well No. ED-2, PZ 59-83

Table 1. *Deuterium and oxygen-18 contents of water from wells and springs*--Continued

Hydrologic unit	Sample number	Laboratory number or reference	State well number	Latitude (deg/min)	Longitude (deg/min)	Altitude of land surface (meters above or below (-) sea level)	Total well depth (meters)	Water-table depth (meters)	δD (per mil)	$\delta^{18}O$ (per mil)	Collection date	Notes
	X26-03	3458-18	13S/18E-33A01	32/59.8	115/04.2	107	222	--	-68	--	03/01/82	T = 82
	X26-04	B		32/44.12	115/02.8	152	213	--	-56	-7.1	08/17/70	Erma Mine area well
	X26-05	3458-35		32/57.9	114/55.3	152	244	--	-55	--	03/04/82	T = 38
	X26-06	3458-21		32/52.8	114/51.8	152	213	118	-56	-6.9	03/01/82	T = 36, PL 157
	X26-07	B		32/44.2	114/53.4	52	--	--	-104	-12.5	09/17/70	Rest Stop, Sand Hills
Yuma	X27-01	3458-22		32/44.7	114/45.9	76	122	--	-114	-14.7	03/01/82	
	X27-02	3458-08		32/44.5	114/38.2	30	168	--	-111	--	02/25/82	
San Diego Drainage Province												
Santa Margarita	Z02-01	3457-01		33/33.4	116/38.5	1,219	30	6	-64	--	02/20/82	PL 24

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