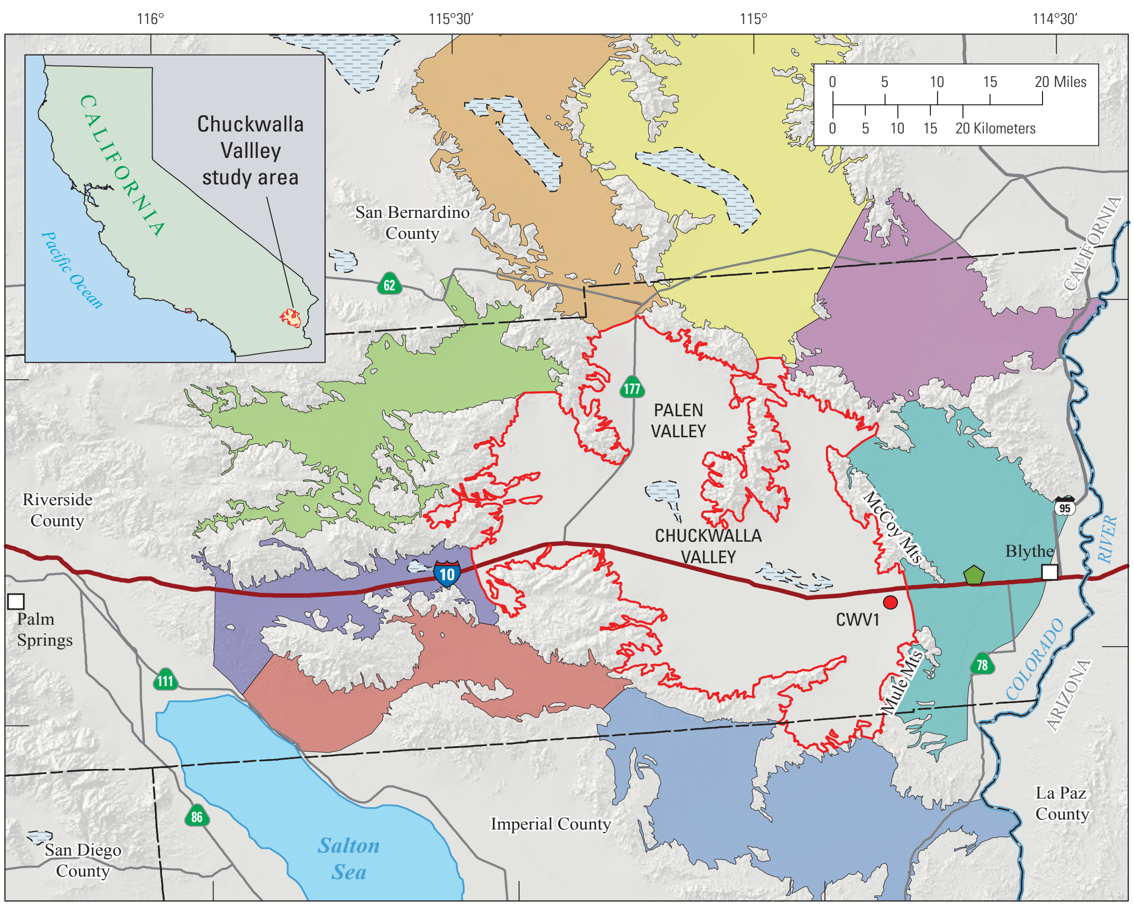
Prepared in cooperation with U.S. Bureau of Land Management, California Desert District

Chuckwalla Valley Multiple-well Monitoring Site, Chuckwalla Valley, Riverside County, California

The U.S. Geological Survey (USGS), in cooperation with the Bureau of Land Management, is evaluating the geohydrology and water availability of the Chuckwalla Valley, California (fig. 1). As part of this evaluation, the USGS installed the Chuckwalla Valley multiple-well monitoring site (CWV1) in the southeastern portion of the Chuckwalla Basin (fig. 1). Data collected at this site provide information about the geology, hydrology, geophysics, and geochemistry of the local aquifer system, thus enhancing the understanding of the geohydrologic framework of the Chuckwalla Valley. This report presents construction information for the CWV1 multiple-well monitoring site and initial geohydrologic data collected from the site.

Study Area

The Chuckwalla Valley groundwater basin underlies the Palen and Chuckwalla Valleys, is located primarily in eastern Riverside County, California, and covers approximately 940 square miles (fig. 1). The basin is mostly surrounded by mountains and highlands. Its water-bearing units consist of Quaternary to Pliocene-aged deposits that are classified into three major formations: the Quaternary alluvium (of Holocene and Pleistocene age), the Pleistocene-age Pinto Formation, and the Pliocene-age Bouse Formation (California Department of Water Resources, 1979). The maximum thickness of the deposits is about 1,200 feet (ft), and the average specific yield is estimated to be 10 percent (California Department of Water Resources, 1979). The basin receives subsurface inflow from the Pinto Valley, Cadiz Valley, and Orocopia groundwater basins and is recharged by the combined percolation of runoff from the surrounding mountains and precipitation on the valley floor (California Department of Water Resources, 1979 and 2003). Average annual precipitation in the basin is about 4 inches, and there are no perennial streams (Rantz, 1969; California Department of Water Resources, 1979). Data from the meteorological station BLH (*http://www.cnrfc.noaa.gov/rainfall_data.php*, accessed November 26, 2012) at the Blythe Airport (fig. 1), east of the Chuckwalla Valley, indicated that annual precipitation from 2002 through 2012 ranged from 0.73 to 7.93 inches and averaged 3.12 inches. Groundwater flows southeastward from the basin's boundary with the Cadiz Valley and Pinto



EXPLANATION

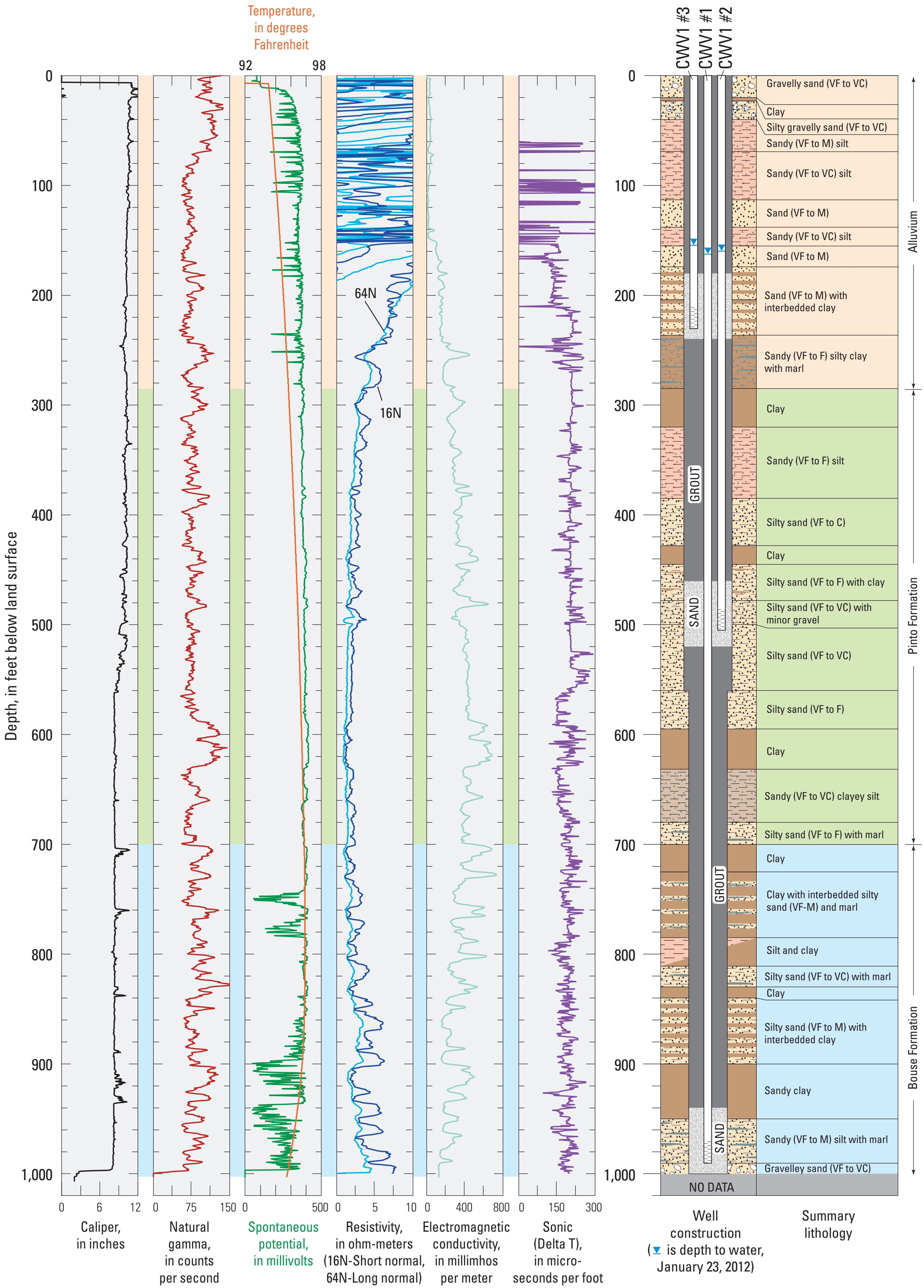
Groundwater basin boundaries

- Chuckwalla Valley
- Arroyo Seco Valley
- Cadiz Valley
- Chocolate Valley
- Orocopia Valley
- Palo Verde Mesa
- Pinto Valley
- Rice Valley
- Ward Valley

- **County boundary**
- **Dry lake**
- **Airport**
- **City**
- **Multiple-well monitoring site (CWV1)**

Shaded relief base created from 30-m digital elevation model from USGS National Elevation Dataset (NED); North America Vertical Datum 1988 (NAVD88)
Hydrology sourced from 1:24,000-scale National Hydrography Dataset, 1974 -2009
Place names sourced from USGS Geographic Names Information System, 1974 -2009
Albers Projection, NAD83

Figure 1. The Chuckwalla Valley in Riverside County, southeast California.



Temperature, in degrees Fahrenheit
92
98
Depth, in feet below land surface
0
100
200
300
400
500
600
700
800
900
1,000
64N
16N
0
6
12
Caliper, in inches
0
75
150
Natural gamma, in counts per second
0
500
Spontaneous potential, in millivolts
0
5
10
Resistivity, in ohm-meters (16N-Short normal, 64N-Long normal)
0
400
800
Electromagnetic conductivity, in millimhos per meter
0
150
300
Sonic (Delta T), in micro-seconds per foot
CWV1 #3
CWV1 #1
CWV1 #2
GROUT
SAND
GROUT
SAND
NO DATA
Well construction (▼ is depth to water, January 23, 2012)
Gravelly sand (VF to VC)
Clay
Silty gravelly sand (VF to VC)
Sandy (VF to M) silt
Sandy (VF to VC) silt
Sand (VF to M)
Sandy (VF to VC) silt
Sand (VF to M)
Sand (VF to M) with interbedded clay
Sandy (VF to F) silty clay with marl
Clay
Sandy (VF to F) silt
Silty sand (VF to C)
Clay
Silty sand (VF to F) with clay
Silty sand (VF to VC) with minor gravel
Silty sand (VF to VC)
Silty sand (VF to F)
Clay
Sandy (VF to VC) clayey silt
Silty sand (VF to F) with marl
Clay
Clay with interbedded silty sand (VF-M) and marl
Silt and clay
Silty sand (VF to VC) with marl
Clay
Silty sand (VF to M) with interbedded clay
Sandy clay
Sandy (VF to M) silt with marl
Gravelley sand (VF to VC)
Summary lithology
Alluvium
Pinto Formation
Bouse Formation

Valley Basins through the narrows between the McCoy and Mule Mountains and into the adjacent Palo Verde Mesa Basin (Steinemann, 1989). Measured groundwater levels range from an altitude of 500 ft in the western portion of the basin to less than 275 ft near the eastern outlet of the basin (Steinemann, 1989). The California Department of Water Resources reports that groundwater levels in the basin were generally stable between the early 1950s and 1962 (California Department of Water Resources, 1963), indicating that discharge and recharge were roughly balanced during that period.

The Chuckwalla Valley is an area with high potential for solar energy development. Two large-scale solar energy projects are being constructed, and at least nine additional projects are approved or proposed in this basin, which is the largest number of solar projects in any single basin in California (Godfrey and others, 2012). Water needs associated with proposed solar energy projects within the basin have generated concern about potential detrimental effects on local groundwater resources and phreatophytic-vegetation habitats.

Well Completion

The CWV1 borehole was drilled to a depth of 1,000 ft below land surface (ft bls) using standard mud-rotary drilling techniques. Drill cuttings were collected at 10-ft intervals during the drilling process to determine the lithology (fig. 2). To assist in the identification of lithologic and stratigraphic units, geophysical logging of the borehole was done prior to well construction by using techniques described in USGS Techniques of Water-Resources Investigations Reports (Keys and MacCary, 1971; Shuter and Teasdale, 1989; Keys, 1990). Three 2-inch-diameter wells were installed with screened intervals from 973 to 993 (CWV1 #1), 485 to 505 (CWV1 #2), and 210 to 230 (CWV1 #3) ft bls (fig. 2, table 1). A filter pack of #3 sand was installed around each screen, and a low-permeability bentonite grout was placed in the depth intervals between the filter packs to isolate each of the wells. Installation of multiple wells within a single borehole allows for analysis of the hydrologic properties of discrete vertical zones within the aquifer system, as well as the collection of depth-specific water-chemistry samples and the determination of vertical hydraulic gradients.

Figure 2. Well construction, summary lithology, and geophysical-log data from multiple-well monitoring site CWV1, Chuckwalla Valley, California. Abbreviations: VF, very fine; F, fine; M, medium; C, coarse; VC, very coarse.

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Geology at the CWV1 site

Geologic units beneath the CWV1 site include Pliocene- to Quaternary-age continental deposits that are divided into three formations: alluvium composed of fine to coarse sand interbedded with gravel, silt, and clay; the Pinto Formation composed of coarse fanglomerate containing boulders and lacustrine clay; and the Bouse Formation composed of a basal limestone overlain by interbedded clay, silt, and sand, and a tufa (California Department of Water Resources, 1963 and 2003; Metzger and others 1974). The drill cuttings and geophysical logs indicated that the CWV1 borehole penetrated mostly fine-grained sediments, which are interbedded with coarse-grained sediments (fig. 2). Interpretation of the geophysical logs and observed changes in the lithology indicated that the borehole encountered undifferentiated alluvium from the land surface to about 285 ft bls, the Pinto Formation from about 285 to 700 ft bls, and the Bouse Formation from 700 ft bls to the bottom of the hole at 1,000 ft bls. Several thick clay units (238–320, 595–630, and 900–950 ft bls) were encountered throughout the borehole.

Hydrology

The clay units likely isolate, to a degree, the water-bearing units of the formations from those vertically adjacent. Although the lateral extents of these clays are unknown, their thicknesses indicate they extend some distance from the site, and differences in water-level elevations among wells were consistent with restricted hydraulic connections between water-bearing units. Manual depth-to-water measurements made in late January 2012, and again in early May, showed vertical hydraulic gradients were downward and that water levels were stable, changing by a maximum of 0.2 ft during this period.

Slug tests were performed on each of the wells to estimate the hydraulic conductivity of the aquifer material next to the screened interval. The tests were performed by using techniques described by Stallman (1971). Computations were performed by using spreadsheet-based tools (Halford and Kuniansky, 2002) and were analyzed by using methods developed by Butler and others (2003) for formations of high hydraulic conductivity. The

Table 1. Identification, construction, and sampling information for the CWV1 multiple-well monitoring site, Chuckwalla Valley, Riverside County, California.

Common well name	USGS Site ID (hyperlinked to NWISWeb)	Construction information						Sampling information	
		Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Depth to top sand pack (ft below LSD)	Depth to bottom sand pack (ft below LSD)	Altitude of LSD (ft above-NAVD 88)	Date sampled (m/d/yyyy)	Time sampled (hhhh)
CWV1 #1	*333527114511901*	993	973	993	943	1,000	417.7	6/6/12	1650
CWV1 #2	*333527114511902*	505	485	505	459	523	417.7	6/6/12	1200
CWV1 #3	*333527114511903*	230	210	230	177	243	417.7	6/6/12	1330

The fifteen-digit U.S. Geological Survey (USGS) Site ID is used to uniquely identify the well. The common name is used throughout the report for quick reference. Land-surface datum (LSD) is a datum plane that is approximately at land surface at each well. The altitude of the LSD is described in feet above the North American-Vertical Datum of 1988 (NAVD 88). Abbreviations: NWISWeb, National Water Information System Web page; ft, feet; m, month; d, day; yyyy, year; hhhh, hour.

shallowest well (CWV1 #3) had the lowest estimated hydraulic conductivity (K) value at 1.8 feet per day (ft/day); the middle well (CWV1 #2) had the highest estimated K value at 7.5 ft/day. The deepest well (CWV1 #1) had an estimated K value of 6.9 ft/day. The hydraulic conductivity estimates were consistent with the lithology in the screened intervals; CWV1 #3 was completed in sandy silty clay, whereas the other two wells were completed in silty sand (CWV1 #2) and sandy silt (CWV1 #1).

Geochemistry

To delineate the chemical characteristics and source of the groundwater, water samples were collected in accordance with the protocols established by the USGS National Field Manual (U.S. Geological Survey, variously dated, book 9) and analyzed for major-ion chemistry; selected minor and trace elements; nutrients; organic carbon; the stable isotopes of hydrogen (deuterium) and oxygen (oxygen-18) in water, and of carbon (carbon-13) in dissolved inorganic carbon; and carbon-14 activities. Analyses were performed by the USGS National Water Quality Laboratory in Lakewood, Colorado, and the USGS Stable Isotope Laboratory in Reston, Virginia, by following standard methods outlined by Fishman and Friedman (1989); Coplen and others (1991); Patton and Truitt (1992, 2000); Brenton and Arnett (1993); Fishman (1993); Coplen (1994); Struzeski and others (1996); Garbarino (1999); Garbarino and others (2006); and Patton and Kryskalla (2011). Carbon-13 and carbon-14 analyses were performed by Woods Hole Oceanographic Institute under contract with the USGS using standard methods described by Vogel and others (1987) and Donahue and others (1990). Results presented in this report are limited to those that exceed threshold concentrations for drinking water or aid in understanding the source of the groundwater.

The water samples from the CWV1 wells had total dissolved solids concentrations ranging from 2,100 to 10,700 milligrams per liter (mg/L; table 2), which is greater than the U.S. Environmental Protection Agency (EPA) secondary maximum contaminant level (SMCL-US) of 500 mg/L (*http://water.epa.gov/drink/contaminants/secondarystandards.cfm*, accessed January 3, 2013). Chloride, fluoride, and sulfate concentrations also were greater than their respective SMCL-USs in all of the samples. In addition, to protect human health, fluoride has a maximum contaminant level (MCL-US) of 4 mg/L; the water sample from CWV1-1 had a concentration above this MCL. Concentrations of arsenic were greater than the MCL-US of 10 micrograms per liter in all samples.

Nitrate concentrations, reported as nitrogen (NO_3^--N), in the shallower wells (CWV1 #2, and CVW1 #3) were greater than the U.S. EPA maximum contaminant level (MCL-US) of 10 mg/L (table 2). The NO_3^--N in the shallower wells is hypothesized to be from natural sources or processes, rather than fertilizers in irrigation return flow, because there is little agricultural activity in the vicinity.

The stable isotopes oxygen-18 (^{18}O) and deuterium (^{2}H) in groundwater reflect the altitude, latitude, and temperature of recharge and the extent of evaporation before water entered the groundwater system. The isotopic values of water samples from the three wells were progressively lighter (more negative) with depth (fig. 3, table 3). The isotopic compositions from the two shallower wells were similar to each other, indicating that these zones could have similar sources of recharge. The isotopic composition of the sample from the deeper well (CWV1 #1) was much lighter than the shallower wells, indicating that the source of recharge for this zone was higher in altitude, lower in temperature, or both, compared to the shallower wells. The differences in isotopic and chemical compositions measured in the wells indicated that hydraulic communication between the geologic formations is limited.

Carbon-14 is a radioactive isotope of carbon with a half-life of about 5,700 years (Godwin, 1962). Carbon-14 activities are used to determine the age (time since recharge) of groundwater on time scales ranging from recent to more than 20,000 years before present (Izbicki and Michel, 2003). Carbon-14 ages presented in this report do not account for changes in carbon-14 activities resulting from chemical reactions or mixing and, therefore, are considered uncorrected ages. In general, uncorrected carbon-14 ages are older than the actual ages of the water after correction. Uncorrected ages (in years before present) were calculated by using the following equation (Stuiver and Polach, 1977): Estimated age = 8,033 * natural log (percent modern carbon / 100 percent). Uncertainties concerning the

Table 2. Water-quality indicators (field parameters), selected trace elements and major ions, nitrate, and total dissolved solids, detected in samples collected from the CWV1 multiple-well monitoring site, Chuckwalla Valley, Riverside County, California.

Common well name	Dissolved oxygen, field (mg/L) (00300)	pH, field (standard units) (00400)	Specific conductance, field (µS/cm at 25C) (00095)	Arsenic (µg/L) (01000)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Sulfate (mg/L) (00945)	Nitrate, as nitrogen (mg/L) (00618)	Total dissolved solids (mg/L) (70300)
Threshold type	na	SMCL-US	SMCL-CA[1]	MCL-US	SMCL-US	SMCL-US	SMCL-US	MCL-US	SMCL-US
Threshold level	na	6.50–8.5	900	10	250	2	250	10	500
CWV1 #1	1.6	8.2	3700	17.3	944	7.47	324	<0.04	2100
CWV1 #2	4.1	7.9	16000	11.6	4090	2.47	2500	32.0	10700
CWV1 #3	1.1	7.9	5800	27.0	927	2.75	1570	20.5	4160

1 The SMCL-CA for specific conductance has recommended and upper threshold values. The upper value is shown in parentheses.

The five-digit U.S. Geological survey (USGS) parameter code below the constituent name is used to uniquely identify a specific constituent or property. Threshold type: MCL-US, U.S. Environmental Protection Agency maximum contaminant level; SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. Abbreviations: mg/L, milligrams per liter; na, not available; µS/cm, microsiemens per centimeter; °C, degrees Celsius; µg/L, micrograms per liter; <, less than.

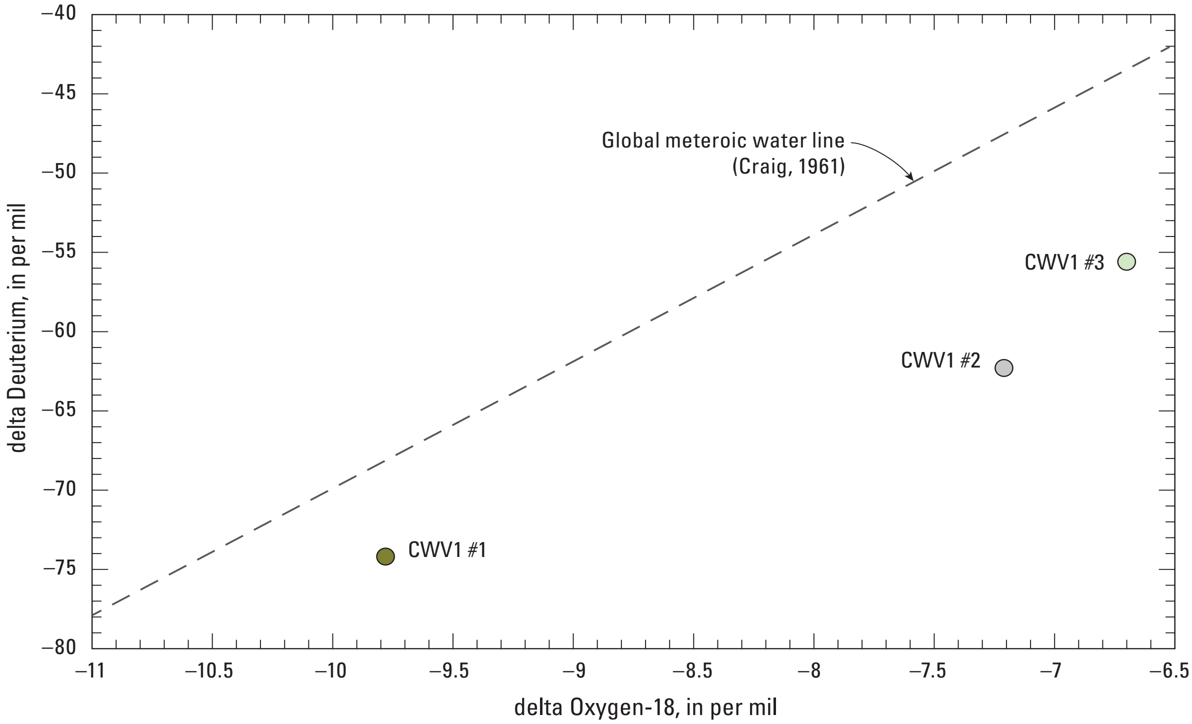

Figure 3. Isotopic composition of groundwater collected from the Chuckwalla Valley multiple-well monitoring site CWV1, Chuckwalla Valley, Riverside County, California

Common well name	$\delta^{18}O$ (per mil) (82085)	$\delta^{2}H$ (per mil) (82082)	$\delta^{13}C$ (per mil) (82081)	Carbon-14 (percent modern) (49933)	Carbon-14 (counting error) (49934)	Estimated age since recharge based on uncorrected carbon-14, years before present
CWV1 #1	-9.78	-74.20	-8.58	9.920	.070	18,600
CWV1 #2	-7.21	-62.30	-10.00	19.05	.110	13,300
CWV1 #3	-6.70	-55.60	-11.62	30.86	.130	9,400

The five-digit U.S. Geological survey (USGS) parameter code below the constituent name is used to uniquely identify a specific constituent or property. Threshold type: MCL-US, U.S. Environmental Protection Agency maximum contaminant level; SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level.

Table 3. Results for analyses of stable isotopes, carbon-14 activities, and estimated age since recharge in samples collected from the CWV1 multiple-well monitoring site, Chuckwalla Valley, Riverside County, California.

initial value of carbon-14 in recharge waters add uncertainties to the groundwater-age estimations made using carbon-14 data; without more comprehensive geochemical modeling, the carbon-14 ages are treated as relative estimates of age rather than accurate absolute estimates of age. Estimated carbon-14 ages for the three wells ranged from 9,400 to 18,600 years before present (table 3).

Accessing Data

Users of the data presented in this report are encouraged to access information through the USGS National Water Information System (NWIS) web page (NWISWeb) located at *http://waterdata.usgs.gov/nwis/*. NWISWeb serves as an interface to a database of site information and groundwater, surface-water, water-chemistry and real-time data collected from locations throughout the 50 states and elsewhere. NWISWeb is updated from the database on a regular basis.

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

References

Brenton, R.W., and Arnett, T.L., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of dissolved organic carbon by UV-promoted persulfate oxidation and infrared spectrometry: U.S. Geological Survey Open-File Report 92–480, 12 p., Method ID: O-1122-92

Butler, J.J., Jr., Garnett, E.J., and Healey, J.M., 2003, Analysis of slug tests in formations of high hydraulic conductivity: Ground Water, v. 41, no. 5, p. 620-630.

California Department of Water Resources, 1963, Data on water wells and springs in the Chuckwalla Valley area, Riverside County, California: California Department of Water Resources Bulletin No. 91-7, p. 77.

California Department of Water Resources, 1979, Sources of power-plant cooling water in the desert area of southern California- reconnaissance study: California Department of Water Resources Bulletin 91-24, 55 p.

California Department of Water Resources, 2003, California's groundwater: Individual basin descriptions, Chuckwalla Valley: California Department of Water Resources Bulletin 118, 246 p. accessed January 3, 2013, at *http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/7-5.pdf*

Coplen, T.B., 1994, Reporting of stable hydrogen, carbon, and oxygen isotopic abundances: Pure & Applied Chemistry, v. 66, p. 273–276.

Coplen, T.B., Wildman, J.D., and Chen, J., 1991, Improvements in the gaseous hydrogen-water equilibration technique for hydrogen isotope ratio analysis: Analytical Chemistry, v. 63, p. 910–912.

Craig, H., 1961, Isotopic variations in meteoric waters: Science, v. 133, p. 1702–1703.

Donahue, D.J., Linick, T.W., and Jull, A.J.T., 1990, Isotope-ratio and background corrections for accelerator mass spectrometry radiocarbon measurements: Radiocarbon, v. 32, book 2, p. 135–142.

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p.

Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p. Method ID: I-2781-85 , I-2587-89 , I-2327-85 , I-2057-85 , I-2371-85 , I-2700-85 , I-1750-89 , I-2030-89

Garbarino, J.R., 1999, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of dissolved arsenic, boron, lithium, selenium, strontium, thallium, and vanadium using inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 99–093, 31 p. Method ID: I-2477-92

Garbarino, J.R., Kanagy, L.K., and Cree, M.E., 2006, Determination of elements in natural-water, biota, sediment and soil samples using collision/reaction cell inductively coupled plasma-mass spectrometry: U.S. Geological Survey Techniques and Methods, book 5, sec. B, chap.1, 88 p. Method ID: I-2020-05

Godfrey, P., Ludwig, N., Salve, R., 2012, Groundwater and large-scale renewable energy projects on federal land: Chuckwalla Valley Groundwater Basin: Arizona Hydrological Society 2012 Annual Water Symposium, September 19, 2012.

Godwin, H, 1962, Half-life of radiocarbon: Nature, v. 195, p. 984.

Halford, K.J., and Kuniansky, E.L., 2002, Documentation of spreadsheets for the analysis of aquifer-test and slug-test data: U.S. Geological Survey Open-File Report 02–197, 54 p.

Izbicki, J.A. and Michel, R.L., 2003, Movement and age of ground water in the western part of the Mojave Desert, southern California, USA: U.S. Geological Survey Water-Resources Investigations Report 03–4314, 35 p.

Keys, W.S., 1990, Borehole geophysics applied to groundwater investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chap. E2, 150 p.

Keys, W.S., and MacCary, L.H., 1971, Application of borehole physics to water-resources investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chap. E1, 126 p.

Metzger, D.G., Loeltz, O.J., and Irelan, Burdge, 1974, Geohydrology of the Parker-Blythe-Ciboloa area, Arizona and California. U.S. Geological Survey Professional Paper 486-G. 130 p.

Patton, C. J., and Kryskalla, J. R., 2011, Colorimetric determination of nitrate plus nitrite in water by enzymatic reduction, automated discrete analyzer methods: U.S. Geological Survey Techniques and Methods, book 5, chap. B8, Method ID: I-2547-11.

Patton, C.J., and Truitt, E.P., 1992, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of total phosphorus by a Kjeldahl digestion method and an automated colorimetric finish that includes dialysis: U.S. Geological Survey Open-File Report 92–146, 39 p., Method ID: I-2610-91.

Patton, C.J., and Truitt, E.P., 2000, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of ammonium plus organic nitrogen by a Kjeldahl digestion method and an automated photometric finish that includes digest cleanup by gas diffusion: U.S. Geological Survey Open-File Report 00-170, 31 p., Method ID: I-2515-91.

Rantz, S. E., 1969, Mean annual precipitation in the California region: U.S. Geological Survey open-file map.

Shuter, Eugene, and Teasdale, W.E., 1989, Application of drilling, coring and sampling techniques to test holes and wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chap. F1, 97 p.

Stallman, R.W., 1971, Aquifer-test design, observation, and data analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. B1, 26 p.

Steinemann, A.C., 1989, Evaluation of nonpotable ground water in the desert area of southeastern California for power-plant cooling: U.S. Geological Survey Water-Supply Paper 2343, 44 p.

Struzeski, T.M., DeGiacomo, W.J., and Zayhowski, E.J., 1996, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of dissolved aluminum and boron in water by inductively compled plasma-atomic emission spectrometry: U.S. Geological Survey Open-File Report 96–149, 17 p., Method ID: I-1472-95.

Stuiver, M., and Polach, H.A., 1977, Reporting of 14C data: Radiocarbon, v. 19, p. 355–363.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, available online at *http://pubs.water.usgs.gov/twri9A*.

Vogel, J.S., Nelson, D.E., and Southon, J.R., 1987, 14C background levels in an accelerator mass spectrometry system: Radiocarbon, v. 29, book 3, p. 323–333.

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