

# CHEMISTRY AND AGE OF GROUND WATER IN THE SOUTHWESTERN HUECO BOLSON, NEW MEXICO AND TEXAS

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U.S. DEPARTMENT OF THE INTERIOR  
U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 02-4237

Prepared in cooperation with

EL PASO WATER UTILITIES



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By Scott K. Anderholm and Charles E. Heywood

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Albuquerque, New Mexico  
2003

U.S. DEPARTMENT OF THE INTERIOR  
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY  
Charles G. Groat, Director

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For additional information write to:

District Chief  
U.S. Geological Survey  
Water Resources Division  
5338 Montgomery Blvd. NE, Suite 400  
Albuquerque, NM 87109-1311

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## CONVERSION FACTORS, DATUMS, AND ABBREVIATED WATER-QUALITY UNITS

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
meter (m)	3.281	foot (ft)

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

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

Specific conductance is reported in microsiemens per centimeter at 25 °C (μS/cm).

Water-quality data are given in milligrams per liter (mg/L), micrograms per liter (μg/L), and picoCuries per liter (pCi/L).

**Sea level:** In this report, “sea level” refers to the National Geodetic Datum of 1929--A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

**Elevation,** as used in this report, refers to distance above sea level.

# CHEMISTRY AND AGE OF GROUND WATER IN THE SOUTHWESTERN HUECO BOLSON, NEW MEXICO AND TEXAS

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## ABSTRACT

This report, prepared in cooperation with El Paso Water Utilities, presents the results of an investigation to determine the chemistry and age of ground water on the southwestern side of the Hueco Bolson. The radioactive isotope carbon-14 was used to estimate the length of time that water from wells has been isolated from the atmosphere, which is the modern carbon-14 reservoir.

Nine wells on the southwestern side of the Hueco Bolson were sampled for analysis of common constituents, nutrients, total organic carbon, trace elements, stable isotopes, and radioactive isotopes. Dissolved-solids concentrations in water from the wells sampled ranged from 269 to 2,630 milligrams per liter. Sodium concentrations generally increased linearly with chloride concentrations, possibly indicating mixing of dilute recharge water with sodium chloride brine. Concentrations of nutrients and trace elements generally were small. The deuterium and oxygen-18 composition in all samples except those from wells adjacent to the Rio Grande indicates that infiltration of precipitation is the main source of water to these wells and that evaporation has not affected the isotopic composition of the water. The source of water from wells adjacent to the Rio Grande is probably not the same source as the water from wells adjacent to the Franklin Mountains. The calculated apparent carbon-14 ages ranged from 12,100 to 25,500 years.

## INTRODUCTION

The Hueco Bolson is a large alluvial basin in south-central New Mexico and western Texas. The basin-fill deposits in the southern Hueco Bolson are an important source of ground water for the city of El Paso, Texas. Little is known about ground-water flow rates in the basin-fill aquifer in this area.

This report, prepared in cooperation with El Paso Water Utilities, presents the results of an investigation to determine the chemistry and age of ground water on the southwestern side of the Hueco Bolson. The

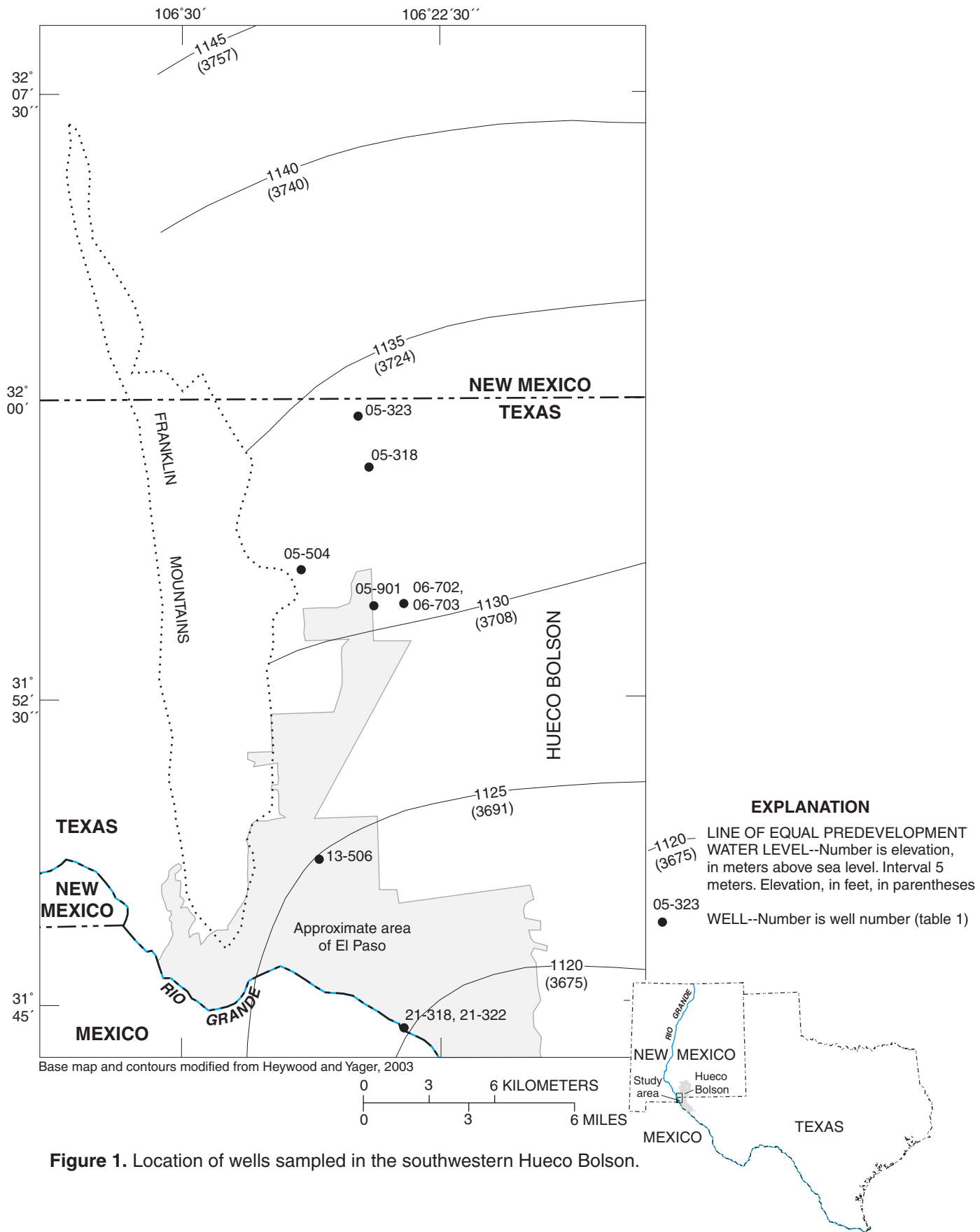
radioactive isotope carbon-14 was used to estimate the length of time that water from wells has been isolated from the atmosphere, which is the modern carbon-14 reservoir.

In September 1997, water samples were collected for analysis of common constituents, nutrients, trace elements, total organic carbon, deuterium, oxygen-18, carbon-13, tritium, and carbon-14 from nine wells on the southwestern side of the Hueco Bolson near El Paso, Texas (fig. 1). Seven of the wells were monitoring wells, and two were municipal supply wells. A portable pump was used to sample six of the monitoring wells (one of the monitoring wells had an existing pump). One to three casing volumes of water were purged from the monitoring wells prior to collection of water samples. Samples were not collected until measured values of the field properties water temperature, dissolved oxygen, specific conductance, and pH had stabilized. The two municipal supply wells sampled were pumped continuously for several days prior to collection of the water samples. Therefore, stabilization of field properties was not required before sampling these wells.

## Hydrologic Setting

The Franklin Mountains bound the southwestern side of the Hueco Bolson near El Paso, Texas (fig. 1). The mountains, which rise to 3,000 ft above the relatively flat bolson floor, are composed of igneous, metamorphic, and sedimentary rocks. The Rio Grande, which is the major surface-water feature, has eroded a valley through the basin-fill deposits in the Hueco Bolson. This valley is about 200 to 250 ft below the surface of the bolson floor (White and others, 1997). Mean annual precipitation in El Paso is about 10.2 in. (U.S. Department of Commerce, 2001).

Basin-fill deposits of Tertiary age compose the main aquifer in the southwestern Hueco Bolson. Ground water also occurs in shallow alluvium of Quaternary age near the Rio Grande (Knowles and Kennedy, 1958). The principal source of recharge to



**Figure 1.** Location of wells sampled in the southwestern Hueco Bolson.

the ground-water system in this area is infiltration of precipitation and runoff along the base of the Franklin Mountains (Knowles and Kennedy, 1958, p. 18). Ground water moves eastward and southward from the Franklin Mountains (Knowles and Kennedy, 1958, p. 18). Before large withdrawals of ground water from the basin-fill deposits, ground water moved from the recharge areas southeastward toward the Rio Grande Valley where potentiometric heads were greater than the elevation of the river (Knowles and Kennedy, 1958, p. 18 and 19). Ground water probably discharged to the Rio Grande Valley prior to ground-water pumpage in the valley area. Part of this water discharged to the Rio Grande and part of the water was used by native vegetation in the valley (White and others, 1997). Saline water occurs in deeper parts of the basin-fill aquifer and in the shallow alluvium adjacent to the Rio Grande (Knowles and Kennedy, 1958, p. 19 and 26).

Ground-water pumpage from the basin-fill deposits has resulted in changes in predevelopment ground-water flow directions. White and others (1997) indicated that saline ground water from deeper parts of the aquifer is moving upward. They also indicated that saline water from the shallow alluvium adjacent to the Rio Grande Valley as well as water infiltrating from the Rio Grande has been moving downward since the 1940's.

## Acknowledgments

Access and sampling of the wells would not have been possible without the cooperation of personnel from El Paso Water Utilities, Fort Bliss Military Reservation, and Biggs Army Airfield. Roger Sperka of El Paso Water Utilities assisted in the collection of water samples and freely shared his vast knowledge of the geology and hydrology of the area. Roger's assistance and input are greatly appreciated. Tyler Coplen of the U.S. Geological Survey supplied the stable isotope data for the Rio Grande.

## GROUND-WATER CHEMISTRY

The wells sampled were located in two general areas in the southwestern part of the Hueco Bolson. Seven of the wells sampled were east of the Franklin Mountains (fig. 1). Water from the wells east of the Franklin Mountains probably represents water that recharged the basin-fill aquifer along the Franklin Mountains and moved southeastward and mixed with

water moving south. Two monitoring wells (21-318 and 21-322) are adjacent to the Rio Grande southeast of the Franklin Mountains. The area where water from these wells recharges the aquifer is not clear; however, some water from these wells probably infiltrates from the Rio Grande.

The casing material of the seven wells sampled adjacent to the Franklin Mountains was steel, and the casing material of the wells sampled adjacent to the Rio Grande was polyvinylchloride (PVC). The length of screened interval in four monitoring wells (06-703, 06-702, 13-506, and 05-318) sampled near the Franklin Mountains ranged from 20 to 50 ft (table 1) and in well 05-323 was 200 feet. The length of screened interval in the municipal supply wells was 379 (05-901) and 671 (05-504) ft. The top of the screened interval in five of the seven wells adjacent to the Franklin Mountains was at or within 20 ft of the water level in the well and in the other two wells (06-703 and 13-506) was about 180 and 400 ft below the water level, respectively. Water levels in the wells near the Franklin Mountains ranged from 316 to 378 ft below land surface. The length of screened interval in the two monitoring wells adjacent to the Rio Grande was 10 ft. The top of the screened interval in well 21-318 was 348 ft below land surface and in well 21-322 was 659 ft below land surface. The water level in these wells was about 100 ft below land surface. The relatively short screened interval (less than 50 ft) in many of the wells allowed sample collection from discrete parts of the aquifer, usually near the top of the zone of saturation. Samples from wells with large screened intervals represent mixtures of water from larger parts of the aquifer.

## Field Properties

Specific conductance, pH, temperature, and dissolved oxygen were measured in the field. The specific conductance of water from the wells ranged from 431 to 4,350  $\mu\text{S}/\text{cm}$  (table 1) and from all but three of the wells was less than or equal to 742  $\mu\text{S}/\text{cm}$ . The pH of water samples ranged from 7.34 to 8.30. The pH of water from the two wells adjacent to the Rio Grande generally was higher than the pH in wells adjacent to the Franklin Mountains. Water temperatures ranged from 23.1 to 28.7 °C. Water from the wells adjacent to the Rio Grande generally had the lowest temperature, and water from the deepest well (05-504) (a well with 671 ft of screened interval) had the highest temperature. Dissolved-oxygen concentrations ranged from 0.05 to 5.0 mg/L and were



largest in the municipal wells. Oxygen from the unsaturated zone may be drawn into water pumped through these wells because the water levels in these wells were below the top of the screened interval.

## Common Constituents

The sampled water can be grouped into two types on the basis of dissolved-solids concentration and percentage of chloride relative to the sum of chloride, sulfate, and bicarbonate (in milliequivalents) (table 1 and fig. 2). The differences in water types are probably related to the composition of recharge water and the dominant factors affecting geochemical evolution of the ground water. Processes that could be affecting the composition of water include dissolution and (or) precipitation of gases and minerals, ion exchange, and mixing of dilute recharge water with more saline water such as a sodium chloride brine.

The dissolved-solids concentration in water from three wells (06-703, 21-318, and 21-322) ranged from 662 to 2,630 mg/L and was larger than concentrations in water from any other wells sampled (listed as "Solids residue at 180 deg C, dissolved" in table 1). The percentage of chloride relative to the sum of chloride, sulfate, and bicarbonate was also larger in water from these three wells (greater than 70 percent) (fig. 2). Two of these wells (21-318 and 21-322) are adjacent to the Rio Grande. Well 06-703 is located farther east of the Franklin Mountains than most of the other wells sampled (fig. 1). Sodium and chloride are the dominant ions in water from these three wells (fig. 2). The relatively large dissolved-solids concentration and large sodium and chloride concentrations in water from wells 21-318, 21-322, and 06-703 could be due to larger concentrations of sodium and chloride in water recharging the aquifer near these wells or to dilute recharge water mixing with a sodium chloride brine as water moves through the aquifer toward these wells.

The dissolved-solids concentration in water from the other six wells (06-702, 13-506, 05-323, 05-318, 05-504, and 05-901), which are adjacent to the Franklin Mountains, ranged from 269 to 455 mg/L (table 1). The percentage of chloride relative to the sum of chloride, sulfate, and bicarbonate was less than 50 in water from these wells (fig. 2). Sodium plus potassium, bicarbonate, and chloride generally are the dominant ions in water from these wells (fig. 2). Although the concentrations of individual cations vary among the samples, the percentage of sodium plus potassium, calcium, and magnesium relative to the sum of these

ions is relatively constant in water from these wells. The percentage of sulfate relative to the sum of chloride, sulfate, and bicarbonate is also relatively constant, whereas the percentage of bicarbonate in water decreases as the percentage of chloride increases (fig. 2).

Although wells 06-702, 13-506, 05-323, 05-318, 05-504, and 05-901 are not along the same precise flow path, differences in the composition of water from these wells can be used to infer processes that might be important during the chemical evolution of water from these wells. Processes that could be affecting the composition of water recharging the basin-fill deposits along the Franklin Mountains include evapotranspiration of precipitation during infiltration, dissolution and (or) precipitation of gases and minerals, ion exchange, and mixing of dilute water and brine. Water from well 05-504, which is the well closest to the Franklin Mountains, is probably the most representative sample of the composition of recharge water in the area. Water from this well has small concentrations of sodium, potassium, and chloride and generally larger concentrations of calcium and bicarbonate than water from the other sampled wells (fig. 3 and table 1). Sodium concentrations generally increase linearly with increasing chloride concentrations in water from the sampled wells, possibly indicating that dilute recharge water mixes with sodium chloride brine as the water moves away from the recharge area (fig. 3A). The relation between potassium, calcium, sulfate, and bicarbonate with chloride (fig. 3B, C, D, and E) is not as clear as the relation between sodium and chloride, indicating processes in addition to mixing that affect potassium, calcium, sulfate, and bicarbonate concentrations. Trend lines (linear regression) show that potassium and sulfate (fig. 3B and D) generally increase with increasing chloride, which could mean that mixing is an important process affecting the concentrations of these ions. Calcium and bicarbonate concentrations are larger in water from well 05-504 than in water from the other wells adjacent to the Franklin Mountains (fig. 3C and E), which are farther from the recharge area. Bicarbonate generally decreases with increasing chloride concentration (fig. 3E), which is consistent with calcite precipitation as ground water moves through the aquifer. With the exception of water from well 05-504, calcium concentrations are positively correlated with sulfate concentrations (fig. 3F), indicating dissolution of gypsum in the water. Dissolution of gypsum causes calcium concentrations to increase, possibly causing calcite to precipitate.

**Table 1.** Water-quality data for wells sampled in the southwestern Hueco Bolson, September 1997

[--, no data;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius (deg C); mm, millimeters; mg/L, milligrams per liter; water whole, unfiltered sample; dis, dissolved; pCi/L, picocuries per liter; it, incremental titration; gran t. field, field gran titration of filtered sample; <, less than]

Station number	Date	Time	Well number (fig. 1)	Elevation of land surface (feet above sea level)	Depth of well, total (feet)	Depth to top of screened interval (feet)	Depth to bottom of screened interval (feet)	Water level (feet below land surface)
315452106203202	08-22-97	1200	06-703	3,914	550	510	550	329.2
315452106203201	08-27-97	1900	06-702	3,914	360	320	360	326.0
314831106260001	08-20-97	1900	13-506	3,884	736	716	736	316.0
315932106245101	08-19-97	1330	05-323	4,038	500	300	500	--
315816106243201	08-21-97	1620	05-318	4,015	500	450	500	378.4
315543106263201	08-27-97	0900	05-504	4,120	1,152	481	1,152	--
315448106242401	08-27-97	1120	05-901	3,940	727	348	727	--
314421106233403	08-26-97	1930	21-318	3,686	378	348	358	91.0
314421106233407	08-26-97	1100	21-322	3,686	678	659	669	107.6

Well number (fig. 1)	Specific conductance, field ( $\mu\text{S}/\text{cm}$ )	Specific conductance, lab ( $\mu\text{S}/\text{cm}$ )	pH water whole, field (standard units)	pH water whole, lab (standard units)	Temperature water (deg C)	Barometric pressure (mm of Hg)	Oxygen, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)
06-703	1,920	1,870	7.34	7.27	24.8	--	0.05	77
06-702	740	711	7.90	7.97	25.5	--	0.8	28
13-506	480	463	8.20	8.20	26.0	--	0.1	22
05-323	431	415	7.78	7.99	26.5	658	2.9	19
05-318	704	677	7.85	8.02	26.4	659	4.0	36
05-504	572	557	7.48	7.70	28.7	658	5.0	41
05-901	742	724	7.61	7.96	26.9	660	4.3	29
21-318	4,350	4,170	8.10	7.74	24.3	669	0.2	180
21-322	1,190	1,140	8.30	8.24	23.1	669	0.8	30

**Table 1.** Water-quality data for wells sampled in the Hueco Bolson, September 1997--Continued

Well number (fig. 1)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate water dit, field (mg/L as HCO <sub>3</sub> )	Alkalinity		Sulfate, dissolved (mg/L as SO <sub>4</sub> )	Fluoride, dissolved (mg/L as F)
					water whole gran t., field (mg/L as CaCO <sub>3</sub> )	Alkalinity, lab (mg/L as CaCO <sub>3</sub> )		
06-703	18.2	245	9.8	82	68	61	24	0.5
06-702	6.0	109	5.6	155	126	125	52	0.8
13-506	9.4	63	5.3	204	165	159	25	0.6
05-323	4.0	60	4.1	126	101	102	33	0.9
05-318	8.4	91	7.6	187	152	151	74	0.8
05-504	18.0	49	3.9	258	210	209	49	1.6
05-901	9.0	104	9.6	182	147	149	78	1.0
21-318	80.6	560	20	--	--	132	330	0.4
21-322	4.9	190	3.8	98	86	86	59	0.8

Well number (fig. 1)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO <sub>2</sub> )	Solids, residue at 180 deg C, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO <sub>2</sub> +NO <sub>3</sub> , dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, dis (mg/L as N)	Phosphorus, dissolved (mg/L as P)
06-702	110	23	428	0.09	1.71	<0.015	<0.2	0.05
13-506	29	26	297	0.01	1.54	0.032	<0.2	<0.01
05-323	37	29	269	<0.01	1.81	<0.015	<0.2	<0.01
05-318	70	31	433	<0.01	1.82	<0.015	<0.2	<0.01
05-504	19	30	357	<0.01	1.70	<0.015	<0.2	<0.01
05-901	83	30	455	<0.01	1.54	<0.015	<0.2	<0.01
21-318	1,080	30	2,630	<0.01	0.05	0.018	<0.2	<0.01
21-322	270	32	662	<0.01	<0.05	0.036	<0.2	<0.01

**Table 1.** Water-quality data for wells sampled in the Hueco Bolson, September 1997--Continued

Well number (fig. 1)	Phosphorus, ortho, dissolved (mg/L as P)	Carbon, organic, total (mg/L as C)	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium, dissolved (µg/L as Cd)
06-703	<0.01	0.1	4	<1	<1	210	<1	<1
06-702	<0.01	0.1	3	<1	<1	41	<1	<1
13-506	<0.01	1.1	4	<1	4	150	<1	<1
05-323	<0.01	0.3	3	<1	3	47	<1	<1
05-318	<0.01	0.1	3	<1	4	78	<1	<1
05-504	0.014	0.1	4	<1	1	140	<1	<1
05-901	0.012	0.1	4	<1	4	42	<1	<1
21-318	<0.01	1.2	8	<2	2	100	<2	<2
21-322	<0.01	0.2	7	<1	20	67	<1	<1

Well number (fig. 1)	Chromium, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Uranium natural, dissolved (µg/L as U)
06-703	<1	<1	<1	4,100	<1	74	3	1	<1
06-702	1	<1	<1	24	<1	29	6	<1	2
13-506	<1	<1	<1	120	<1	14	6	<1	2
05-323	4	<1	<1	20	<1	23	5	<1	1
05-318	7	<1	<1	4	<1	<1	8	<1	4
05-504	3	<1	12	<3	1	<1	18	<1	6
05-901	7	<1	2	<3	<1	<1	7	<1	5
21-318	<2	<2	<2	<9	<2	61	6	3	16
21-322	<1	<1	<1	<3	<1	6	5	<1	<1

**Table 1.** Water-quality data for wells sampled in the Hueco Bolson, September 1997--Concluded

Well number (fig. 1)	Selenium, dissolved ( $\mu\text{g/L}$ as Se)	Silver, dissolved ( $\mu\text{g/L}$ as Ag)	Zinc, dissolved ( $\mu\text{g/L}$ as Zn)	H-2/H-1 stable isotope ratio per mil	O-18/O-16 stable isotope ratio per mil	C-13/C-12 stable isotope ratio per mil	Tritium, total (pCi/L)	Carbon-14 water filtered (percent), modern	Carbon-14 counting error water filtered (percent)
06-703	1	<1	350	-71.9	-10.17	-7.19	0.38	4.56	0.14
06-702	2	<1	73	-67.4	-9.67	-8.36	0.42	5.66	0.12
13-506	<1	<1	<1	-65.6	-9.33	-9.33	0.74	11.92	0.18
05-323	2	<1	140	-65.8	-9.28	-7.47	1.2	13.18	0.17
05-318	4	<1	83	-66.9	-9.48	-7.92	0.74	18.22	0.21
05-504	1	<1	21	-63.0	-8.96	-8.17	0.83	23.20	0.3
05-901	4	<1	5	-69.8	-9.78	-8.13	0.48	10.80	0.16
21-318	<1	<2	8	-76.8	-9.82	-9.71	25.5	73.13	0.49
21-322	<1	<1	1	-76.4	-10.43	-10.51	1.1	6.60	0.13

Most samples are at saturation or are supersaturated with respect to calcite (table 2), so calcite would tend to precipitate, especially if calcium was added to solution because of dissolution of gypsum as the water moves through the aquifer.

Silica concentrations in the six samples from wells near the Franklin Mountains ranged from 23 to 31 mg/L (table 1). The silica concentration in water from well 05-504 was 30 mg/L, indicating that most of the silica dissolves in water during recharge or near the recharge area. The lack of variation in silica concentrations in the water indicates that silica is not dissolving appreciably after water recharges the ground-water flow system.

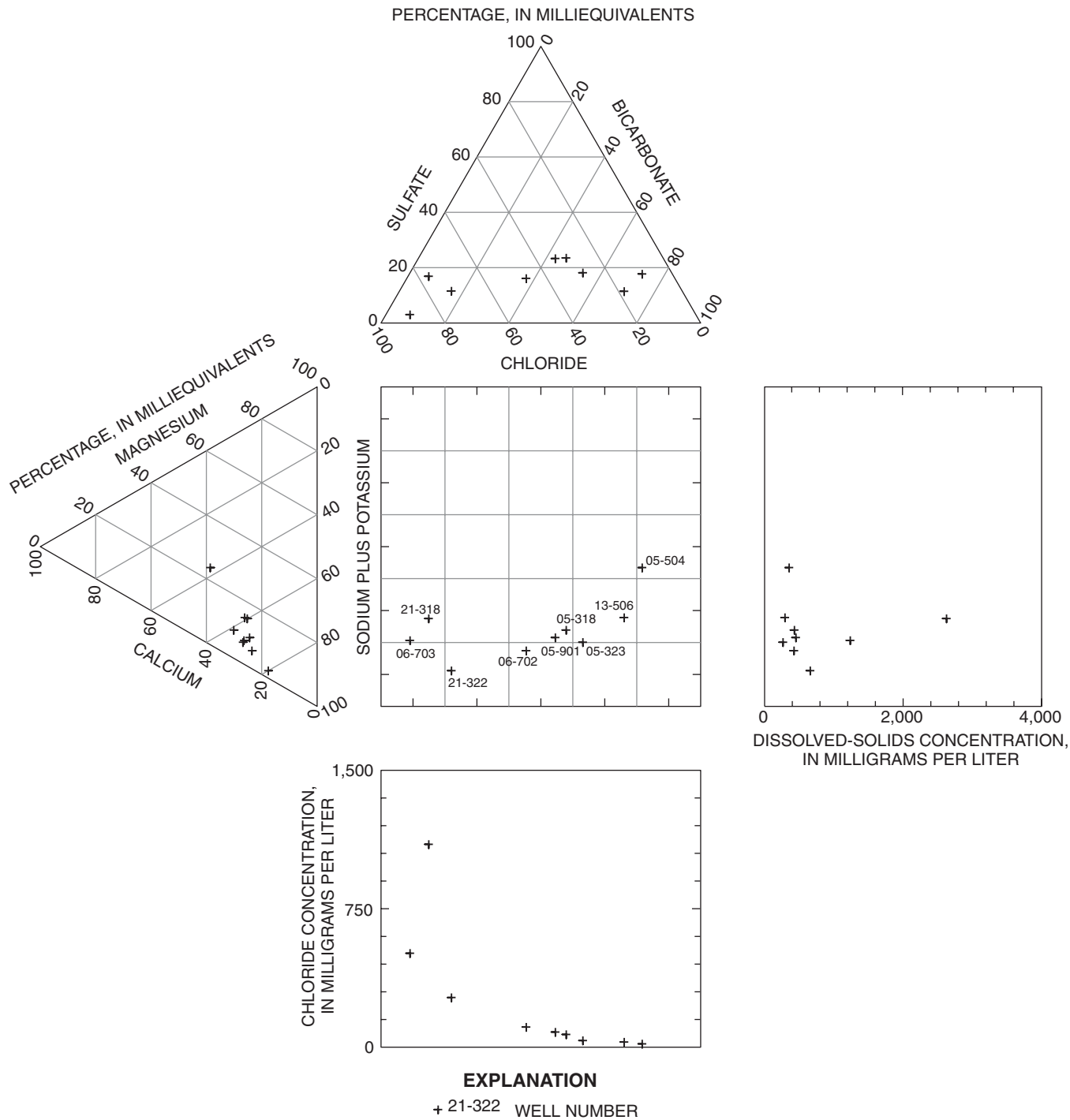
## Nutrients and Total Dissolved Carbon

Nutrient concentrations generally were small (less than 0.05 mg/L) with the exception of dissolved nitrite ( $\text{NO}_2$ ) plus nitrate ( $\text{NO}_3$ ) (table 1). The nitrite plus nitrate concentrations in the samples from the two wells adjacent to the Rio Grande were less than 0.05 and 0.05 mg/L as N. Nitrite plus nitrate concentrations ranged from 1.05 to 1.82 mg/L as N in the other seven samples. Nitrite concentrations generally were less than 0.01 mg/L as N, indicating nitrate as the dominant nitrogen species in the samples. Dissolved phosphorus concentrations generally were less than 0.01 mg/L.

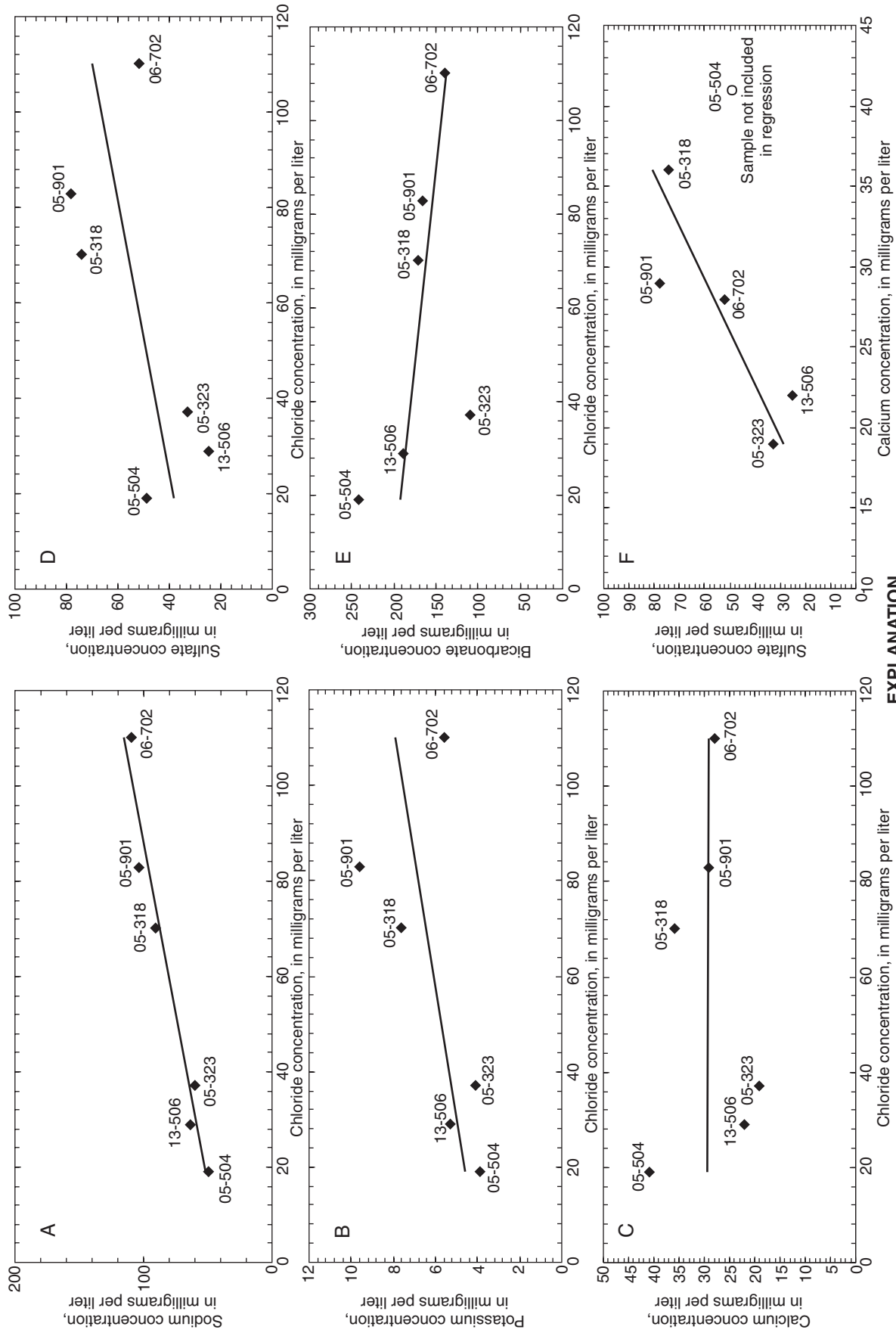
Dissolved organic carbon concentrations ranged from 0.1 to 1.2 mg/L as C and were 0.3 mg/L or less in seven of nine samples. The presence of nitrite plus nitrate greater than 1 mg/L in seven of nine samples and dissolved oxygen greater than 0.5 mg/L in five of these seven samples indicates that ground water is generally oxidized and that nitrate in recharge water is not reduced by bacteria to ammonia or nitrogen gas (nitrate reduction). Nitrate could have been reduced in water from wells 21-318 and 21-322 (fig. 1), which are both located near the Rio Grande, because dissolved-oxygen and nitrate concentrations are small and ammonia was detected in samples from both wells. The relatively small organic carbon concentrations (0.3 mg/L or less) (table 1) and similarity in the partial pressure of carbon dioxide (table 2) in most of the samples indicate few chemical reactions involving organic carbon in the unsaturated or saturated zone.

## Trace Elements

Concentrations of most trace elements in the nine samples were generally small or less than the detection limit of 1  $\mu\text{g/L}$  and had little variation (table 1). Aluminum, arsenic, chromium, selenium, and uranium were detected in most samples at concentrations less than 5  $\mu\text{g/L}$ . These relatively small concentrations indicate no significant processes in the area that contribute to these trace-element concentrations.



**Figure 2.** Durov plot of ground-water composition in the southwestern Hueco Bolson.



**Figure 3.** Relation between chloride concentration and (A) sodium, (B) potassium, (C) calcium, (D) sulfate, and (E) bicarbonate concentrations and between (F) calcium and sulfate concentrations in the southwestern Hueco Bolson.

**Table 2.** Measured carbon-13 and carbon-14 composition, calculated partial pressure of carbon dioxide, saturation index for calcite, and apparent age of water in the southwestern Hueco Bolson

Well number (fig. 1)	Carbon-13/carbon-12 ratio, in permil	Carbon-14, in percent modern	Partial pressure of carbon dioxide, in atmospheres	Saturation index, calcite	Apparent age, in years
06-703	-7.19	4.56	-2.46	0.41	25,500
06-702	-8.36	5.66	-2.7	0.06	23,700
13-506	-9.33	11.92	-2.9	0.40	17,600
05-323	-7.47	13.18	-2.7	-0.26	16,800
05-318	-7.92	18.22	-2.6	0.20	14,100
05-504	-8.17	23.20	-2.1	0.07	12,100
05-901	-8.13	10.80	-2.4	-0.13	18,400
21-322	-10.51	6.60	-3.3	0.24	22,500

The concentrations of barium, iron, manganese, molybdenum, and zinc were greater than 5 µg/L in many of the samples and varied considerably (table 1). This indicates that factors affecting the concentrations of these trace elements vary in different areas of the Hueco Bolson. The variations in concentrations of these trace elements could be related to variations in the composition of recharge water, spatial variations in the abundance of minerals containing trace elements in the aquifer, differences in oxidation/reduction conditions in the aquifer, or mixing of recharge water with sodium chloride brine that contains trace elements.

Barium was detected in the samples at concentrations ranging from 41 to 210 µg/L (table 1). Because larger barium concentrations were not related to a particular area of the Hueco Bolson, the variation in barium concentrations is probably not related to variations in the abundance of barium-containing minerals in particular areas of the bolson. What is affecting the barium concentrations in ground water in the area is not clear.

Iron and manganese concentrations varied considerably in the samples. In general, the largest iron and manganese concentrations were in samples with smaller dissolved-oxygen concentrations, indicating that iron and manganese concentrations are affected by oxidation/reduction conditions. Water from the well

with the largest iron and manganese concentrations, well 06-703, also had the smallest measured dissolved-oxygen concentration (0.05 mg/L); water from this well indicates reducing conditions with respect to iron and manganese.

Molybdenum concentrations ranged from about 5 to 7 µg/L in eight of the samples; water from well 05-504 had a molybdenum concentration of 18 µg/L. Why the molybdenum concentration in water from this well was larger than those in the other samples is not clear. Zinc concentrations ranged from less than 1 to 350 µg/L (table 1). The reason for the large range is not known. Some iron, manganese, and zinc detected in the samples could be due to leaching from steel well casings.

### Stable Isotopes

The delta deuterium and delta oxygen-18 composition in all but the two samples from the wells adjacent to the Rio Grande (21-318 and 21-322) trends along the Mean Global Meteoric Water Line (MWL) (Craig, 1961) (fig. 4), a line that represents the composition of precipitation throughout the world. Samples that trend along the MWL represent precipitation (meteoric water) that has infiltrated and recharged the ground-water flow system. Evaporation,



mixing with non-meteoric water, or isotopic exchange at high temperatures can explain sample compositions that deviate from the MWL. Samples from the wells adjacent to the Rio Grande (21-318 and 21-322) plot significantly below the MWL. The type of displacement from the MWL shown in these two samples could be the result of evaporation but not evaporation of water sampled from the area adjacent to the Franklin Mountains. The source of recharge water to these two wells is probably different from the source of recharge to the other seven wells sampled because these two samples are isotopically lighter than samples from the area adjacent to the Franklin Mountains. On the basis of isotopic composition of modern Rio Grande water (fig. 4), these two samples have not evolved from modern Rio Grande water. The source of recharge water to the wells near the Rio Grande is not known.

A plot of delta deuterium and chloride concentration indicates that delta deuterium decreases with increasing chloride concentration in most of the samples (fig. 5). This could mean that dilute recharge water with relatively heavy delta deuterium is mixing with a sodium/chloride-rich brine that has a relatively light delta deuterium. The plot of sodium and chloride concentration (fig. 3A) also indicates that dilute recharge water is mixing with a sodium/chloride-rich brine as the water moves through the ground-water flow system.

The delta carbon-13 composition of the samples ranges from -10.51 to -7.19 per mil (table 1). The samples from the wells adjacent to the Rio Grande (21-318 and 21-322) are generally lighter (more negative) than the other samples. Delta carbon-13 is useful for determining how the carbon-14 composition in the samples has been affected by chemical reactions because both carbon-13 and carbon-14 compositions are affected by chemical reactions during recharge and as water moves through the aquifer. The relatively small variation in delta carbon-13 composition in the samples from wells adjacent to the Franklin Mountains (-9.33 to -7.19) indicates that similar processes have affected the carbon composition in water from these wells during recharge or ground-water movement through the basin-fill aquifer. The lighter delta carbon-13 in samples from the wells adjacent to the Rio Grande relative to the other samples indicates differences in reactions occurring or different delta carbon-13 composition of recharge water in the different areas.

## Radioactive Isotopes

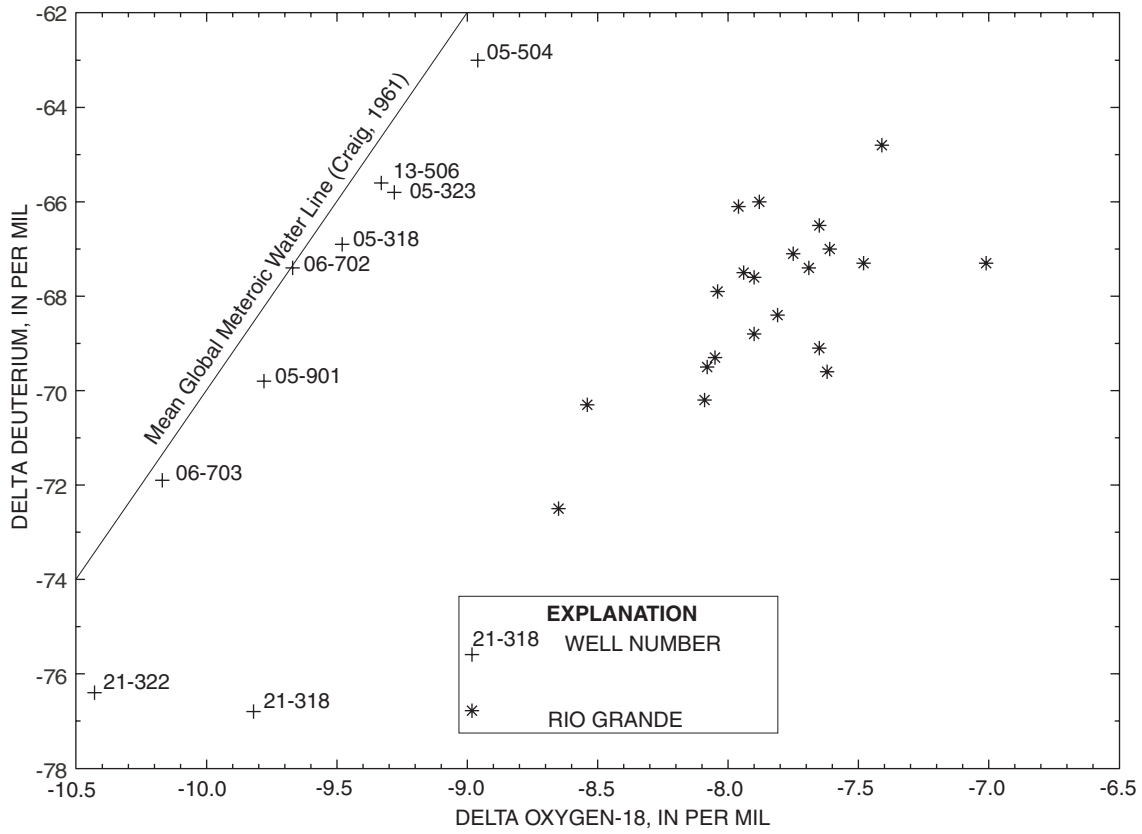
Because tritium activity generally was small in most of the samples (table 1), the ground water probably has been isolated from the atmosphere for more than 50 years. The tritium activity of 25.5 pCi/L in the sample from the 378-ft-deep well adjacent to the Rio Grande (21-318) indicates that water from this well has a significant amount of relatively modern recharge water (water less than 50 years old). Water from the 678-ft-deep well adjacent to the Rio Grande (21-322) had a tritium activity of 1.1 pCi/L, and water from the 500-ft-deep well adjacent to the Franklin Mountains (05-323) had a tritium activity of 1.2 pCi/L, indicating a small amount of relatively modern water in these wells or the introduction of small amounts of tritium to the samples during sample collection. The rest of the samples had tritium activities between 0.38 and 0.83 pCi/L, indicating little or no modern recharge water mixing with these samples.

Carbon-14 compositions ranged from 4.56 to 73.13 percent modern (table 1). The sample from the 378-ft-deep well adjacent to the river (21-318) had a carbon-14 composition of 73.13 percent modern, indicating a significant amount of relatively modern water. The use of carbon-14 to calculate the apparent age of water from well 21-318 is not possible because of the large amount of modern water in the sample. The other eight samples had carbon-14 compositions between 4.56 and 23.20 percent modern, and apparent ages were calculated.

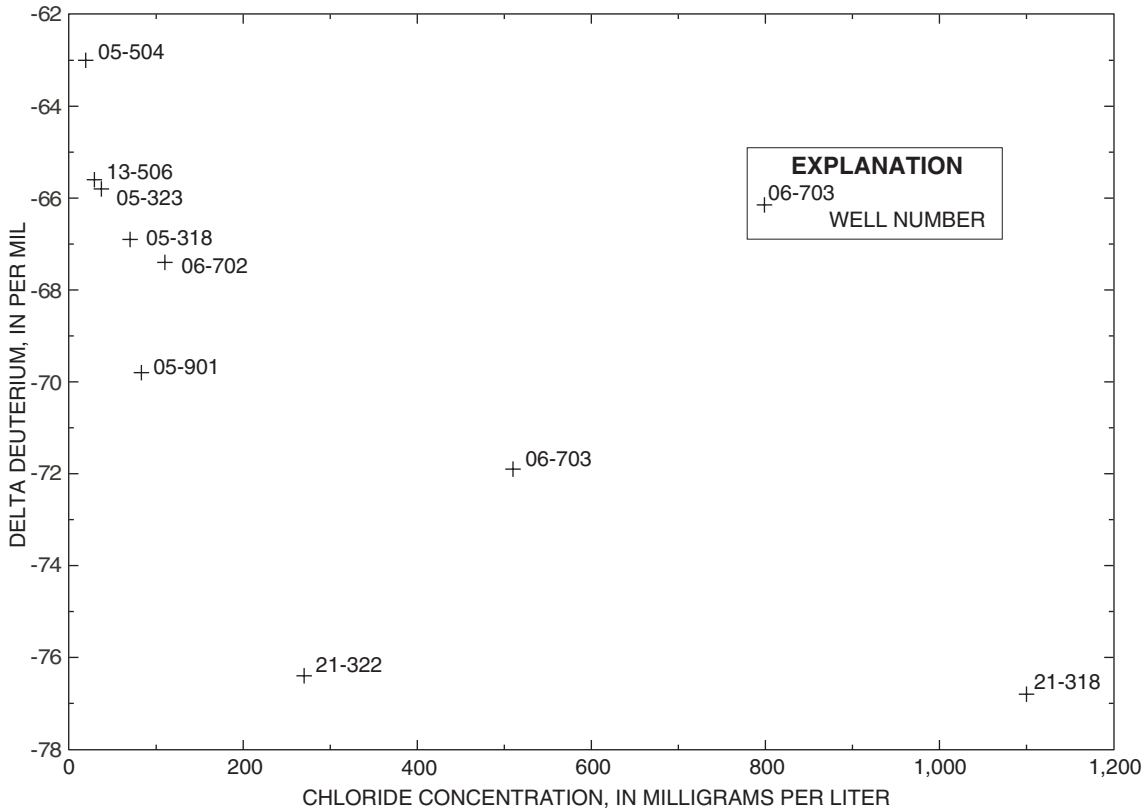
## AGE OF GROUND WATER

The time since water from a well has been isolated from the atmosphere (apparent age) can be estimated using its carbon-14 composition. In general, water is isolated from the atmosphere (the modern carbon-14 reservoir) when water moves from the unsaturated zone to the ground-water flow system. The carbon-14 composition of ground water is the result of two main factors: (1) chemical reactions that affect the inorganic carbon concentrations and carbon-14 composition in the water as the water infiltrates through the unsaturated zone or moves through the aquifer and (2) radioactive decay of carbon-14 in the water.

Two common chemical reactions affecting the inorganic carbon concentrations, carbon-13 composition, and carbon-14 composition in ground water include dissolution of carbon dioxide and



**Figure 4.** Relation between delta oxygen-18 and delta deuterium in ground water and water from the Rio Grande in the southwestern Hueco Bolson.



**Figure 5.** Relation between chloride concentration and delta deuterium in ground water in the southwestern Hueco Bolson.

dissolution of carbonate minerals. These reactions could occur in the unsaturated zone during infiltration of water or as ground water moves through the aquifer. Dissolution of carbon dioxide gas, most of which generally occurs in the unsaturated zone by infiltrating water, is an important reaction that affects the carbon-14 composition of ground water. Infiltrating water and dissolving carbon dioxide gas in the unsaturated zone would have a carbon-14 composition of about 100 percent modern because carbon dioxide gas diffuses from the atmosphere and because plants respire carbon dioxide gas to the soil zone or unsaturated zone that is 100 percent modern. Water that has dissolved carbon dioxide gas and is infiltrating through the unsaturated zone or moving through the aquifer can also dissolve carbonate minerals, which increases dissolved inorganic carbon concentrations and can affect the carbon-14 composition of the water. The carbon-14 composition of water generally decreases during dissolution of carbonate minerals because the carbon-14 composition of carbonate minerals is small relative to carbon dioxide gas. The dissolution of carbonate minerals can reduce the carbon-14 composition of ground water significantly. Although other chemical reactions can also affect the carbon-14 composition of ground water, these two reactions are probably the most important reactions affecting inorganic carbon/carbon-14 in ground water in the Hueco Bolson.

The carbon-14 composition of water decreases with time because of radioactive decay of the carbon-14. The half-life of carbon-14 is about 5,730 years; therefore, water with 100 percent modern carbon-14 would have a carbon-14 composition of 50 percent modern after 5,730 years as the result of radioactive decay.

Before determining how long ground water has been isolated from the atmosphere or from the modern carbon-14 reservoir, the effect of chemical reactions on the carbon-14 composition of ground water needs to be determined. After the carbon-14 composition of ground water has been corrected for changes due to chemical reactions ( $A_0$ ), age can be estimated on the basis of radioactive decay of carbon-14. Investigators have developed several models to adjust or estimate the carbon-14 composition of water resulting from processes in the unsaturated zone and aquifer ( $A_0$ ) (Mook, 1980). These models range from simple models that require little data to complex models that require much information about the carbon isotopic composition (carbon-13 and carbon-14) of gas in the

unsaturated zone, carbon isotopic composition of carbonate minerals in the unsaturated zone and aquifer, and reactions that occur as water moves through the aquifer. Much of the data needed for these models have not been collected and are not available for the Hueco Bolson. These data were collected in the Middle Rio Grande Basin, however, and are considered applicable to the Hueco Bolson.

The Middle Rio Grande Basin, which is about 200 mi north of the Hueco Bolson, is an alluvial basin similar to the Hueco Bolson. Rock types in the mountains adjacent to the basin and bolson are similar igneous and metamorphic rock of Precambrian age to sedimentary rock of Paleozoic age. The basin-fill deposits of Tertiary age (principal aquifer) in the Middle Rio Grande Basin are similar to the basin-fill deposits in the Hueco Bolson (sand, silt, and clay fluvial and alluvial-fan deposits). Recharge to the basin and bolson is along the margins as the result of infiltration of precipitation, and depths to water in the recharge areas along the margins are similar (generally greater than 300 ft).

In the Middle Rio Grande Basin delta carbon-13 compositions in ground water generally range from -10.4 to -6.0 per mil (values similar to those for the Hueco Bolson), and the carbon-14 composition of the water before radioactive decay and after chemical reactions ( $A_0$ ) was estimated to be about 100 percent modern (Neil Plummer, U.S. Geological Survey, oral commun., 2001). Because of the similarity of the basin-fill deposits, hydrology, and carbon-13 composition of ground water in the basin and bolson, an  $A_0$  of 100 percent modern was assumed for the Hueco Bolson. Choosing a smaller  $A_0$  would cause the calculated apparent age to be younger (less).

The following equation was used to estimate the apparent age of ground water in the Hueco Bolson:

$$t = (5,730/\ln 2) \ln (A_0/A_s) \quad (1)$$

where  $t$  = apparent age, in years;

$A_0$  = carbon-14 composition of water before radioactive decay and after chemical reactions, in percent modern; and

$A_s$  = carbon-14 composition measured in the sample, in percent modern.

The calculated apparent age of the water sampled ranged from about 12,100 to 25,500 years (table 2). If the water was isolated from the atmosphere

when it recharged the ground-water system, the carbon-14 ages are estimates of the time water takes to move through the aquifer from the recharge area to the well or sampling point. There is some indication that recharge water mixes with a sodium chloride brine as water moves through the ground-water flow system. If the brine was much older than the recharge water, the calculated apparent ages would indicate travel times greater than actual travel times. Water from well 05-504, which is the closest well to the Franklin Mountains (a possible recharge area), had the youngest apparent age (12,100 years). Considering the apparent age of water from this well and its proximity to the possible recharge area, flow rates could be slow in this area, possibly because of small rates of recharge to the aquifer in this area. Water from well 06-703, which has a screened interval of 500 to 550 ft below land surface, had the oldest apparent age (25,500 years). Water from well 06-702, which is next to well 06-703 and has a screened interval about 200 ft closer to land surface than that of well 06-703, had an apparent age of 23,700 years, indicating that ground-water age increases with depth near these wells or that mixing with relatively old sodium chloride brine has affected the age of water from the deeper well. Water from the well near the Rio Grande (21-322) had an age of 22,500 years. The small amount of tritium in this sample (table 1) could mean a small amount of modern water in the sample, which would cause the calculated apparent age of the water to be younger than that of other water in this area that has not mixed with modern water.

## SUMMARY

This report, prepared in cooperation with El Paso Water Utilities, presents the results of an investigation to determine the chemistry and age of ground water on the southwestern side of the Hueco Bolson. The radioactive isotope carbon-14 was used to estimate the length of time that water from wells has been isolated from the atmosphere or modern carbon-14 reservoir. Basin-fill deposits, which compose the main aquifer in the southern Hueco Bolson, are an important source of ground water for the city of El Paso, Texas. Infiltration of precipitation and runoff from the Franklin Mountains and leakage from the Rio Grande Valley are important sources of recharge to these basin-fill deposits.

Seven wells adjacent to the Franklin Mountains and two wells adjacent to the Rio Grande were sampled

for analysis of common constituents, nutrients, total organic carbon, trace elements, stable isotopes, and radioactive isotopes. Dissolved-solids concentrations ranged from 269 to 2,630 mg/L. The dissolved-solids concentrations in water from one well adjacent to the Franklin Mountains (1,240 mg/L) and the two wells adjacent to the Rio Grande (662 and 2,630 mg/L) were larger than those in the other six wells sampled, which ranged from 269 to 455 mg/L. Sodium and chloride are the dominant ions in water with larger dissolved-solids concentrations, and sodium, chloride, and bicarbonate are the dominant ions in water with smaller dissolved-solids concentrations. Sodium concentrations generally increased linearly with chloride concentrations, possibly indicating mixing of dilute recharge water with sodium chloride brine.

The delta deuterium and delta oxygen-18 composition in all samples except those from the two wells adjacent to the Rio Grande indicates that infiltration of precipitation is the main source of water to these wells and that evaporation has not affected the isotopic composition of the water. The source of water from wells adjacent to the Rio Grande is probably not the same as the source of water from wells adjacent to the Franklin Mountains. Delta carbon-13 ranges from -9.33 to -7.19 per mil in samples adjacent to the Franklin Mountains, indicating that similar chemical reactions have affected the carbon composition in this water.

Calculating the age of water from one well located near the Rio Grande was not possible because water from this well contained a significant amount of modern recharge water based on the tritium concentration of 25.5 pCi/L. The calculated apparent carbon-14 ages of eight of the samples with tritium concentrations equal to or less than 1.2 pCi/L ranged from 12,100 to 25,500 years. Water from the well closest to the Franklin Mountains was the youngest; considering the proximity of this well to the recharge area, however, flow rates could be slow in this area.

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U.S. Department of the Interior  
U.S. Geological Survey, WRD  
5338 Montgomery Blvd. NE, Suite 400  
Albuquerque, NM 87109-1311

## **BOOK RATE**

S.K. Anderholm and C.E. Heywood—CHEMISTRY AND AGE OF GROUND WATER IN THE SOUTHWESTERN HUECO BOLSON,  
NEW MEXICO AND TEXAS—U.S. Geological Survey Water-Resources Investigations Report 02-4237