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Hydrology of the Shallow Aquifer and Uppermost Semiconfined Aquifer Near El Paso, Texas

Water-Resources Investigations Report 97–4263

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

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Bruce Babbitt, Secretary

U.S. GEOLOGICAL SURVEY

Thomas J. Casadevall, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
8011 Cameron Rd.
Austin, TX 78754–3898

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Hydrology of the Shallow Aquifer and Uppermost Semiconfined Aquifer Near El Paso, Texas

By Donald E. White[1], E.T. Baker, Jr.[1], *and* Roger Sperka[2]

Abstract

The availability of fresh ground water in El Paso and adjacent areas that is needed to meet increased demand for water supply concerns local, State, and Federal agencies. The Hueco bolson is the principal aquifer in the El Paso area. Starting in the early 1900s and continuing to the 1950s, most of the municipal and industrial water supply in El Paso was pumped from the Hueco bolson aquifer from wells in and near the Rio Grande Valley and the international border. The Rio Grande is the principal surface-water feature in the El Paso area, and a major source of recharge to the shallow aquifer (Rio Grande alluvium) within the study area is leakage of flow from the Rio Grande.

The shallow aquifer and the underlying Hueco bolson aquifer are in general hydrologic connection, but wells that penetrate these aquifers have different water levels and water quality. The configuration (slope) of the predevelopment (pre-1903) water table indicates that ground water in the Hueco bolson flowed south from the Texas-New Mexico State line toward the El Paso Valley and the Rio Grande. There the water moved upward from the Hueco bolson fill through the alluvium and discharged as seepage at the land surface or through evapotranspiration on the river flood plain. Subsequent (post-January 1903) development of the Hueco bolson has caused water levels to decline in both the bolson aquifer and the shallow aquifer, and these declines have reversed the original vertical hydraulic gradient and now cause vertical leakage downward. Water-level declines in the shallow aquifer have in turn induced increasing amounts of leakage from the Rio Grande and from irrigation canals.

The reversal from upward to downward in vertical hydraulic gradient between the Rio Grande alluvium and the underlying Hueco bolson aquifer has induced shallow water in the alluvium to move downward into the deeper aquifer. The introduction of water from the alluvium probably has led to a gradual water-quality deterioration of ground water in the Hueco bolson aquifer. The extent of any deterioration is a major concern because the dissolved solids concentration in water from some wells is approaching 1,000 milligrams per liter and already has exceeded this limit in other wells.

[1] Hydrologist, U.S. Geological Survey.
[2] Geologist, El Paso Water Utilities-Public Service Board.

INTRODUCTION

The El Paso area, which includes the city of El Paso, Fort Bliss Military Reservation-Biggs Army Airfield, and Ciudad Juárez, Chihuahua, Mexico, is located in the far western tip of Texas (fig. 1). Starting in the early 1900s and continuing to the 1950s, most of the municipal and industrial water supply in El Paso was pumped from wells completed in the Hueco bolson aquifer in and near the Rio Grande Valley and the international border. This area has been referred to as the "artesian" or "El Paso Valley" part of the Hueco bolson in Gates and Stanley (1976, p. 4 and 14) (fig. 1). It includes about 42 square miles (mi^2) of mostly urban area in central and southeastern El Paso. The Hueco bolson aquifer, principal source of water for the city of El Paso and for Fort Bliss Military Reservation-Biggs Army Airfield, is the only source of water for Ciudad Juárez, Mexico. A shallow aquifer supplies only small quantities of water to parts of the El Paso area. The availability of fresh ground water in and near El Paso to meet increased demand for municipal, industrial, and military supply concerns local, State, and Federal

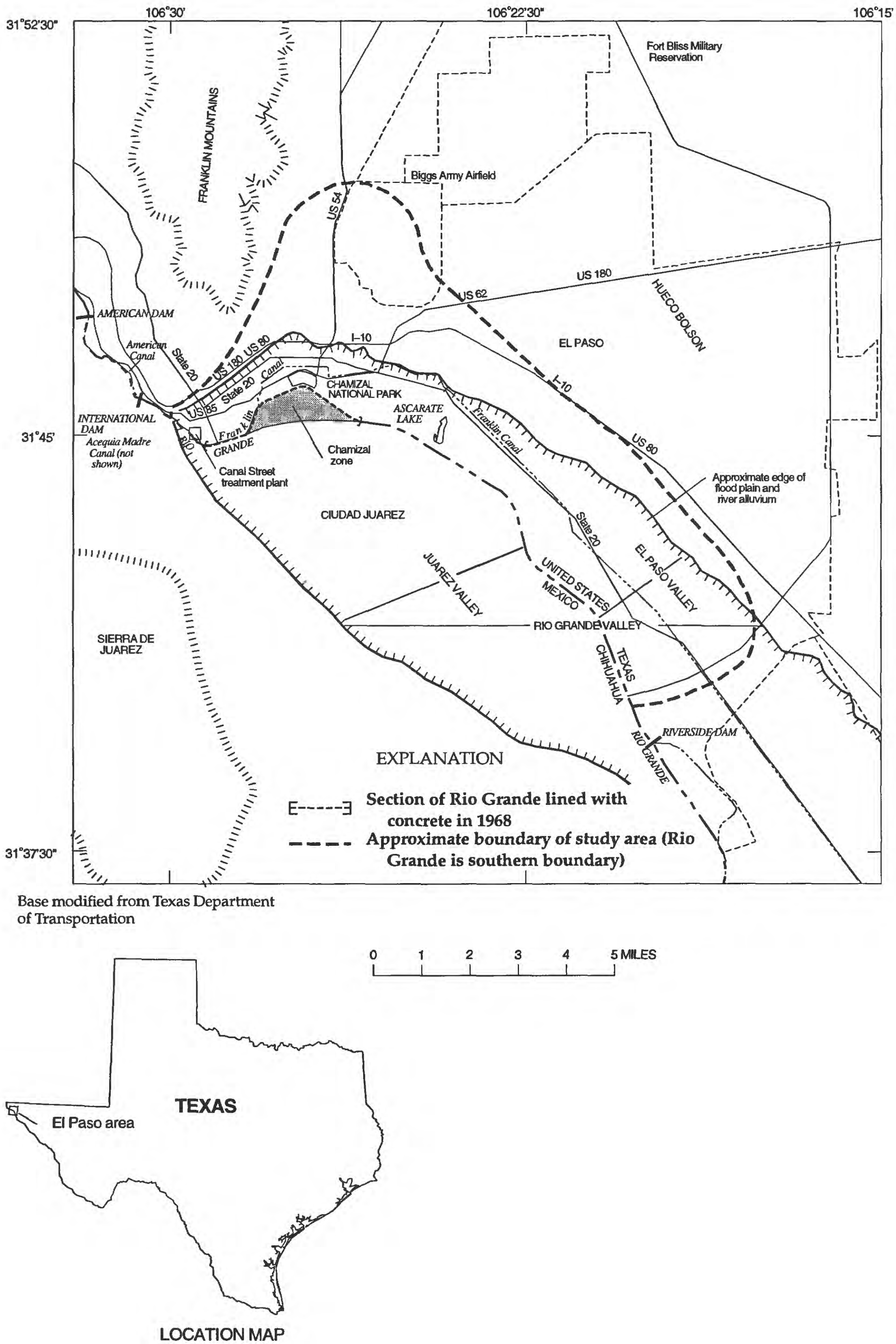


Figure 1. Location of study area.

agencies, as well as the United States and Mexico Sections of the International Boundary and Water Commission.

In 1989, the U.S. Geological Survey (USGS), in cooperation with the El Paso Water Utilities-Public Service Board (EPWU), began a study to evaluate the hydrology of the El Paso Valley area. Specifically, the study was done to characterize the hydrology of the shallow aquifer and the uppermost semiconfined part of the Hueco bolson aquifer including the water quality of these aquifers and of the Rio Grande and Franklin Canal.

Purpose and Scope

This report discusses the hydrology (emphasis on ground water, surface water, and water quality, including some aspects of leakage) of the shallow aquifer and the uppermost semiconfined part of the Hueco bolson aquifer in and near the El Paso Valley. Most of the discussion in this report pertains to the El Paso Valley study area as shown on plate 1 and figure 1, although some data and observations from Ciudad Juárez and from the Hueco bolson north of the El Paso Valley are included to represent hydrologic conditions, well locations, well fields, and water use in those areas. Much of the discussion in this report references information from two previous reports (White, 1983; Land and Armstrong, 1985).

Well-Numbering System

Water wells and test holes in Texas included in this report have been assigned a permanent State well number. The well numbers are part of a statewide well-numbering system used by the Texas Water Development Board. This system is based on the division of the State into quadrangles formed by degrees of latitude and longitude and the repeated division of these quadrangles into smaller ones as shown in figure 2. The two-letter prefix of each State well number designates the county in which the well is located. El Paso County is indicated by the prefix "JL." On plate 1, the first four digits of the Texas well numbers are shown in each 7–1/2 minute quadrangle, and the last three digits are shown adjacent to each well symbol.

Wells in Ciudad Juárez are identified by their Junta Municipal de Aguas y Saneamiento (JMAS) number. Locations of selected wells and well fields within the study area in El Paso and Ciudad Juárez are shown on plate 1.

HYDROGEOLOGIC SETTING

The Hueco bolson and the El Paso Valley are the two major hydrogeologic features in the study area (fig. 1). The Hueco bolson occurs throughout the non-mountainous areas north and east of El Paso. The El Paso Valley borders the Rio Grande and contains alluvial deposits that overlie the Hueco bolson fill. More detailed descriptions of the geology and hydrology of the El Paso area are in the partial list of reports included in the "Selected References" section of this report.

The Hueco bolson (fig. 1) is a downthrown basin between the Franklin Mountains on the west and the Hueco Mountains located about 10 miles (mi) east of the study area (White, 1983, fig. 1). The basin forms a V-shaped bedrock trough (Cliett, 1969). The lowest part of the trough is near and approximately parallel to the Franklin Mountains. The basin was formed when tectonic forces caused sporadic faulting that resulted in uplifting of the Franklin Mountains, and of the Hueco Mountains to a lesser extent, and tilting of the basin floor toward the Franklin Mountains. The basin then was filled with alluvial material eroded from highlands in New Mexico, Texas, and Mexico (Cliett, 1969). The total vertical movement along the faulting between the Franklin Mountains and the bolson is not known, but subsurface data indicate that movement was greater than 9,000 feet (ft) (Davis and Leggat, 1967, p. 8). The pediment at the eastern edge of the Franklin Mountains is covered with an apron of alluvial material, so the precise locations of the fault scarps that mark the sites of the faults are not known.

The bolson deposits are composed of fluvial and lacustrine material that was eroded from adjacent mountains. The material was deposited as lenses of gravel, sand, silt, and clay. Many of the lenses are predominantly sand, silt, or clay, but others are poorly sorted and contain a secondary lithology. For example, a sand lens could contain enough clay to be described as a clayey sand; or a clay lens could contain enough sand or silt to be described as a sandy clay or a silty clay.

At some time after the Hueco bolson aggraded to its present level, the Rio Grande breached the gap between the southern end of the Franklin Mountains and the adjacent mountains in Mexico. Southeast of the gap at the southern end of the Franklin Mountains, the Rio Grande eroded a valley (Rio Grande Valley, fig. 1) in the bolson deposits that locally is known as the El Paso Valley on the northern side of the river in the United States and as the Juárez Valley on the southern side of the river in Mexico (pl. 1; fig. 1). The surface of

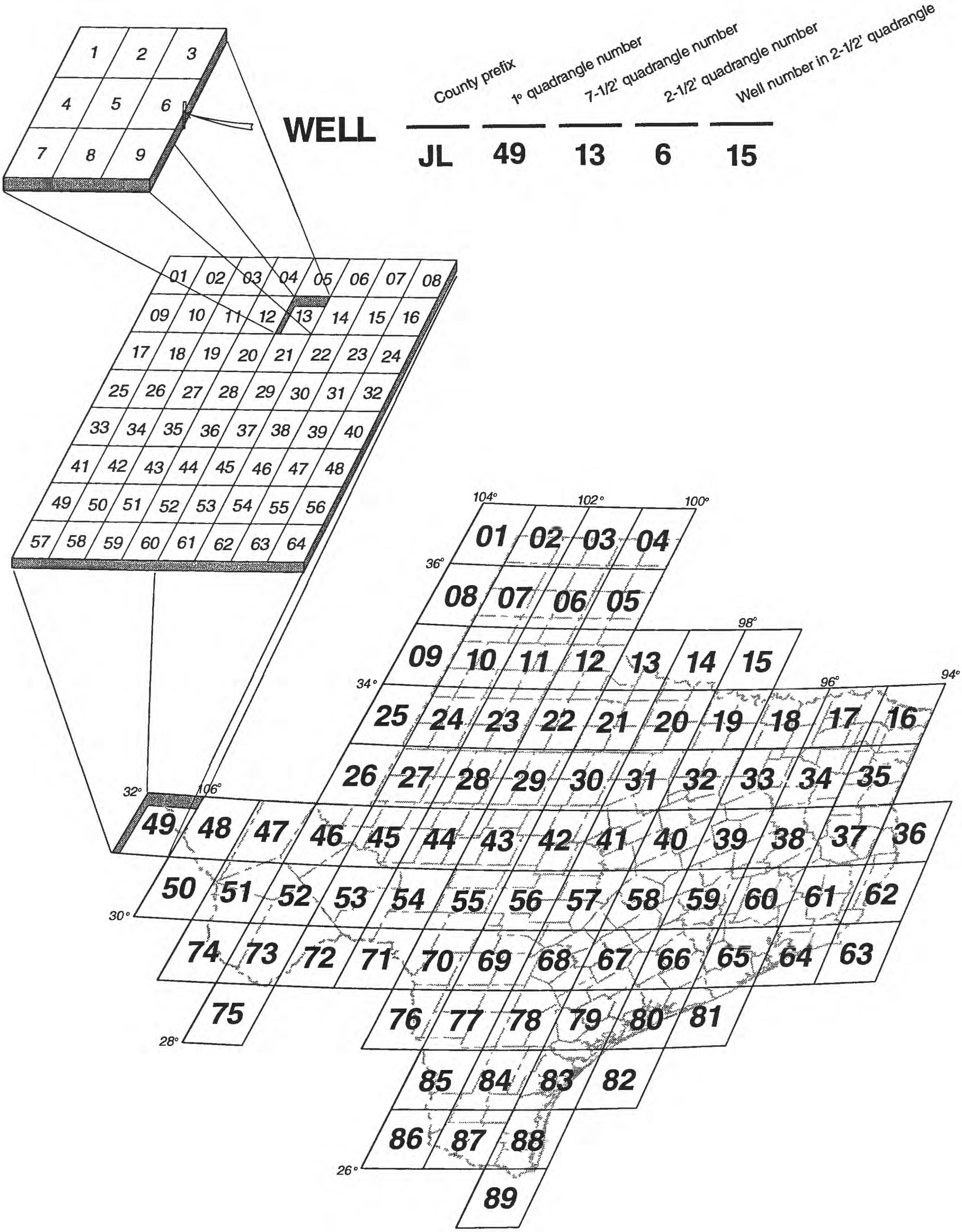


Figure 2. System of numbering wells in Texas.

the Rio Grande Valley is 200 to 250 ft lower than the surface of the Hueco bolson on the uplands adjacent to the valley. The Rio Grande has deposited alluvium as much as 200-ft thick in the valley, according to Davis (1967, p. 5). The valley ranges in width from less than 1 mi at the gap to greater than 5 mi southeast of the gap.

The Rio Grande alluvium and underlying bolson deposits commonly have not been differentiated because of the similarity in the visual characteristics of the two deposits; thus, the base of the alluvial deposits can only be approximated. Because of hydraulic-head and water-quality differences, however, two aquifers have been designated—the shallow aquifer and the Hueco bolson aquifer. The shallow aquifer generally coincides with the Rio Grande alluvium in the El Paso and Juárez Valleys but also includes some of the underlying shallow saturated deposits of bolson fill that normally contain brackish water in and near the El Paso Valley.

The Rio Grande is the principal surface-water feature in the study area. Water is diverted from the river for irrigation of cropland in the El Paso and Juárez Valleys and for municipal supply in the city of El Paso. The water is diverted at the American, International, and Riverside (diversion) Dams via the American and Franklin Canals (canals merge south of downtown El Paso) and Riverside Canal in the El Paso Valley and via the Acequia Madre Canal (route not shown) in the Juárez Valley (pl. 1).

Recharge, movement, and discharge of ground water in the shallow aquifer (Rio Grande alluvial aquifer) and in the Hueco bolson aquifer are interrelated. Prior to the development of ground water in the early 1900s, recharge to the shallow aquifer was by vertical upward movement of ground water in the underlying Hueco bolson aquifer, which was under a higher hydraulic head than the shallow aquifer. The Hueco bolson aquifer was, in turn, recharged principally by precipitation and runoff along the flanks of the mountains bordering the aquifer outcrop. Ground water originally was discharged from the shallow aquifer by a continuation of the upward movement of the water and eventual seepage and flow into the Rio Grande as well as by evapotranspiration on and near the aquifer outcrop in the El Paso Valley (Sayre and Livingston, 1945, p. 61).

Subsequently, large-scale development of ground water reversed much of the movement directions. Reducing the hydraulic pressure in the Hueco bolson aquifer by pumping lowered the hydraulic heads below that of the shallow aquifer and caused ground water in the shallow aquifer to move vertically downward (a discharge of water) into the underlying Hueco bolson aquifer (a recharge of water). The Rio Grande thus became a source of recharge to the shallow aquifer over which the river flows (Sayre and Livingston, 1945, p. 67, 69, 73).

Downward movement of mostly slightly saline water from the shallow aquifer has been a source of substantial recharge to the Hueco bolson since the 1940s. The main source of freshwater recharge to the Hueco bolson aquifer currently (1993) remains the inflow of precipitation and runoff along and near the intersection of the adjacent mountains with the aquifer outcrop. A smaller increment of recharge is by infiltration of precipitation and deep percolation of farm and lawn irrigation water on the outcrop of the Hueco bolson aquifer. Because the heavily pumped zone in the Hueco bolson aquifer has lower pressure than surrounding zones, an upward movement of water within the deeper parts of the aquifer (below the screen settings in the production wells) recharges the heavily pumped zone from below. Unfortunately, this relatively small increment of water is more saline than the water above that is pumped by wells.

GROUND WATER

Ground water is the principal source of municipal, industrial, and military supply in the El Paso area. The two aquifers in the study area, the shallow aquifer and the Hueco bolson aquifer, are in general hydrologic connection but wells that penetrate these aquifers have different water levels and water quality. A discussion of the hydrologic principles of recharge, movement, and discharge of ground water in the shallow aquifer and in the Hueco bolson aquifer is in the following sections of the report.

Shallow Aquifer

The shallow aquifer includes the saturated deposits in the Rio Grande alluvium and the saturated uppermost section of Hueco bolson fill in and near the El Paso Valley. The aquifer supplies only small quantities of water in the study area, primarily because of limited well yields and dissolved solids concentrations that generally exceed 1,000 milligrams per liter (mg/L). The shallow aquifer is separated from freshwater in the Hueco bolson aquifer by a zone of relatively low permeability that contains mostly slightly to moderately saline water (Gates and others, 1978, p. 94). This zone functions as a semiconfining unit and averages about

300 ft in thickness. The water levels in the shallow aquifer are higher than water levels in the underlying freshwater section of the Hueco bolson aquifer, which is heavily pumped.

During recent years, water production from the shallow aquifer within the study area has been restricted to wells at Evergreen Cemetery and at Ascarate Park Golf Course and Lake (pl. 1). Pumpage from these wells was estimated to total 820 acre-feet (acre-ft) in 1988 on the basis of power-discharge tests and power-consumption records.

The direction and rate of flow in the shallow aquifer has changed substantially since the early 1900s (White, 1983, p. 33). Contours of the water-table altitudes in the shallow aquifer in April 1936, July 1967, and January 1980 are shown in figure 3 from downtown El Paso southeast to Ysleta (pl. 1). Depths to water and contours of the water table for the shallow aquifer, December 1990–January 1991, are shown on plate 2. This mapped area includes the areas mapped in 1936 and 1967, but is larger.

During 1936, ground-water flow generally was down the valley but also toward wells and irrigation drains. Depths to water generally were 5 to 10 ft below land surface. At that time sump pumps were used to drain some of the basements in downtown El Paso.

Water levels in the shallow aquifer declined as much as 20 ft from 1936 to 1967. The declines are attributed to urbanization of the valley, which paved over much of the formerly irrigated fields and drainage areas, and to the increased pumpage and declining heads in the underlying bolson deposits inducing downward leakage from the alluvium.

The rate of water-level declines in the shallow aquifer accelerated after the river was lined from downtown El Paso through the Chamizal zone in 1968 (White, 1983, p. 33). Water levels declined as much as 80 ft from 1967 to 1980 (fig. 3). However, part of the increase in the rate of declines can be attributed to a general increase in withdrawals from the Hueco bolson aquifer in El Paso and to a marked increase in withdrawals in Ciudad Juárez (fig. 4; table 1 at end of report). From July 1967 to December 1990–January 1991, water levels in wells in the shallow aquifer declined about 15 to 20 ft near the downstream end of the lined section of the river and about 80 ft in downtown El Paso (pl. 2; fig. 3). In the downtown area, the water level in observation well JL–49–21–101 (pl. 1) in the shallow aquifer declined from about 25 ft below land surface in September 1968 to 51 ft below land surface in December 1971, when it went dry. The water level in a 150-ft-deep replacement well (JL–49–21–104) drilled in 1975 declined from about 76 ft below land surface in September 1975 to 108 ft below land surface in January 1991.

The configuration (slope) of the December 1990–January 1991 water-level contours on plate 2 indicates that ground-water flow in the shallow aquifer in the eastern part of the El Paso Valley is northeasterly away from the river. Additionally, ground-water flow near the downstream end of the lined section of the Rio Grande is to the north and west, also away from the river, toward discharge centers of pumping from Hueco bolson wells. The directions of ground-water flow indicate that in most of the study area, the Rio Grande throughout much of its unlined course is now a major source of recharge to the shallow aquifer rather than one of discharge of ground water by seepage outflow to the river and by evapotranspiration, as was the case in the early 1900s (White, 1983, p. 37). Recharge to the shallow aquifer in the early 1900s was from the underlying Hueco bolson aquifer by upward flow of water.

Hueco Bolson Aquifer

The Hueco bolson aquifer is the principal source of freshwater for municipal, industrial, and military supply in the El Paso area. Records of ground-water withdrawals from the Hueco bolson aquifer within the Rio Grande Valley and adjacent areas began in 1903 (table 1). The records have been compiled through cooperative studies between the USGS and the EPWU, U.S. Department of the Army-Fort Bliss, and Texas Water Development Board. The records include data on the use of water for municipal, industrial, and military supply in El Paso and for municipal-industrial supply in Ciudad Juárez. Records of Ciudad Juárez withdrawals were furnished by JMAS.

The historical records of annual withdrawals from wells and well fields within the Rio Grande Valley and adjacent areas have been documented by the USGS and EPWU in thousand gallons. Withdrawals for 1992 and cumulative withdrawals, in both acre-feet and thousand gallons, are listed in table 2 (at end of report). The locations of selected wells and well fields are shown on plate 1.

Annual withdrawals of ground water from the Hueco bolson aquifer in the Rio Grande Valley and adjacent areas, 1903–92, are shown in figure 4 and in table 1. The largest sustained increase in withdrawals from the Hueco bolson aquifer was in Ciudad Juárez starting in the late 1960s and continuing to the late 1980s. During that time, withdrawals in Ciudad Juárez increased from 4,867,820 thousand gallons (gal) (about 14,900 acre-ft) in 1969 to 21,141,192 thousand gal (about 64,900 acre-ft) in 1989. During the same time, the total withdrawals in El Paso and Fort Bliss increased from 7,514,818 thousand gal (about 23,100 acre-ft) in 1969 to a maximum of 11,056,315 thousand gal (about 33,900 acre-ft) in 1987. After 1987, total pumpage in El Paso and Fort Bliss decreased every year to 6,915,990 thousand gal (about 21,200 acre-ft) in 1992, the smallest amount of water pumped since 1981 (table 1). The decrease in withdrawals might be related to the increase in dissolved solids concentrations in the water and the initiation of a water conservation program in 1991 by the EPWU.

Recharge of freshwater to the Hueco bolson aquifer mainly occurs along the mountains bordering the bolson and, at times, locally along the Rio Grande by downward leakage of some of the flow in the river (Gates and others, 1980, p. 93). Before the Rio Grande cut through the bolson and became the drain for the Hueco bolson aquifer, ground water probably flowed to depressions or lakes in the lowest parts of the bolson where it discharged through evapotranspiration. After the river cut through the bolson, the flood plain served as the discharge zone. On the basis of digital-model studies, Meyer (1976, p. 18) estimated that the annual recharge around the western boundary of the bolson, including the Sierra de Juárez in Mexico and the Organ Mountains in New Mexico, was about 5,640 acre-feet per year (acre-ft/yr). Starting in the 1940s a larger increment of recharge to the Hueco bolson aquifer has been leakage from the overlying shallow aquifer by downward movement of ground water in the El Paso Valley (Meyer, 1976, table 1).

Ground water in the Hueco bolson aquifer currently (1993) flows from the areas of recharge to the many wells that discharge the water. The rate of movement is slow, normally less than 1 foot per day (ft/d) or a few hundred feet per year and is controlled by the ability of the aquifer to transmit water (hydraulic conductivity) and by the slope (gradient) of the water table (White, 1983, p. 30).

Water-level contours are shown on plate 3 for 1903 and December 1990–January 1991 in the central part of the Hueco bolson in the United States. The 1903 (predevelopment) contours were drawn from early water-level measurements, which were adjusted for estimated changes before the date of measurement, and from steady-state digital-model simulations by Meyer (1976). The water-level profiles for the two time periods are shown in a north-south section through the study area on plate 4. Plate 1 shows the location of the section.

Before and during the early 1900s, ground water in the Hueco bolson aquifer flowed south from the Texas-New Mexico State line (16 mi north of downtown El Paso) and east to southeast from the Sierra de Juárez. The general direction of movement was toward the Rio Grande Valley. There, the water moved upward through the shallow alluvium and discharged as seepage or through evapotranspiration (White, 1983, p. 33).

The historical (1903–92) withdrawals of ground water from the Hueco bolson aquifer in the study area, totaling 395,411,073 thousand gal (about 1.21 million acre-feet (Macre-ft)) in El Paso and Fort Bliss and 397,980,455 thousand gal (about 1.22 Macre-ft) in Ciudad Juárez, have caused large water-level declines. These declines substantially have changed the direction and rate of ground-water flow, and currently (1993), most of the flow is toward centers of pumping such as the Chamizal zone along the Rio Grande and international border where water levels declined about 167 ft from 1903 to December 22, 1992 (EPWU well 14A, table 3 at end of report).

The historical records of water levels and water-level declines in the Hueco bolson aquifer within the study area are listed in table 4 (at end of report).

The depths to water in the 32 wells in the well fields listed in table 4 ranged from 37.26 to 352.10 ft below land surface during December 1992–January 1993. The 1903 to December 1992–January 1993 declines for individual wells ranged from about 19 to 167 ft. The maximum decline was in EPWU well 14A (JL–49–13–727). Well locations are shown on plate 1.

Table 5 (at end of report) lists the rates of water-level decline in 24 Hueco bolson aquifer production wells. The rates were computed from linear statistical analyses (El Paso Water Utilities-Public Service Board, written commun., 1996) and from linear graphical approximations on well hydrographs. The hydrographs of four wells (JL–49–13–702, 710, 804, and 909) were selected as representative of the 24 wells and are shown in figure 5. The rates of decline shown by the graphical approximations ranged from 3.2 to 5.0 feet per year (ft/yr). Rates of decline in all 24 wells ranged from 2.2 to 6.1 ft/yr (graphical estimates, table 5). The average rate of decline in the 24 wells is about 3.0 ft/yr based on both methods.

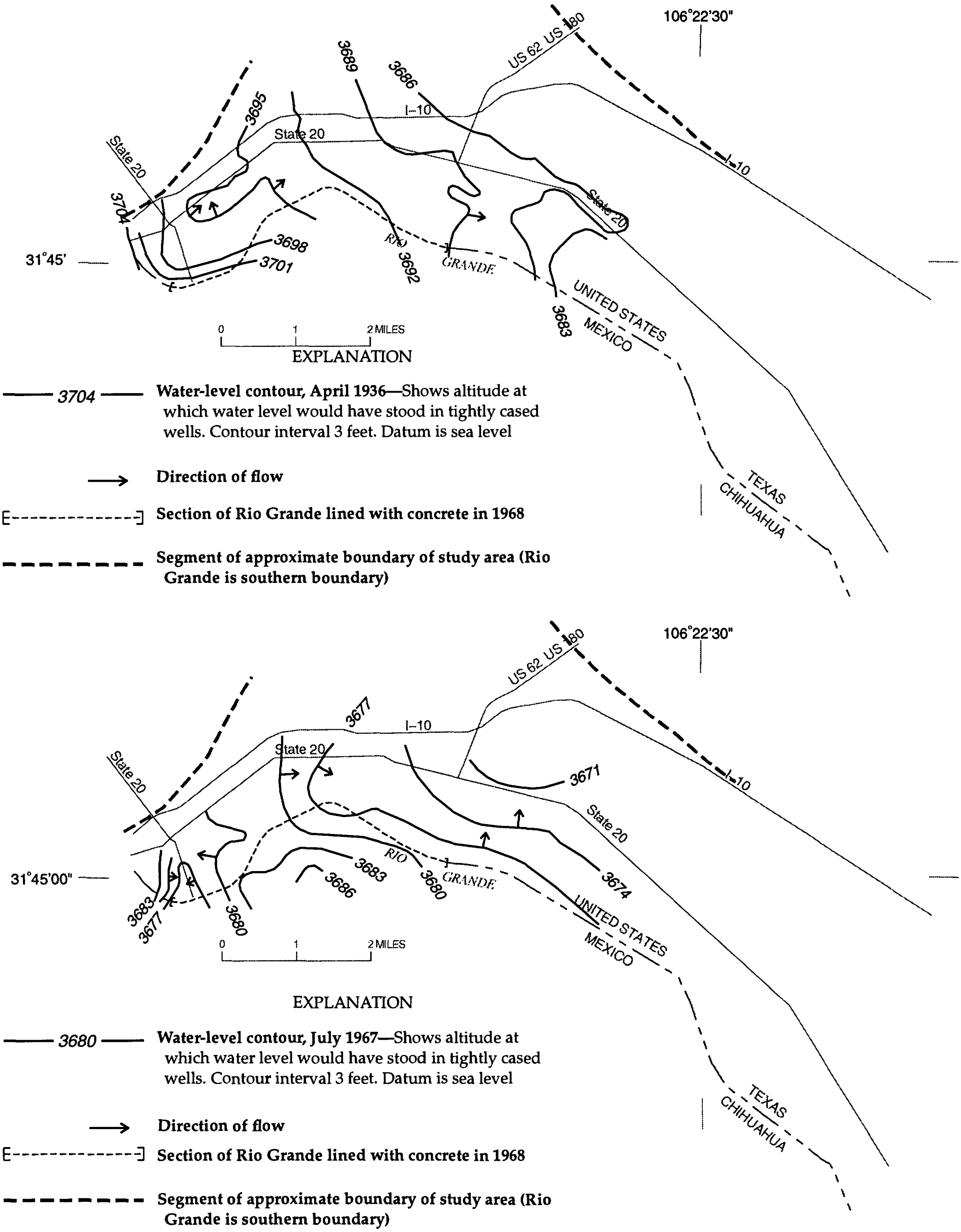


Figure 3. Approximate altitude of water levels in the shallow aquifer, April 1936, July 1967, and January 1980 (modified from Land and Armstrong, 1985, fig. 7).

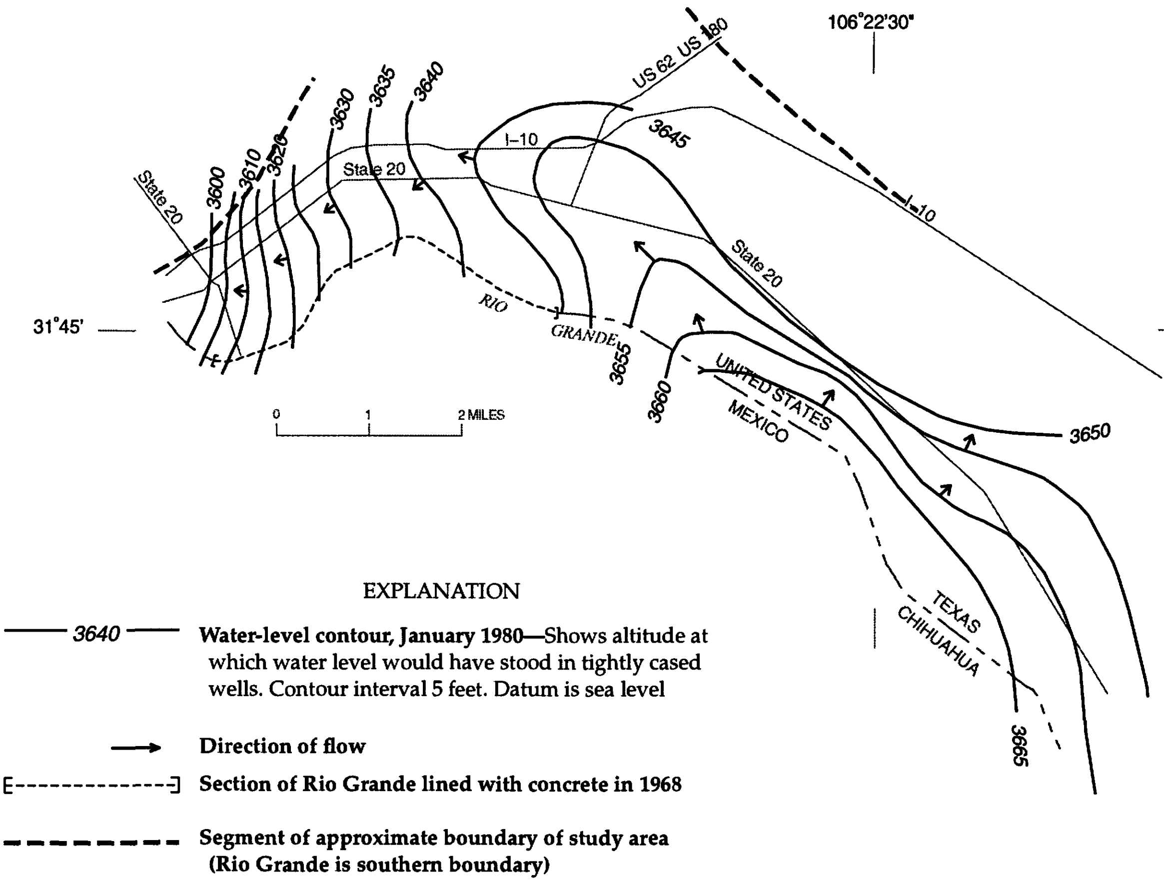


Figure 3.—Continued.

Leakage Between Aquifers

The shallow aquifer and Hueco bolson aquifer are hydraulically connected by a semiconfining unit that separates the aquifers. Declines in water levels in deep wells since predevelopment conditions in 1903 have reversed the 1903 vertical gradient, which was upward from deep to shallow, to downward from shallow to deep. This reversal has caused water levels in shallow wells to decline about 100 ft (April 1936 to December 1990–January 1991) in the downtown El Paso-Chamizal National Park area (pl. 2; fig. 3) through vertical leakage. Also pumping of water from shallow wells in this area possibly caused part of the decline (Sayre and Livingston, 1945, p. 55–56). Water-level declines in the shallow aquifer have in turn induced increasing amounts of leakage from the Rio Grande and irrigation canals.

Digital-model studies by Meyer (1976) of the Hueco bolson aquifer in the United States and Mexico indicate that the Rio Grande exchanged substantial quantities of water with the shallow aquifer as leakage and that there was substantial leakage of ground water between the shallow aquifer and Hueco bolson aquifer. The average annual exchange of water from 1903 to 1991 between the Rio Grande and the shallow aquifer and between the shallow aquifer and the underlying Hueco bolson aquifer based on the model studies follows:

Period	Average annual leakage between shallow aquifer and Hueco bolson aquifer (acre-ft/yr) (+, out of bolson; -, into bolson)	Average annual leakage to/from Rio Grande (acre-ft/yr) (+, to river; -, from river)
1903–20	+4,680	+6,860
1920–36	-3,420	+353
1936–48	-7,980	-4,590
1948–53	-11,800	-7,620
1953–58	-19,700	-13,500
1958–63	-24,600	-18,800
1963–68	-23,500	-19,200
1968–73	-33,300	-12,800
1973–91	-41,500	-21,100

The amount of ground water contributed to the Hueco bolson aquifer by leakage from the shallow

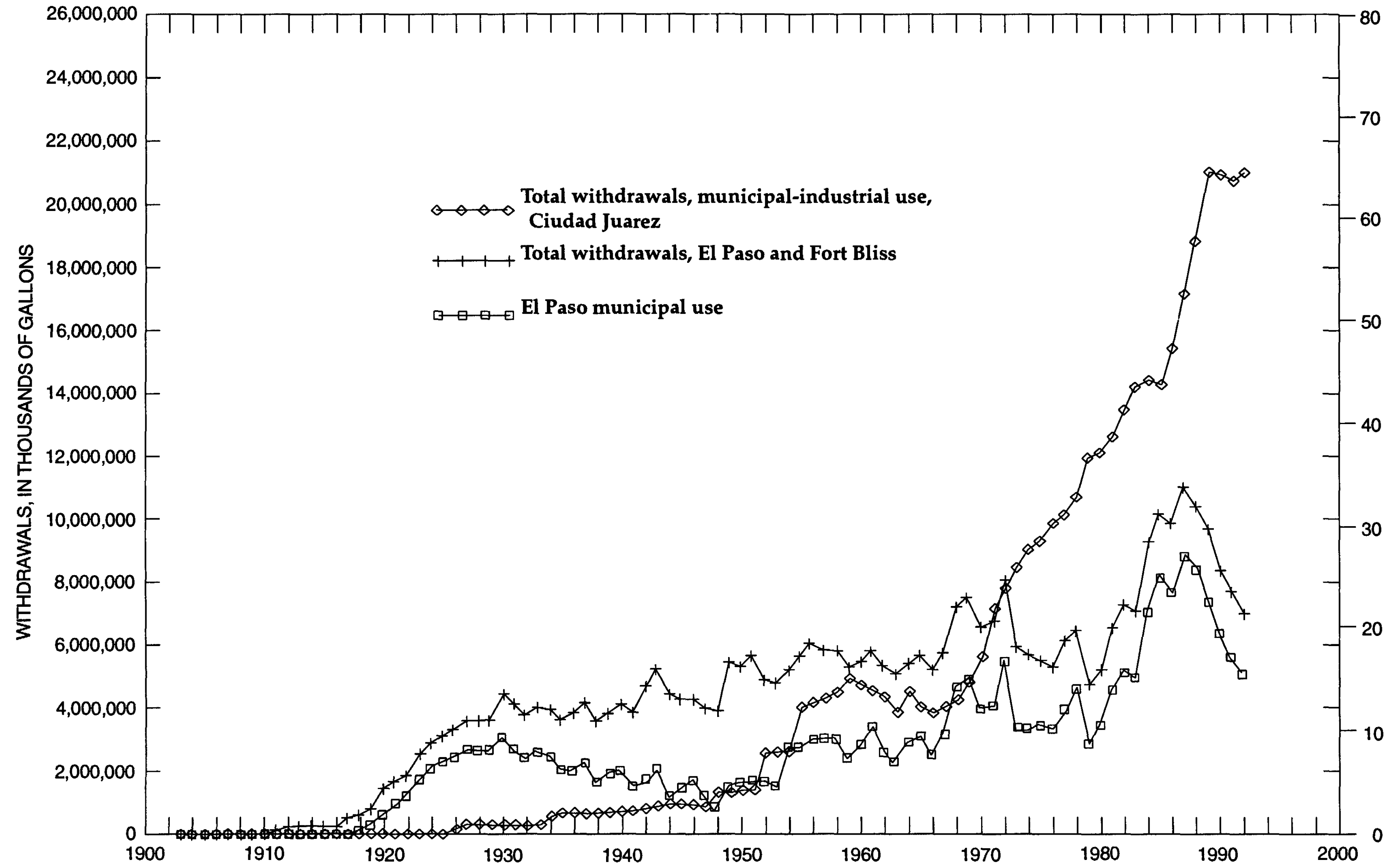


Figure 4. Annual withdrawals of ground water from the Hueco bolson aquifer in the Rio Grande Valley and adjacent areas, 1903–92.

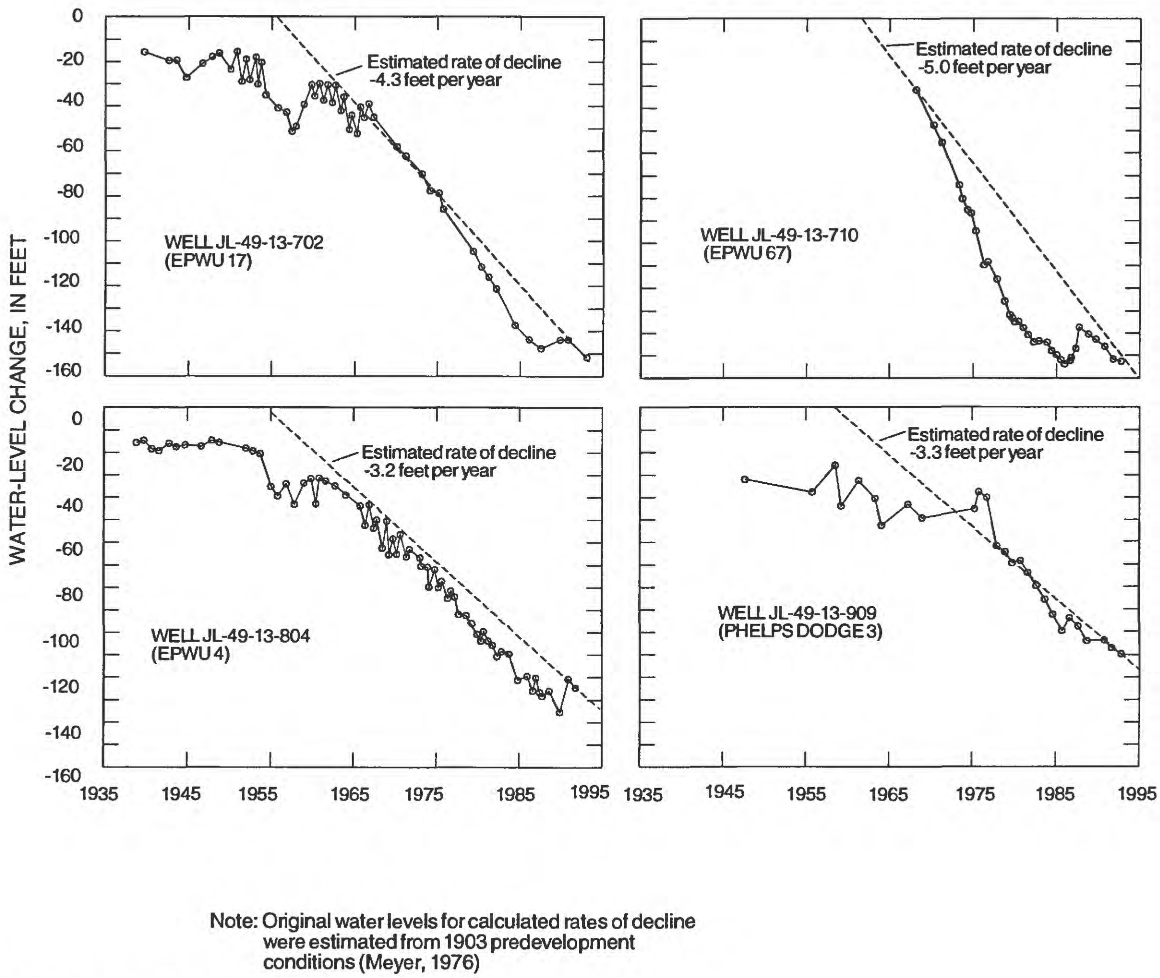


Figure 5. Hydrographs of four wells in the Hueco bolson aquifer.

aquifer is essentially the sum of the amount of leakage from the Rio Grande and the amount removed from storage in the shallow aquifer. The data show that the Rio Grande was a gaining stream until the mid 1930s, after which the river began to lose water at a rate that increased for each given time period until 1968, when a part of the Rio Grande channel was lined with concrete. In the following 5-year period (1968–73), the annual leakage averaged 12,800 acre-ft as compared to an annual average of 19,200 acre-ft in the preceding 5-year period (1963–68).

The digital model developed by Meyer (1976) projected that the 1973–91 leakage from the shallow aquifer to the Hueco bolson aquifer would average 41,500 acre-ft/yr in El Paso and Ciudad Juárez. This rate of leakage is 64 percent of the recorded 64,574 acre-ft average annual ground-water withdrawal within the 75-mi^2 El Paso-Juárez study area during those years (table 1).

SURFACE WATER

Flow in the Rio Grande is regulated by Elephant Butte and Caballo Reservoirs upstream 115 and 90 mi, respectively, in New Mexico. Water is diverted from the river at the El Paso narrows (at the American and International Dams) for crop irrigation in the El Paso and Juárez Valleys by way of the American and Franklin Canals in the United States (pl. 1) and the Acequia Madre Canal in Mexico, according to an international treaty and interstate compact. Water also is diverted from the Franklin Canal for municipal supply to El Paso (International Boundary and Water Commission, United States and Mexico, 1943–91). Streamflow records maintained by the International Boundary and Water Commission and the Bureau of Reclamation indicate that increasing amounts of flow in the Rio Grande are being lost by leakage to the shallow aquifer in the El Paso and Juárez Valleys.

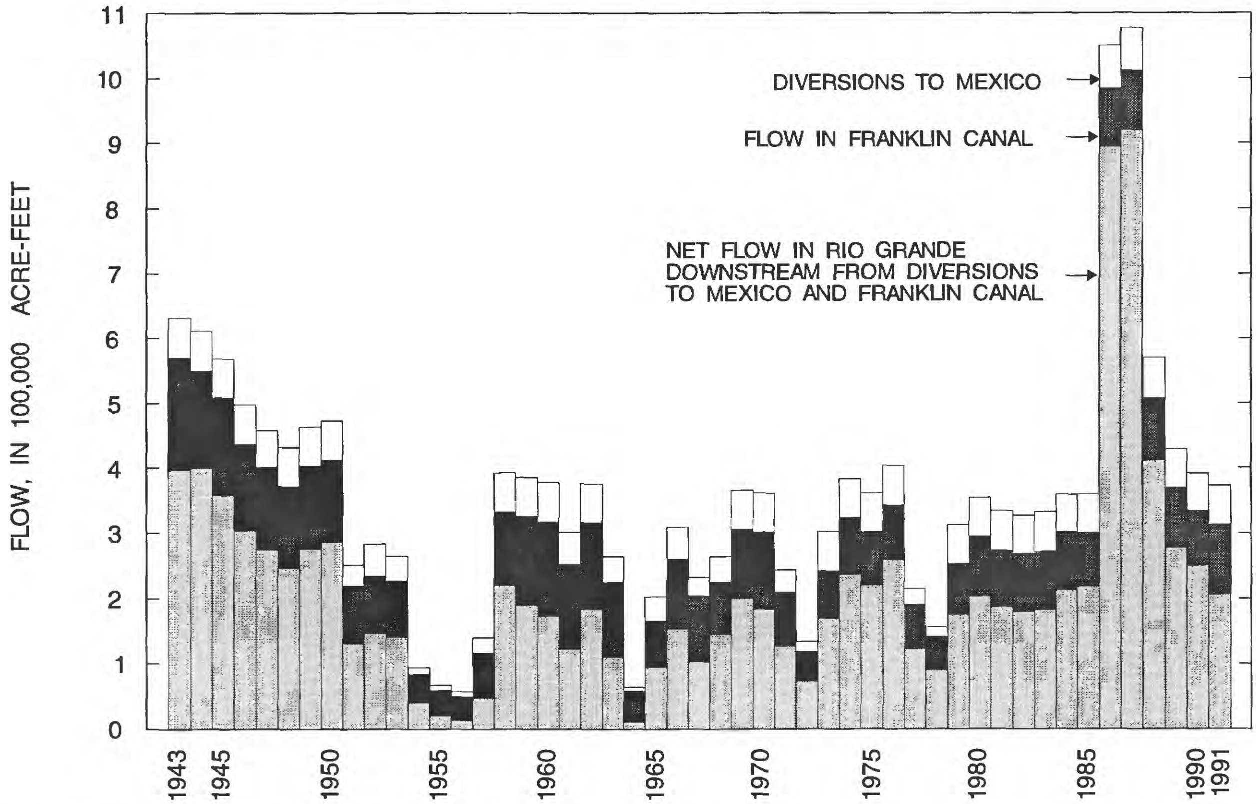


Figure 6. Annual flow in the Rio Grande at El Paso, flow in the Franklin Canal, and diversions to Mexico, 1943–91.

Flow in the Rio Grande and Franklin Canal

During 1943–91, flow in the Rio Grande at El Paso ranged from a low of about 57,500 acre-ft in 1956, during a period of severe drought, to about 1,080,000 acre-ft in 1987 (fig. 6; table 6 at end of report), during a period of large runoff. Flow in the Franklin Canal during 1943–91 (fig. 6; table 6) ranged from a low of about 36,100 acre-ft in 1956 to a high of about 173,000 acre-ft in 1943.

Leakage to the Shallow Aquifer

A major source of recharge to the shallow aquifer within the study area is leakage of flow from the Rio Grande in the unlined sections of the river. Land and Armstrong (1985, p. 11–21) estimated leakage losses from the river between the El Paso narrows to the Riverside Dam.

A water budget for the Rio Grande between the El Paso narrows to the Riverside Dam during 1959–83 is listed in table 7 (at end of report). Data for inflow to the system and net loss from the system are shown in figure 7. The 25-year average inflow and net loss from the system were 317,000 and 20,100 acre-ft, respectively.

Land and Armstrong (1985, p. 11) cited a second water-budget study that was made by the International Boundary and Water Commission for the 9.3-mi reach downstream from the concrete-lined section in the Chamizal zone to the Riverside Dam (fig. 1). The results of the study (International Boundary and Water Commission, written commun., 1984) are as follows:

Year	Inflow (acre-ft)	Outflow (acre-ft)	Loss (acre-ft)
1981	201,000	175,000	26,400
1982	229,000	196,000	33,000
1983	230,000	193,000	36,300
Average	220,000	188,000	31,900

The last year of record for streamflow-gaging stations located between the concrete-lined section of the Rio Grande and Riverside Dam was 1983.

The Commission estimated that there was about 620 acre-ft/yr of unmeasured diversions to the irrigated lands along the river in Mexico, and that about 884 acre-ft/yr of water evaporated. The average loss of

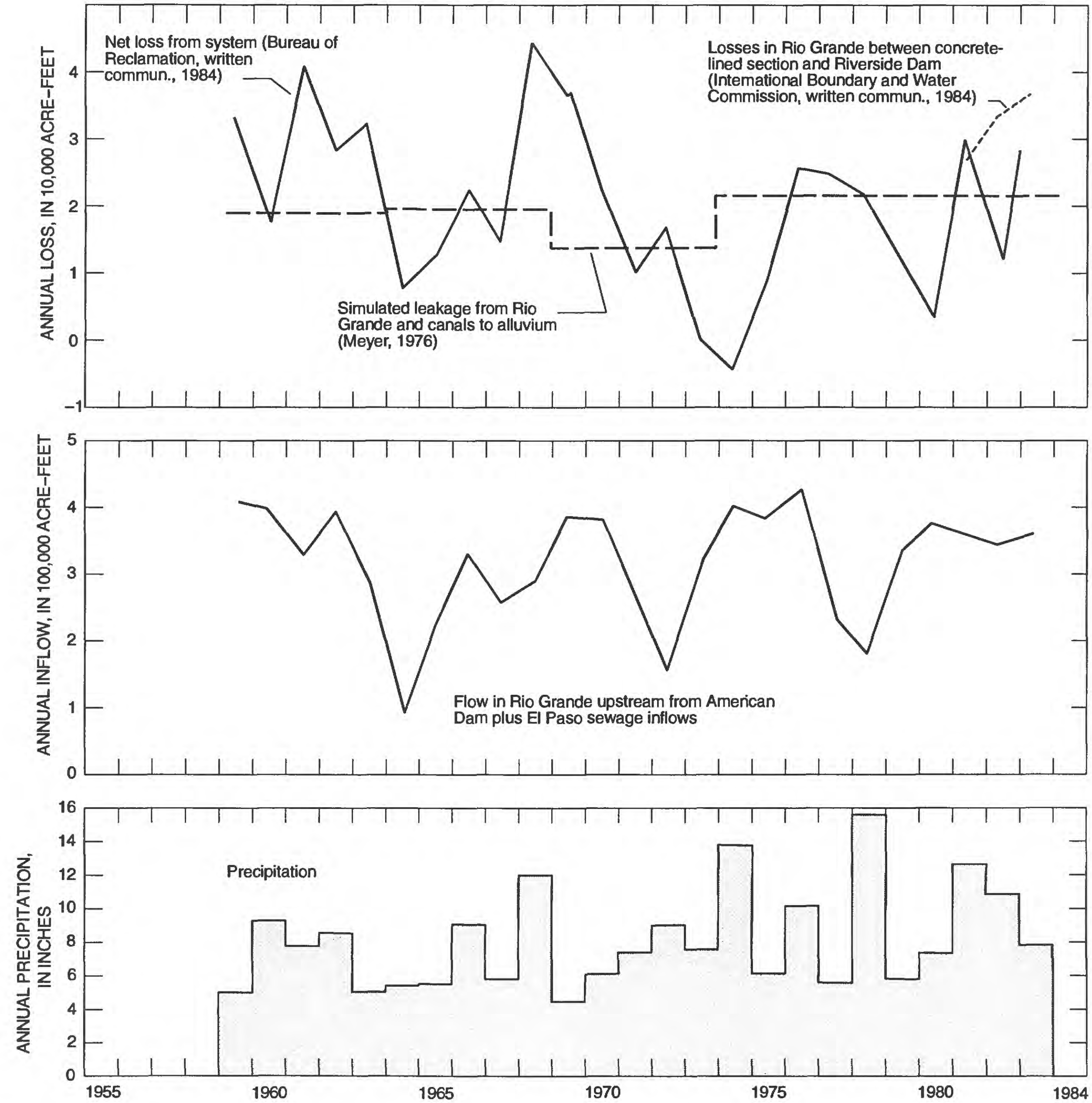


Figure 7. Annual net loss of water, inflow to the Rio Grande, and precipitation at El Paso, 1959–83 (modified from Land and Armstrong, 1985, fig. 9).

31,900 acre-ft/yr for 1981–83 was 14.5 percent of the average upstream inflow. The losses exceed the average 1981–83 net loss from the system (table 7) by about 7,900 acre-ft/yr and also exceed the previously cited Meyer (1976) simulated 1973–91 average loss by 10,800 acre-ft/yr. Land and Armstrong (1985, p. 21) evaluated the two water-budget studies and concluded:

Based on the two data sets and the above discussion, a reasonable estimate of the recent leakage [seepage] from the Rio Grande to the aquifer system is an average 31,900 of the 1981–83 International Boundary and Water Commission data—31,000 acre-feet per year of streamflow loss less 620 and 884 acre-feet per year to unmeasured diversions and evaporation, respectively, for an average leakage loss of about 30,000 acre-feet of water per year. Using the long-term Bureau of Reclamation data for trends as shown in figure 9 [fig. 7 in this report], the leakage to the aquifer system is projected back to about 15,000 acre-feet in 1968 when the existing lining of the river was completed. Thus, the leakage may have been increasing at about an average of 1,000 acre-feet per year since 1968. No estimates are made prior to 1968.

There is good agreement between rates of pumping from the Hueco bolson aquifer and the estimated average leakage loss cited above. Pumpage from the Hueco bolson aquifer in the Rio Grande Valley and adjacent areas increased from 11,389,623 thousand gal (about 35,000 acre-ft) in 1968 to 20,736,165 thousand gal (about 63,600 acre-ft) in 1982 and was 28,054,647 thousand gal (about 86,100 acre-ft) in 1992 (table 1). The ratio of estimated 1968 leakage (15,000 acre-ft) to 1968 pumpage is 0.43, and the ratio of estimated 1982 leakage (30,000 acre-ft) to 1982 pumpage is 0.47. If the average of these two ratios (about 0.45) is extended to the 1992 pumpage, the estimated leakage from the Rio Grande in that year would be about 39,000 acre-ft. This rate is an average of about 4,200 acre-feet per mile (acre-ft/mi) of leakage for the unlined 9.3-mi river reach extending downstream from the end of the concrete-lined section to Riverside Dam.

The shallow aquifer also is recharged by leakage from the Franklin Canal. Streamflow-loss data for a 5.25-mi unlined section of the canal from a Bureau of Reclamation survey during January–April 1984 (Land and Armstrong, 1985, table 3) are listed in table 8 (at end of report). The losses were measured between the Bureau of Reclamation streamflow-gaging station in the concrete-lined section of the Franklin Canal and a temporary gaging station which was located 6.47 mi downstream, near the Ascarate wasteway heading (fig. 8).

The 1984 measurements showed losses ranging from 0.5 to 18.2 cubic feet per second (ft^3/s) (table 8). The average upstream flow for 19 measurements was 132.6 ft^3/s. The average loss was 4.3 ft^3/s or about 3 percent of the upstream flow. However, the flow data obtained at the temporary gaging station upstream from Ascarate wasteway heading could have been in error because of backwater effects from a check dam on the canal downstream from Ascarate wasteway heading (David P. Overvold, Bureau of Reclamation, oral commun., 1991).

During 1990–92, the USGS conducted additional leakage surveys in the Franklin Canal (fig. 8; table 9 at end of report) in about the same section of the canal as that surveyed by the Bureau of Reclamation in 1984. However, streamflow losses computed by the USGS (table 9) are substantially larger than those computed by the Bureau of Reclamation (table 8). The 1990–92 USGS-computed losses ranged from 6.0 to 29.2 ft^3/s for 16 sets (days) of measurements. For the 16 days of measurements, the average loss was 21.3 ft^3/s, or about 10 percent of the average upstream flow of about 213 ft^3/s at site 1 (table 9).

Flow in the Franklin Canal averaged about 94,400 acre-ft/yr during 1987–91, the last 5 years of record listed in table 6. Leakage and evaporation losses from the canal between the end of the lined section and the Ascarate wasteway heading were estimated during the current study to average about 9,300 and 160 acre-ft/yr, respectively, for those years for a total loss of about 9,460 acre-ft or about 10 percent of the annual upstream flow.

The combined leakage losses from the Rio Grande and Franklin Canal currently (1993) could be as much as about 48,000 acre-ft/yr. Part of the leakage likely is intercepted by drains in the southeastern part of the study area where the shallow water table is still above the bottom of the drains. This includes a deep drain adjacent to the Rio Grande in Mexico.

WATER QUALITY

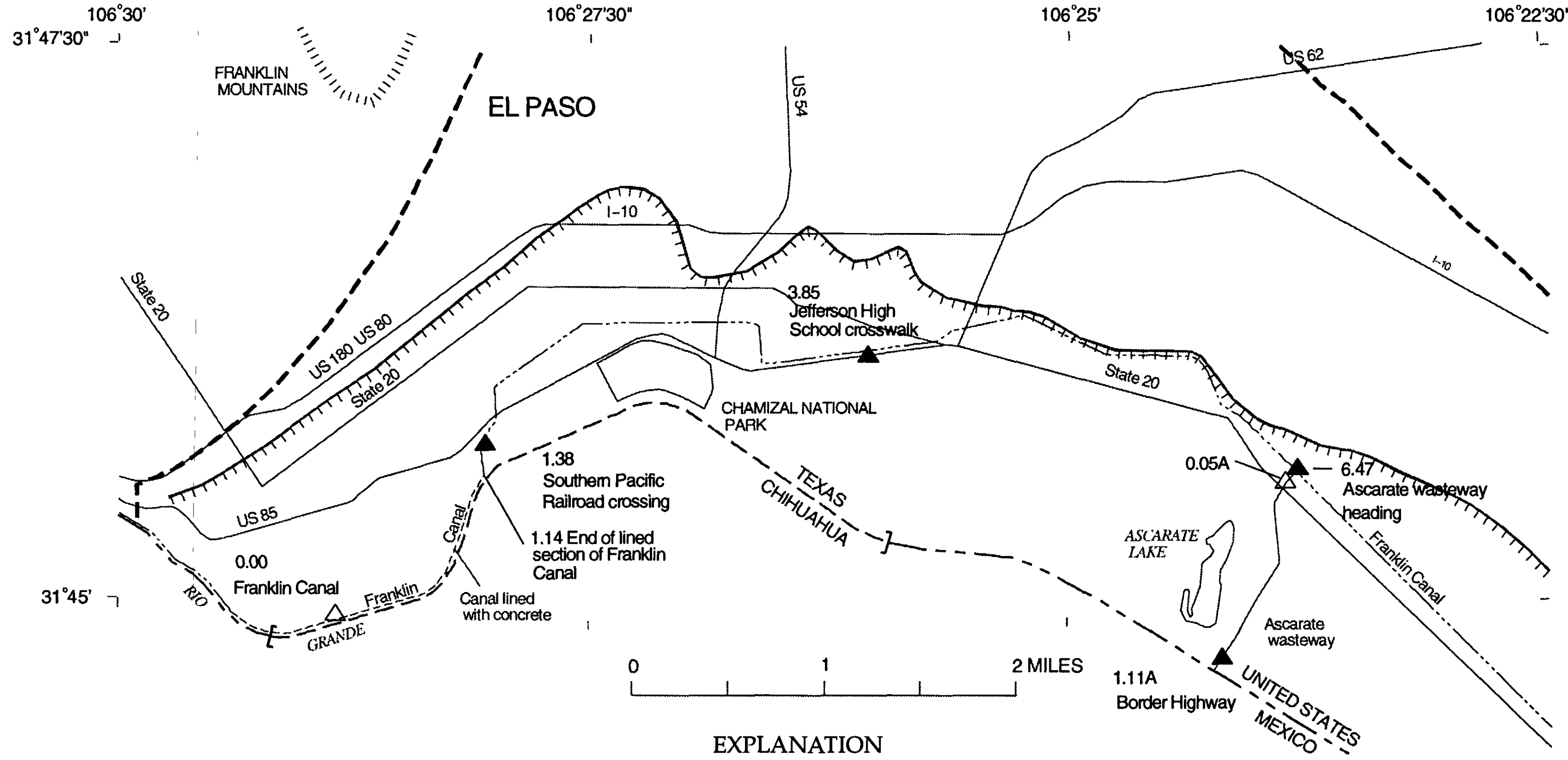
Concentrations of dissolved solids are a major limiting factor in the use of water in the El Paso area (Alvarez and Buckner, 1980). The following general classification of water is based on concentrations of dissolved solids (Winslow and Kister, 1956, p. 5).

Description	Dissolved solids concentration (mg/L)
Fresh	less than 1,000
Slightly saline	1,000 – 3,000
Moderately saline	3,000 – 10,000
Very saline	10,000 – 35,000
Brine	greater than 35,000

The source, significance, and concentration range of dissolved mineral constituents and properties of water from wells in the El Paso area were summarized by Alvarez and Buckner (1980). Discussion of water quality in this report focuses on dissolved solids concentrations and changes in concentrations within the study area.

Rio Grande and Franklin Canal

Streamflow data for the Rio Grande at El Paso have been published in annual bulletins of the International Boundary and Water Commission, United States and Mexico (1943–91). Annual summaries of



EXPLANATION

- Section of Rio Grande lined with concrete in 1968
- Section of Franklin Canal lined with concrete
- Approximate edge of flood plain and river alluvium
- Segment of approximate boundary of study area (Rio Grande is southern boundary)
- 0.05A △ Bureau of Reclamation streamflow-gaging station—Number followed by "A" indicates distance from Ascarate wasteway heading, in miles
- 3.85 ▲ U.S. Geological Survey streamflow-measuring site, 1990–92—Number indicates distance from Bureau of Reclamation gaging station, in miles. Number followed by "A" indicates distance from Ascarate wasteway heading, in miles

Figure 8. Locations of streamflow-gaging stations and streamflow-measuring sites on Franklin Canal and Ascarate wasteway.

streamflow and dissolved solids concentration data for the Rio Grande for 1943–91 are listed in table 6. The average of monthly samples for dissolved solids concentrations ranged from 643 mg/L in 1986 to 1,905 mg/L in 1956 (table 6). For 1943–76, the dissolved solids concentrations in monthly samples averaged 1,143 mg/L and the discharge-weighted dissolved solids concentration averaged 819 mg/L (White, 1983, p. 68).

Return flows from drains and sewage outfalls contribute most of the low flow in the Rio Grande at El Paso, which accounts for the wide range in dissolved solids concentrations (table 6). In general, the dissolved solids concentrations are highest during periods of low flow and are lowest during periods of high flow when water is released from upstream storage (White, 1983, p. 68).

Table 10 (at end of report) lists chemical analyses of water diverted from the Franklin Canal at the EPWU Canal Street treatment plant (fig. 1) from November 18, 1991, to October 19, 1992. Dissolved solids concentrations in the 21 samples ranged from 660 to 1,389 mg/L and averaged 812 mg/L. All of the samples have hardness exceeding 200 mg/L and would be rated as very hard (Alvarez and Buckner, 1980, p. 31). The treatment plant uses the lime process to decrease hardness and mineralization prior to distribution.

Shallow Aquifer

The quality of water in the shallow aquifer is variable and, within certain depths and areas, generally is not suitable for domestic or public supply because of the large concentrations of dissolved solids or of individual chemical constituents. Alvarez and Buckner (1980, figs. 12 and 13) indicate that water in the upper 100 ft of the aquifer is fresh only in a few small areas but mostly is slightly to moderately saline. Furthermore, the quality of the water deteriorates with depth to about 200 ft.

Water samples were collected from 10 wells in the shallow aquifer during 1989 (fig. 9). Dissolved solids concentrations measured during 1989 ranged from 749 to 3,920 mg/L and averaged 2,145 mg/L (table 11 at end of report). Only one well produced water with less than 1,000 mg/L dissolved solids. This well is near the corner of Charles and Seventh Streets (site 10, fig. 9; table 11) next to unlined sections of the Franklin Canal and Rio Grande (pl. 1).

Water quality in the shallow aquifer can be degraded by surficial contamination. Four of the 10 wells in table 11 (sites 4, 7, 8, and 9) were drilled to monitor possible migration of surficial pollutants to the water table. Water samples from one well near the corner of Martinez and Rosa Streets (site 3, fig. 9; table 11) had a large increase in dissolved solids concentrations from 1,700 mg/L (June 3, 1976) to 3,520 mg/L (June 20, 1989) and a very large concentration (48.0 mg/L) of dissolved nitrite plus nitrate as nitrogen in the June 20, 1989, sample. This well is in a low area subject to flooding and is near an urban flood-control structure and a cemetery. The source of the high dissolved solids and nitrogen concentrations in the 1989 sample has not been determined but is thought to be local.

Hueco Bolson Aquifer

The quality of water pumped from Hueco bolson wells within the study area ranges from fresh to slightly saline. Dissolved solids concentrations in water samples from most of the production wells have increased from when the wells were first put into production. Tabulations of chemical analyses of samples from 40 wells within the study area were made by EPWU. The average and range of dissolved solids concentrations for early (1939–85) samples and 1992–93 samples are listed below.

Well field (pl. 1)	Number of wells sampled during 1992–93	Average and range of dissolved solids concentrations (mg/L)		Number of 1992–93 samples exceeding 1,000 mg/L
		Early sample[1]	1992–93 samples	
Airport[2]	1	568	652	0
Lower valley[2]	22	607 391–836	919 705–1,272	8
Town[2]	3	708 571–963	852 714–998	0
Water plant[2]	5	493 456–525	928 508–1,461	2
Fort Bliss Post	3	438 255–526	510 450–542	0
Industrial-miscellaneous	6	612 467–734	951 652–1,176	3
Average of all samples		587	883	13

[1] Early samples were collected when wells were first put into production (1939–85).

[2] EPWU well field.

The average dissolved solids concentration in samples from the 40 wells has increased about 50 percent. Water from 13 of the wells sampled during 1992–93 had dissolved solids concentrations that exceed 1,000 mg/L, the limit of freshwater. Water from some

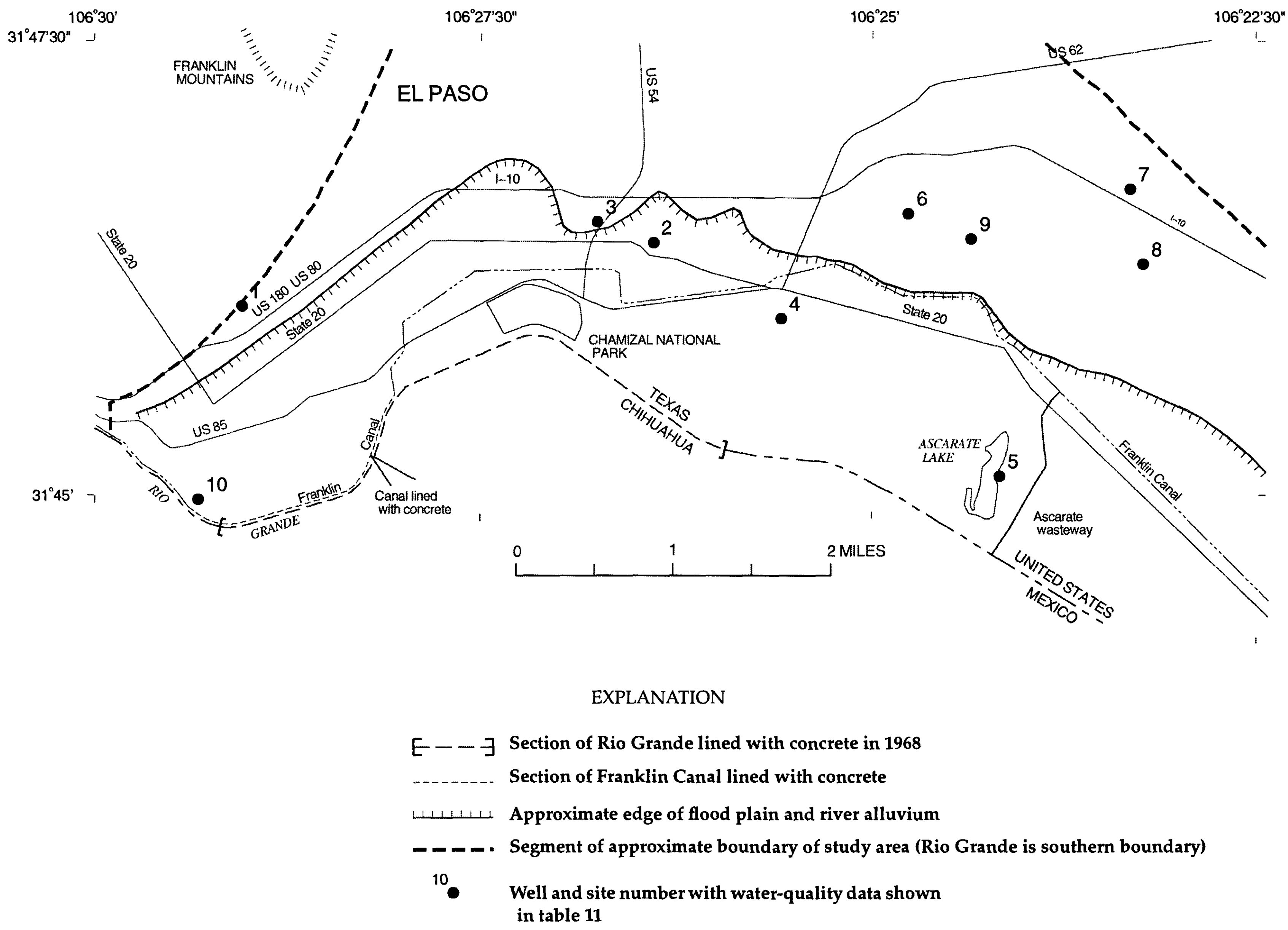


Figure 9. Locations of 10 monitoring wells in the shallow aquifer sampled for water-quality analyses, 1989.

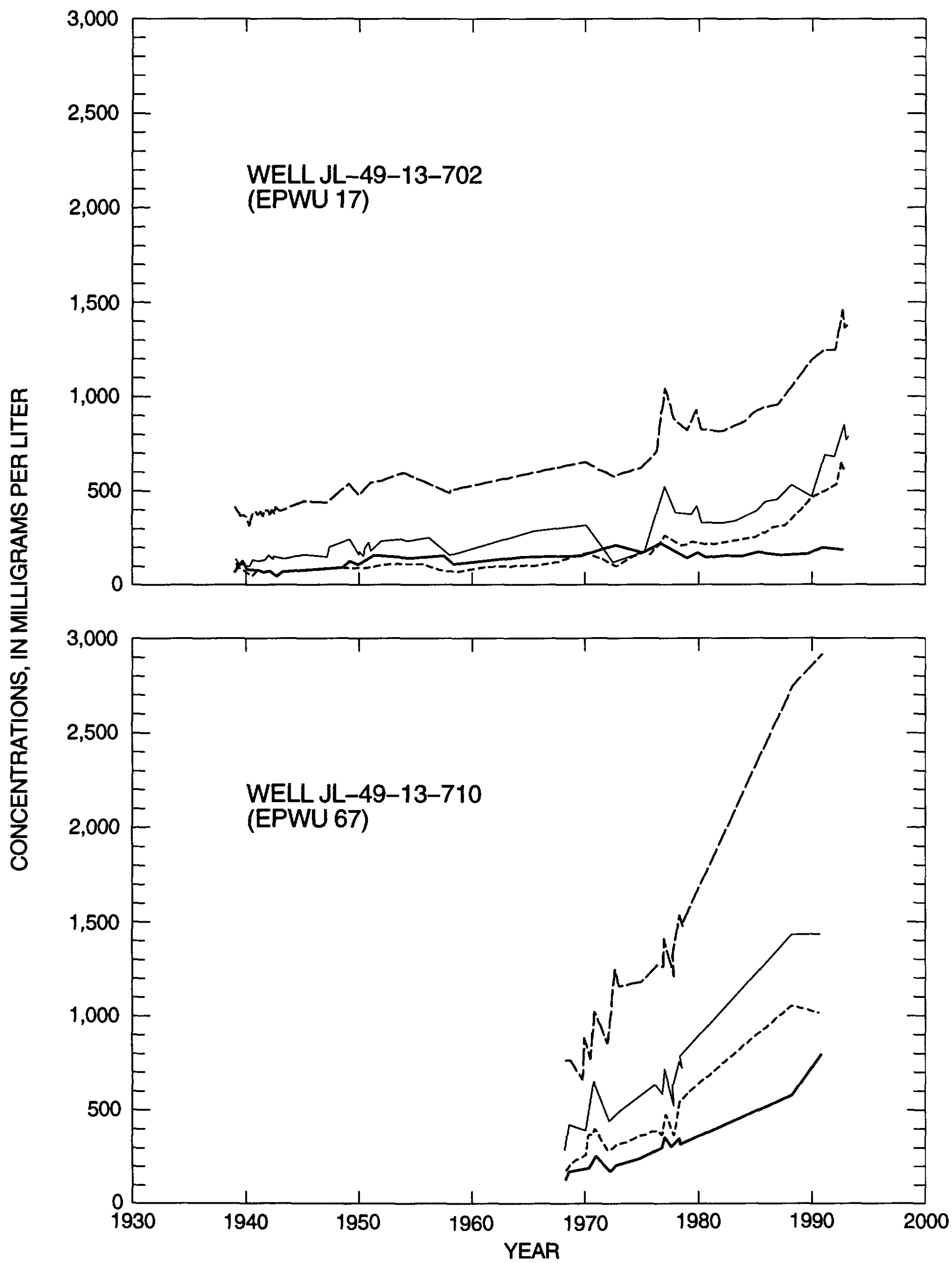


Figure 10. Changes in dissolved solids, hardness, chloride, and sulfate concentrations with time in water from selected wells in the Hueco bolson aquifer.

of these wells is blended with better-quality water from other wells in the well field or with surface-water diversions before treatment and distribution (El Paso Water Utilities-Public Service Board, oral commun., 1993).

Early (1939–85) and 1990–91 dissolved solids concentrations in 16 production wells are listed in table 5. The average dissolved solids concentration in early samples is 561 mg/L and in 1990–91 samples is 1,042 mg/L. The 16 wells had increases in dissolved solids concentrations between 1939–85 and 1990–91 that ranged from 2.1 to 125 milligrams per liter per year ((mg/L)/yr) and averaged 39.9 (mg/L)/yr. Graphs of water-quality data for four wells are shown in figure 10 to represent different patterns of increases in dissolved solids, hardness, chloride, and sulfate concentrations.

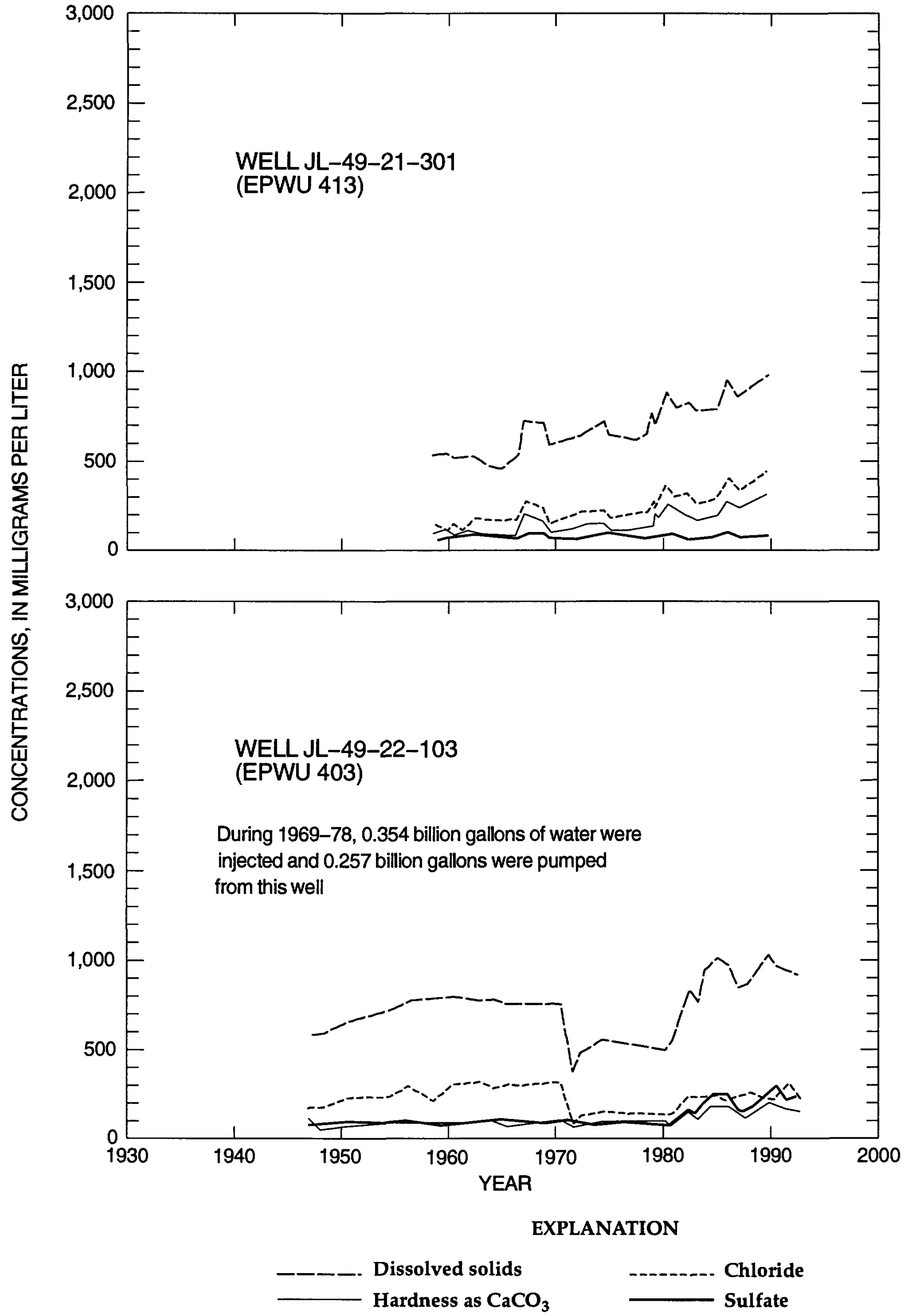


Figure 10.—Continued.

The water quality of the producing zones of the Hueco bolson aquifer, in all probability, is being affected by the inflow of inferior-quality water from the overlying shallow aquifer as well as from the deeper parts of the Hueco bolson aquifer. The increase in dissolved solids concentrations in water from Hueco bolson production wells within the study area probably is attributable mainly to vertical (downward) leakage of slightly to moderately saline water from the shallow aquifer above the freshwater section to the bolson aquifer. For example, the average salinity of the water sampled from 10 wells in the shallow aquifer during

1989 (table 11) normally is much higher than the average salinity of the water in production wells in the underlying Hueco bolson aquifer. Additionally, the water quality of the Hueco bolson aquifer likely is being degraded in some areas by vertical (upward) movement of saline water below the freshwater in the bolson aquifer. Plate 4 shows the position of mostly slightly saline water in the bolson aquifer just below the lowermost slotted or screened intervals in several of the wells operated by EPWU.

SUMMARY

The El Paso Valley, which is emphasized in this report, includes about 42 mi^2 of mostly urban area in central and southeastern El Paso and along the Rio Grande. Most of the hydrology presented pertains to the United States although some data for Ciudad Juárez, Mexico, across the Rio Grande are included to represent hydrologic conditions, well locations, well fields, and water use in that area. Most of the municipal, industrial, and military supply in El Paso and all of the supply for Ciudad Juárez are pumped from the Hueco bolson aquifer, which is interstate and international in extent.

Records of withdrawals of ground water from the Hueco bolson aquifer within the Rio Grande Valley and adjacent areas began in 1903. By 1992 withdrawals were 6,915,990 thousand gal (about 21,200 acre-ft) in El Paso and 21,138,657 thousand gal (about 64,900 acre-ft) in Ciudad Juárez. The historical (1903–92) cumulative withdrawals for the two cities are essentially the same, totaling about 395,411,073 thousand gal (about 1.21 Macre-ft) in El Paso and 397,980,455 thousand gal (about 1.22 Macre-ft) in Ciudad Juárez.

The historical withdrawals of fresh ground water from the Hueco bolson have caused water levels to decline about 167 ft as indicated in a bolson well near the Chamizal zone bordering the Rio Grande and international border. The water-level declines have induced slightly to moderately saline water to leak downward from the overlying shallow aquifer. The leakage, in all probability, has increased the salinity of the water pumped from production wells in the Hueco bolson aquifer and increased the rate of leakage from the Rio Grande to the shallow aquifer. Additionally, the water quality of the production zones of the Hueco bolson aquifer likely is being degraded in some areas by vertical (upward) leakage of saline water from the deeper parts of the bolson aquifer.

Dissolved solids concentrations in early (1939–85) samples from 40 wells averaged 587 mg/L. In recent (1992–93) samples from these wells, the average concentration is 883 mg/L. Dissolved solids concentrations in samples from 13 wells exceed 1,000 mg/L, the upper limit for freshwater. Dissolved solids concentrations in samples from 16 wells had increases between 1939–85 and 1990–91 that ranged from 2.1 to 125 (mg/L)/yr and averaged 39.9 (mg/L)/yr.

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Table 1. Annual ground-water withdrawals from the Hueco bolson aquifer in the Rio Grande Valley and adjacent areas, 1903–92

Year	Ground-water withdrawals[1] (thousand gallons)[2]					
	Municipal use, El Paso[1]	Industrial-miscellaneous use, El Paso	Military use, Fort Bliss	Total, El Paso and Fort Bliss	Total, municipal-industrial use, Ciudad Juárez	Total, El Paso, Fort Bliss, and Ciudad Juárez
1903	0	36,471	0	36,471	0	36,471
1904	0	48,471	0	48,471	0	48,471
1905	0	48,471	0	48,471	0	48,471
1906	0	48,471	66,364	114,835	0	114,835
1907	0	48,471	66,364	114,835	0	114,835
1908	0	48,471	66,364	114,835	0	114,835
1909	0	48,471	66,364	114,835	0	114,835
1910	0	48,471	66,364	114,835	0	114,835
1911	0	48,471	66,364	114,835	0	114,835
1912	0	62,846	66,364	129,210	0	129.210
1913	0	62,846	66,364	129,210	0	129,210
1914	0	185,573	66,364	251,937	0	251,937
1915	0	185,573	66,364	251,937	0	251,937
1916	0	185,573	66,364	251,937	0	251,937
1917	0	235,047	272,667	507,714	0	507,714
1918	115,764	235,047	272,667	623,478	0	623,478
1919	278,091	235,047	272,667	785,805	0	785,805
1920	574,273	328,576	496,000	1,398,849	0	1,398,849
1921	937,249	328,576	375,000	1,640,825	0	1,640,825
1922	1,215,096	328,576	292,000	1,835,672	0	1,835,672
1923	1,732,556	484,730	292,000	2,509,286	0	2,509,286
1924	2,052,956	484,730	334,000	2,871,686	0	2,871,686
1925	2,246,196	484,730	385,000	3,115,926	0	3,115,926
1926	2,379,229	484,730	421,000	3,284,959	155,000	3,439,959
1927	2,597,745	509,730	452,000	3,559,475	377,500	3,936,975
1928	2,570,557	558,730	410,000	3,539,287	357,501	3,896,788
1929	2,602,220	595,310	370,900	3,568,430	334,258	3,902,688
1930	2,999,653	962,348	434,000	4,396,001	313,500	4,709,501
1931	2,654,590	974,822	421,000	4,050,412	291,949	4,342,361
1932	2,389,670	886,658	422,000	3,698,328	271,600	3,969,928
1933	2,561,823	987,428	436,000	3,985,251	248,600	4,233,851
1934	2,407,833	1,018,230	462,000	3,888,063	567,586	4,455,649
1935	1,965,106	1,120,850	471,687	3,557,643	654,300	4,211,943
1936	1,939,612	1,414,819	449,813	3,804,244	655,527	4,459,771
1937	2,173,951	1,487,121	498,236	4,159,308	661,727	4,821,035
1938	1,628,623	1,401,386	470,445	3,500,454	654,858	4,155,312

Footnotes at end of table.

Table 1. Annual ground-water withdrawals from the Hueco bolson aquifer in the Rio Grande Valley and adjacent areas, 1903–92—Continued

Year	Ground-water withdrawals[1] (thousand gallons)[2]					
	Municipal use, El Paso[1]	Industrial-miscellaneous use, El Paso	Military use, Fort Bliss	Total, El Paso and Fort Bliss	Total, municipal-industrial use, Ciudad Juárez	Total, El Paso, Fort Bliss, and Ciudad Juárez
1939	1,885,182	1,345,330	548,491	3,779,003	652,940	4,431,943
1940	1,967,453	1,414,909	701,986	4,084,348	690,800	4,775,148
1941	1,540,990	1,394,200	894,477	3,829,667	753,000	4,582,667
1942	1,730,049	1,838,997	1,071,172	4,640,218	827,927	5,468,145
1943	2,014,556	2,074,575	1,136,654	5,225,785	920,635	6,146,420
1944	1,211,945	2,167,467	991,796	4,371,208	977,956	5,349,164
1945	1,431,565	1,818,472	1,007,106	4,257,143	986,399	5,243,542
1946	1,641,464	1,690,600	882,693	4,214,757	921,580	5,136,337
1947	1,178,581	2,034,014	737,577	3,950,172	868,797	4,818,969
1948	807,732	2,160,965	882,551	3,851,248	1,362,654	5,213,602
1949	1,514,073	1,730,337	2,159,410	5,403,820	1,406,222	6,810,042
1950	1,669,978	1,620,265	1,980,162	5,270,405	1,449,151	6,719,556
1951	1,662,758	1,954,360	2,021,464	5,638,582	1,385,127	7,023,709
1952	1,611,457	1,358,534	1,828,925	4,798,916	2,541,741	7,340,657
1953	1,468,280	1,306,144	1,934,027	4,708,451	2,543,104	7,251,555
1954	2,748,016	1,577,455	850,414	5,175,885	2,544,831	7,720,716
1955	2,725,488	2,201,926	660,143	5,587,557	4,010,030	9,597,587
1956	2,954,262	2,699,610	342,473	5,996,345	4,180,643	10,176,988
1957	2,934,718	2,481,836	382,965	5,799,519	4,260,261	10,059,780
1958	2,911,807	2,453,704	416,583	5,782,094	4,458,593	10,240,687
1959	2,374,157	2,329,630	525,787	5,229,574	4,902,156	10,131,730
1960	2,755,530	2,135,686	509,652	5,400,868	4,676,292	10,077,160
1961	3,381,128	2,050,055	361,532	5,792,715	4,483,903	10,276,618
1962	2,523,833	2,247,901	509,569	5,281,303	4,278,883	9,560,186
1963	2,217,047	2,282,585	491,751	4,991,383	3,791,096	8,782,479
1964	2,912,529	2,168,040	366,948	5,447,517	4,474,724	9,922,241
1965	3,060,449	2,176,683	432,511	5,669,643	3,977,372	9,647,015
1966	2,419,356	2,133,955	541,862	5,095,173	3,780,973	8,876,146
1967	3,130,392	1,988,246	602,331	5,720,969	4,025,407	9,746,376
1968	4,647,247	1,967,535	524,604	7,139,386	4,250,237	11,389,623
1969	4,816,856	2,090,649	607,313	7,514,818	4,867,820	12,382,638
1970	3,898,883	2,016,663	530,375	6,445,921	5,563,653	12,009,574
1971	4,002,915	2,038,707	661,085	6,702,707	7,072,530	13,775,237
1972	5,506,018	2,035,293	533,614	8,074,925	7,783,962	15,858,887
1973	3,330,788	1,982,752	581,124	5,894,664	8,516,794	14,411,458
1974	3,286,507	1,750,045	589,035	5,625,587	8,999,565	14,625,152
1975	3,378,096	1,627,747	450,025	5,455,868	9,305,285	14,761,153
1976	3,250,092	1,512,117	457,873	5,220,082	9,837,282	15,057,364
1977	3,923,011	1,545,473	612,613	6,081,097	10,155,183	16,236,280
1978	4,536,716	1,455,564	439,414	6,431,694	10,714,636	17,146,330

Footnotes at end of table.

Table 1. Annual ground-water withdrawals from the Hueco bolson aquifer in the Rio Grande Valley and adjacent areas, 1903–92—Continued

Year	Ground-water withdrawals[1] (thousand gallons)[2]					
	Municipal use, El Paso[1]	Industrial-miscellaneous use, El Paso	Military use, Fort Bliss	Total, El Paso and Fort Bliss	Total, municipal-industrial use, Ciudad Juárez	Total, El Paso, Fort Bliss, and Ciudad Juárez
1979	2,753,432	1,458,523	472,942	4,684,897	11,944,358	16,629,255
1980	3,439,111	1,363,540	401,841	5,204,492	12,144,829	17,349,321
1981	4,521,705	1,532,346	411,368	6,465,419	12,649,779	19,115,198
1982	5,098,754	1,593,749	539,371	7,231,874	13,504,291	20,736,165
1983	4,908,210	1,719,595	413,792	7,041,597	14,289,526	21,331,123
1984	6,987,177	1,803,946	454,214	9,245,337	14,519,041	23,764,378
1985	8,116,064	1,750,656	316,928	10,183,648	14,370,196	24,553,844
1986	7,602,172	1,799,129	459,471	9,860,772	15,500,535	25,361,307
1987	8,803,334	1,709,934	543,047	11,056,315	17,247,669	28,303,984
1988	8,389,333	1,957,291	26,063	10,372,687	18,947,581	29,320,268
1989	7,282,051	2,050,438	286,089	9,618,578	21,141,192	30,759,770
1990	6,311,559	1,733,486	196,412	8,241,457	21,043,654	29,285,111
1991	5,544,070	1,558,136	487,037	7,589,243	20,795,397	28,384,640
1992	5,001,468	1,622,656	291,866	6,915,990	21,138,657	28,054,647
Total	231,743,137	117,166,322	46,501,614	395,411,073	397,980,455	793,391,528

[1] Data for Texas withdrawals from El Paso Water Utilities-Public Service Board, U.S. Department of the Army-Fort Bliss, and Texas Water Development Board; data for Ciudad Juárez withdrawals from Junta Municipal de Aguas y Saneamiento.

[2] Multiply thousand gallons by 0.003068887 to convert to acre-feet.

Table 2. Ground-water withdrawals, 1992, and cumulative ground-water withdrawals, 1903–92, in the Rio Grande Valley and adjacent areas

Use of water	Number of wells pumped, 1992	Ground-water withdrawals, 1992[1]		Cumulative ground-water withdrawals, 1903–92[1]	
		(acre-feet)	(thousand gallons)	(acre-feet)	(thousand gallons)
			El Paso and Fort Bliss		
Municipal, El Paso	36	15,349	5,001,468	711,194	231,743,137
Industrial-miscellaneous, El Paso	10	4,980	1,622,656	359,570	117,166,322
Military, Fort Bliss	3	896	291,866	142,708	46,501,614
Total	49	21,225	6,915,990	1,213,472	395,411,073
			Ciudad Juárez		
Municipal-industrial	60	64,872	21,138,657	1,221,357	397,980,455
			Total (El Paso, Fort Bliss, and Ciudad Juárez)		
	109	86,097	28,054,647	2,434,829	793,391,528

[1] Data for Texas withdrawals from El Paso Water Utilities-Public Service Board, U.S. Department of the Army-Fort Bliss, and Texas Water Development Board; data for Ciudad Juárez withdrawals from Junta Municipal de Aguas y Saneamiento.

Table 3. Selected data for seven El Paso Water Utilities-Public Service Board production well pairs in the Hueco bolson aquifer, El Paso Valley and adjacent areas

[ft, feet; mg/L, milligrams per liter; SWL, static water level; E, estimated; >, greater than; --, not determined]

Well no. State (JL–49–) (pl. 1)	Well no. El Paso Water Utilities	Land-surface altitude (ft)	Electrical resistivity log Date	Electrical resistivity log Interval (ft below land surface)	Estimated depth to freshwater (ft below land surface) Top	Estimated depth to freshwater (ft below land surface) Base	Casing screened interval (ft below land surface)	Depth to water Date	Depth to water (ft below land surface)	Dissolved solids concentration Date	Dissolved solids concentration Computed (mg/L)
13–609	30	3,920	04/13/56	38–1,589	SWL	1,039	316–983	1903	236 E	06/21/56	570
								12/18/58	259.5	08/03/77	623
								01/14/81	291.65	12/23/82	1,190
13–627	30A	3,919	10/23/80	45–1,205	335	1,039	539–1,021	1903	235 E	11/09/81	639
								12/24/80	312.7	11/08/90	636
								12/09/88	324.24	12/21/92	652
13–704	14	3,700	12/01/38	35–904	110	>904	255–695	1903	9 E	04/20/37	507
								01/29/40	25.49	06/20/80	673
								12/09/81	135.24		
13–727	14A	3,700	12/11/81	5–973	267	>1,086	481–960	1903	9 E	01/19/82	571
			12/15/81	10–1,086				01/19/82	142.1	06/21/90	834
								12/05/80	154.98	12/30/91	844
								12/22/92	176.14		
13–709	10	3,706	Driller's log only 03/14/30	0–807	--	660	360–660	1903	10.5 E	06/25/37	565
								12/22/34	16.57	06/05/40	487
								12/27/65	41.16	02/18/58	488
13–711	10A	3,706	01/20/68	7–1,116	61	633	300–641	1903	10.5 E	02/16/68	525
								02/15/68	45.48	11/06/78	794
								01/89	156 E	01/31/90	1,260
										12/10/92	1,340
13–806	18	3,700	12/01/38	21–902	110	848	304–642	1903	14 E	08/30/40	631
								01/06/53	25.79	07/31/74	679
								06/17/75	88.77		
13–830	18A	3,700	08/12/75	46–964	181	825	533–788	1903	14.5 E	09/22/75	590
								12/15/75	87.57	06/21/90	684
								12/05/90	153.05	01/05/93	714
								12/22/92	163.27		
14–710	406	3,830	07/22/53	20–688	SWL	550	244–550	1903	156 E	10/13/54	499
								08/09/53	165	05/25/81	540
								12/18/80	202.05		
14–722	406A	3,830	10/27/81	61–803	SWL	550	347–610	1903	156 E	12/03/81	561
								11/30/81	209.15	07/11/90	721
								01/89	235 E	10/19/92	767

Table 3. Selected data for seven El Paso Water Utilities-Public Service Board production well pairs in the Hueco bolson aquifer, El Paso Valley and adjacent areas—Continued

Well no.		Land-surface altitude (ft)	Electrical resistivity log		Estimated depth to freshwater (ft below land surface)		Casing screened interval (ft below land surface)	Depth to water		Dissolved solids concentration	
State (JL–49–) (pl. 1)	El Paso Water Utilities		Date	Interval (ft below land surface)	Top	Base		Date	(ft below land surface)	Date	Computed (mg/L)
14–711	405	3,755	05/25/52	40–488	176	>488	260–479	1903	82.5 E	06/10/52	389
								02/03/60	98.35	07/21/70	598
								12/13/83	139.31	04/11/90	1,160
14–724	405A	3,754	04/29/87	8–618	319	>618	426–506	1903	81.5 E	09/30/92	779
								12/18/92	164.50		
22–102	412	3,810	12/07/56	50–568	SWL	353	90–316	1903	138.5 E	11/05/58	528
								01/02/57	144	02/03/83	715
								08/15/83	176.4		
22–134	412A	3,810	09/22/83	54–556	241	355	250–370	1903	138.5 E	10/25/83	659
								12/21/83	174.98	09/21/90	981
								01/89	198 E	10/19/92	1,010

Table 4. Average depth to water in well fields, December 1992–January 1993, and water-level decline, 1903 to December 1992–January 1993

Well field (pl. 1)	Number of wells with water levels measured	Well-field average depth to water December 1992–January 1993 (feet below land surface)	Water-level decline 1903 to December 1992–January 1993 (feet)
Cielo Vista[1]	2	349.04	107.54
Lower valley[1]	14	115.15	73.07
Town[1]	3	171.54	160.31
Water plant[1]	4	162.49	153.24
Fort Bliss Post	2	300.94	110.94
Industrial-miscellaneous	7	197.52	111.02
Average for 32 wells		170.60	104.09

[1] El Paso Water Utilities-Public Service Board well field.

Table 5. Rates of water-level decline and changes in dissolved solids concentration for 25 production wells completed in the Hueco bolson aquifer, El Paso Valley and adjacent areas

[ft/yr, feet per year; mg/L, milligrams per liter; (mg/L)/yr, milligrams per liter per year; EPWU, El Paso Water Utilities-Public Service Board; --, no data; NR, no record; EPCC, El Paso Community College; ( ), number in parentheses indicates number of wells used to obtain average]

Well no.		Rate of water-level decline in Hueco bolson aquifer (ft/yr)		Dissolved solids concentration, early and 1990–91 analyses, and change in concentration				
State (JL–49–) (pl. 1)	Local	Estimated by statistical analysis[1]	Graphical estimate[2]	Date (early)	Concentration (mg/L)	Date (1990–91)	Concentration (mg/L)	Change [(mg/L)/yr]
City of El Paso production wells								
13–702	EPWU 17	3.62	4.3	02/04/39	341	02/05/91	1,335	+78
13–705	EPWU SP1	0	3.8	10/26/65	491	02/05/91	782	+57
13–706	EPWU SP2	0	3.9	03/18/70	482	02/05/91	762	+48
13–710	EPWU 67	3.04	5.0	02/08/68	803	09/12/90	3,034	+125
13–727	EPWU 14A	0	2.4	01/19/82	571	06/21/90	834	+30
13–804	EPWU 4	3.10	3.2	--	--	--	--	--
13–830	EPWU 18A	3.82	4.4	09/22/75	590	06/21/90	684	+18
13–831	EPWU 81	3.52	3.4	12/09/75	635	10/09/90	764	+8.8
13–902	EPWU 401	0	3.1	--	--	--	--	--
13–912	EPWU 402	1.74	2.2	--	--	--	--	--
21–301	EPWU 413	4.37	4.0	08/01/57	587	12/19/89	1,057	+23
21–310	EPWU 420	6.17	6.1	10/12/82	597	02/12/90	803	+29
22–103	EPWU 403	2.59	2.7	03/03/47	517	10/18/90	1,093	+9.8
22–122	EPWU 73	1.57	2.2	--	--	--	--	--
22–124	EPWU 83	3.41	3.3	12/30/75	659	10/10/89	1,154	+60
22–128	EPWU 88	2.34	2.3	12/18/78	430	11/13/90	894	+74
22–129	EPWU 415	3.11	3.1	01/28/81	710	11/13/90	1,121	+52
22–139	EPWU 418	2.65	2.8	05/23/85	590	04/02/91	1,253	+14
Industrial and military production wells								
13–524	Fort Bliss 9A	2.43	3.4	12/06/83	434	05/14/91	450	+2.1
13–630	Fort Bliss 7A	NR	NR	--	--	--	--	--
13–828	Chamizal	5.04	3.8	05/31/75	546	05/31/91	653	+9.7
13–903	Chevron 7	1.39	2.6	--	--	--	--	--
13–909	Phelps Dodge 3	3.68	3.3	--	--	--	--	--
13–949	Texas Highway Department	2.24	2.2	--	--	--	--	--
14–713	EPCC	3.17	3.7	--	--	--	--	--
Average		(24) 2.62	(24) 3.38		(16) 561		(16) 1,042	(16) +39.9

[1] Linear statistical analysis at 99-percent confidence level with emphasis on most recent rates of water-level change (El Paso Water Utilities-Public Service Board, written commun., 1996).

[2] Linear projections of rates of water-level change on well hydrographs.

Table 6. Annual flow and dissolved solids concentrations in the Rio Grande at El Paso, 1943–91

[All data from International Boundary and Water Commission (1943–91), unless otherwise stated. acre-ft, acre-feet; mg/L, milligrams per liter; --, no data]

Year	Flow (acre-ft)			Dissolved solids concentration (mg/L)		
	El Paso station	Diverted to Mexico	Franklin Canal[1]	Range of monthly samples	Average of monthly samples	Discharge-weighted average
1943	631,800	61,309	173,380	669–1,221	862	750
1944	611,900	61,798	149,660	677–1,250	903	787
1945	568,900	60,684	150,475	669–1,324	889	802
1946	497,900	60,466	133,650	713–1,236	914	816
1947	458,860	58,012	126,670	669–1,294	981	824
1948	431,680	60,689	124,480	691–1,324	968	838
1949	463,540	60,256	127,160	655–1,221	870	750
1950	472,630	60,602	126,020	669–1,294	916	772
1951	252,000	33,059	87,826	809–1,375	1,072	905
1952	283,680	49,890	86,580	530–1,530	1,032	736
1953	264,500	37,760	86,050	655–1,537	1,000	743
1954	93,725	10,147	43,330	684–2,229	1,249	956
1955	67,089	8,185	38,615	802–2,839	1,502	1,015
1956	57,481	7,864	36,128	993–3,200	1,905	1,052
1957	139,571	23,290	69,081	427–3,832	1,858	596
1958	392,863	60,050	113,100	655–3,251	1,267	721
1959	385,810	60,110	135,530	610–1,750	1,130	831
1960	378,260	60,320	145,100	669–1,706	1,154	860
1961	300,690	48,610	130,170	713–1,670	1,119	867
1962	376,116	60,057	132,823	677–1,618	1,044	802
1963	263,711	39,693	113,912	713–1,655	1,174	875
1964	64,307	6,653	47,337	809–2,640	1,522	1,059
1965	202,392	36,658	71,274	434–2,273	1,341	566
1966	308,782	49,618	105,903	552–2,111	1,117	691
1967	232,744	29,829	99,786	655–1,743	1,131	816
1968	264,408	39,677	79,752	728–1,670	1,155	890
1969	365,407	59,884	105,583	610–1,831	1,100	780
1970	360,719	60,065	117,830	684–1,618	1,070	824
1971	244,156	34,847	82,983	684–1,677	1,116	824
1972	133,568	16,077	45,406	691–2,162	1,328	905
1973	301,789	60,000	72,937	588–2,118	1,181	831
1974	382,953	60,050	86,319	588–1,699	1,014	750
1975	360,959	60,052	81,093	728–1,559	1,025	846
1976	402,835	60,172	83,973	588–1,530	943	780
1977	214,553	24,824	67,550	691–2,008	1,206	--
1978	156,024	14,903	51,522	521–2,560	1,373	--
1979	312,594	60,055	77,048	432–2,260	1,059	--
1980	353,983	60,033	91,960	531–1,710	985	--
1981	333,329	60,262	86,499	552–1,710	972	--
1982	326,642	59,257	87,942	610–1,600	1,001	--
1983	331,955	60,621	89,024	637–1,570	962	--
1984	359,361	58,588	88,988	543–1,480	866	--
1985	359,917	60,276	81,392	510–1,400	916	--
1986	1,048,972	66,163	89,566	370–1,400	643	--
1987	1,076,182	65,866	91,885	383–1,172	667	--
1988	570,032	61,935	96,064	394–1,300	833	--
1989	428,248	58,854	93,009	537–1,460	944	--
1990	391,899	58,352	83,936	575–1,470	956	--
1991	372,077	59,242	107,139	661–1,530	949	--

[1] Data from Bureau of Reclamation (written commun., 1992).

Table 7. Rio Grande water budget, El Paso narrows to Riverside Dam, 1959–83

[Data from International Boundary and Water Commission (1943–91); Land and Armstrong (1985, table 1). acre-ft, acre-feet; values rounded to three significant figures; ( ), numbers in parentheses indicate a gain]

Year	Inflow to system[1]	Outflow from system (acre-ft)					Total outflow from system (acre-ft)	Net loss from system (acre-ft)
	Flow in Rio Grande at El Paso plus El Paso sewage[2] (acre-ft)	Diverted to Mexico	Diverted to El Paso	Franklin Canal, net diversion	Diverted to Riverside Dam	Rio Grande flow downstream from Riverside Dam		
1959	405,000	60,100	9,040	95,800	195,000	12,400	372,000	33,000
1960	397,000	60,300	8,390	92,800	203,000	15,500	380,000	17,400
1961	321,000	48,600	7,330	76,200	139,000	8,010	279,000	41,200
1962	397,000	60,100	9,090	77,400	205,000	17,000	369,000	28,000
1963	284,000	39,700	9,970	67,300	131,000	4,540	252,000	32,300
1964	86,200	6,650	3,800	41,700	23,200	4,150	79,500	6,740
1965	225,000	36,700	6,130	57,500	106,000	6,260	213,000	12,700
1966	332,000	49,600	12,100	75,200	160,000	13,600	310,000	22,300
1967	254,000	29,800	15,500	57,400	132,000	5,010	239,000	14,300
1968	284,000	39,700	11,900	55,600	124,000	7,990	240,000	44,800
1969	385,000	59,900	13,000	65,600	206,000	4,130	349,000	35,900
1970	382,000	60,100	14,000	67,200	201,000	17,200	360,000	22,600
1971	269,000	34,800	15,500	50,100	156,000	2,380	259,000	9,700
1972	154,000	16,100	9,370	25,200	84,500	2,270	137,000	16,600
1973	323,000	60,000	16,400	53,700	190,000	4,970	325,000	(1,910)
1974	406,000	60,000	17,900	66,400	236,000	31,200	412,000	(5,160)
1975	385,000	60,100	18,300	55,400	228,000	14,300	376,000	8,930
1976	427,000	60,200	14,900	64,600	259,000	2,760	402,000	25,600
1977	238,000	24,800	11,100	41,200	135,000	767	213,000	25,400
1978	180,000	14,900	7,230	31,800	97,200	7,100	158,000	21,500
1979	340,000	60,100	14,600	57,900	177,000	16,700	326,000	13,200
1980	381,000	60,000	20,100	57,200	227,000	12,200	376,000	4,670
1981	360,000	60,300	21,900	45,800	175,000	26,900	330,000	29,800
1982	354,000	59,300	18,900	56,900	185,000	21,200	341,000	12,800
1983	359,000	60,600	22,400	46,400	174,000	26,600	330,000	29,400
25-year total	7,930,000	1,180,000	329,000	1,480,000	4,150,000	285,000	7,430,000	502,000
25-year average	317,000	47,200	13,200	59,200	166,000	11,400	297,000	20,100

[1] Inflow from urban runoff is unaccounted for.

[2] Flow in Rio Grande at El Paso is sum of flow diverted to American Canal and flow in river below American Dam.

Table 8. Streamflow-loss data for a 5.25-mile unlined section of the Franklin Canal, January–April 1984

[Data from Bureau of Reclamation (written commun., 1984) in Land and Armstrong (1985, table 3). ft^3/s, cubic feet per second]

Date	Upstream flow (ft^3/s)	Downstream flow (ft^3/s)	Streamflow loss (ft^3/s)
01/20/84	48.2	46.8	1.4
	47.5	47.0	.5
	50.0	47.4	2.6
01/31/84	44.6	40.4	4.2
02/14/84	78.2	74.3	3.9
02/22/84	100.2	99.2	1.0
02/25/84	110.2	103.3	6.9
02/27/84	104.0	100.4	3.6
03/06/84	106.0	102.1	3.9
03/16/84	158.9	153.6	5.3
03/23/84	190.1	185.9	4.2
03/27/84	182.4	169.3	13.1
03/30/84	190.5	187.2	3.3
04/03/84	181.0	178.4	2.6
04/06/84	182.5	164.3	18.2
04/10/84	188.6	184.8	3.8
04/13/84	188.8	188.0	.8
04/17/84	181.5	180.4	1.1
04/20/84	186.2	185.6	.6
Total	2,519.4	2,438.4	81.0
Average	132.6	128.3	4.3

Table 9. Streamflow measurements in the Franklin Canal and Ascarate wasteway, 1990–92

[EPCWID, El Paso County Water Improvement District No. 1; mi, miles; USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; BR, Bureau of Reclamation; B, footbridge measurement; W, wading measurement; --, no data; ft, feet; RR, railroad; *, average for date; A, Ascarate wasteway; hwy., highway; in., inches]

Site number	EPCWID station[1] (mi)	USGS station[2] (mi)	Site description	1990 Date	1990 Time	1990 Streamflow (ft^3/s)	1990 Date	1990 Time	1990 Streamflow (ft^3/s)	1991 Date	1991 Time	1991 Streamflow (ft^3/s)
1	1.60	0.00	BR gaging station in lined section of Franklin Canal between Kansas and Campbell Sts., extended	04/20	0800	B 219	09/11	0832	B 216	04/08	0730	B 266
					0845			0901			0803	
				04/21	0710	B 216	09/12	0728	B 217	04/09	0705	B 267
					0753			0800			0740	
				04/23	0821	B 215		1104	B 217	04/10	0655	W 145
					0902			1136			0710	
							09/13	0720	B 183	04/11	0715	W 144
								0751			0740	
2	2.50	1.14	End of concrete-lined section of Franklin Canal	--	--	--	--	--	--	--	--	--
3	2.70	1.38	Franklin Canal, 100 ft above Southern Pacific RR crossing at EPCWID station 2.70	--	--	--	--	--	--	04/10	0800	W 144
											0822	
4	6.15	3.85	Franklin Canal, 100 ft below Jefferson High School crosswalk at EPCWID station 6.15	--	--	--	--	--	--	04/10	1133	W 144
											1207	
										04/11	1047	W 138
											1119	
5	8.41	6.47	Franklin Canal, 100 ft above Ascarate wasteway at EPCWID station 8.41	--	--	--	09/12	0815	W 192	04/10	1024	W 134
								0902			1046	
								0947	W 186	04/11	1310	W 138
								1010	*189		1331	
							09/13	0930	W 160			
								0954				
								0956	W 163			
								1018	*161.5			

Footnotes at end of table.

Table 9. Streamflow measurements in the Franklin Canal and Ascarate wasteway, 1990–92—Continued

Site number	EPCWID station[1] (mi)	USGS station[2] (mi)	Site description	1990 Date	1990 Time	1990 Streamflow (ft^3/s)	1990 Date	1990 Time	1990 Streamflow (ft^3/s)	1991 Date	1991 Time	1991 Streamflow (ft^3/s)
6	8.41	6.47	Franklin Canal, 100 ft below Ascarate wasteway	04/20	0958 1053	W 133	09/11	0935 0959	W 64.2	04/08	0933 0945	W 94.1
				04/21	0830 0837	W 174				04/09	1016 1030	W 88.8
				04/23	0925 0945	W 82.3						
7	--	0.05A	Ascarate wasteway, 270 ft below headgates at BR gaging station	04/20	0925 0950	W 69.5	09/11	1013 1028	W 129	04/08	0958 1018	W 143
				04/21	0910 0929	W 22.4				04/09	0920 1004	B 151
				04/23	0950 1010	W 117						
8	--	1.11A	Ascarate wasteway and Border hwy., 1.11 mi downstream from headgates on Franklin Canal	04/20	1053 1106	W 70.5	--	--	--	--	--	--
				04/21	0940 1000	W 21.8						
				04/23	1230 1245	W 118						
Net streamflow loss in Franklin Canal—flow at site 1 minus flow at site 5, or combined flows at sites 6 and 7				04/20 04/21 04/23		16.5 19.6 15.7	09/11 09/12 09/13		22.8 28.0 21.5	04/08 04/09 04/10 04/11		28.9 27.2 11.0 6.0
Average streamflow loss (ft^3/s)						17.3			24.1			18.3
Average streamflow loss (percent of streamflow at site 1)						8.0			11.7			8.2

Footnotes at end of table.

Table 9. Streamflow measurements in the Franklin Canal and Ascarate wasteway, 1990–92—Continued

Site number	EPCWID station[1] (mi)	USGS station[2] (mi)	Site description	1991 Date	1991 Time	1991 Streamflow (ft^3/s)	1992 Date	1992 Time	1992 Streamflow (ft^3/s)
1	1.60	0.00	BR gaging station in lined section of Franklin Canal between Kansas and Campbell Sts., extended	09/03	0712	B 243	04/13	0747	B 209
					0748			0816	
					1230	B 245		1152	B 203
					1316	*244		1223	*206
				09/04	0821	B 241	04/14	0738	B 196
					0839			0809	
					1341	B 229		1101	B 199
					1409	*235		1138	*197.5
				09/05	0701	B 239	04/15	0719	B 193
					0727			0747	
					1010	B 229		1057	B 196
					1038	*234		1126	*194.5
2	2.50	1.14	End of concrete-lined section of Franklin Canal	--	--	--	--	--	--
3	2.70	1.38	Franklin Canal, 100 ft above Southern Pacific RR crossing at EPCWID station 2.70	--	--	--	--	--	--
4	6.15	3.85	Franklin Canal, 100 ft below Jefferson High School crosswalk at EPCWID station 6.15	--	--	--	--	--	--
5	8.41	6.47	Franklin Canal, 100 ft above Ascarate wasteway at EPCWID station 8.41	09/03	1349	W 215	04/13	0959	W 186
					1417			1023	
				09/04	0946	W 206		1252	W 180
					1007			1311	*183
					1104	W 210	04/14	0835	W 182
					1125			0902	
					1440	W 207		1242	W 178
					1501	*207.7		1303	*180
				09/05	0756	W 215	04/15	0817	W 172
					0818			0837	
					1102	W 210		1231	W 167
					1122	*212.5		1250	*169.5

Footnotes at end of table.

Table 9. Streamflow measurements in the Franklin Canal and Ascarate wasteway, 1990–92—Continued

Site number	EPCWID station[1] (mi)	USGS station[2] (mi)	Site description	1991 Date	1991 Time	1991 Streamflow (ft^3/s)	1992 Date	1992 Time	1992 Streamflow (ft^3/s)
6	8.41	6.47	Franklin Canal, 100 ft below Ascarate wasteway	09/03	0920 0956	W 139		-- --	-- --
7	--	0.05A	Ascarate wasteway, 270 ft below headgates at BR gaging station	09/03	1006 1020	W 75.5		-- --	-- --
8	--	1.11A	Ascarate wasteway and Border hwy., 1.11 mi downstream from headgates on Franklin Canal	--	--	--	--	--	
Net streamflow loss in Franklin Canal—flow at site 1 minus flow at site 5, or combined flows at sites 6 and 7				09/03 09/04 09/05		29.2 27.3 21.5	04/13 04/14 04/15		23.0 17.5 25.0
Average streamflow loss (ft^3/s)						26.0			21.8
Average streamflow loss (percent of streamflow at site 1)						8.2			11.0

[1] Stations stenciled on abutments.
[2] Stations measured on scale of 1 in. = 300 ft, El Paso Water Utilities-Public Service Board street map, and shown on figure 8.

Table 10. Chemical analyses of water diverted from the Franklin Canal at El Paso Water Utilities-Public Service Board Canal Street treatment plant, November 1991–October 1992

[All analyses by El Paso Water Utilities-Public Service Board. µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; <, less than]

Date sampled	Specific conductance (µS/cm)	pH (standard units)	Hardness as $CaCO_3$ (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Bicarbonate (mg/L)	Alkalinity, total as $CaCO_3$ (mg/L)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)	Dissolved solids, calculated, sum of constituents (mg/L)	Nitrate, dissolved, as N[1] (mg/L)	Phosphate, dissolved, as P[1] (mg/L)
11/18/91	1,950	8.4	428	124	28	273	11	281	262	420	228	0.9	28	1,389	4.2	0.1
03/23/92	1,093	8.4	224	68	13	132	7.0	178	166	218	95	.8	11	725	1.5	<.09
04/06/92	1,040	8.4	240	72	14	136	6.8	185	168	229	105	.8	11	760	1.4	.1
04/13/92	1,230	8.4	273	82	16	164	7.8	204	191	273	108	.5	20	871	1.9	.1
04/20/92	1,020	8.4	239	71	15	149	7.4	188	164	241	100	.7	12	779	1.3	<.09
05/11/92	1,030	8.5	242	71	15	127	6.9	185	172	217	95	.7	12	732	2.2	.1
06/22/92	958	8.6	230	69	14	122	6.5	188	166	211	85	.7	9	704	1.0	<.09
06/29/92	1,001	8.6	236	70	15	123	8.3	202	174	214	90	.7	12	729	1.0	.1
07/13/92	995	8.8	233	69	15	122	7.3	201	175	229	70	.8	15	721	.7	<.09
07/20/92	977	8.6	230	69	14	127	4.9	181	164	208	85	.6	12	699	.1	<.09
07/27/92	977	8.5	222	67	13	129	7.3	179	161	224	88	.8	15	717	.9	<.09
08/03/92	911	8.3	216	65	13	111	6.9	168	142	211	80	.6	9	660	1.7	.1
08/10/92	1,080	8.4	248	75	15	154	7.0	200	172	246	108	.7	14	811	.7	<.09
08/17/92	993	8.5	222	67	13	136	7.1	178	162	223	90	.7	13	725	.4	<.09
08/24/92	996	8.5	234	70	14	134	6.9	185	168	226	82	.7	16	729	.6	.1
09/08/92	1,050	8.4	241	73	14	142	7.5	192	177	241	100	.7	12	783	.9	<.09
09/14/92	1,140	8.5	270	79	18	162	8.1	229	208	258	115	.6	12	883	1.0	<.09
09/21/92	1,250	8.6	267	81	16	148	7.7	209	195	233	112	.6	10	823	1.6	.1
10/05/92	1,250	8.4	269	84	14	161	7.5	212	196	261	120	.5	12	874	1.4	.1
10/12/92	1,270	8.5	290	94	14	158	7.6	220	204	255	128	.7	14	893	2.0	.1
10/19/92	1,440	8.7	344	104	21	191	8.2	255	235	298	150	1.3	15	1,048	3.0	.1

[1] Nitrate and phosphate concentrations reported by El Paso Water Utilities-Public Service Board lab as NO_3 and PO_4. To convert NO_3 to N divide by 4.43, and to convert PO_4 to P divide by 3.07.

Table 11. Chemical analyses of water samples collected from 10 wells in the shallow aquifer, El Paso Valley

[ft, feet; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; $CaCO_3$, calcium carbonate; mg/L, <, less than]

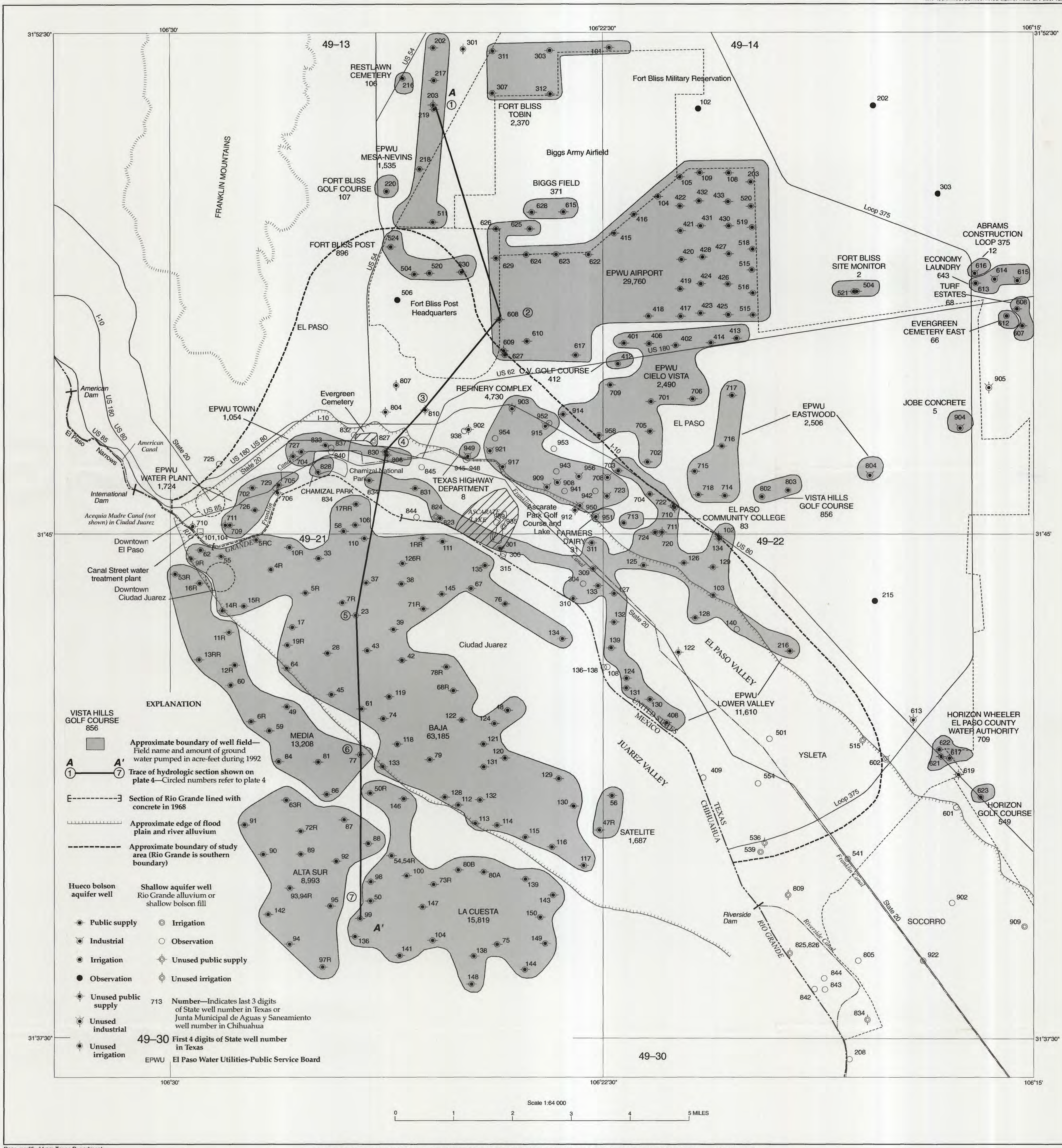
Site no. (fig. 9)	State well no. (JL–49–) (pl. 1)	Local identification	Water-yielding unit	Depth or producing interval (ft)	Date sampled	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Hardness as $CaCO_3$ (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)
1	13–725	Houston Park	RGA–HB	200–220	06/03/76	5,430	8.0	--	870	230	71
					06/19/89	6,410	7.9	27.0	560	140	51
2	13–827	Evergreen Cemetery	RGA–HB	145–225	07/31/80[1]	1,900	7.8	--	184	51	14
					08/04/89	2,370	8.0	23.5	240	61	22
3	13–832	Martinez and Rosa Sts.	RGA	100–110	06/03/76	2,820	7.8	--	300	82	23
				150–160	06/20/89	5,460	7.8	22.5	620	150	59
4	13–845	U.S. Post Office, Paisano B–7	RGA	120–130	06/20/89	2,940	7.9	23.0	480	120	49
5	13–935	Ascarate Lake	RGA	112–192	09/20/79[1]	3,700	7.8	--	640	164	56
					07/14/89	1,730	7.9	20.5	170	39	17
6	13–938	Clark and Cleveland Sts.	RGA–HB	155–165	06/02/76	2,480	8.3	--	380	90	37
				205–215	06/20/89	3,250	7.8	23.0	450	100	48
7	13–952	Chevron HW–31	RGA–HB	237–290	10/11/89	1,670	7.8	--	380	98	33
8	13–953	Chevron HW–39	RGA–HB	170–230	11/02/89	2,730	7.1	23.5	750	190	68
9	13–954	Chevron HW–16	RGA–HB	140–180	10/12/89	5,880	7.7	--	1,100	270	93
10	21–104	Charles and 7th Sts.	RGA	120–125	04/23/75	1,590	8.0	--	250	79	13
				145–150	06/19/89	1,210	8.2	19.5	240	71	16

[1] Analysis by El Paso Water Utilities-Public Service Board.

[2] Sodium plus potassium as sodium.

milligrams per liter; N, nitrogen; µg/L, micrograms per liter; RGA, Rio Grande alluvium; HB, Hueco bolson; --, no data;

Sodium, dissolved (mg/L)	Percent sodium	Sodium adsorption ratio	Potassium, dissolved (mg/L)	Bicarbonate (mg/L)	Alkalinity, total as $CaCO_3$ (mg/L)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)	Dissolved solids, calculated, sum of constituents (mg/L)	Nitrite + nitrate, dissolved, as N (mg/L)	Boron, dissolved (µg/L)
790	66	12	18	222	182	420	1,400	0.80	29	3,070	1.30	--
1,200	82	22	20	210	172	550	1,700	2.1	45	3,810	5.80	870
[2]350	80	--	--	272	223	270	320	.70	27	1,270	<1.00	--
420	79	12	9.1	283	232	350	420	.10	29	1,450	.100	280
500	78	13	9.5	240	197	480	450	.90	29	1,700	2.60	--
1,100	79	19	18	472	387	1,000	920	.50	39	3,520	48.0	1,200
470	68	9	13	318	261	770	340	.40	37	1,960	.100	220
680	--	--	<1.0	495	406	720	650	.80	34	2,770	<1.00	--
310	80	10	6.2	325	267	360	170	1.0	35	1,100	.100	340
400	69	9	16	376	308	400	380	1.4	44	1,560	.700	--
560	73	12	19	386	317	430	620	1.4	48	2,020	1.30	600
210	53	5	26	204	167	270	300	.40	51	1,090	1.90	--
300	46	5	33	316	259	620	420	.30	48	1,830	1.30	--
940	65	13	46	692	568	860	1,300	.60	66	3,920	3.50	--
250	68	7	6.7	308	253	330	160	.70	24	1,020	.010	--
170	60	5	6.9	260	213	230	110	.50	17	749	.330	250



Base modified from Texas Department of Transportation

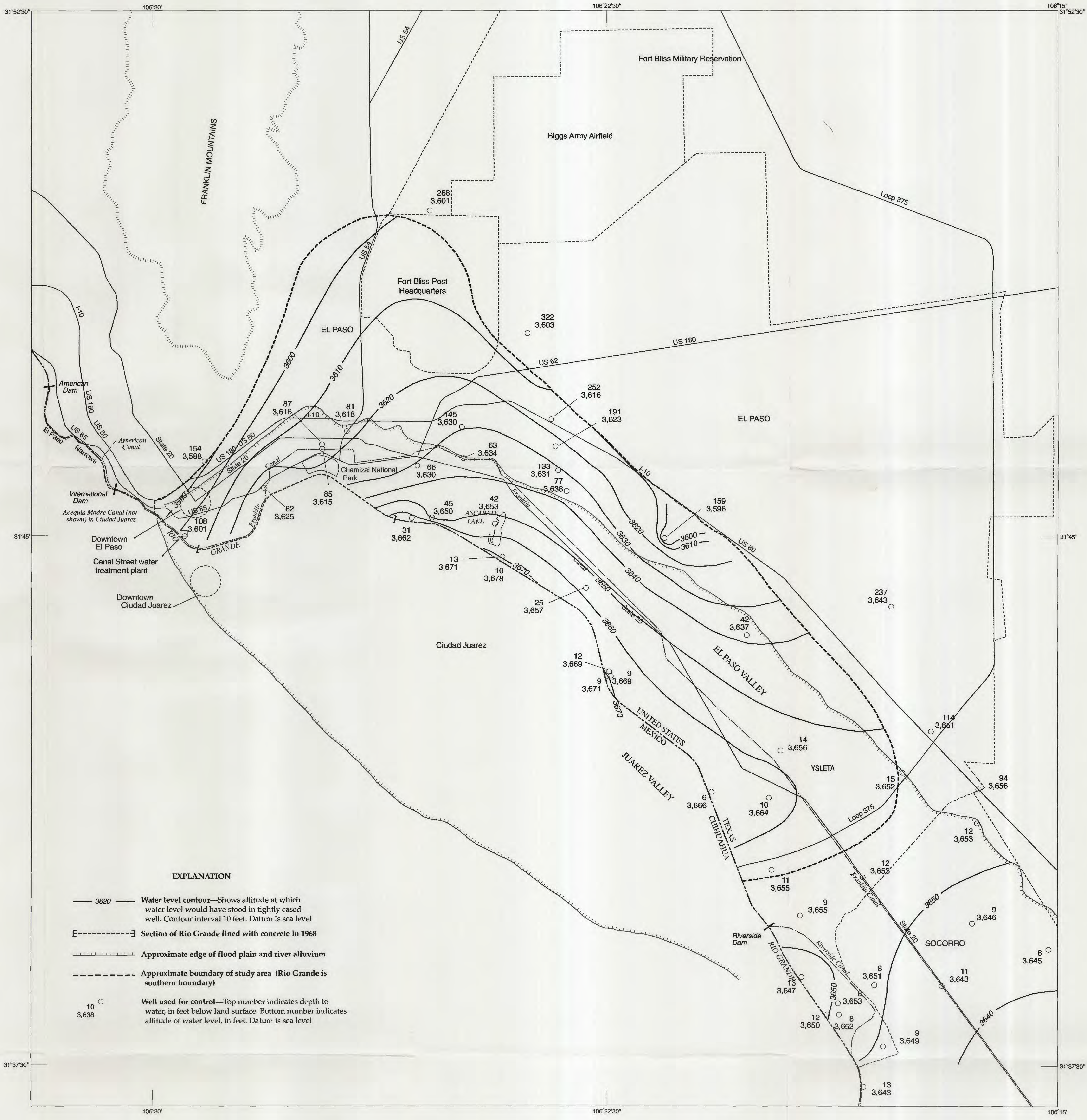
MAP SHOWING LOCATION OF SELECTED WELLS AND WELL FIELDS IN THE RIO GRANDE VALLEY AND ADJACENT AREAS

By
Donald E. White, E.T. Baker, Jr., and Roger Sperka
1997

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

PREPARED IN COOPERATION WITH THE
EL PASO WATER UTILITIES-PUBLIC SERVICE BOARD

WATER-RESOURCES INVESTIGATIONS REPORT 97–4263
Water levels in the shallow aquifer—PLATE 2 OF 4
White, D.E., and others, 1997, Hydrology of the shallow aquifer and uppermost semiconfined aquifer near El Paso, Texas



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MAP SHOWING APPROXIMATE ALTITUDE OF WATER LEVELS IN THE SHALLOW AQUIFER, DECEMBER 1990–JANUARY 1991, IN THE EL PASO VALLEY AND ADJACENT AREAS

By

Donald E. White, E.T. Baker, Jr., and Roger Sperka

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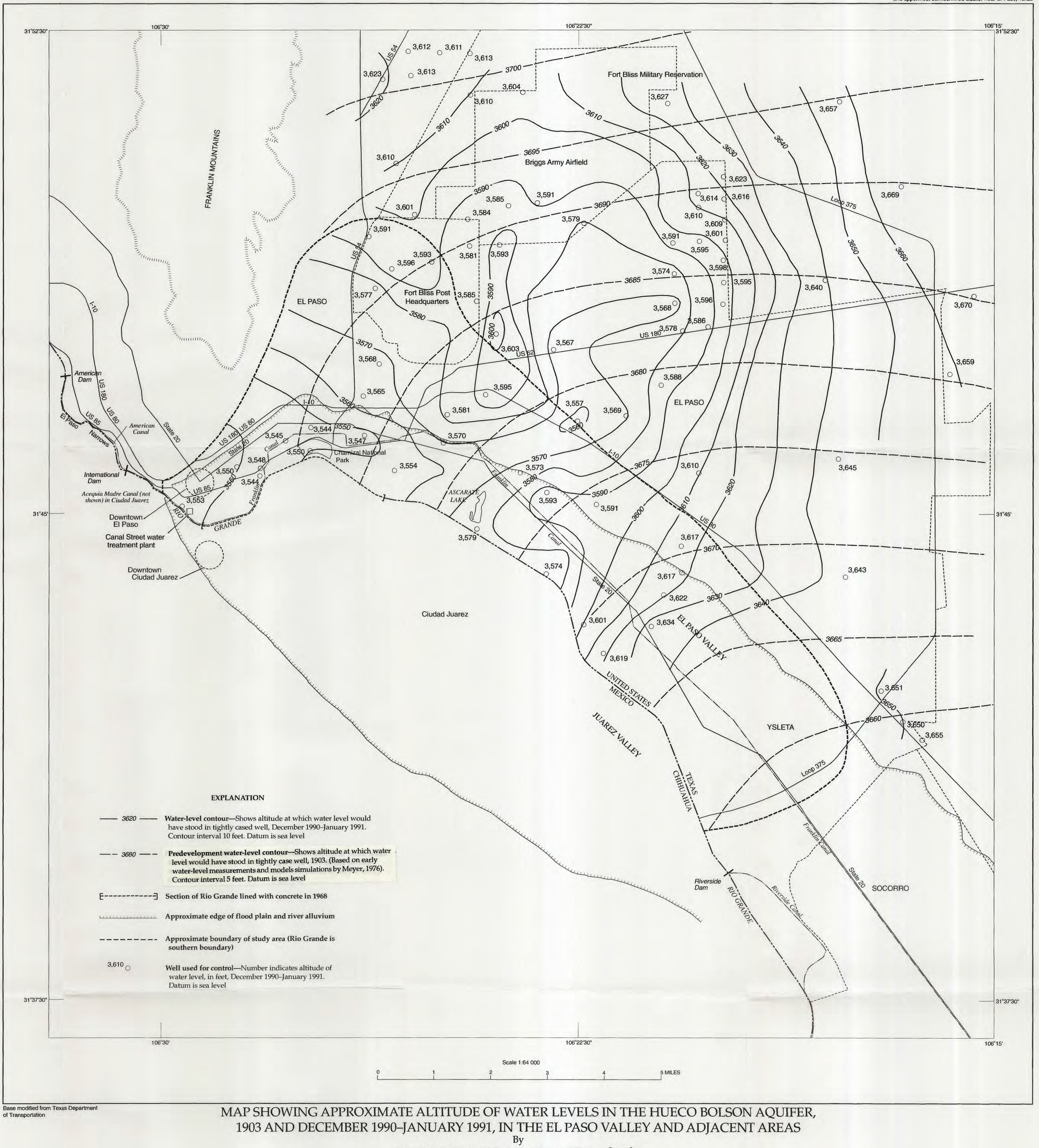

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MAP SHOWING APPROXIMATE ALTITUDE OF WATER LEVELS IN THE HUECO BOLSON AQUIFER, 1903 AND DECEMBER 1990–JANUARY 1991, IN THE EL PASO VALLEY AND ADJACENT AREAS

By
Donald E. White, E.T. Baker, Jr., and Roger Sperka

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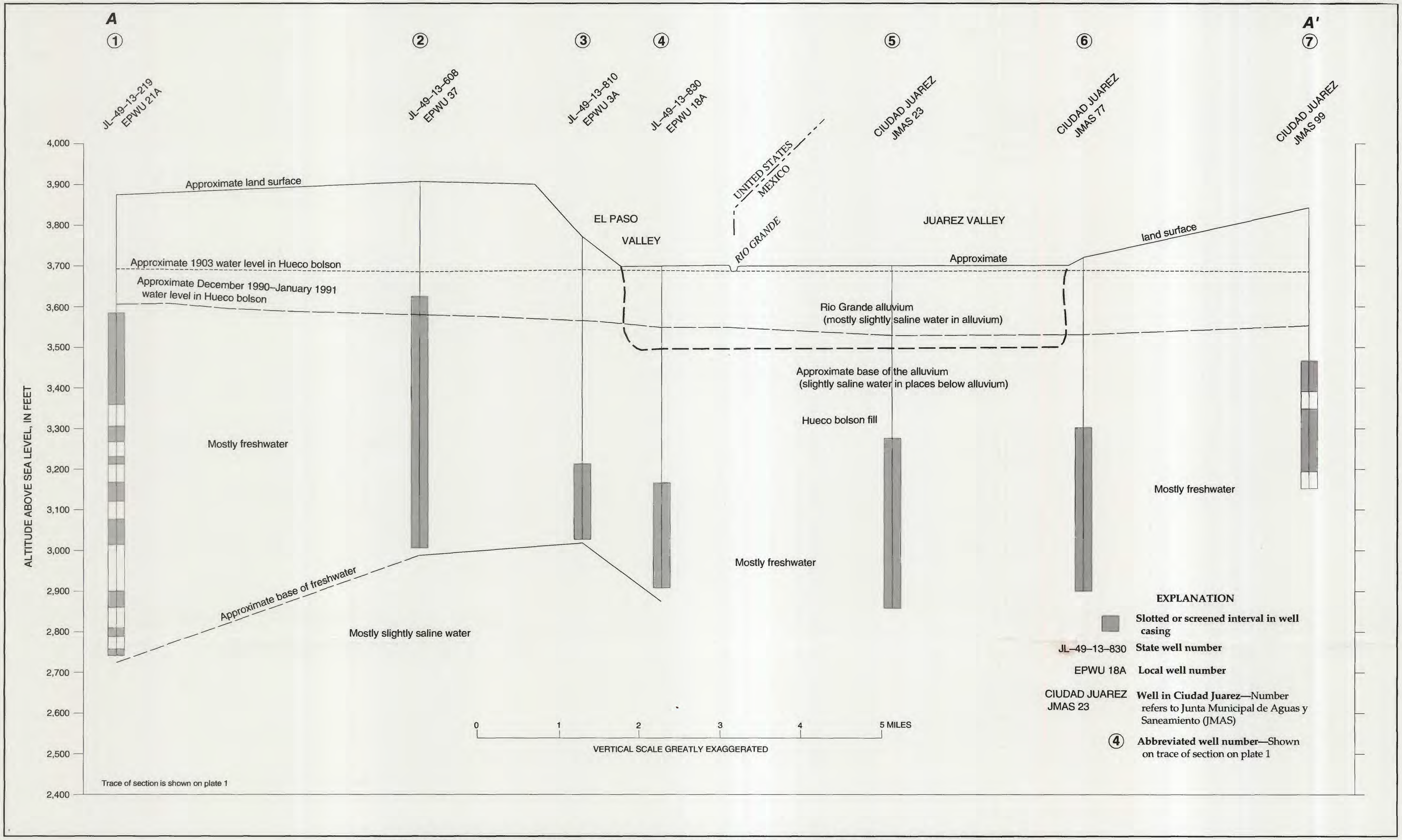

HYDROLOGIC SECTION *A–A'*, HUECO BOLSON AND RIO GRANDE ALLUVIUM, EL PASO VALLEY, JUAREZ VALLEY, AND ADJACENT AREAS

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