GROUND-WATER CONDITIONS IN PECOS COUNTY, TEXAS, 1987

By Ted A. Small and George B. Ozuna

U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS REPORT 92-4190

Prepared in cooperation with the
CITY OF FORT STOCKTON, TEXAS

Austin, Texas

1993

U.S. DEPARTMENT OF THE INTERIOR

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[Plates are in pocket]

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233.49	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06308	liter per second
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
	Temperature	
degree Fahrenheit (°F)	5/9 X (°F - 32)	degree Celsius (°C)

Sea level: In this report, "sea level" refers to the National Geodetic Vertical 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.

Abbreviations:

MCL - maximum contaminant level
µS/cm - microsiemens per centimeter at 25 °C
mg/L - milligrams per liter
SMCL - secondary maximum contaminant level

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ABSTRACT

A comparison of 1987 water levels with historical (1940-49) water levels in the Edwards-Trinity (Plateau) aquifer indicated that water levels declined more than 50 feet in three locations--in the Leon-Belding irrigation area, in an area north of Fort Stockton, and in a well east of Bakersfield. Maximum measured declines were 54 and 82 feet in the Leon-Belding irrigation area. The maximum measured rise was 55 feet in one well in east-central Pecos County.

The chemical quality of water in the Edwards-Trinity aquifer of Pecos County varied greatly during 1987. Most wells in the eastern, southern, and southwestern parts of the county had water with a specific conductance of 1,000 μS/cm (microsiemens per centimeter at 25 °C) or less. Three areas that had anomalously large specific conductances in ground water in north-central Pecos County are associated with water issuing from Santa Rosa, Diamond Y, and Comanche Springs. Specific conductance in water from wells and springs ranged from 311 μS/cm in south-central Pecos County to 9,600 μS/cm in the north. Dissolved sulfate concentrations ranged from 17 to 2,300 mg/L (milligrams per liter), and dissolved chloride concentrations ranged from 12 to 1,400 mg/L. Dissolved-solids concentrations ranged from 251 to 5,580 mg/L. Total nitrite plus nitrate concentrations (considered to be all nitrate for this report) ranged from less than 0.1 to 8.9 mg/L. Chemical water types range from calcium bicarbonate to calcium sulfate to sodium chloride.

Historical (1940-49) and 1987 dissolved-solids concentrations were compared to identify potential changes in water quality. In some local areas, dissolved-solids concentrations decreased as much as 1,630 mg/L. The increase in dissolved-solids concentrations in water from wells and springs ranged from 5 to 4,894 mg/L. Maximum increases in dissolved-solids concentrations were 3,290 mg/L in water from Comanche Springs and 4,894 mg/L in water from Santa Rosa Springs. The increases may represent a mixing of Edwards-Trinity water with moderately saline water from underlying rocks of Permian age, or an accumulation of salts from surface-water sources.

Comanche Springs, dry since 1961, began flowing again in October 1986, following several weeks of record or near-record precipitation in Fort Stockton and the Trans-Pecos region. Accelerated recharge from the increased precipitation, combined with a cessation of irrigation pumpage in August 1986, probably were responsible. The springs ceased flowing in May 1987, following the start of irrigation pumpage in February 1987. Correlation between flow from Comanche Springs and water levels in Fort Stockton city well no. 2 in the Leon-Belding irrigation area indicates that the springs are unlikely to flow when the depth to water in this well exceeds about 232 feet.

INTRODUCTION

Comanche Springs, located in Fort Stockton (fig. 1), historically had been a major asset to Fort Stockton and Pecos County because of its aesthetic appeal, recreational value, and supply of water. The flow from the major spring and several smaller springs began to diminish in the late 1950's and ultimately ceased in 1961. The springs began flowing again in October 1986, following several weeks of record precipitation and major flooding in the Fort Stockton area. Because of the return of the spring flow, the residents in the area have a renewed interest in Comanche Springs flowing on a permanent basis. This interest results from the aesthetic appeal of the springs and from the possible revitalization of the tourist industry and local economy. In addition, the importance of a fresh ground-water resource is recognized as an essential requirement for the prosperity of the area. Consequently, considerable interest is being given to conserving and protecting the ground-water resources of Pecos County.

The U.S. Geological Survey, in cooperation with the city of Fort Stockton, began a study in 1987 with the following major objectives:

1. Define 1987 water-level and water-quality characteristics of the Edwards-Trinity (Plateau) aquifer, hereafter referred to as the Edwards-Trinity aquifer;
2. Determine, if possible, water-level and water-quality characteristics prior to major ground-water development in the area (before 1950);
3. Define and delineate water-level and water-quality changes in the aquifer since major development began (about 1950); and
4. Define relations between ground-water levels and flow from Comanche Springs.

Purpose and Scope

The purpose of this report is to present the data and findings of the study described above. Most of the report describes the Edwards-Trinity aquifer; however, some reference is made to the Cenozoic alluvium, Santa Rosa, Rustler, and Capitan Limestone aquifers. The description of the water quality emphasizes dissolved solids and includes major inorganic constituents and nutrients in the Edwards-Trinity aquifer.

Previous Investigations

Adkins (1927) made a comprehensive study of the geology of the Fort Stockton quadrangle. Dennis and Lang (1941) investigated the ground-water resources of Pecos County from 1939 through 1941 as part of a study of the Pecos River basin. Dante (1947) compiled records of wells and springs in the northern part of Pecos County. Maley and Huffington (1953) mapped the thick Cenozoic fill in northern Pecos County and adjoining areas. Audsley (1956) made a reconnaissance of ground-water development in the area north and west of Fort Stockton. Armstrong and McMillion (1961) described the geology and ground-water resources of Pecos County in the late 1950's. Hiss (1976) described the geology and ground-water characteristics of the Capitan Limestone aquifer in West Texas and southeastern New Mexico. Muller and Price (1979) estimated the ground-water availability in Texas through 2030. Rees and Buckner (1980) described the geology and ground-water resources of the Edwards-Trinity aquifer in the Trans-Pecos region. Brune (1981) described the major and historical springs of Texas. Rees (1987) compiled records of wells,

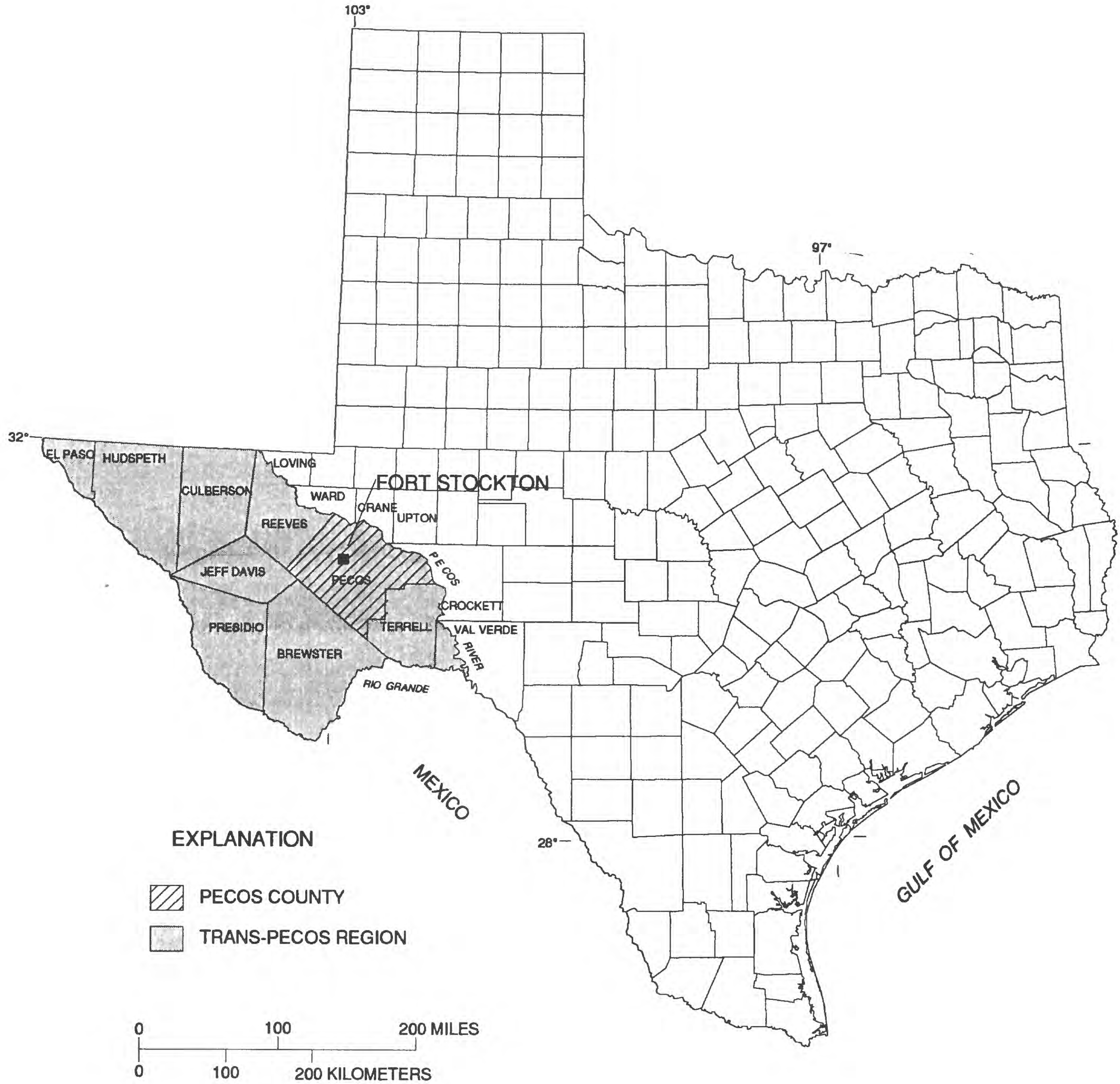


Figure 1.--Location of Pecos County.

water levels, withdrawals, and chemical analyses of water from selected wells in parts of the Trans-Pecos region for 1968-80.

Description of Study Area

Pecos County is located west of the Pecos River in the Trans-Pecos region, which consists of that part of Texas west of the Pecos River (fig. 1). Pecos County is the second largest county in Texas and has an area of 4,776 mi^2. In 1987, the county population was reported to be 15,038 (A.H. Belo Corp., 1989, p. 2,34). Fort Stockton, the county seat and chief commercial center, had an estimated population of 9,090 in 1987. Iraan (fig. 2), population of about 1,269, is an important center for the oil industry on the eastern side of the county. Smaller population centers in the county include Bakersfield, Belding, Coyanosa, Girvin, Imperial, and Sheffield (fig. 2).

The county lies in parts of five physiographic subdivisions (fig. 3): (1) The irregularly dissected Stockton Plateau, which is separated from the Edwards Plateau by the Pecos River; (2) the relatively flat Toyah basin; (3) the Marathon basin, characterized by ridges and isolated buttes and mesas; (4) the moderately rugged Glass Mountains; and (5) the Barilla Mountains. The Pecos River, a large tributary of the Rio Grande, drains all except the southern part of the county and is the only perennial stream. The other streams flow only after intense precipitation. During years of normal precipitation, minimal surface runoff reaches the Pecos River.

Methods of Investigation

During 1987, water levels were measured in about 200 wells and selected water-quality properties were determined in water samples from 91 wells and springs. Samples from 33 wells and 2 springs were collected for detailed water-quality analysis, including dissolved calcium, magnesium, sodium, potassium, sulfate, chloride, fluoride, and silica concentrations. Where access was permitted, wells with historical water-level and water-quality data were measured and sampled. For those wells where samples could be collected, onsite measurements were made for specific conductance, pH, temperature, and total alkalinity.

Many wells in the county were unmeasurable. Wherever possible, wells in nearby Brewster, Crockett, and Reeves Counties were measured and sampled in place of the unmeasurable wells near the Pecos County line. In addition, wells were not always available in some areas, and wells across the county line were substituted.

Well-Numbering System

The well-numbering system used by the Texas Water Development Board throughout the State was used in this report (fig. 4). With this system, a two-letter prefix is used to identify the county in which the well is located. The prefixes used in this report are BK (Brewster County), HJ (Crockett County), US (Pecos County), and WD (Reeves County). The prefix is used in the text, tables, and some illustrations. The location of well US-53-20-601 is shown in figure 4. Some wells were not given 7-digit numbers because of insufficient well data. These wells have a 5-digit number. Where two or more wells with 5-digit numbers are in the same 2 1/2-minute quadrangle, they are distinguished with a letter of the alphabet beginning with A.

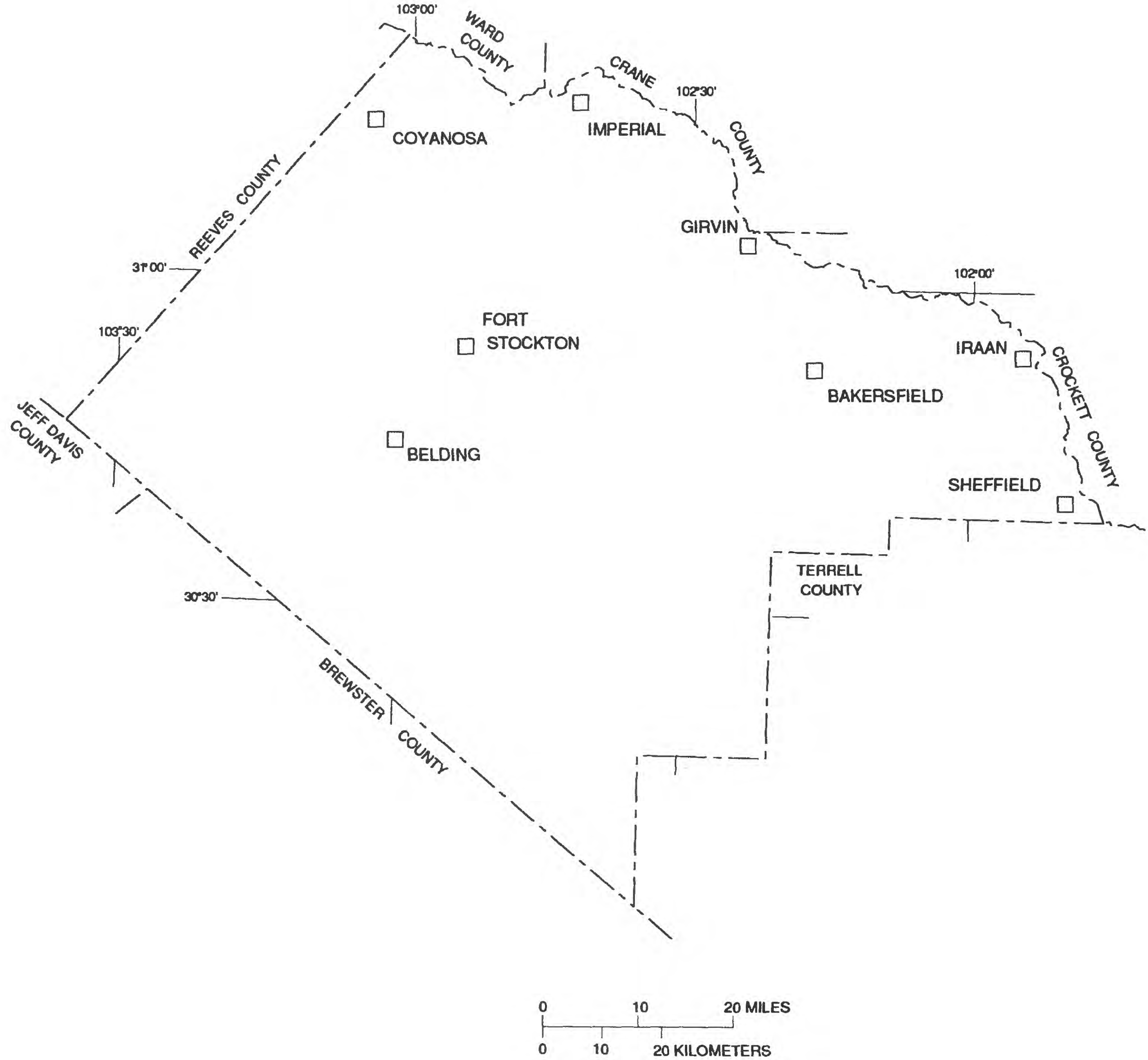
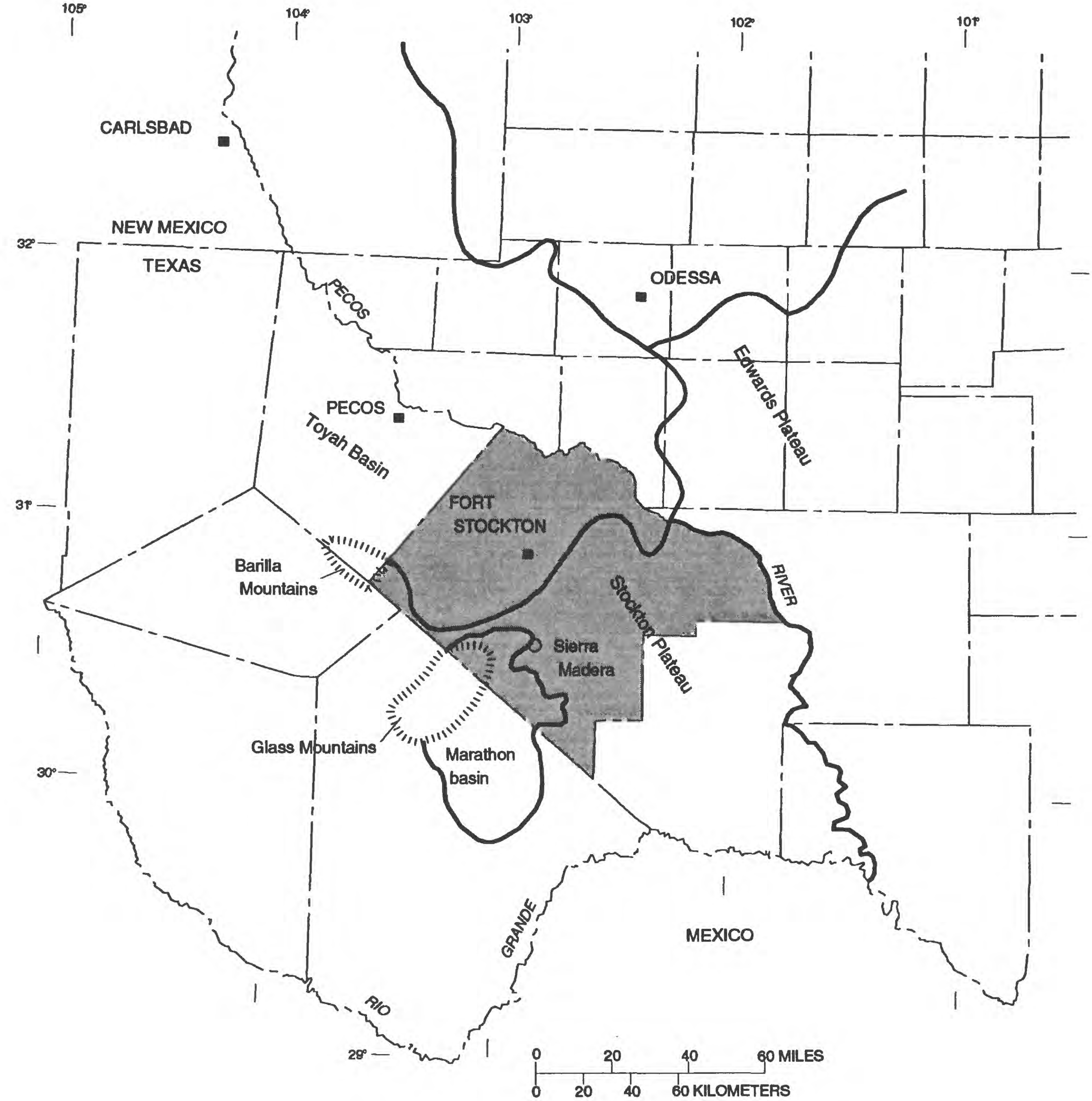


Figure 2.--Location of population centers in Pecos County.



EXPLANATION

PECOS COUNTY

BOUNDARY BETWEEN PHYSIOGRAPHIC SUBDIVISIONS

Figure 3.--Physiographic subdivisions in the vicinity of Pecos County. (Modified from Armstrong and McMillion, 1961.)

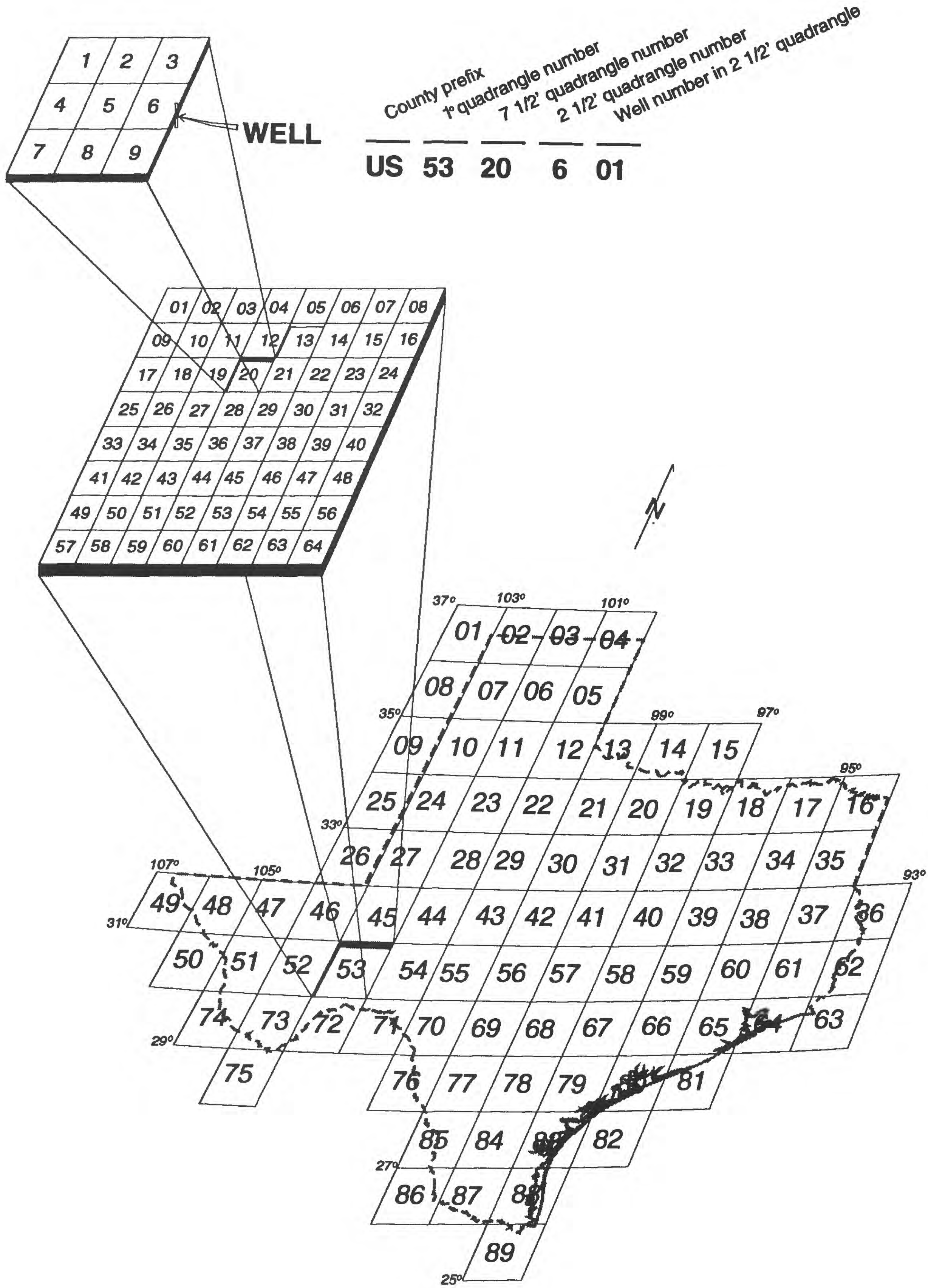


Figure 4.--Well-numbering system.

Acknowledgments

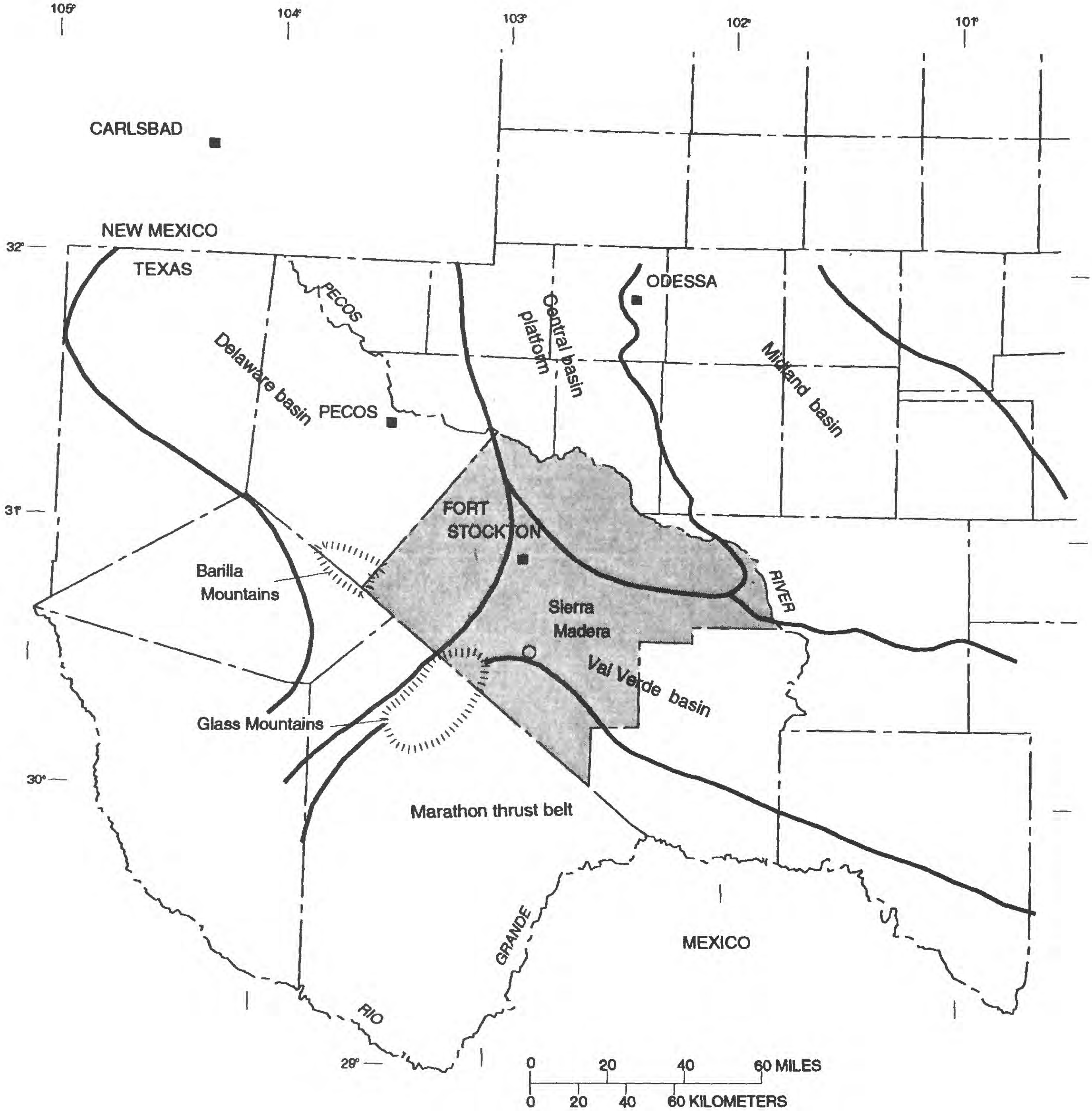
Special thanks are extended to Phil Nordstrom, Stephen Gifford, and Gerald Adair, Texas Water Development Board, for their assistance in locating and compiling data from the State files; and to the city officials of Fort Stockton, particularly Frank Salvato, City Water Superintendent, and Jesse Garcia, City Manager. Joe Henggeler, Irrigation Engineer for the Texas Agricultural Extension Service, supplied irrigation and crop data; Frank Carpenter and E.E. (Gene) Drennan of the University Lands, University of Texas System, supplied well data and helped locate wells at the University Lands Vineyards; Tom Childs of St. Genevieves Vineyards gave permission to measure and sample wells there; and J.R. Kinnard of Transwestern Pipeline assisted in locating wells and gave information regarding other producers in the area. Appreciation is extended to William F. Guyton, Guyton Associates, Inc., for information regarding Comanche Springs; to Mary Kay Shannon, curator at Riggs Museum, for information regarding the caves associated with Comanche Springs; and to Dr. C.I. Smith, University of Texas at Arlington, for valuable information regarding the stratigraphy of the lower Cretaceous limestones. Many farmers and ranchers gave the authors permission to measure water levels and collect water samples from wells on their property; their cooperation is appreciated.

GEOLOGY

Pecos County is located in the southern part of the Permian Basin and includes parts of the following structural and physiographic features: The Delaware basin, the Central basin platform, the Midland basin, the Val Verde basin, the Marathon thrust belt, the Glass Mountains, and the Barilla Mountains (fig. 5). Sedimentary rocks of Pennsylvanian, Permian, Triassic, and Cretaceous age, extrusive volcanic rocks of Tertiary age, and Cenozoic alluvium are exposed at land surface (fig. 6). Geologic section A-A' (fig. 7) shows the subsurface stratigraphic relations along a line trending generally northeast, from slightly northwest of the Glass Mountains through Fort Stockton to near the Pecos River.

The Delaware basin in the western and northern parts of the county and the Val Verde basin in the central and southern parts of the county (fig. 5) were an essentially continuous trough formed by downwarping during Late Pennsylvanian and Early Permian time (Vertrees and others, 1959). Pressure from the Marathon thrust belt in the south constricted the trough during Early Permian time, and separation of the two basins was completed during Late Permian time by the Capitan barrier reef, which encircled the northern end of the trough.

In Pecos County, remnants of the almost 5-mi-wide Capitan barrier reef (Hiss, 1976) trend north-northeast from the Glass Mountains to the Sierra Madera, and then follow the boundary of the Delaware basin north into Ward County. The Sierra Madera is believed to be a cryptoexplosion structure caused by the impact of an extraterrestrial body in either Late Cretaceous or early Tertiary time (Shoemaker and Eggleton, 1964; Wilshire and others, 1972). The Central basin platform is an uplift formed during Late Pennsylvanian time that separates the Delaware basin from the Midland basin (fig. 5). The subsurface Marathon thrust belt (exposed in the Marathon basin in Brewster and southern Pecos Counties) includes complexly folded, faulted, and uplifted Paleozoic rocks. The folding began during the Pennsylvanian and culminated with the overthrusting of the folded beds during Early Permian time (Vertrees



EXPLANATION

PECOS COUNTY

BOUNDARY OF STRUCTURAL FEATURES

Figure 5.--Structural features of the southern Permian Basin. (Modified from Hills, 1972.)

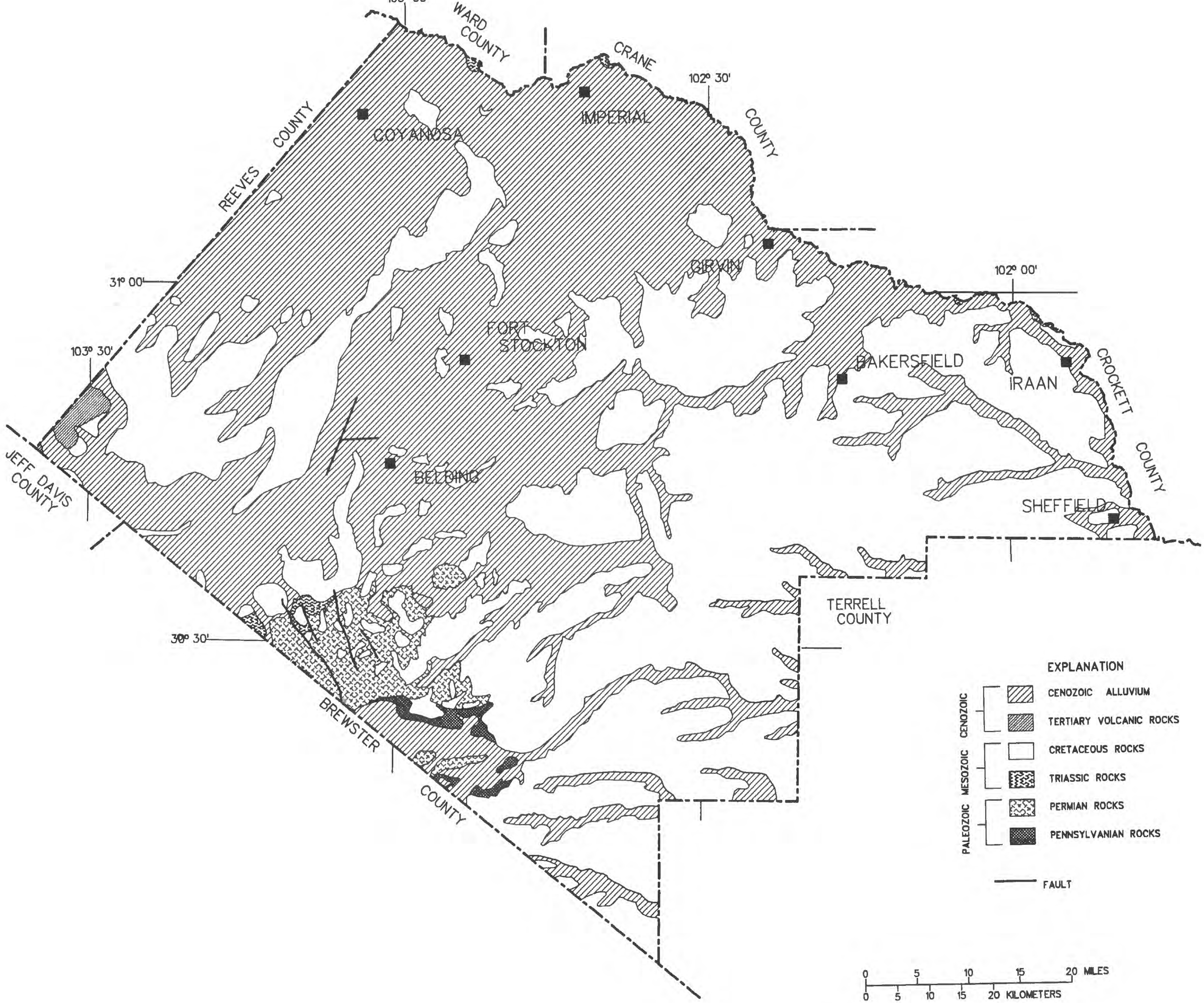


Figure 6.--Generalized geologic outcrop map, Pecos County. (Modified from Armstrong and McMillion, 1961.)

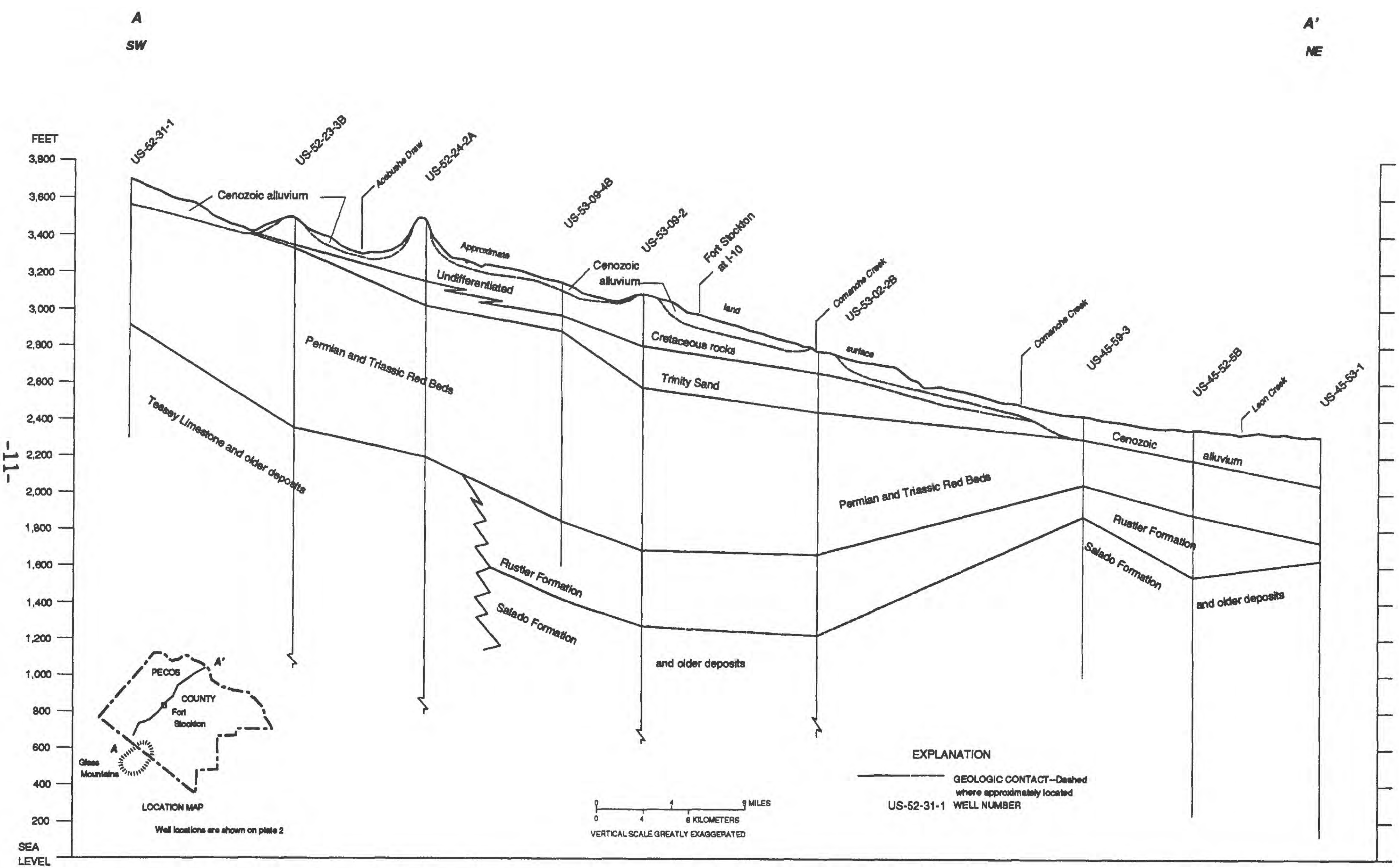


Figure 7.--Geologic section ***A-A'*** showing stratigraphic relations in Pecos County.

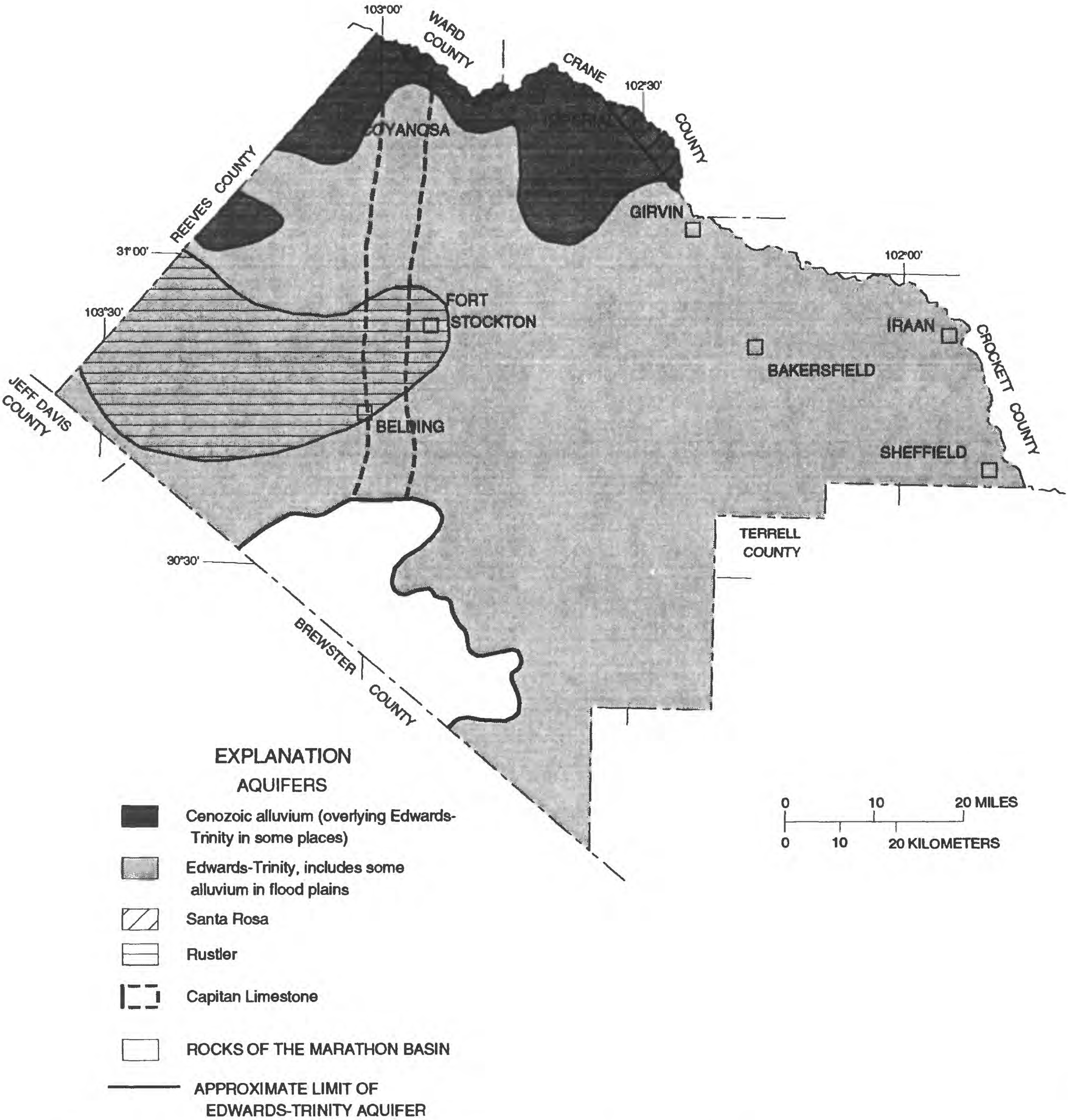


Figure 8.--Approximate areal extent of major aquifers in Pecos County. (Modified from Rees, 1987.)

and others, 1959). The Glass Mountains join the Marathon thrust belt west of Pecos County and are comprised mainly of the Permian age Capitan and Tessey Limestones.

Limestones and sandstones of Cretaceous age and Cenozoic alluvium crop out over most of Pecos County (fig. 6). These limestones and sandstones overlie, in descending order, Triassic sandstone, Permian and Triassic Red Beds, Late Permian evaporites, and folded and faulted Permian and older rocks. In northwestern Pecos County (in the Delaware basin), ground water migrating upward from the north-trending Capitan reef dissolved and removed the soluble halite from the overlying Castile and Salado Formations of Late Permian age (Hiss, 1976). The overlying nonsoluble Permian, Triassic, and Cretaceous rocks collapsed, and a trough was formed that extended north from near Belding (fig. 2) into southeastern New Mexico. Probable late Tertiary and Quaternary age alluvium partly filled this trough (Hiss, 1976), and in the trough the Cretaceous rocks were dissected by pre-Quaternary erosion and juxtaposed against the overlying Cenozoic alluvium (Rees and Buckner, 1980). The upper Permian and Cretaceous rocks in the southeastern part of the county in the Val Verde basin are a continuous unit and are relatively undisturbed since their original deposition (Rees and Buckner, 1980).

AQUIFERS

The Edwards-Trinity aquifer is the principal and most extensive aquifer in Pecos County. Other aquifers in the county are the Cenozoic alluvium, Santa Rosa, Rustler, and Capitan Limestone (Rees, 1987). The approximate areal extent of these aquifers in Pecos County is shown in figure 8.

Edwards-Trinity

The Edwards-Trinity aquifer comprises water-yielding, Lower Cretaceous sands and limestones of the Washita, Fredericksburg, and Trinity Groups, according to Rees and Buckner (1980). The "Edwards" part of the Edwards-Trinity aquifer is comprised of rocks of the Fort Lancaster (Smith and Brown, 1983) and Fort Terrett Formations of the Edwards Group (Rose, 1972) in eastern Pecos County. The Buda Limestone and the Boracho and Finlay Formations of the Sixshooter Group (Brand and DeFord, 1958) are in the western part of the county (table 1, at end of report). The Edwards Group part of the aquifer is about 550 to 575 ft thick, and the lower section of the Edwards Group yields small to large quantities of fresh to moderately saline water to irrigation, public-supply, livestock, domestic, and industrial wells throughout most of the county.

The water-yielding unit below the base of the Edwards Group is called the Trinity Sand by Armstrong and McMillion (1961). Characteristically, the Trinity Sand is a crossbedded, fine- to coarse-grained, poorly to well-cemented quartz sand. Locally, it contains silt, shale, and limestone. The sand ranges in thickness from about 35 to 350 ft and is present over most of Pecos County (Armstrong and McMillion, 1961, p. 38). It yields small to moderate quantities of fresh to slightly saline water (table 1) for irrigation, public-supply, livestock, domestic, and industrial uses. The approximate altitude of the base of the Edwards-Trinity aquifer is shown on plate 1 (Rees and Buckner, 1980, fig. 2). The altitude of the base ranges from about 1,000 ft below sea level in the southeast to about 3,600 ft above sea level in the south-central area.

Cenozoic Alluvium

The Cenozoic alluvium aquifer consists of unconsolidated silt, sand, gravel, clay, boulders, caliche, gypsum, and conglomerate of Quaternary and Tertiary age (table 1). In the northern and western part of the county, the aquifer is about 200 to 350 ft thick (Armstrong and McMillion, 1961, p. 42). In the Coyanosa Draw area (western Pecos County), the Cenozoic alluvium is known to be at least 600 to 700 ft thick, but is reported to be as much as 1,150 ft thick by Armstrong and McMillion (1961, p. 42). In some areas in western and northern Pecos County, the Cenozoic alluvium overlies and is juxtaposed against the Edwards-Trinity aquifer (Armstrong and McMillion, 1961). In these areas, the two aquifers are hydraulically connected (Rees and Buckner, 1980), and some wells obtain water from both aquifers. The extent of the Cenozoic alluvium aquifer in northern Pecos County (Muller and Price, 1979, p. 36) is shown in figure 8. The water is for irrigation, public-supply, livestock, and domestic uses.

Santa Rosa

The Santa Rosa aquifer is part of the Dockum Group of Triassic age (table 1). The name "Santa Rosa aquifer" is adopted here for hydrologic purposes to comply with local usage and does not indicate stratigraphic equivalence with the Santa Rosa Sandstone of the Tucumcari basin of eastern New Mexico or elsewhere (Chatterjee, 1987). The aquifer is about 600 ft thick (table 1). In general, the Santa Rosa aquifer is a reddish-brown to gray, coarse-grained sandstone that supplies small to moderate quantities of fresh to slightly saline water to wells in the northern part of the county (Rees, 1987). The approximate extent of this aquifer is shown in figure 8.

Rustler

The Rustler aquifer (fig. 8) consists of the Rustler Formation of Permian age. According to Armstrong and McMillion (1961, p. 34), the Rustler ranges in thickness from 0 to about 450 ft in Pecos County. The Rustler Formation has a basal unit of red shale and sandstone 10 to 100 ft thick, according to Hills (1972, p. 2,320). The remainder of the formation consists of anhydrite, dolomite, limestone, conglomerate, and localized beds of halite (Armstrong and McMillion, 1961; Rees, 1987). According to Rees (1987), the Rustler aquifer is cavernous and the availability of ground water is sporadic because of the irregular distribution of the cavernous openings. The upper part of the Tessey Limestone, which crops out in the Glass Mountains and in the Sierra Madera, is equivalent to the Rustler Formation, according to Armstrong and McMillion (1961). The Rustler aquifer yields small to large quantities of slightly to moderately saline water to irrigation and livestock wells.

Capitan Limestone

The Capitan Limestone aquifer (fig. 8, table 1) is of Permian age, directly underlies the Rustler Formation west of Fort Stockton, and has a maximum thickness of about 1,650 ft (Armstrong and McMillion, 1961, p. 31). It consists of massive, poorly bedded limestone, dolomite, and reef talus (Armstrong and McMillion, 1961; Dunham, 1972) that plunges to a depth of more than 4,000 ft north of Fort Stockton (Armstrong and McMillion, 1961, p. 31). Because of its depth and moderately saline water, the Capitan Limestone is not an important aquifer in Pecos County. Hiss (1976) reported that in Pecos County water with a chemical quality suitable for human consumption can be obtained from the Capitan Limestone solely in a poorly defined area in the Glass

Mountains. The Capitan Limestone aquifer yields moderate to large quantities of moderately saline water to irrigation wells.

GROUND-WATER HYDROLOGY

Recharge

Recharge to the Edwards-Trinity aquifer in Pecos County results predominantly from two major processes; runoff from precipitation, and underflow. Direct infiltration of precipitation is too small to be considered a source of recharge (Armstrong and McMillion, 1961). Average precipitation in Pecos County is about 12 in/yr. A large part of this precipitation is lost to evaporation and transpiration; the annual rate of potential evapotranspiration is 70 to 80 in/yr (Rees and Buckner, 1980, p. 2).

Some precipitation becomes runoff and infiltrates through gravels in valleys and foothills throughout Pecos County as it recharges the underlying aquifers in localized areas. Recharge occurs where runoff crosses outcrops of aquifers, especially where the rocks are jointed or fractured or where cavernous limestone crops out. Some recharge in western Pecos County may occur as runoff discharges from the Davis Mountains (about 60 mi west-southwest of Fort Stockton) and Barilla Mountains in western Pecos and adjoining Jeff Davis and Reeves Counties. This runoff percolates through underlying volcanic rocks and into the gravels along slopes of the mountains in western and southwestern Pecos County. Recharge to the Edwards-Trinity aquifer probably is negligible where clays and shales overlie the limestones of the aquifer. Ground-water movement generally is perpendicular to the lines of equal water level on the potentiometric surface.

Recharge to the Edwards-Trinity aquifer from underflow or upward leakage from underlying formations in Pecos County has not been specifically documented (Armstrong and McMillion, 1961). However, underflow to the aquifer may occur from pre-Cretaceous limestones in Brewster County, near the Glass Mountains. Saline water from the Rustler aquifer may migrate through the Permian and Triassic Red Beds and into the Edwards-Trinity aquifer in north-central Pecos County (Armstrong and McMillion, 1961). Adkins (1927, p. 88) reported that because ground water in western Pecos County is "uniformly of excellent quality" in comparison to ground water in the eastern part of the county, the aquifer in the west may be protected by an impervious layer of clay below the Trinity Sand. Where this impervious clay layer is missing and upward water-level gradients prevail, an upward ground-water migration from pre-Cretaceous rocks may exist. Two wells in the Belding area, US-52-16-608 and US-52-16-609, completed in the Rustler aquifer, had water levels about 40 ft higher than nearby Edwards-Trinity wells when measured in February 1987. Upward leakage is possible from sources deeper than the Rustler. Hiss (1976) reported that the hydraulic connection between the Edwards-Trinity and the Capitan Limestone aquifers in southern Pecos County is probably good wherever joints, fractures, or faults are well developed. However, in the Delaware basin, migration of substantial quantities of water from the deep Capitan Limestone aquifer are impeded by the beds of anhydrite in the Castile Formation. Other pathways for upward vertical migration of ground water could exist in poorly sealed or inadequately cased wells.

Another source of recharge might result from the deep percolation of irrigation return flow. Irrigation return flow is the excess of pumped water that infiltrates back to the aquifer after losses to runoff and evapotranspiration. In irrigated areas, deep percolation from irrigated fields may be an important local source of ground-water recharge. This can be an asset if the irrigation return flow has a dissolved-solids concentration of less than 3,000 mg/L and the water table remains at least 3 to 6 ft below the root zone of the crop. Recharge from irrigation return flow may become a problem if the water contains dissolved-solids concentrations in excess of 3,000 to 5,000 mg/L, or if it causes the water table to rise to the level where waterlogging occurs (Bouwer, 1978).

Previous investigations by Adkins (1927), Audsley (1956), Armstrong and McMillion (1961), and Rees and Buckner (1980) did not compute total recharge to the Edwards-Trinity aquifer in Pecos County. Armstrong and McMillion (1961, p. 43) reported that recharge to the Edwards-Trinity aquifer in Pecos County before 1946 was approximately equal to the discharge by springs, underflow, and evapotranspiration (estimated to be about 78,000 acre-ft) because little or no water was being added to or taken away from storage. Computations by Rees and Buckner (1980, p. 15), using recharge and discharge data for the Edwards-Trinity aquifer, indicate that 150,000 to 190,000 acre-ft of water is available on an annual basis from the aquifer in the entire Trans-Pecos region.

Discharge

Under natural conditions, discharge from the Edwards-Trinity aquifer in Pecos County is by springs, evapotranspiration, base flow to the Pecos River, and outflow into Terrell County (Armstrong and McMillion, 1961). Armstrong and McMillion (1961, p. 47) also stated that in 1958, discharge from the Edwards-Trinity aquifer by wells and springs in Pecos County was about 200,000 acre-ft. Total flow from all springs was less than 2,000 acre-ft.

Rees and Buckner (1980) discussed ground-water use in Pecos County in detail and estimated the ground-water withdrawals for irrigation, public-supply, livestock, domestic, and industrial uses. Major areas irrigated with ground water (fig. 9) are Bakersfield, Fort Stockton, Girvin, Leon-Belding, North Coyanosa, and South Coyanosa (Rees and Buckner, 1980). During 1979, the total area irrigated with ground water was about 26,300 acres, and the estimated withdrawal from all aquifers in Pecos County for irrigation was about 90,000 acre-ft (Texas Department of Water Resources, 1981, p. 61). According to Rees and Buckner (1980), ground water is the source of public supply for Fort Stockton, Iraan, and Sheffield in Pecos County and McCamey in southwestern Upton County. (McCamey's wells are located in Pecos County.) These cities had a combined annual water use of about 4,000 acre-ft in 1979 (Rees, 1987, p. 6). Livestock and domestic wells supply small quantities of water throughout Pecos County. Industrial use of ground water is primarily for the production of oil, gas, and electricity. Secondary recovery operations in oil reservoirs use a small quantity of ground water as does the cooling of natural gas before it is placed in pipelines for transport. The latter use has decreased recently because many of the gas plants in the area are no longer in operation. An unknown quantity of ground water was used for cooling in the generation of electrical power.

GROUND-WATER CONDITIONS

Water Levels

Ground-water levels rise or decline in response to several factors. Abnormally large quantities of precipitation for long or even short periods

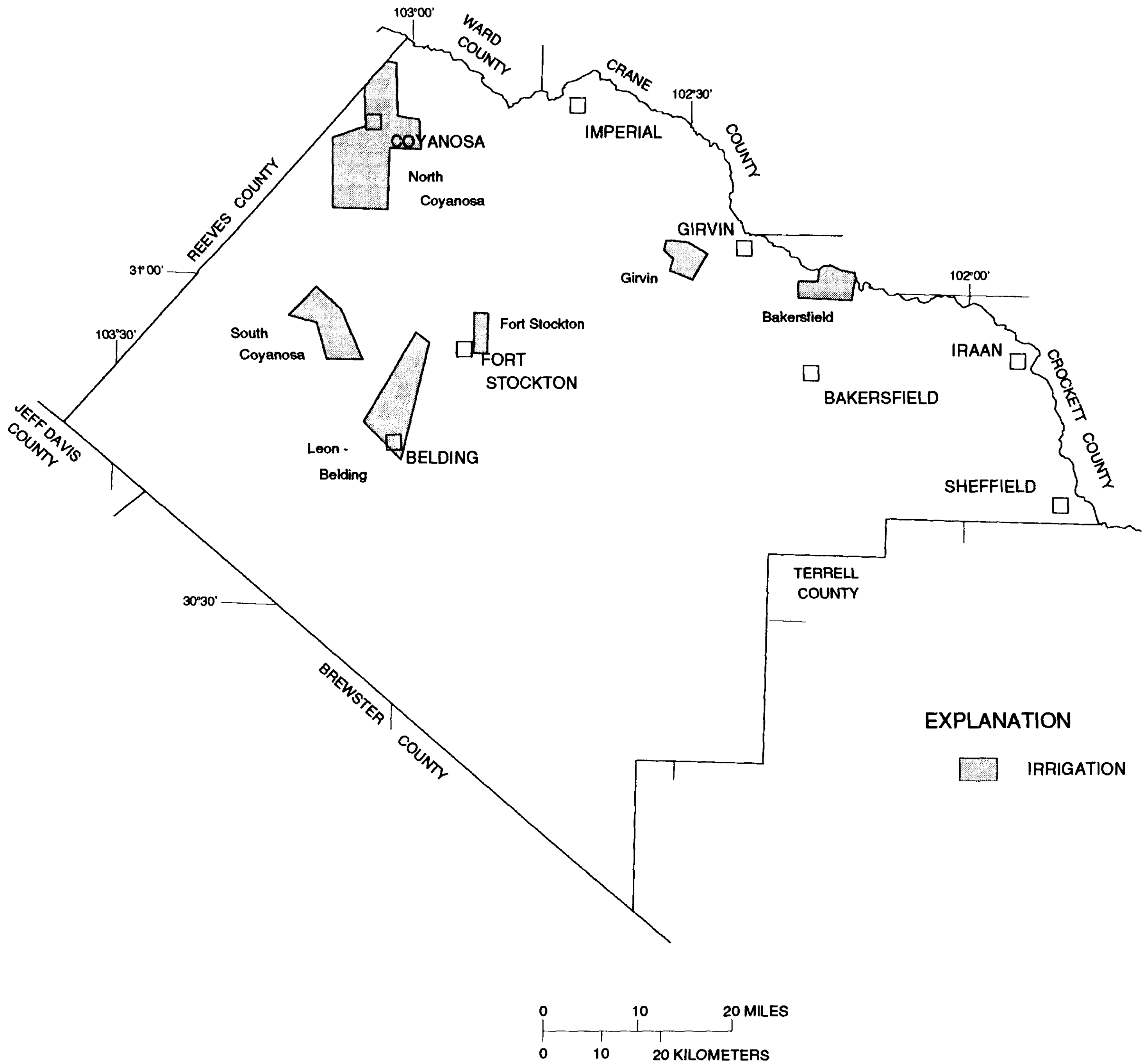


Figure 9.--Major ground-water irrigation areas in Pecos County.
(Modified from Rees and Buckner, 1980.)

may result in enough recharge to cause water levels to rise. Unusually large withdrawals or less-than-normal precipitation for extended periods can cause water levels to decline. When conditions of recharge and discharge balance for long periods, ground-water levels are relatively stable.

1987 Conditions

All wells from which data were used in this report are shown on plate 2. Records of these wells are given in table 2 (at end of report). Water levels in about 200 wells were measured during early 1987. The altitude of the water level at each well was calculated by subtracting the depth to water in the well from the altitude of the land surface, which was estimated from U.S. Geological Survey 7-1/2-minute quadrangle topographic maps. Water-level altitudes are shown on plate 3. The water levels are highest adjacent to Jeff Davis and Brewster Counties and lowest along the Pecos River. Ground-water movement, for the most part, is perpendicular to the contours that depict equal water-level altitudes. The water-level contours indicate that the water in the Edwards-Trinity aquifer generally moves from the west and southwest toward the north and northeast.

Historical Changes

The quantity of water stored in a ground-water reservoir is indicated by ground-water levels. Seasonal, or even year-to-year water-level differences of 3 to 5 ft are normal and result from short-term imbalances between recharge and discharge. Long-term water-level declines in excess of 10 ft, however, generally result from increasing rates of ground-water withdrawal. Large rises of short duration in water levels occur most often in response to recharge from the infiltration of runoff following intense precipitation. Water levels also rise in response to discontinued pumpage or lessening rates of ground-water withdrawal, reflecting the process of reestablishing an equilibrium within the aquifer system. Water-level changes in Pecos County during the last 30 years can be attributed primarily to changes in the patterns of precipitation and ground-water withdrawal.

Water-level data from 1940-49 were used to construct a water-level contour map of historical conditions (pl. 4). These data were compiled from water-level records obtained from the Texas Water Development Board. Reported (unmeasured or estimated) water levels were not used. The data indicate that the movement of ground water prior to development was towards the Pecos River.

Maps that show water-level change over long periods are useful in judging the long-term effects of recharge or discharge. The effects sometimes appear as anomalies that are difficult to detect by simply comparing successive water-level maps. The 1987 water levels and historical water-level data from 1940-49 were used to construct the water-level-change map on plate 5. The change between the 1940-49 and 1987 water-level measurements was determined for those wells that had measurements for each time period. These measurements were supplemented by subtracting interpretive water-level contours for the two periods (pls. 3 and 4). Data were insufficient to construct a change map for the eastern and southeastern parts of Pecos County. Ranges of water-level changes were used on plate 5 rather than the more precise contours because data were insufficient to construct reliable contours.

Measured water levels have declined more than 50 ft at three locations. One area, associated with the Leon-Belding irrigation area, is southwest of Fort Stockton. The water levels in wells US-52-08-801 and US-52-24-201 in that area declined 54 and 82 ft, respectively. The water level in well US-53-02-102 in the second area, north of Fort Stockton, declined 53 ft. The third location, associated with the Bakersfield irrigation area, is east of Bakersfield, where the water level in well US-53-08-401 declined 53 ft. The maximum rise in measured water levels was 55 ft at well US-53-05-902 in east-central Pecos County.

Repeated measurements of water levels in wells can be used to construct hydrographs. Hydrographs can indicate the effects of changes in the rates of ground-water withdrawal and replenishment. Long-term hydrographs (fig. 10) for four wells and Comanche Springs were plotted along with annual precipitation at Fort Stockton to compare water-level, spring-flow, and precipitation trends. Water levels were obtained from previous reports (Audsley, 1956; Armstrong and McMillion, 1961; and Rees and Buckner, 1980) and from records of the Texas Water Development Board. The general trend is similar in all hydrographs. The first two hydrographs show a gradual decline from 1950 to 1958, which totaled about 40 ft in well US-53-02-102. This decline corresponds to the 7 consecutive years of less-than-average annual precipitation during the 1950-56 drought. Continued decline through 1965 may have been caused by the withdrawal of large quantities of water from wells during this period. From 1965 to 1969, water levels rose in response to increased precipitation during this period. The sharp declines indicated in 1976 for well US-46-48-602 and in 1977 for well US-53-02-102, probably are caused by measurements taken shortly after the wells began to pump. From 1983 through 1987, a gradual recovery is evident in all hydrographs, except for well US-46-48-602. This rise was caused by greater-than-normal precipitation during this period and possibly by reduced withdrawals.

Water Quality

Variations in the chemical quality of ground water are caused by substances dissolved in the water, reactions among these substances, and reactions between these substances and the rocks through which the water flows. Some of the natural environmental factors that affect the chemical composition of ground water include: Climate, types of rocks and soils through which the water percolates, duration of contact with the rocks or soils, temperature and pressure, and biochemical effects associated with life cycles of plants and animals. Human activities may modify water composition extensively through direct effects of pollution and indirect results of water development. The source and significance of selected properties and dissolved inorganic constituents commonly reported in water analyses are given in table 3 (at end of report).

The U.S. Environmental Protection Agency (USEPA) has established regulations for drinking water that apply to public-supply systems. These regulations do not apply to privately owned wells used for irrigation, livestock, or individual domestic supplies. To assist the reader in evaluating the water-quality data tabulated in this report, the public-water system MCL's and SMCL's established by the U.S. Environmental Protection Agency (1990a,b) for selected properties and constituents are given in table 4 (at end of report).

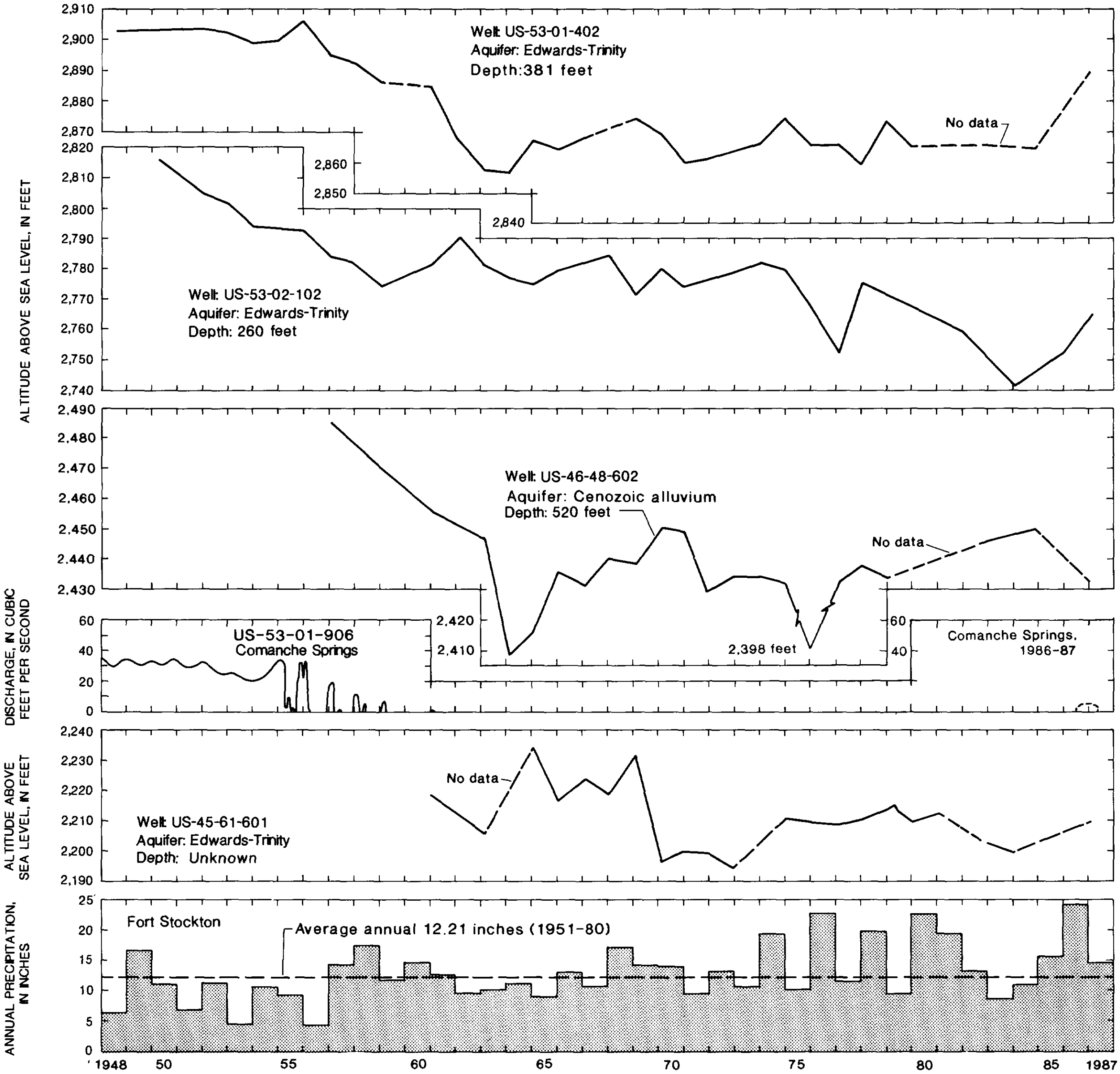


Figure 10.--Water levels in selected wells, flow from Comanche Springs, and precipitation at Fort Stockton, 1948-87. (Water levels from Audsley, 1956; Armstrong and McMillion, 1961; and Rees and Buckner, 1980; and from records of the Texas Water Development Board. Precipitation data from U.S. Department of Commerce, 1987.)

1987 Conditions

Water samples were collected during 1987 to describe the quality of ground water in Pecos County. Wells having available historical water-quality data were selected when possible so that comparisons could be made to the 1987 water-quality data. Field and laboratory analyses were made for specific conductance, pH, temperature, and total alkalinity on 91 samples. Water samples were collected and analyzed for dissolved solids in 33 wells and 2 springs by the Geological Survey and in 11 wells by the Texas Water Development Board. Dissolved-solids concentrations in water from some of the other wells and springs were estimated from specific conductances (table 5, at end of report). The samples from the 33 wells and 2 springs collected by the Geological Survey also were analyzed for hardness and noncarbonate hardness; dissolved calcium, magnesium, sodium, potassium, sulfate, chloride, fluoride, and silica concentrations; dissolved-solids concentrations; and several nitrogen species and phosphorus concentrations (table 6, at end of report).

Thirteen of the wells sampled during 1987 were public-supply wells completed in the Edwards-Trinity aquifer. Concentrations of constituents in samples from those wells did not exceed USEPA MCL's for drinking water. Sulfate, chloride, and dissolved-solids concentrations in a sample from one public-supply well exceeded USEPA SMCL's for drinking water. Dissolved-solids concentrations in samples from six other public-supply wells also exceeded the SMCL.

Specific conductance

Specific conductance is the ability of water to transmit an electric current and depends on the concentrations of ionized constituents dissolved in the water. Conductance determinations are useful in areal extrapolation of ground-water analyses where laboratory analyses are available only for some of the sampled wells (Hem, 1985). Specific conductance was measured during 1987 in the field at wells where samples could be obtained (table 5). The field data were used to prepare the map showing lines of equal specific conductance (pl. 6).

To estimate dissolved-solids concentrations in water samples for which only specific conductance was measured, the following linear regression equation was developed:

$$DS = 0.762\ (SC) - 91.2, \qquad (1)$$

where DS = dissolved-solids concentration, in milligrams per liter; and
SC = specific conductance, in microsiemens per centimeter at 25 °C.
The equation was developed from samples collected from the Edwards-Trinity aquifer by the Geological Survey during 1987 throughout Pecos County (35 pairs of values) with a range of 251 to 8,330 mg/L dissolved-solids concentrations. The variance was 99.7 percent, and the standard deviation was 130.6. The equation was used to estimate dissolved-solids concentrations only in water from wells completed in the Edwards-Trinity aquifer because the reliability of the equation for the other aquifers is unknown. The greatest error in this estimate was for water with large sulfate and chloride concentrations.

In Pecos County, ground water that had a measured specific conductance of 1,500 μS/cm had an estimated dissolved-solids concentration of about 1,050 mg/L. Water containing less than 1,000 mg/L dissolved solids is considered freshwater (table 3). The specific-conductance map for 1987 (pl. 6) indicates that ground water with a specific conductance of 1,000 μS/cm or less is present in most wells in the eastern, central, southern, and southwestern parts of Pecos County. The three areas with unusually large specific conductances, located in north-central Pecos County, are associated with ground water issuing from the Santa Rosa, Diamond Y, and Comanche Springs. During 1987, specific conductances of water samples in the Edwards-Trinity aquifer ranged from 311 μS/cm in well US-53-27-3 to 9,600 μS/cm in Santa Rosa Springs.

Sulfate concentrations

Dissolved sulfate concentrations in water from wells completed only in the Edwards-Trinity aquifer during 1987 (pl. 7) ranged from 17 mg/L in well US-52-22-101 in southwestern Pecos County to 2,300 mg/L in Diamond Y Springs, US-45-57-801 (table 6), in north-central Pecos County. Sulfate concentrations in water from the Cenozoic alluvium aquifer ranged from 430 mg/L in well US-46-56-201 to 2,300 mg/L in well US-45-59-501. Almost one-half of the samples had sulfate concentrations exceeding the SMCL of 250 mg/L given in table 4. Most of the samples with large sulfate concentrations were from wells in north-central Pecos County (pl. 7). These large concentrations may be a result of the distance between the wells and the major recharge area in the southern part of the county, and of the possible vertical migration of moderately saline water from deeper formations such as the Rustler aquifer.

Chloride concentrations

Dissolved chloride concentrations in water from wells completed only in the Edwards-Trinity aquifer (pl. 7) ranged from 12 mg/L in well US-52-13-901 to 1,400 mg/L in Diamond Y Springs (US-45-57-801) (table 6). Chloride concentrations in water from the Cenozoic alluvium aquifer ranged from 120 mg/L in well US-46-56-201 to 3,100 mg/L in well US-45-59-501 (table 6). Water from well US-45-63-703 had a dissolved chloride concentration of 3,200 mg/L. This well is completed in the Cenozoic alluvium and the underlying Edwards-Trinity aquifers. Less than one-third of all the samples collected had chloride concentrations that exceeded the SMCL of 250 mg/L given in table 4. Most of the samples with large chloride concentrations, like those with large sulfate concentrations, were from wells in north-central Pecos County. Assuming a hydraulic connection exists between the Capitan Limestone aquifer and the Edwards-Trinity aquifer (Hiss, 1976), ground water migrating upward from the Capitan Limestone aquifer through the Salado and Castile Formations may dissolve halite from both formations and mix it with ground water in the Rustler and Edwards-Trinity aquifers.

Dissolved-solids concentrations

Dissolved-solids concentrations in samples collected during 1987 from wells in the Edwards-Trinity aquifer (pl. 7, table 6) ranged from 251 mg/L in well US-53-45-501 in southeastern Pecos County to 5,580 mg/L in Diamond Y Springs (US-45-57-801) in north-central Pecos County. In the Cenozoic alluvium aquifer, the range was from 990 mg/L in well US-46-56-201 to 8,330 mg/L in water from well US-45-59-501. Most of the samples that did not exceed the SMCL of 500 mg/L (table 4) were collected in southern Pecos County (pl. 7) near the major recharge area for the Edwards-Trinity aquifer.

Nutrients

The nutrient analysis included total nitrite, total nitrite plus nitrate, total ammonia, ammonia plus total organic nitrogen, total nitrogen, and total phosphorus. The total nitrite as nitrogen concentrations for the Edwards-Trinity aquifer samples were at or below the detection threshold of 0.01 mg/L. The total nitrite plus nitrate as nitrogen concentrations for water from the Edwards-Trinity aquifer ranged from less than 0.1 mg/L in a sample collected from well US-53-01-907 to 8.9 mg/L in a sample collected from US-53-01-906 (Comanche Springs). Because the total nitrite as nitrogen concentration is negligible, the total nitrite plus nitrate concentration can be considered as all nitrate, and this concentration can be compared to the MCL of 10 mg/L for nitrate (table 4) established by the USEPA. Samples from wells in the Edwards-Trinity aquifer that exceeded the MCL for nitrate were not evident; however, water from an irrigation well, US-45-63-703 (Cenozoic alluvium and the underlying Edwards-Trinity aquifers), had a total nitrite plus nitrate concentration of 12 mg/L, which does exceed the MCL.

Chemical Types

Stiff (1951) diagrams graphically show dissolved-solids concentrations in milliequivalents per liter and the proportions of selected major ions. These diagrams can be a relatively distinctive method of showing differences and similarities in water chemistry. The width of the pattern is an approximate indication of dissolved solids. A comparison of the diagrams can be used in identifying different chemical types of water.

Edwards-Trinity aquifer

The Stiff diagrams (pl. 8) are similar for water from the following wells: BK-52-30-104, US-52-06-603, US-52-13-901, US-53-08-601, US-53-13-203, US-53-19-101, US-53-20-601, US-53-45-501, US-54-17-402, and US-54-18-506. The major cation in water from these wells is calcium, the major anion is bicarbonate, reported as alkalinity in table 6, and small sodium and sulfate concentrations also are present. These diagrams are presumed to represent the distinctive pattern for freshwater in the Edwards-Trinity aquifer. The Stiff diagrams representing wells US-46-63-802, US-52-07-303, and US-53-31-201 indicate an increase in the percentage of sodium and sulfate. The water chemistry represented by these diagrams may identify a transition to slightly saline water in the downgradient direction or the mixing of water from adjacent formations. The Stiff diagram for Comanche Springs, US-53-01-906, has large amounts of bicarbonate (shown as alkalinity), sulfate, and chloride anions, as well as a large amount of the sodium cation. This diagram may represent the distinctive pattern of moderately saline water in the Edwards-Trinity aquifer, or may be an indication of mixing ground water from the Rustler and Capitan Limestone aquifers with water from the Edwards-Trinity aquifer. Stiff diagrams for two wells completed in the Cenozoic alluvium and Cretaceous rocks, US-45-52-901 and US-45-63-703, are similar. Water from these wells probably originates from the underlying Edwards-Trinity aquifer.

Cenozoic alluvium aquifer

Water samples from four wells in the Cenozoic alluvium aquifer were analyzed for their chemical constituents. Stiff diagrams of the water chemistry at wells US-46-48-701 and US-46-56-201 (pl. 8), located in the North Coyanosa irrigation area (fig. 9), have similar patterns and may represent the fresh to slightly saline water in the Cenozoic alluvium aquifer. The Stiff diagram for well US-45-59-501 may represent the pattern for moderately saline water in the downgradient direction or the presence of brine from oil and gas production.

Historical Changes

Many of the wells and springs in the Edwards-Trinity aquifer that were selected for a water-quality analysis have historical (1940-49) water-quality data. Changes in dissolved-solids concentrations with time are shown on plate 9. These data indicate the general areas where the dissolved-solids concentrations of the ground water have changed substantially. The greatest decrease in dissolved-solids concentrations was 1,630 mg/L in water from Diamond Y Springs (US-45-57-801), between Santa Rosa and Comanche Springs (table 5). These three springs form a pattern of large specific conductances that is shown on plate 6. Thus, the large decrease in dissolved-solids concentrations in water from Diamond Y Springs was unexpected. Dissolved-solids concentrations in water from wells US-45-50-602 and US-52-08-801 decreased by 844 and 773 mg/L, respectively (pl. 9). These were the greatest decreases in dissolved-solids concentrations detected in the well samples. Increases in dissolved-solids concentrations of 3,290 mg/L in water from Comanche Springs (US-53-01-906) and 4,894 mg/L in water from Santa Rosa Springs (US-45-41-7B) were the greatest changes. The increase in dissolved solids of 837 mg/L in water from well US-52-16-101 in the Leon-Belding irrigation area was the largest increase in water from a well. The smallest change in dissolved solids was a 5-mg/L increase in water from well US-53-16-101 in eastern Pecos County.

Water from one-half of the wells had decreases in dissolved-solids concentrations between 1940-49 and 1987 (pl. 9). However, the 1987 water samples were collected within 4 to 6 months after the intense precipitation during 1986, which may have affected some of the samples by diluting the dissolved-solids concentration. The reason for the detected increases in dissolved-solids concentrations in water from Santa Rosa and Comanche Springs and well US-52-16-101 is uncertain; however, the increases may be caused in part by the migration of moderately saline water from underlying Permian rocks.

COMANCHE SPRINGS

The location of the group of springs known as Comanche Springs is shown in figure 11. Prior to 1961, spring flow probably issued from most or all of the springs shown. Since 1986, spring flow has been from either the Chief spring or the Main spring, or both. The Main spring is a small spring at the lowest opening and is located beneath the swimming pool.

Baker and Bowman (1917) described Comanche Springs as either fissure springs, rising along fault lines, or springs in solution channels in the limestone of Comanchean age. Comanchean refers to the lower Cretaceous formations in the Trinity, Fredericksburg, and Washita Groups. This relation is shown in table 1. The system of solution channels in the Comanchean limestone extends from the Belding fault zone to Leon Springs, about 7 mi west of Fort Stockton (pl. 2), and to Comanche Springs (Armstrong and McMillion, 1961). Armstrong and McMillion (1961) state that the system of channels was developed and probably enlarged by water percolating through open fractures in the limestone. Brune (1981) states that the flow from Comanche Springs issues from a fault in the Comanchean limestone.

Mary Kay Shannon, curator of the Riggs Museum in Fort Stockton, has been in the caves associated with Comanche Springs and has furnished the Geological Survey with color slides photographed inside the caves. Most of the passages visible in the slides appear to have developed along vertical or near vertical

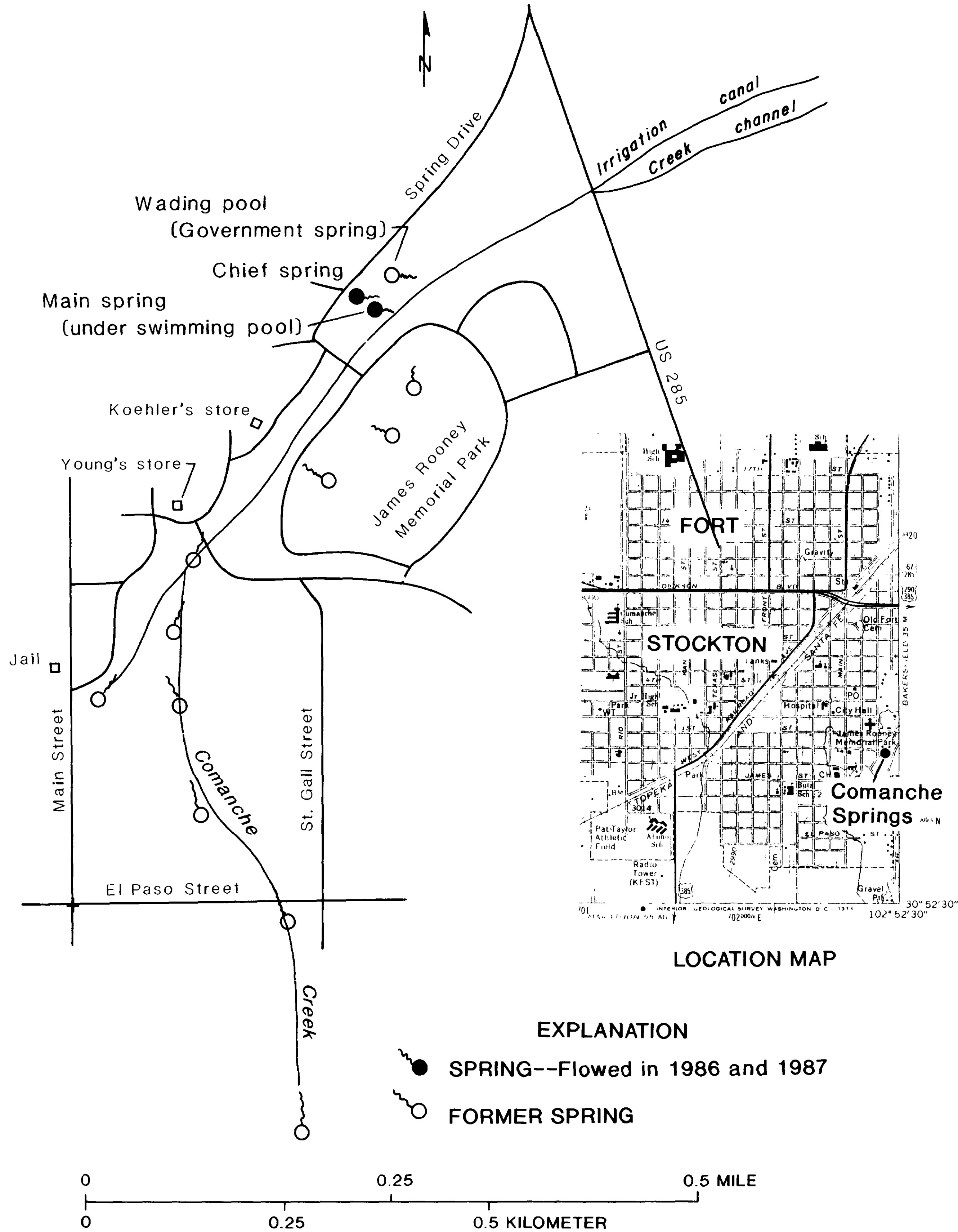


Figure 11.--Location of the group of springs called Comanche Springs in Fort Stockton. (Modified from Brune, 1981.)

joints; however, Ms. Shannon's description of a passage in one slide suggests a solution channel along a fault.

Recharge to Comanche Springs probably occurs south of the Belding fault (pl. 1), because north of the fault the Comanchean limestone is overlain by clay that restricts downward percolation of recharge water (Armstrong and McMillion, 1961). Recharge water enters at the Belding fault, flows north mostly through solution cavities and joints in the limestone toward Leon Springs, and then flows east toward Fort Stockton and Comanche Springs (Armstrong and McMillion, 1961).

Flow from Comanche Springs was reported to be 66 ft^3/s in 1899 and 64 ft^3/s in 1904 (Taylor, 1904, p. 15) and between 42 and 49 ft^3/s during 1919-46 (Brune, 1975, p. 58). The exact reason for the decrease in flow of about 20 ft^3/s prior to major development is unknown. Discharge from the springs decreased because of pumpage for irrigation during 1946-55, ceased for 90 days during the 1955 irrigation season, and ceased for longer periods during the 1956 and 1957 irrigation seasons (Armstrong and McMillion, 1961, p. 45). The water level in well US-52-08-902 (P-79) in the Leon-Belding irrigation area fell to about 60 ft below land surface in April 1956 (Armstrong and McMillion, 1961, p. 156). Comanche Springs ceased to flow in March 1958, but began to flow again in January 1959 when the water level in the well US-52-08-902 rose to about 35 ft below land surface (Armstrong and McMillion, 1961, pl. 12). Flow ceased again in March 1961 (Brune, 1975).

The resumption of flow at Comanche Springs (US-53-01-906) in early October 1986 followed about 7 in. of precipitation near Fort Stockton during the first week of October 1986 (U.S. Department of Commerce, 1987). Most of the Trans-Pecos region had received greater-than-normal precipitation during the previous 2 months. Precipitation in a part of the Trans-Pecos region during 1986 is shown in figure 12. The largest quantity of precipitation fell during the last half of the year, which correlates with the rise in water levels in three wells in the Edwards-Trinity aquifer shown in figure 10, and with the beginning of flow from Comanche Springs. Short-term hydrographs (fig. 13) for wells US-52-16-802, US-52-16-903 (Fort Stockton city well no. 2), and US-53-01-902 (Fort Stockton city observation well) were plotted with monthly precipitation at Fort Stockton and spring-flow periods at Comanche Springs (US-53-01-906) during January 1979 to June 1988. The short-term hydrographs show frequent water-level changes of about 45 ft. The hydrographs indicate some correlation between water levels, spring flow, and precipitation. Water levels usually rise following periods of greater-than-normal precipitation and decline during periods of less-than-normal precipitation. Comanche Springs started flowing again in October 1986, possibly as the result of the cessation of irrigation pumpage in August 1986 and several weeks of record or near-record precipitation near Fort Stockton. However, the rise in water levels during December 1987 to February 1988 and the resumption of flow in Comanche Springs in early 1988 are probably in response to a decrease in irrigation pumpage rather than above-normal precipitation.

The depth to water in well US-52-16-903 (Fort Stockton city well no. 2) was about 235 ft when the springs began to flow in October 1986. Depth to water in well US-52-16-903 was about 214 ft when pre-planting irrigation pumpage began in February 1987, and the springs ceased to flow from the Chief spring outlet (fig. 11) on March 11, 1987, when the depth to water in well US-52-16-903 was about 218 ft. The springs may have started flowing when the water level was 17 ft lower (October 1986) than when the springs stopped

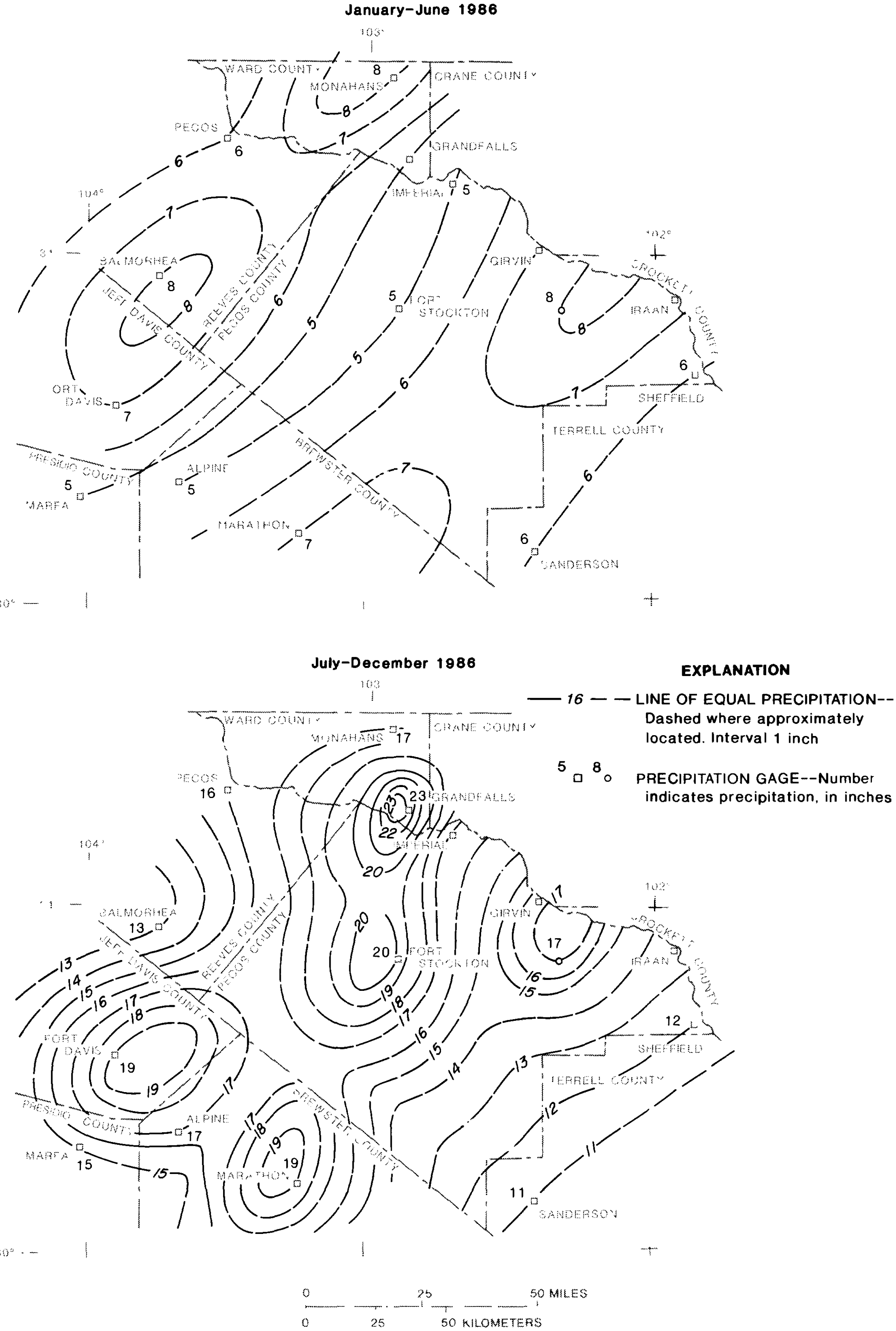


Figure 12.--Lines of equal precipitation in Pecos County and parts of adjacent counties, 1986. (Data from U.S. Department of Commerce, 1987.)

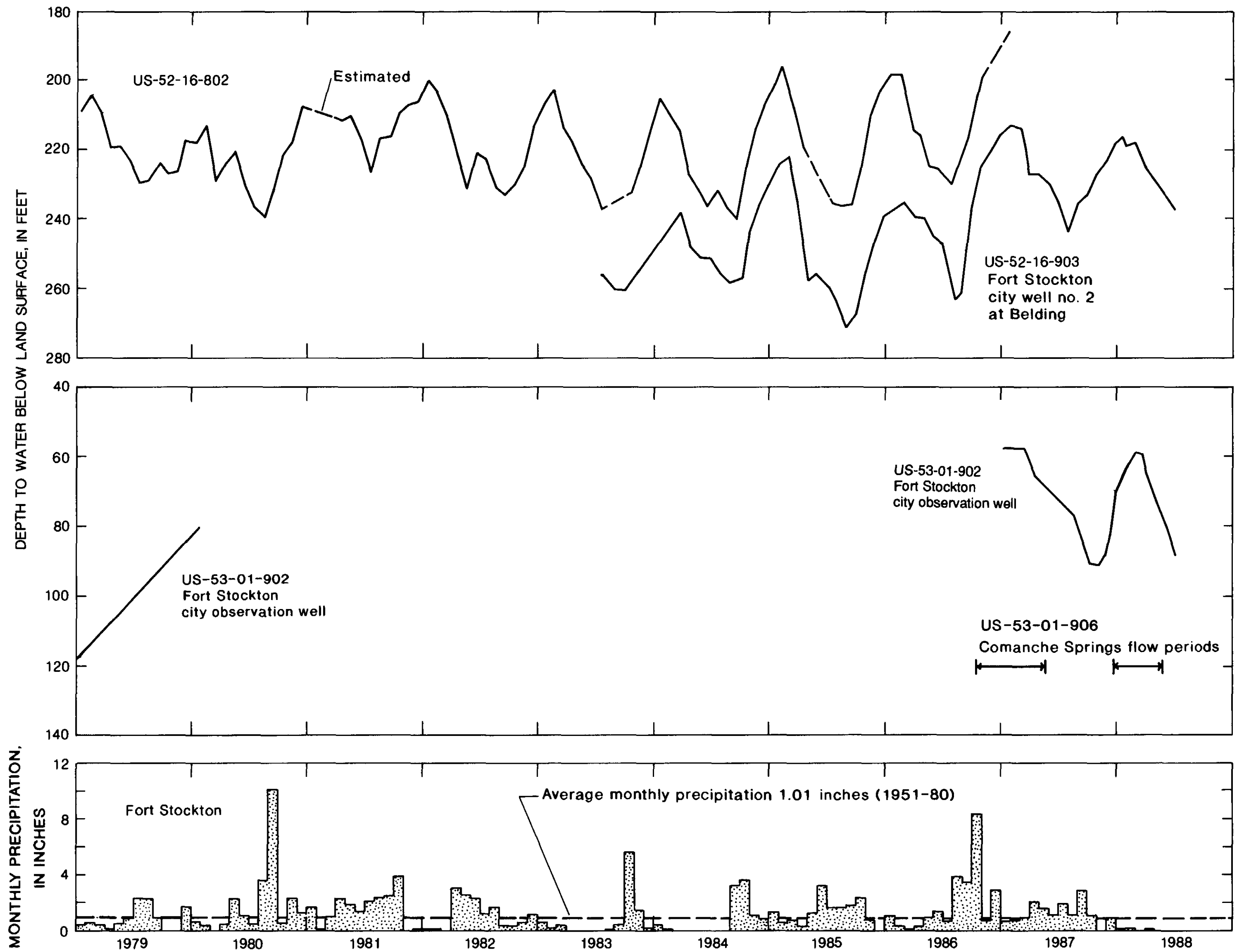


Figure 13.--Water levels in selected wells, Comanche Springs flow periods, and monthly precipitation at Fort Stockton, 1979-88. (Precipitation data from U.S. Department of Commerce, 1987.)

flowing (March 11, 1987) because major flooding caused by the intense precipitation at Fort Stockton in October 1986 recharged the Comanche Springs cave and the solution channels in the limestone leading directly to the cave. Water continued to flow from the Main spring (fig. 11) until May 15, 1987, when the depth to water in well US-52-16-903 was about 228 ft. Water rose to about 3 ft below the outlet of the Chief spring in late December 1987, and the Main spring began to flow about the same time. The depth to water in well US-52-16-903 was about 218 ft at this time. The Main spring continued to flow until May 20, 1988. Depth to water was about 232 ft in well US-52-16-903 when spring flow ceased.

The specific conductance of water from the Main spring in 1987 was 6,050 μS/cm, much larger than the 2,100 to 2,200 μS/cm reported in the years before the spring ceased to flow (Armstrong and McMillion, 1961, p. 285-286). A comparison of the quality of the 1987 water samples with the quality of the water from samples taken when the springs flowed during 1932-58 is shown by Stiff diagrams in figure 14.

Adkins (1927, p. 88) attributed the "poorer Cretaceous water" in Comanche, Leon, Monument, Salado, Santa Rosa, and Tunas Springs primarily to faulted or fissured limestone beneath the springs that permitted local upward leakage to the springs of saline water from the underlying Permian Castile and Salado Formations.

The change in water quality in Comanche Springs as indicated by the 1987 analysis might be explained as follows: The decline in water levels left the caves and solution openings that compose the spring systems in the Cretaceous rocks largely unsaturated for about 25 years (1961-86). During that time, numerous precipitation and runoff events allowed infiltration of salt-laden surface waters into the caves and solution openings with a consequent accumulation of salts, including relatively large nitrate concentrations. Therefore, the large nitrate concentration (table 6) in water from Comanche Springs might reflect a surface-water source in addition to the potential upward leakage from the deep-lying Permian rocks, particularly because analyses from deep wells in the Permian Rustler aquifer in the vicinity of Comanche Springs show little or no nitrate (Armstrong and McMillion, 1961).

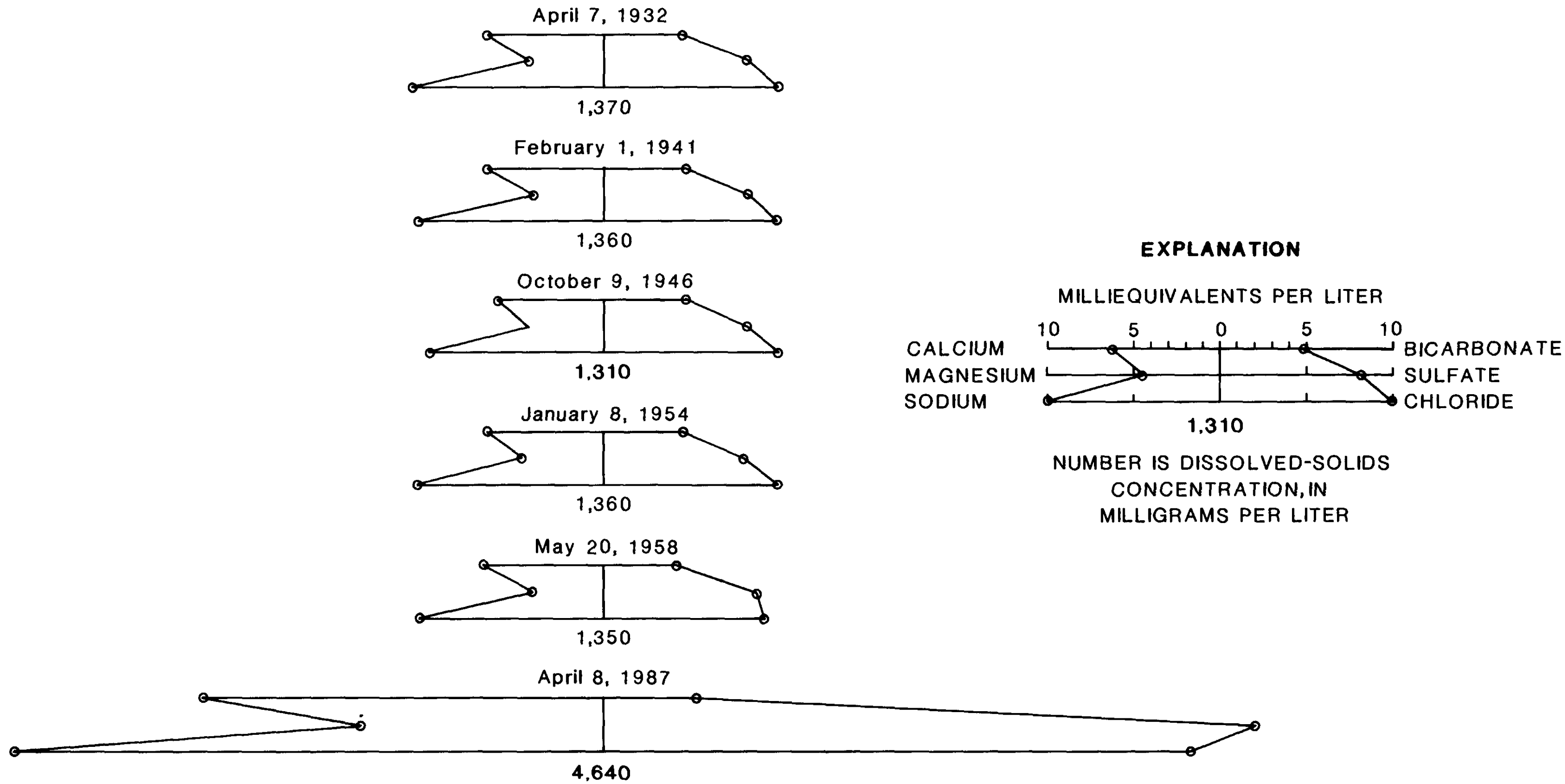


Figure 14.--Changes in concentrations of major ions in water from Comanche Springs, 1932-87. (Data prior to 1987 from Armstrong and McMillion, 1961.)

SUMMARY AND CONCLUSIONS

Pecos County is in the southern part of the Permian Basin, which is an area of relatively complex geology because of its proximity to the juncture of the Delaware basin, the Val Verde basin, and the Marathon thrust belt. Rocks of Pennsylvanian to Quaternary age crop out on the surface. Cretaceous limestones and sandstones and Cenozoic alluvium are common at the surface in most of the county.

The Edwards-Trinity aquifer supplies most of the water needs of Pecos County, except in the northern part where this aquifer is absent and water is obtained from the Cenozoic alluvium aquifer. The Santa Rosa aquifer also supplies water to small areas in northern Pecos County, and the Rustler aquifer supplies water for irrigation and livestock in western Pecos County. Water from the Capitan aquifer, also in western Pecos County, is used for irrigation, but the depth and salinity of the aquifer have limited its development.

Recharge to the Edwards-Trinity aquifer occurs through the infiltration of runoff during times of intense precipitation and as underflow, or upward leakage from underlying formations. Recharge by direct precipitation is negligible because the annual precipitation is about 12 in., and the rate of potential evapotranspiration is 70 to 80 in/yr. However, recharge resulting from runoff from intense local precipitation can be substantial in areas where the runoff flows over gravels or over limestone that is fractured. Recharge caused by underflow has not been specifically documented in Pecos County, but may occur from pre-Cretaceous limestones in Brewster County, near the Glass Mountains. Discharge from the Edwards-Trinity aquifer is by spring flow, evapotranspiration, base flow to the Pecos River, outflow into Terrell County, and by withdrawals from wells, primarily for irrigation.

Most 1987 water levels in the Leon-Belding irrigation area, in an area north of Fort Stockton, and in a well east of Bakersfield are much lower than the historical (1940-49) water levels. The changes in measured water levels range from an 82-ft decrease in the Leon-Belding area to a 55-ft increase in east-central Pecos County. The relation between the long-term hydrographs of selected wells and precipitation data at Fort Stockton shows that the water levels rise in response to precipitation. The hydrographs also show a water-level decline that can be associated with pumping for irrigation.

In 1987, dissolved sulfate concentrations in water from wells and springs in the Edwards-Trinity aquifer ranged from 17 to 2,300 mg/L, and dissolved chloride concentrations ranged from 12 to 1,400 mg/L. Total nitrite plus nitrate concentrations, which for this report can be considered as all nitrate, ranged from less than 0.1 to 8.9 mg/L in the Edwards-Trinity aquifer.

The chemical type of ground water varies with its location in the county. The water in wells in the far western part of the county is mostly a calcium bicarbonate type. Water in wells farther north and east ranges in type from calcium bicarbonate to calcium sulfate to sodium chloride.

Dissolved-solids concentrations from historical (1940-49) and 1987 water samples from the Edwards-Trinity aquifer were compared to determine if water quality had changed substantially. One-half of the wells had decreases in dissolved-solids concentration ranging from 17 to 1,630 mg/L. However, dissolved-solids concentrations in water from Comanche and Santa Rosa Springs increased by 3,290 and 4,894 mg/L, respectively. The dissolved-solids concentration in water from one well in the Leon-Belding irrigation area increased 837 mg/L. The increased dissolved-solids concentrations at Comanche and Santa Rosa Springs may represent a mixing of Edwards-Trinity water with moderately saline water from underlying Permian rocks, or an accumulation of salts from surface-water sources.

Comanche Springs, dry since 1961, flowed briefly from October 1986 to May 1987 and from late December 1987 to May 1988. Correlation between flow from Comanche Springs and water levels in Fort Stockton city well no. 2 in the Leon-Belding irrigation area indicates that the springs are unlikely to flow when the depth to water in this well exceeds about 232 ft.

SELECTED REFERENCES

Adkins, W.S., 1927, Geology and mineral resources of the Fort Stockton quadrangle: University of Texas Bulletin 2738, 164 p.

A.H. Belo Corp., 1989, Texas almanac, 1990-91 (55th ed.): The Dallas Morning News, 607 p.

American Public Health Association and others, 1975, Standard methods for the examination of water and wastewater (14th ed.): Washington, D.C., American Public Health Association, 1,193 p.

Armstrong, C.A., and McMillion, L.G., 1961, Geology and ground-water resources of Pecos County, Texas: Texas Board of Water Engineers Bulletin 6106, v. I, 241 p., v. II, 295 p.

Audsley, G.L., 1956, Reconnaissance of ground-water development in the Fort Stockton area, Pecos County, Texas: U.S. Geological Survey open-file report, 68 p.

Baker, C.L., and Bowman, W.F., 1917, Geologic exploration of the southeastern front range of Trans-Pecos, Texas: Austin, University of Texas Bulletin 1753, p. 67-172.

Bishop, M.S., 1960, Subsurface mapping: New York and London, John Wiley and Sons, 198 p.

Bouwer, Herman, 1978, Groundwater hydrology: McGraw-Hill Book Co., 480 p.

Brand, J.P., and DeFord, R.K., 1958, Comanchean stratigraphy of Kent quadrangle, Trans-Pecos, Texas: American Association of Petroleum Geologists Bulletin, v. 42, no. 2, p. 371-386.

Brown, J.B., Rogers, L.T., and Baker, B.B., 1965, Reconnaissance investigation of the ground-water resources of the middle Rio Grande basin, Texas, in Reconnaissance investigation of the ground-water resources of the Rio Grande basin, Texas: Texas Water Commission Bulletin 6502, p.1-80.

Brune, Gunnar, 1975, Major and historical springs of Texas: Texas Water Development Board Report 189, p. 56-99.

----- 1981, Springs of Texas: v. 1, p. 356-363.

Chatterjee, Sankar, 1987, The Late Triassic Dockum vertebrates: Their stratigraphic and paleobiogeographic significance, in Padian, Kevin, ed., The beginning of the age of dinosaurs: Faunal change across the Triassic-Jurassic boundary: Cambridge University Press (ISBN 0-521-30328-1), p. 139-149.

Dante, J.H., 1947, Records of wells and springs in northern Pecos County, Texas: Texas Board of Water Engineers miscellaneous publication, 87 p.

Dennis, P.E., and Lang, J.W., 1941, Water resources of the Pecos River basin, v. 2. Records of wells and springs and analyses of water in Loving, Ward, Reeves and northern Pecos Counties, Texas: Texas Board of Water Engineers miscellaneous publication, 177 p.

Dunham, R.J., 1972, Capitan reef, New Mexico and Texas: Facts and questions to aid interpretation and group discussion: Society of Economic Paleontologists and Mineralogists, no. 72-14, 263 p.

Flawn, P.T., Goldstein, August, Jr., King, P.B., and Weaver, C.E., 1961, The Ouachita System: Austin, University of Texas, Bureau of Economic Geology Publication 6120, 401 p.

Hem, J.D., 1970, Study and interpretation of the chemical characteristics of natural water (2d ed.): U.S. Geological Survey Water-Supply Paper 1473, 363 p.

----- 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hills, J.M., 1972, Late Paleozoic sedimentation in west Texas Permian Basin: American Association of Petroleum Geologists Bulletin, v. 56, pt. 12, p. 2,303-2,333.

Hiss, W.L., 1976, Stratigraphy and ground-water hydrology of the Capitan aquifer, southeastern New Mexico and western Texas: University of Colorado, Ph.D. dissertation, 501 p.
King, P.B., 1930, The geology of the Glass Mountains, Texas, part 1, descriptive geology: Austin, University of Texas Bulletin 3038, 167 p.
Maley, V.C., and Huffington, R.M., 1953, Cenozoic fill and evaporite solution in the Delaware basin, Texas and New Mexico: Geological Society of America Bulletin, v. 64, no. 5, p. 539-545.
McGowan, J.H., Granata, J.H., and Seni, S.J., 1979, Depositional framework of the lower Dockum group (Triassic) Texas panhandle: Austin, University of Texas, Bureau of Economic Geology Report of Investigations 97, 60 p.
McKee, J.E., and Wolf, H.W., 1963, Water quality criteria (2d ed.): California State Water Quality Board Publication, no. 3-A, 548 p.
Muller, D.A., and Price, R.D., 1979, Ground-water availability in Texas: Texas Department of Water Resources Report 238, 77 p.
National Academy of Sciences, National Academy of Engineering, 1973 [1974], Water quality criteria, 1972: Washington, D.C., Report of the Committee on Water Quality Criteria, 594 p.
National Technical Advisory Committee to the Secretary of the Interior, 1968, Water quality criteria: Washington, D.C., U.S. Government Printing Office, 234 p.
Rees, R.W., 1987, Records of wells, water levels, pumpage, and chemical analyses from selected wells in parts of the Trans-Pecos region, Texas, 1968-1980: Texas Water Development Board Report 301, 325 p.
Rees, R.W., and Buckner, A.W., 1980, Occurrence and quality of ground water in the Edwards-Trinity (Plateau) aquifer in the Trans-Pecos region of Texas: Texas Department of Water Resources Report 255, 46 p.
Reeves, R.D., and Small, T.A., 1973, Ground-water resources of Val Verde County, Texas: Texas Water Development Board Report 172, 145 p.
Rose, P.R., 1972, Edwards Group, surface and subsurface central Texas: Austin, University of Texas, Bureau of Economic Geology Report of Investigations 74, 198 p.
Shoemaker, E.M., and Eggleton, R., 1964, Re-examination of the stratigraphy and structure of Sierra Madera, Texas: Astrogeologic studies annual progress report summary, Aug. 25, 1962 - July 1, 1963, pt. B, Crater Investigations, p. 98-106.
Smith, C.I., and Brown, J.B., 1983, Introduction to road log Cretaceous stratigraphy: West Texas Geological Society Field Trip Guidebook no. 83-77, p. 1-4.
Stiff, H.A., Jr., 1951, The interpretation of chemical water analyses by means of patterns: Journal of Petroleum Technology, v. 3, no. 10, p. 15-17.
Taylor, T.U., 1904, The water powers of Texas: U.S. Geological Survey Water Supply and Irrigation Paper 105, 116 p.
Texas Department of Water Resources, 1981, Inventories of irrigation in Texas, 1958, 1964, 1969, 1974, and 1979: Texas Department of Water Resources Report 263, 295 p.
U.S. Department of Commerce, 1987, Climatological data, Texas, annual summary: National Oceanic and Atmospheric Administration, Environmental Data and Information Service, v. 92, no. 13, 809 p.
U.S. Environmental Protection Agency, 1990a, Maximum contaminant levels (subpart B of Part 141, National primary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, parts 100 to 149, revised as of July 1, 1990, p. 559-563.

----- 1990b, Secondary maximum contaminant levels (section 143.3 of part 143, National secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, parts 100 to 149, revised as of July 1, 1990, p. 674.
University of Texas, Bureau of Economic Geology, 1982, Geologic atlas of Texas, Fort Stockton sheet: Scale 1:250,000.
Vertrees, C., Atchison, C.H., and Evans, G.L., 1959, Paleozoic geology of the Delaware and Val Verde basins: West Texas Geological Society Field Trip Guidebook, p. 64-73.
Wilshire, H.G., Offield, T.W., Howard, K.A., and Cummings, David, 1972, Geology of the Sierra Madera cryptoexplosion structure, Pecos County, Texas: U.S. Geological Survey Professional Paper 599-H, 42 p.
Winslow, A.G., and Kister, L.R., 1956, Saline-water resources of Texas: U.S. Geological Survey Water-Supply Paper 1365, 105 p.

Table 1.--Stratigraphic units

[Water-yielding properties: Yields (gallons per minute) --small, less than 50; moderate 50 to 500; large, more than 500. Classification

ERA	SYSTEM	SERIES OR GROUP	STRATIGRAPHIC UNIT	APPROXIMATE MAXIMUM THICKNESS (feet)
Cenozoic	Quaternary and Tertiary		Alluvium	1,150
Cenozoic	Tertiary		Volcanic rocks, undivided	1,000+
Mesozoic	Cretaceous	Gulfian Series; Terlingua Group	Boquillas Formation	250
Mesozoic	Cretaceous	Comanchean Series; Washita Group	West 1/ and East 2/: Buda Limestone 3/	West 1/: 100; East 2/: 200
Mesozoic	Cretaceous	Comanchean Series; Washita Group	West 1/: Sixshooter Group 3/: Boracho Formation 3/; East 2/: Edwards Group 4/: Fort Lancaster Formation 5/	West 1/: 410; East 2/: 350
Mesozoic	Cretaceous	Comanchean Series; Washita Group	West 1/: Sixshooter Group 3/: University Mesa Marl 5/; East 2/: Edwards Group 4/: Burt Ranch Member 4/	
Mesozoic	Cretaceous	Comanchean Series; Fredericksburg Group	West 1/: Sixshooter Group 3/: Finlay Formation 3/; East 2/: Edwards Group 4/: Fort Terrett Formation 4/	West 1/: 165; East 2/: 200
Mesozoic	Cretaceous	Comanchean Series; Trinity Group	Trinity Sand	350
			MISSING	MISSING
Mesozoic	Triassic	Dockum Group	Middle	600
Mesozoic	Triassic	Dockum Group	Lower	70
Paleozoic	Permian	Ochoan Series	Dewey Lake Red Beds	600
Paleozoic	Permian	Ochoan Series	South 6/: Tessey Limestone; North 7/: Rustler Formation	South 6/: 1,050; North 7/: 450
Paleozoic	Permian	Ochoan Series	North 7/: Salado Formation	North 7/: 2,200
Paleozoic	Permian	Ochoan Series	North 7/: Castile Formation	North 7/: 2,300
Paleozoic	Permian	Guadalupian Series; Whitehorse Group	Gilliam Limestone; Capitan Limestone; Guadalupian formations, undivided	870; 1,650; 1,900
Paleozoic	Permian	Guadalupian Series	Lower Guadalupian formations, undivided	2,000
Paleozoic	Permian		Lower Permian formations, undivided	10,000
Paleozoic	Pennsylvanian		Pennsylvanian formations, undivided	6,000

1/ Western Pecos County
2/ Eastern Pecos County
3/ Brand and DeFord, 1958
4/ Rose, 1972
5/ Smith and Brown, 1983
6/ Southern Pecos County
7/ Northern Pecos County

[shaded box] MISSING

and their water-yielding properties.

of water (dissoved-solids concentration, in milligrams per liter).-- fresh, less than 1,000; slightly saline, 1,000 to 3,000; moderately saline, 3,000 to 10,000)

<table>
<tr><th colspan="3">CHARACTER OF ROCKS</th><th colspan="2">WATER-YIELDING PROPERTIES</th><th>AQUIFER (if known)</th></tr>
<tr><td colspan="3">Unconsolidated silt, sand, gravel, clay, boulders, caliche, gypsum, and conglomerate</td><td colspan="2">Yields range from small to large quantities of fresh to moderately saline water</td><td>Cenozoic alluvium</td></tr>
<tr><td colspan="3">Lavas, pyroclastic tuffs, volcanic ash, tuff breccias, fragmental breccias, agglomerates; few thin beds of conglomerates, sandstones, and freshwater limestones</td><td colspan="2">Yields small quantities of freshwater</td><td></td></tr>
<tr><td colspan="3">Brown to red flaggy limestone interbedded with shale</td><td colspan="2">Not known to yield water</td><td></td></tr>
<tr><td colspan="3">Soft nodular limestone, marl, and thin-bedded hard granular limestone</td><td colspan="2">Does not yield water in most of study area; however, may yield small quantities in Reeves County</td><td rowspan="5">Edwards-Trinity</td></tr>
<tr><td colspan="3">Hard massive limestone, thin-bedded limestone, and soft nodular limestone with some clay</td><td colspan="2">Yields small quantities of water</td></tr>
<tr><td colspan="3">Soft nodular limestone, marl, and hard massive ledge-forming limestone</td><td colspan="2">Yields small quantities of water</td></tr>
<tr><td colspan="3">Massive ledge-forming limestone and soft nodular limestone</td><td colspan="2">Yields small to large quantities of fresh to moderately saline water</td></tr>
<tr><td colspan="3">Crossbedded, fine- to coarse-grained, poorly to well-cemented quartz sand with some silt, shale, and limestone</td><td colspan="2">Yields small to moderate quantities of fresh to slightly saline water</td></tr>
<tr><td colspan="3">Reddish-brown to gray coarse-grained sandstone</td><td colspan="2">Yields small to moderate quantities of fresh to slightly saline water</td><td>Santa Rosa</td></tr>
<tr><td colspan="3">Red shale and siltstone</td><td colspan="2">Not known to yield water</td><td rowspan="3"></td></tr>
<tr><td colspan="3">Sand, shale, gypsum, and anhydrite</td><td colspan="2">Not known to yield water</td></tr>
<tr><td>South 6/</td><td colspan="2">North 7/</td><td>South 6/</td><td>North 7/</td></tr>
<tr><td rowspan="3">Limestone and dolomite</td><td colspan="2">Red shale, sandstone, anhydrite, dolomite, limestone, conglomerate, and halite</td><td rowspan="3">Not known to yield water</td><td>Yields small to large quantities of slightly to moderately saline water</td><td>Rustler</td></tr>
<tr><td colspan="2">Mostly halite, with anhydrite and some dolomite</td><td>Not known to yield water</td><td rowspan="2"></td></tr>
<tr><td colspan="2">Mostly calcareous anhydrite, with halite and associated salts and some limestone</td><td>Not known to yield water</td></tr>
<tr><td>Limestone, dolomite, and sandstone</td><td>Limestone, dolomite, and reef talus</td><td>Dolomite, limestone, anhydrite, shale, and sandstone</td><td>Yields freshwater to a few wells in the Glass Mountains</td><td>Yields moderate to large quantities of moderately saline water</td><td>Capitan Limestone</td></tr>
<tr><td colspan="3">Dolomite, dolomitic limestone, limestone, and siliceous shale</td><td colspan="2">Yields small to large quantities of moderately saline water</td><td rowspan="3"></td></tr>
<tr><td colspan="3">Shale, siliceous shale, limestone, dolomitic limestone. sandstone, and basal conglomerate</td><td colspan="2">Yields small quantities of water</td></tr>
<tr><td colspan="3">Limestone, sand, sandstone, shale chert, and conglomerate</td><td colspan="2">Yields small quantities of water</td></tr>
</table>

Modified from Armstrong and McMillion, 1961; Rees and Buckner, 1980; and Smith and Brown, 1983

Table 2.--Records of wells and springs in Pecos County and adjacent counties

County prefix: BK, Brewster; HJ, Crockett; US, Pecos; WD, Reeves
Aquifer: ET, Edwards-Trinity; CA, Cenozoic alluvium; K, Cretaceous rocks, undifferentiated; PR, Permian Rustler; PU, Permian undivided
Spring: SA, Santa Rosa; DIA, Diamond Y; COM, Comanche; LEO, Leon
Water levels: Reported water levels shown as whole numbers
Use of water: U, unused; S, livestock; H, domestic; I, irrigation; P, public supply

[ft, feet; --, unknown, no data, or not applicable]

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
BK-52-30-104	--	ET	--	--	3,549	02-15-87	233.22	U	--
						1/06-24-87	--		
BK-52-30-1	--	--	--	--	3,549	02-15-87	227.74	S	--
HJ-54-01-901	G.L. Thompson	ET	--	--	2,180	02-04-87	52.06	S	--
US-45-41-7A	J.C. Trees Estate	ET	--	--	2,554	10-24-46	29.60	S	B-43
US-45-41-7B	--	ET,SA	--	--	2,517	2/12-14-49	--	--	B-40
						1/01-29-87	--		
US-45-43-702	--	--	--	--	2,401	01-30-87	25.69	--	C-24
US-45-43-7A	--	--	--	--	--	01-29-87	25.16	--	--
US-45-43-7B	Western Cotton Oil Co.	CA,K	1948	140	2,398	11-08-57	23.50	U	--
						01-29-87	25.16		
US-45-43-804	L.A. Heagy	CA,K	1946	92	2,388	10-21-46	11.80	U	C-47
						01-26-59	18.90		
						01-29-87	21.00		
3/US-45-44-7	--	CA,K	--	--	2,359	01-30-87	14.75	--	--
US-45-49-301	George Atkins Estate	CA,K	1948	--	2,502	01-19-55	25.33	S	B-66
						01-09-80	24.08		
						01-14-81	24.26		
						02-19-87	23.26		
US-45-49-4	D.J. Sibley	ET	1940	100	2,605	12-07-46	67.80	S	B-88
US-45-49-8	D.C. Ogden Wilson	ET	1940	645	2,598	10-24-46	28.00	S	G-3
US-45-49-901	O.C. Ogden Wilson	CA,K	1907	300	2,607	10-23-46	42.80	S	G-5
						05-03-73	76.03		
						01-27-87	23.26		
US-45-49-9	Ralph Johnson	ET	--	57	2,579	10-23-46	53.10	H	G-7
US-45-50-501	--	CA,K	--	150	2,461	02-08-47	24.90	--	--
US-45-50-502	Sunray Midcontinent Oil	ET	--	160	2,442	02-03-87	43.50	U	C-144
US-45-50-602	George Atkins Estate	ET	1948	350	2,484	2/05-08-50	--	I	C-157
						01-28-87	80.59		
US-45-50-8	--	--	--	--	2,518	01-28-87	105.07	U	H-3
US-45-50-9	A.M. Barnes	ET	1933	80	2,515	11-11-48	48.90	S	H-10
3/US-45-51-105	Catholic Foundation	CA	1946	140	2,427	01-26-59	40.92	I	C-103
						01-28-87	22.90		
US-45-51-204	George Atkins Estate	CA,K	1948	120	2,392	09-20-48	24.30	S	C-62
						11-28-49	17.50		
						11-08-57	17.30		
						01-28-87	21.70		
US-45-51-302	L.B. Freeman	CA	1946	100	2,375	10-22-46	13.79	U	D-48
						12-13-56	18.61		
						01-28-87	19.37		
US-45-51-3	H.V. Colls	CA,K	1946	65	2,382	10-22-46	15.00	U	D-14
						01-29-87	21.15		
US-45-51-5	George Atkins Estate	CA,K	1948	210	2,405	05-05-48	35.90	U	C-179
US-45-51-6A	George Atkins Estate	CA,K	1948	120	2,392	09-20-48	32.80	U	C-180
US-45-51-6B	George Atkins Estate	CA,K	1948	173	2,392	05-09-48	24.30	U	C-62
						10-07-57	32.40		
						01-29-87	22.77		

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-45-51-7	Burk Royalty Co.	CA,K	1946	122	2,449	07-09-48	24.00	H	H-13
						01-29-87	65.36		
US-45-51-8	A.C. Hoover	CA,K	--	67	2,433	02-06-47	11.80	--	H-19
						07-07-48	13.10		
						01-29-87	48.79		
3/US-45-52-105	--	--	--	--	2,372	01-30-87	22.90	--	--
US-45-52-5A	H.J. Eaton	CA,K	--	--	2,365	11-17-57	24.90	U	D-68
						01-30-87	27.88		
4/US-45-52-5B	L.M. Mueller	--	--	2,118	2,362	--	--	U	D-73
US-45-52-601	N.A. Holladay	--	1946	100	2,340	12-12-46	12.50	U	D-78
						01-28-59	17.20		
						01-30-87	18.90		
US-45-52-6	N.A. Holladay	--	1946	70	2,339	10-22-46	9.20	U	D-80
						10-10-57	15.20		
						01-30-87	16.07		
US-45-52-901	H.F. Neal	CA,K	--	100	2,392	06-06-40	44.70	S	J-16
						02-03-46	44.40		
						01-30-87	61.74		
						1/04-09-87	--		
4/US-45-53-1	R.L. Ewing	--	--	2,203	2,325	--	--	U	D-86
US-45-53-401	W.J. Holladay	CA	1946	105	2,331	10-22-46	14.10	U	D-95
						01-28-59	16.90		
						01-30-87	18.38		
US-45-53-4	S.S. Millspaugh	--	1947	118	2,335	06-10-47	15.00	U	D-89
US-45-53-8	S.S. Millspaugh	--	--	21	2,321	10-08-57	12.90	S	K-3
						01-30-87	10.79		
US-45-57-201	Reed Estate	ET	--	--	2,690	02-03-87	73.02	S	--
US-45-57-601	Bill Hargis	ET	--	96	2,722	10-23-46	53.10	--	G-16
						09-20-58	75.54		
						01-11-78	88.49		
						02-19-87	42.15		
US-45-57-801	Henry Wilbanks	ET,DIA	--	--	2,790	2/05-10-43	--	S	G-30
						1/04-09-87	--		
US-45-58-1	J.R. Bennett	ET	--	452	2,633	12-06-46	36.50	U	G-13
US-45-58-2	--	--	--	--	2,562	01-29-87	31.93	U	--
US-45-58-301	A.C. Hoover	--	--	65	2,531	01-28-87	87.60	S	H-32
US-45-58-3	San Pedro Ranch	ET	1943	80	2,522	10-30-46	24.40	S	H-34
US-45-58-4	J.R. Bennett	ET	--	66	2,663	12-06-46	44.50	S	H-43
US-45-58-502	San Pedro Ranch	PR	1940	1,364	2,664	1/01-28-87	--	S,I	H-76
US-45-58-604	Farmland Industries	ET	1977	355	2,576	07-18-77	120.00	U	--
						01-31-87	81.12		
US-45-58-605	A.C. Hoover	ET	--	80	2,601	10-30-46	21.10	S	H-47
						10-10-57	17.90		
						01-28-87	55.34		
US-45-58-7	J.R. Bennett	ET	1935	370	2,880	12-06-46	209.90	S	G-38
US-45-58-802	San Pedro Ranch	ET	1942	260	2,770	11-21-46	85.00	S	H-79
						04-25-58	154.30		
						02-03-87	115.30		
US-45-58-8A	J.R. Bennett	ET	1938	400	2,880	12-16-46	179.40	S	G-39
US-45-58-8B	San Pedro Ranch	ET	1947	94	2,737	05-28-48	17.90	U	H-99
US-45-58-9	San Pedro Ranch	ET	1945	70	2,658	11-21-46	19.30	S	H-75
US-45-59-2	--	--	--	--	2,461	01-31-87	21.80	S	--
4/US-45-59-3	- Fromme	--	--	1,440	2,437	--	--	U	J-35

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-45-59-501	Buena Vista Ranch	CA	--	--	2,485	07-11-50	52.70	S	J-37
						10- -57	60.00		
						1/04-09-87	--		
US-45-59-8__	C.R. McKenzie	CA,K	1971	310	2,624	01-31-87	220.28	S	--
US-45-59-901	A.C. Hoover	--	--	--	2,545	10-16-57	167.30	S	J-41
						01-31-87	177.20		
US-45-60-301	- Franklin	ET	1957	--	2,390	01-31-87	56.82	I	J-21
US-45-60-4__	Neal & Ratliff	ET	1946	146	2,457	01-31-87	56.82	S	J-34
US-45-60-7__	Neal & Ratliff	ET	1946	200	2,475	02-04-47	132.10	S	J-42
						11-15-48	90.40		
						01-31-87	121.22		
US-45-60-8__	John W. Garner	ET	--	170	2,451	02-04-47	81.00	S	J-61
US-45-60-902	Sher Bar Land & Cattle Co.	ET	1957	400	2,446	02-05-58	115.70	I	J-59
						02-06-67	157.20		
						01-30-87	120.86		
US-45-61-2__	S.S. Millspaugh	ET	--	68	2,349	10-08-57	15.40	--	K-2
						01-30-87	33.82		
US-45-61-402	Agriculture Inc.	ET	--	182	2,361	08-19-57	39.70	U	K-11
						01-30-87	36.86		
US-45-61-5__	Wes Poole	ET	--	68	2,323	02-03-47	33.00	U	K-14
US-45-61-601	West Tex. Utilities Co.	ET	1930	--	2,335	12-18-46	116.80	U	K-30
						01-14-81	123.05		
						02-21-87	125.02		
US-45-61-607	West Tex. Utilities Co.	ET	1971	256	2,353	1/04-09-87	--	U	--
US-45-61-9__	R.G. Hollingsworth	ET	1943	152	2,431	01-27-47	133.30	S	K-44
US-45-62-4__	J.C. Mitchell	ET	1948	120	2,301	12-31-48	40.20	U	K-34
US-45-62-9A	Jack Adamson	ET	1948	--	2,311	12-28-48	53.70	I	L-24
US-45-62-9B	Looney & Haughton	ET	1948	130	2,283	12-28-48	34.80	U	L-57
US-45-63-701	D.S. Warren	ET	1946	138	2,303	12-09-46	53.58	I	L-37
						01-08-80	62.85		
						02-22-87	54.88		
US-45-63-703	Joe Duval	CA,K	1948	199	2,300	01-31-87	56.41	I	L-59
						1/04-09-87	--		
US-45-63-7__	J.W. Robbins	ET	1948	81	2,277	08-20-48	49.60	U	L-69
						10-03-57	70.40		
US-46-48-502	C.E. Davis	CA	1950	724	2,525	01-17-61	160.38	I	A-21
						01-08-74	235.56		
						02-19-87	245.02		
US-46-48-503	A.J. Hoelscher	--	1942	175	2,510	11-22-46	35.60	U	A-1
US-46-48-602	C.E. Davis	CA,K	1957	520	2,526	01-15-57	41.57	I	A-8
						01-14-81	80.27		
						02-19-87	93.71		
US-46-48-603	Crystal Water Farms	CA	1933	75	2,520	1933	50	U	A-10
US-46-48-604	C.E. Davis	CA	1955	425	2,528	01-15-58	132.68	I	A-17
						01-08-74	246.20		
						02-19-87	241.12		
US-46-48-701	Mobil Oil	CA	1964	654	2,683	12-17-64	152.00	U	--
						1/04-07-87	--		
US-46-48-801	Mrs. Branch	CA,K	1957	400	2,578	01-28-58	189.25	U	A-60
						01-11-78	245.49		
						02-19-87	245.92		
US-46-48-802	Hodge Estate	CA	1957	779	2,556	01-20-59	64.20	I	A-26
						01-14-81	121.69		
						02-19-87	136.27		

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well comple- tion	Depth of well (ft)	Altitude of land surface (ft)	Water levels		Use of water	Orig- inal well no.
						Date of measure- ment	Below land- surface datum (ft)		
US-46-48-8	J.W. Wristen	CA	--	187	2,588	01-06-50	73.00	U	A-62
US-46-48-902	A.J. Hoelscher	CA,K	1955	633	2,573	01-28-58	164.08	I	A-50
						01-14-81	244.16		
						02-19-87	234.21		
US-46-55-3	R.M. Reed	--	1906	140	2,625	1933	60	U	A-72
US-46-55-602	W.G. Locker & Sons	CA,K	1953	210	2,691	01-31-58	126.08	I	A-198
						01-09-80	153.47		
						02-19-87	154.97		
US-46-55-603	Gary Klase	CA,K	--	600	2,694	02-06-58	152.47	U	A-202
						01-09-80	237.80		
						02-19-87	217.96		
US-46-55-9A	W.W. Courtney	ET	1907	139	2,710	11-25-46	109.70	U	F-1
US-46-55-9B	W.W. Courtney	ET	--	160	2,720	11-25-46	133.80	U	F-12
US-46-56-1	P.D. Colville	CA	--	--	2,653	11-25-46	97.60	S	A-73
US-46-56-201	Pat Pelzel	CA	1955	865	2,622	01-30-58	212.50	--	A-86
						01-24-59	232.10		
						1/04-07-87	--		
US-46-56-306	R.C. Crabb	ET	--	750	2,554	06-02-76	287.90	U	--
						03-03-77	246.40		
						1/03-24-87	--		
US-46-56-404	Ralph Burkholder	--	1954	560	2,670	01-31-58	249.60	I	--
						01-09-80	411.62		
						02-19-87	376.53		
US-46-56-5	Lowe Bros.	--	1940	107	2,640	05-31-40	98.90	U	A-150
US-46-56-6	D.J. Sibley	ET	--	96	2,630	12-07-46	89.00	U	A-144
US-46-56-8	A.C. Butler	ET	--	147	2,675	11-29-46	120.70	U	A-229
US-46-62-3	Lee Weatherbee	ET	--	150	2,800	05-21-47	101.40	S	E-6
US-46-62-6	Mrs. H.D. Mendel	--	--	150	2,837	09-05-40	125.80	S	E-13
US-46-62-901	Mrs. Ada P. Criswell	--	1939	180	2,893	09-06-40	138.20	S	E-21
US-46-63-1	W.W. Courtney	ET	1900	92	2,740	03-01-40	70.00	S	E-4
US-46-63-201	- Lawrence	ET	--	193	2,813	04-29-58	111.90	--	E-9
						02-03-87	128.13		
US-46-63-5	Mrs. H.D. Mendel	--	--	159	2,850	11-28-46	136.20	S	E-11
3/US-46-63-802	A.B. Foster	ET	1957	372	2,919	08-15-57	202.15	I	F-94
						01-14-81	251.19		
						02-21-87	200.00		
						1/04-07-87	--		
US-46-63-902	Mrs. H.D. Mendel	ET	--	203	2,873	03-08-40	168.50	S	F-93
						01-29-76	177.45		
						02-20-87	180.30		
US-46-64-1	J.H. McIntyre	ET	--	192	2,775	03-08-40	166.60	S	F-62
US-46-64-201	Nelson Lethco	ET	1957	500	2,746	12-06-72	221.10	I	F-50
						01-27-87	296.25		
US-46-64-4	John McIntyre	ET	--	231	2,846	03-08-40	215.20	S	F-80
US-46-64-501	John McIntyre	ET	1938	320	2,825	11- -46	260	S	F-82
US-46-64-601	--	--	--	--	2,800	01-27-87	131.40	--	--
US-46-64-6	Ira Lethco	ET	1948	165	2,794	1948	48	S	F-85
US-46-64-7	Mrs. H.D. Mendel	ET	--	277	2,936	03-08-40	252.90	S	F-91
US-46-64-801	D.J. Sibley	ET	1939	381	2,868	12-04-46	159.40	H	F-89
US-46-64-8	Lee Ripps	ET	1942	160	2,830	11- -46	100	H,S	F-88
US-46-64-9	D.J. Sibley	ET	1945	505	2,922	11-22-46	118.50	S	F-87
US-52-05-9	Henry Wilbanks	ET	--	45	3,225	1947	400	S	M-4
US-52-06-2	J.R. Alexander	ET	1942	310	3,016	11-27-46	139.10	S	N-13
US-52-06-302	Mrs. H.D. Mendel	CA	--	237	2,979	04-17-58	160.85	S	N-11
						01-26-68	170.69		
						01-26-87	220.84		

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-52-06-401	Henry Wilbanks	ET	--	272	3,130	06-14-47	254.00	U	M-2
						01-28-87	231.68		
US-52-06-501	James Ensor	ET	1953	351	3,074	02-20-56	176.70	U	N-16
						01-13-81	188.95		
						02-20-87	188.21		
US-52-06-502	Texas Highway Dept.	ET	1938	225	3,076	06-18-42	172.50	P	N-19
						01-21-59	178.40		
						01-10-61	180.93		
						01-28-87	206.65		
US-52-06-503	Texas Highway Dept.	ET	1973	290	3,074	10-15-73	195.00	P	--
						1/06-23-87	--		
US-52-06-603	Pecos Co. WC&ID No. 1	ET	1987	597	3,040	05-11-87	250.00	P	--
						06-23-87	245.00		
US-52-06-604	Pecos Co. WC&ID No. 1, well 1	ET	1981	550	3,050	01-27-87	239.90	P	--
US-52-06-6A	J.R. Alexander	ET	1941	200	3,060	10-21-46	86.60	S	N-20
US-52-06-6B	City of Ft. Stockton	ET	1987	597	3,050	05-11-87	245.00	P	--
US-52-06-701	J.H. Hayter	--	1944	510	3,237	10-09-57	298.20	S	M-15
						02-09-87	323.90		
US-52-06-801	Emerson Tinkler	--	1956	400	3,168	10-15-57	211.60	S	N-26
						02-09-87	258.93		
US-52-07-303	A.B. Foster	ET	--	500	2,948	1/04-30-87	--	I	--
US-52-07-401	Henry Wilbanks	ET	--	300	3,090	10-15-57	194.90	U	N-25
						02-08-87	278.74		
US-52-07-6__	Mrs. H.D. Mendel	ET	--	160	2,992	11-28-46	97.80	S	P-33
US-52-07-701	M.R. Kennedy	ET	1961	455	3,125	09-06-57	160.49	H	N-30
						01-28-76	144.72		
US-52-07-801	H.D. Mendel	ET	--	205	3,041	09-05-57	122.10	S	N-22
						01-28-87	129.22		
US-52-07-902	- Riley	ET	--	--	--	1/04-29-87	--	--	P-52
US-52-08-3A	D.J. Sibley	ET	1928	350	2,977	12-04-46	20.60	H,S	P-10
US-52-08-3B	C.A. Wadsworth	ET	--	177	2,979	12-02-46	84.00	H	P-15
US-52-08-6__	R.D. Webb	ET	1938	289	3,050	10-31-46	34.00	S	P-18
US-52-08-801	George Baker	ET	--	139	3,086	06-16-47	84.20	S	P-62
						02-14-77	113.10		
						02-18-87	138.51		
US-52-08-902	Chandler Co.	ET	--	290	3,008	04-12-56	62.20	U	P-79
						04-30-59	100.00		
US-52-08-9__	Leon Land & Cattle Co.	ET,LEO	--	--	--	--	--	--	P-138
US-52-13-2__	Ralph Lindsey Estate	ET	--	500	3,312	06-18-47	316.40	H,S	M-20
US-52-13-301	J.H. Hayter	ET	--	360	3,295	06-14-47	334.30	S	M-14
US-52-13-302	--	ET	--	--	3,320	01-27-87	391.82	S	--
US-52-13-303	Emerson Tinkler	ET	--	235	3,383	10-15-57	226.10	S	M-16
						02-08-87	352.40		
US-52-13-7A	J.W. Stone	ET	1943	75	3,531	06-18-47	43.50	S	X-19
US-52-13-901	Gene Cartledge	ET	1941	240	3,488	06-17-47	212.10	H	X-24
						05-09-58	218.00		
						01-27-87	208.87		
						1/06-24-87	--		
US-52-14-1__	J.H. Hayter	ET	--	350	3,198	06-19-47	200.00	S	M-17
US-52-14-3__	Emerson Tinkler	ET	1944	40	--	1/02-09-87	--	S	N-27
US-52-14-801	M.R. Kennedy	ET	1910	200	3,307	09-26-57	96.30	S	Y-15
						01-29-87	101.34		
US-52-14-8__	M.R. Kennedy	ET	1943	230	3,294	05-12-47	187.60	S	Y-16

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-52-15-1__	M.R. Kennedy	ET	1933	415	3,180	06-09-47	194.80	S	N-29
US-52-15-201	M.R. Kennedy	ET	--	240	3,107	09-08-57	116.80	S	N-32
						02-03-87	125.03		
US-52-15-301	M.R. Kennedy	ET	--	160	3,121	09-08-57	135.00	S	P-137
						02-03-87	136.71		
US-52-15-4__	M.R. Kennedy	ET	--	275	3,198	06-09-47	140.50	H	Y-5
						09-26-57	217.80		
						1/02-03-87	--		
US-52-15-501	M.R. Kennedy	--	--	--	3,179	02-03-87	223.61	S	--
US-52-15-502	M.R. Kennedy	PR	--	1,000	3,219	05- -47	200	S	Y-10
						09-26-57	227.20		
						02-03-87	260.92		
US-52-15-901	M.R. Kennedy	ET	--	400	3,471	09- -57	225	S	Y-11
						02-04-87	226.47		
						1/06-24-87	--		
US-52-16-101	George Baker	ET	1946	294	3,162	06-16-47	168.80	S	P-135
						01-16-75	235.58		
						02-02-87	201.86		
US-52-16-1__	George Baker	ET	--	250	3,070	06-16-47	172.80	S	P-136
US-52-16-303	Wesley Whitman	ET	--	--	3,098	11-24-57	117.35	I	P-114
						01-15-81	136.05		
						02-18-87	133.89		
US-52-16-3__	Clayton Williams	ET	1946	446	3,083	12-17-46	66.30	I	P-117
US-52-16-401	George Baker	ET	--	396	3,292	06-16-47	300.40	S	Z-1
US-52-16-503	L.P. Williams	ET	1957	420	3,195	01-23-59	168.95	H	Z-12
						01-14-75	159.20		
						02-13-87	183.09		
US-52-16-5__	Clayton Williams	ET	--	176	3,167	11-19-46	136.50	S	Z-6
US-52-16-603	Clayton Williams	CA,K	1947	425	3,128	01-31-58	115.10	I	P-124
						10-30-62	162.27		
						02-18-87	78.78		
US-52-16-605	Chandler Co.	ET	1955	420	3,175	01-03-56	133.30	--	Z-25
						02-05-58	154.40		
						02-13-87	172.17		
US-52-16-608	Belding Farms	PR	1964	1,600	3,195	10-14-64	160.00	I	--
						01-15-81	166.82		
						02-13-87	143.85		
US-52-16-609	Belding Farms	PR	1964	1,975	3,192	10-15-64	160.00	I	--
						01-15-81	185.40		
						02-13-87	139.56		
US-52-16-610	Belding Farms	ET	1957	528	3,189	02-05-58	159.90	I	Z-26
						02-12-87	182.92		
US-52-16-611	Glenn Honaker	PR	1956	494	3,198	02-06-58	180.10	--	Z-34
						01-23-59	186.80		
						1/04-30-87	--		
US-52-16-6A	Chandler Co.	ET	--	146	3,164	11-19-46	77.80	U	Z-37
US-52-16-6B	--	ET	--	450	3,216	07-15-48	65.30	U	Z-32
US-52-16-802	City of Ft. Stockton	ET	1964	500	3,199	01-20-76	246.88	--	--
						12-11-79	217.80		
						12-17-80	207.85		
						02-22-87	186.40		
US-52-16-903	City of Ft. Stockton	ET	1962	500	3,225	07-15-83	256.00	--	--
						08-30-85	270.10		
						08-04-86	263.00		
						03-27-87	214.00		
US-52-16-904	City of Ft. Stockton	ET	1962	400	3,219	03-05-79	235.00	P	--
						1/03-25-87	--		

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-52-16-907	Ken McIntyre	--	1957	360	3,221	02-08-58	190.80	I	--
						02-13-87	211.88		
US-52-21-301	Gene Cartledge	ET	1941	350	3,517	05- -47	318	S	X-34
US-52-21-9	Graef Bros.	ET	1940	480	3,546	05- -47	329	S	HH-1
US-52-22-101	Gene Cartledge	ET	1941	469	3,387	05-09-58	162.40	S	X-27
						1/06-24-87	--		
US-52-22-1	--	ET	--	--	3,503	01-29-87	413.88	--	--
US-52-22-201	Gene Cartledge	ET	1943	250	3,383	05-08-58	262.10	S	Y-17
						01-29-87	175.13		
US-52-22-6	- Townsend	ET	--	160	3,365	05- -47	155	H	Y-18
US-52-22-7	Graef Bros.	ET	1941	400	--	06-23-56	397.20	S	HH-2
US-52-22-802	David McGill	ET	1956	419	3,484	03-05-56	120.00	I	HH-15
						02-14-77	157.61		
						02-15-87	161.56		
US-52-22-8	David McGill	ET	1928	200	3,438	06-17-47	147.60	S	HH-14
US-52-23-1	M.R. Kennedy	ET	--	460	3,401	09-26-57	346.00	S	Y-13
US-52-23-201	M.R. Kennedy	ET	1956	566	3,605	09-26-57	481.40	U	Y-12
						02-04-87	211.84		
US-52-23-3A	J.S. Oates	--	--	1,000	3,378	06-20-47	214.00	S	Z-60
4/US-52-23-3B	- Harrison	--	--	5,000	3,494	1/02-10-87	--	--	Z-59
US-52-23-501	M.R. Kennedy	ET	--	500	3,487	11-21-57	328.60	S	Y-21
						02-10-87	373.26		
US-52-23-602	Sherman Hammond	ET	--	425	3,385	06- -47	214	S	Z-61
						02-10-87	255.97		
US-52-24-101	Pete McIntyre	ET	--	252	3,310	06-20-47	200.50	S	Z-64
						07-14-48	192.50		
						05-22-57	211.50		
						1/06-24-87	--		
US-52-24-102	Ken McIntyre	ET	1969	350	3,330	02-11-87	256.89	--	--
US-52-24-1	J.S. Oates	ET	--	325	3,333	05-19-47	279.00	S	Z-63
						11- -57	300.00		
						1/02-11-87	--		
US-52-24-201	J.S. Oates	ET	--	560	3,379	06-21-47	267.70	S	Z-68
						11-21-57	314.80		
						02-11-87	349.90		
4/US-52-24-2A	- Alvis	--	1931	3,925	3,493	--	--	U	Z-70
US-52-24-2B	J.S. Oates	ET	--	500	--	05- -47	300	S	Z-72
						1/02-11-87	--		
US-52-24-301	W.I. Buchanan	ET	1956	693	3,377	01-28-58	316.50	I	Z-77
						01-24-59	320.90		
						02-11-87	341.73		
US-52-24-302	Clayton Williams	--	--	--	3,338	01-28-58	301.80	U	Z-75
						01-24-59	304.60		
						02-12-87	315.03		
US-52-24-501	Elsinore Cattle Co.	ET	1983	688	3,529	05-25-83	425.00	U	--
						02-14-87	419.15		
US-52-24-5	Elsinore Cattle Co.	--	1950	1,710	3,582	1950	390	U	Z-81
US-52-24-6	A.F. Buchanan	--	1918	840	--	1/02-11-87	--	S	Z-78
US-52-24-7	--	ET	--	651	3,730	02-14-87	596.00	S	--
4/US-52-31-1	Elsinore Cattle Co.	--	1951	1,400	3,702	--	--	U	HH-19
US-53-01-2	Ernest Riggs	ET	--	400	2,860	06-06-50	31.20	U	Q-8
US-53-01-3	T.W. Hillin	ET	1947	515	2,882	04-10-47	23.00	I	Q-28
US-53-01-402	Ernest Riggs	ET	1947	381	2,919	06-06-47	14.20	S	Q-130
						01-08-80	53.95		
						02-20-87	29.71		

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-53-01-4	Ernest Riggs	ET	--	100	2,905	12-03-46	1.40	S	Q-140
US-53-01-502	Ernest Riggs	ET	1946	335	2,879	12-03-46	38.90	S	Q-133
						02-15-58	28.70		
						01-08-80	47.19		
						02-20-87	29.52		
US-53-01-7__	Leon Land & Cattle Co.	ET	--	--	3,045	03-01-50	17.40	--	Q-156
US-53-01-8__	C.W. Williams	ET	--	346	3,066	06-28-49	137.70	H	Q-173
US-53-01-902	City of Ft. Stockton	ET	1946	180	2,981	10-21-46	51.80	U	Q-199
						01-10-80	80.00		
						02-20-87	57.50		
US-53-01-906	Pecos Co. WC&ID No. 1	ET,COM	--	--	2,928	2/05-20-58	--	U	Q-216
						1/04-08-87	--		
US-53-01-907	City of Ft. Stockton	ET	1956	390	3,045	09-15-53	225.00	P	Q-174
						1/04-29-87	--		
US-53-01-9__	Ft. Stockton ISD	--	--	240	2,973	02-07-87	60.64	P	--
US-53-02-102	Harrison Dyche	ET	1947	260	2,856	04-14-47	38.50	I	Q-40
						01-12-78	80.50		
						02-19-87	91.60		
US-53-02-2A	San Pedro Ranch	ET	1945	81	2,739	11-21-46	25.00	S	R-1
4/US-53-02-2B	San Pedro Ranch	--	--	3,955	--	--	--	U	R-4
US-53-02-3	San Pedro Ranch	ET	--	80	2,769	11- -46	18	S	R-11
US-53-02-403	Lee O. White	ET	1947	310	2,879	10-30-62	77.23	U	Q-72
						01-11-79	87.22		
						02-07-87	75.95		
US-53-02-6	- Word	ET	--	--	2,830	10-18-49	47.10	S	R-6
US-53-02-701	Pecos Co. WC&ID No. 1	ET	1951	297	2,921	09-07-51	67.30	U	Q-267
						02-07-87	53.91		
US-53-02-703	Burney Ligon	ET	1947	642	2,942	01-25-52	61.95	H	Q-286
						01-11-79	76.01		
US-53-02-705	Texas Highway Dept.	ET	1931	220	2,941	10-05-49	54.32	--	Q-222
						02-05-64	122.10		
						02-20-87	49.69		
3/US-53-02-7__	City of Ft. Stockton	ET	--	--	3,025	02-07-87	131.97	U	--
US-53-02-802	C.C. Davenport	ET	1953	300	2,915	11-01-57	75.80	I	R-39
						01-11-79	82.38		
						02-18-87	75.34		
US-53-03-201	University of Texas	CA,K	--	185	2,690	05-03-73	180.47	S	R-19
						01-28-87	161.59		
US-53-03-7	W.A. Stroman	ET	1939	250	2,881	04-14-47	62.30	S	R-26
US-53-03-901	Texas Highway Dept.	ET	--	462	2,876	01-17-48	136.20	U	S-36
						01-26-52	132.10		
						01-09-79	157.97		
						01-27-87	141.03		
US-53-03-9__	University of Texas	ET	--	250	2,984	04-14-47	208.40	S	R-23
US-53-04-2__	John Berry	ET	--	--	2,725	02-04-87	143.42	H	--
US-53-04-301	D.C. Ogden Wilson	ET	--	150	2,510	01-27-87	51.25	U	J-36
US-53-04-401	University of Texas	ET	--	235	2,857	01-28-47	174.70	S	S-33
						06-22-57	176.60		
						02-04-87	161.93		
US-53-04-7	University of Texas	ET	--	157	2,840	02-01-47	93.00	S	S-39
US-53-05-902	University of Texas	ET	--	200	2,542	02-01-47	106.10	S	T-31
						01-27-87	50.93		
US-53-06-3	Marshal Neville	ET	--	--	2,312	01-29-87	78.42	I	--
US-53-06-401	University of Texas	ET	--	--	2,472	04-29-87	74.70	U	--

See footnotes at end of table

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-53-06-501	Roy McDonald	ET	1948	425	2,410	04-23-48	78.10	I	U-50
						02-04-87	95.56		
US-53-06-701	University of Texas	ET	--	200	2,530	04-19-47	137.20	S	T-28
						01-28-87	145.33		
US-53-06-703	University of Texas	ET	1956	200	2,506	04-29-87	56.64	I	--
US-53-06-704	University of Texas	--	--	--	2,492	01-28-87	62.18	I	--
US-53-07-1	James Drgac	ET	--	--	2,311	01-29-87	68.89	I	--
US-53-07-201	M.E. Tripp	CA	1948	134	2,268	08-02-48	37.40	I	L-83
US-53-07-301	W.B. Wilson	CA,K	1948	235	2,264	07-29-48	48.41	I	V-4
US-53-07-3	--	CA,K	--	--	2,324	02-04-87	106.04	S	--
US-53-08-103	City of McCamey	ET	1955	318	2,350	1955	200.00	P	V-10
						1/03-25-87	--		
US-53-08-105	--	ET	--	--	--	1/03-25-87	--	--	--
US-53-08-401	City of McCamey	ET	1928	354	2,365	02-10-47	148.10	P	V-13
						05-24-59	168.90		
						01-30-87	200.93		
US-53-08-404	City of McCamey	ET	1954	328	2,367	05-24-57	192.30	P	V-9
						1/03-25-87	--		
US-53-08-4	Larry & Wilson	ET	1936	830	3,055	04- -47	800	--	V-32
US-53-08-501	City of Iraan	ET	1964	271	2,385	1/03-26-87	--	P	--
US-53-08-601	City of Iraan	ET	1963	260	2,384	08-09-63	157.00	P	--
						1/03-26-87	--		
						1/04-29-87	--		
US-53-08-602	City of Iraan	ET	1963	255	2,385	09-25-63	135.00	P	--
						1/03-26-87	--		
US-53-08-603	City of Iraan	ET	1971	276	2,355	09-16-71	130.00	P	--
						01-30-87	148.91		
						1/03-26-87	--		
US-53-08-8	Larry & Wilson	ET	--	250	2,527	04- -47	250	S	V-28
US-53-09-105	Joe Harrel	ET	1954	200	3,087	01-03-57	106.50	U	Q-322
						01-08-80	140.12		
						01-06-87	116.34		
4/US-53-09-2	University of Texas	--	1942	2,968	3,087	--	--	U	Q-309
US-53-09-301	Page Carson	ET	1954	210	3,012	02-17-58	77.70	U	Q-306
						01-13-81	119.09		
						02-05-87	93.24		
US-53-09-304	Santa Fe Railroad	ET	--	330	3,053	10-25-46	116.40	S	Q-179
						01-17-58	127.80		
						02-05-87	132.66		
US-53-09-3	University of Texas	ET	--	148	3,121	06-16-42	135.80	S	Q-310
US-53-09-403	Dow Puckett	CA,K	--	200	3,100	11-19-46	109.50	--	Q-335
US-53-09-4A	A.L. Price	ET	1915	198	3,208	01-15-42	163.30	H	AA-5
4/US-53-09-4B	Bill Wills	PR	1957	1,553	3,154	06-18-58	87.70	U	AA-6
US-53-09-5	University of Texas	ET	1938	220	--	05-17-58	219.20	S	AA-16
US-53-09-6	Rhoda Kelly	ET	--	211	3,123	11-24-49	112.00	S	AA-18
US-53-09-7	A.C. Mitchell	ET	--	245	3,288	06-15-42	227.10	H	AA-33
US-53-09-8	Dow Puckett	ET	--	325	3,344	11-16-46	283.80	H	AA-14
US-53-10-103	Jeff B. Wade	ET	1934	231	3,096	05-25-58	188.60	S	Q-295
						02-06-87	207.16		
US-53-10-1	Page Carson	ET	1947	1,547	3,009	06-06-47	16.90	U	Q-297
US-53-10-4	Rhoda Kelly	ET	--	170	3,070	11-14-46	126.50	S	Q-296
US-53-10-502	Jeff B. Wade	ET	1942	400	3,123	11-13-46	217.00	S	BB-1
						02-06-87	234.35		
US-53-10-5	A.L. Price	ET	--	300	3,080	11-15-46	46.60	S	BB-4
US-53-10-8	A.L. Price	ET	1941	270	3,119	11-15-46	70.00	S	BB-3
US-53-10-9	E.B. Carson	ET	1906	295	3,164	06-16-42	262.50	H	BB-15

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-53-11-501	Burch Woodward	ET	--	245	2,922	02-06-87	167.73	U	--
US-53-12-203	Jerry McKenzie	ET	1951	--	2,768	01-04-61	24.16	I	S-24
						01-08-80	37.80		
						02-20-87	28.76		
US-53-12-204	Transwestern Pipeline	--	1963	685	2,786	1/04-28-87	--	U	--
US-53-12-205	University of Texas	--	--	188	2,820	02-01-47	83.50	U	S-30
						07-11-57	68.90		
						02-06-87	79.43		
US-53-12-7__	Alph Harral	ET	--	300	2,951	05-07-47	188.80	S	CC-9
US-53-12-801	Laro McKenzie	ET	--	375	2,998	06-04-73	206.00	H	CC-10
						02-06-87	224.78		
US-53-13-1__	University of Texas	ET	--	--	2,644	02-06-87	31.37	S	--
US-53-13-201	University of Texas	ET	--	385	2,750	02- -47	210	S	DD-2
						07-03-57	219.50		
						04-10-87	161.47		
US-53-13-202	University of Texas, well 1	ET	1980	350	2,623	05-20-80	35.00	I	--
						04-08-87	30.83		
US-53-13-203	University of Texas, well 3	ET	1982	230	2,718	08-10-82	141.00	I	--
						1/04-10-87	141.22		
US-53-13-2__	University of Texas, well 16	ET	1984	397	2,638	02-05-84	60.00	I	--
						04-18-87	60.77		
US-53-13-501	University of Texas, well 4	ET	1980	290	2,800	12- -80	152.00	I	--
						04-28-87	152.12		
US-53-14-201	T.W. Hillin	--	--	244	2,660	02-06-87	183.76	U	--
US-53-14-501	Bill McKenzie	ET	--	387	2,910	06-05-73	334.60	S	EE-2
						01-31-87	333.73		
US-53-15-201	White Baker Estate	ET	--	150	2,830	04-19-47	119.30	S	U-80
						02-06-87	145.11		
US-53-15-4A	J.W. Owen	ET	--	400	--	04- -47	360	S	EE-7
US-53-15-4B	- Menzie	--	1926	365	2,820	05- -47	300	U	EE-12
US-53-15-502	Watts Ranch	ET	--	360	2,755	1/04-29-87	--	S	--
US-53-15-601	Sherbino Estate	ET	1939	503	2,924	01-05-47	440	S	FF-2
						01-30-87	270.39		
US-53-16-101	Texas Highway Dept.	ET	--	289	2,636	2/08-07-48	--	I	V-43
						02-04-87	249.16		
US-53-16-4A	F.A. Perry	ET	--	626	3,023	05- -47	590	--	FF-7
US-53-16-4B	F.A. Perry	ET	1940	590	--	05- -47	565	S	FF-9
US-53-16-5__	Worth Odom	ET	1938	634	--	05- -47	620	H	FF-14
US-53-16-7__	F.A. Perry	ET	1903	485	--	05- -47	460	H	FF-8
US-53-16-8__	Worth Odom	ET	1930	360	--	05- -47	360	S	FF-13
US-53-17-5__	Elsinore Cattle Co.	--	1951	1,516	3,445	03- -51	385.00	U	AA-37
US-53-17-9__	Elsinore Cattle Co.	--	1950	2,290	3,558	1950	365	U	KK-9
US-53-18-2A	A.L. Price	ET	1944	305	3,183	11-15-46	273.50	H	BB-16
US-53-18-2B	A.L. Price	ET	--	277	3,188	11-15-46	266.30	S	BB-18
US-53-18-4__	Elsinore Cattle Co.	--	1949	2,513	3,334	11-15-49	255.00	U	AA-42
US-53-18-6__	--	--	--	--	3,480	02-10-87	631.00	--	--
US-53-18-7__	Elsinore Cattle Co.	--	--	1,326	3,412	02- -50	475	U	AA-45
US-53-19-101	E.B. Carson	ET	1925	450	3,291	2/06-16-42	--	S	BB-30
						11- -46	400		
						1/04-11-87	--		
US-53-19-1__	E.B. Carson	ET	1941	430	--	11- -46	400	S	BB-13
US-53-19-801	Floyd Henderson	ET	--	700	3,430	2/10-28-58	--	S	LL-4
						1/04-11-87	--		
US-53-19-802	Floyd Henderson	ET	--	880	3,538	02-04-87	503.50	S	LL-5
US-53-19-902	Floyd Henderson	ET	--	1,064	3,420	1957	560	S	MM-5
						02-09-87	513.00		

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-53-19-9	--	ET	--	--	3,550	02-09-87	538.00	S	--
US-53-20-201	J.W. Robbins	ET	--	--	3,150	02-17-87	402.50	S	--
US-53-20-202	J.W. Robbins	ET	--	450	3,083	02-17-87	340.00	S	CC-30
US-53-20-301	J.W. Robbins	ET	--	550	3,240	1959	520	S	CC-17
						02-11-87	491.30		
US-53-20-302	J.W. Robbins	ET	1927	3,501	3,342	02-27-87	596.00	U	CC-19
US-53-20-401	--	ET	--	--	3,203	02-11-87	435.50	S	--
US-53-20-502	J.W. Robbins	ET	--	465	3,100	1957	430	H	CC-27
						02-11-87	420.75		
US-53-20-601	Transwestern Pipeline	ET	1963	600	2,689	1/04-28-87	--	U	--
US-53-20-6__	--	ET	--	--	3,280	02-17-87	608.00	S	--
US-53-20-7	--	ET	1972	530	3,258	02-04-87	475.00	S	--
US-53-20-901	Jerry Puckett	ET	--	684	3,320	02-17-87	632.00	S	--
US-53-20-9A	--	ET	--	742	3,305	02-11-87	631.00	U	--
US-53-20-9B	--	ET	--	740	3,352	02-17-87	692.00	U	--
US-53-21-301	--	--	--	680	3,220	1957	630	U	DD-19
						02-14-87	554.00		
US-53-21-3__	--	ET	--	--	3,240	02-09-87	561.00	U	--
US-53-21-5A	W.C. Mitchell	ET	1941	700	--	05- -47	520	S	DD-27
US-53-21-5B	Claude Owens	ET	1941	500	3,218	05- -47	470	S	DD-29
US-53-21-702	Jerry Puckett	ET	1956	850	3,326	02-15-87	653.00	S	DD-31
US-53-21-7	--	ET	--	725	3,346	02-09-87	690.50	S	--
US-53-21-901	Claude Owens	ET	--	450	3,035	10- -58	390	S	NN-3
						02-15-87	418.70		
US-53-22-101	W.W. Harral Ranch	ET	1949	587	3,190	1958	537	H	DD-20
						1/02-15-87	--		
US-53-22-201	W.A. Harral Ranch	ET	1905	450	2,970	06- -57	430	H	EE-29
						02-15-87	382.50		
US-53-22-601	Gene May	ET	--	459	2,796	02-14-87	267.10	U	--
US-53-22-602	Gene May	ET	1940	450	2,882	06-25-57	339.60	U	EE-37
						02-14-87	349.50		
US-53-22-901	Gene May	ET	1940	450	2,788	06-25-57	277.70	U	PP-5
						02-14-87	283.50		
US-53-23-201	Hat "A" Ranch	ET	--	--	2,945	02-15-87	475.00	S	--
US-53-23-2__	Arthur Harral	ET	1915	480	--	05- -47	400	H	EE-23
US-53-23-5__	G.A. Henshaw	--	1927	2,517	2,980	1927	595	U	EE-39
US-53-24-301	H.A. Wimberly	--	--	280	2,495	04- -47	175	S	FF-20
US-53-24-4__	Arthur Harral	ET	1940	785	2,930	05- -47	600	S	FF-30
US-53-25-101	Elsinore Cattle Co.	--	--	--	3,735	02-17-87	634.60	S	--
US-53-26-2__	Jack Allison	ET	--	240	3,575	04-04-58	153.10	S	KK-19
						02-15-87	109.80		
US-53-27-2__	--	--	--	--	3,396	02-04-87	657.50	S	--
US-53-27-3__	--	ET	--	--	3,365	02-04-87	677.00	S	--
US-53-27-9	West Pyle Cattle Co.	ET	1949	528	3,480	1949	485	S	MM-19
US-53-28-301	Marsha Lee Daggett	ET	--	--	3,465	02-16-87	740.35	S	--
US-53-28-3	Marsha Lee Daggett	ET	--	--	3,340	02-16-87	640.15	S	--
US-53-28-801	Guy S. Rachel	ET	1940	585	3,470	02- -47	570	S	MM-24
US-53-29-701	Marsha Lee Daggett	ET	--	--	3,310	02-16-87	455.00	S	--
US-53-31-201	Gerald Porter	ET	--	135	2,610	1/04-13-87	--	--	--
US-53-31-2__	P.C. Coats	ET	1907	135	2,528	05-06-47	132.40	H	PP-10
US-53-33-5__	Jack Allison	PU	1932	105	4,440	04- -58	80	S	RR-2
						02-13-87	64.50		

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels		Use of water	Original well no.
						Date of measurement	Below land-surface datum (ft)		
US-53-33-8__	Jack Allison	PU	--	240	4,218	1958	150.00	S	--
						02-07-87	29.00		
US-53-33-901	Jack Allison	PU	1950	220	4,105	04-04-58	113.50	S	RR-6
						1/04-14-87	--		
US-53-34-901	Faith Cattle Co.	ET	--	--	4,040	02-12-87	239.89	S	--
US-53-35-102	Faith Cattle Co.	ET	--	550	3,843	11-08-57	460.00	S	SS-4
						02-13-87	362.00		
						1/04-12-87	--		
US-53-35-802	Faith Cattle Co.	ET	--	--	3,655	02-12-87	95.03	S	--
US-53-36-1__	West Pyle Cattle Co.	ET	1946	337	3,455	1946	290	S	TT-3
US-53-41-101	Walter Groth	PU	--	270	4,187	02-07-87	111.30	S	--
US-53-41-3__	Jack Allison	--	1950	172	4,020	08-11-50	130.70	S	RR-5
US-53-42-401	West Pyle Cattle Co.	--	--	300	4,098	11-08-57	274.70	S	VV-13
						02-07-87	279.20		
US-53-42-901	Faith Cattle Co.	--	1950	360	3,998	1950	352	S	VV-10
						02-12-87	289.15		
						1/04-12-87	--		
US-53-43-1__	J.L. Nutt	--	1951	9,111	2,821	1/02-12-87	--	--	S-17
US-53-43-401	Faith Cattle Co.	--	1937	657	3,924	11- -57	500	S	VV-9
						02-12-87	278.53		
US-53-44-2__	West Pyle Cattle Co.	ET	1952	451	3,610	1952	397.00	S	TT-14
US-53-44-4__	West Pyle Cattle Co.	ET	1949	310	3,610	1949	280.00	S	WW-1
						11-07-57	280.80		
US-53-45-201	C.C. Mitchell	--	1943	565	3,310	02- -57	550	S	UU-22
						02-03-87	513.95		
US-53-45-2__	C.C. Mitchell	--	1928	3,010	3,490	02-04-87	404.32	S	UU-20
US-53-45-401	C.C. Mitchell	ET	--	600	3,210	1957	560.00	S	UU-33
						02-03-87	373.58		
US-53-45-501	C.C. Mitchell	ET	--	525	3,150	1957	400	H	UU-32
						2/10-09-58	--		
						02-03-87	393.45		
						1/04-10-87	--		
US-53-45-601	C.C. Mitchell	ET	1937	600	3,005	02- -57	560	S	UU-28
						1/02-03-87	--		
US-53-45-6__	C.C. Mitchell	ET	1937	600	3,123	1957	560	S	UU-29
						02-03-87	365.17		
US-53-46-101	Mrs. R.F. Spencer	ET	1928	650	3,080	02-03-87	482.00	S	UU-24
US-53-52-4__	H.A. Smith	ET	1940	710	--	10- -40	600	U	WW-15
US-54-01-702	G.C. Murray	ET	--	380	2,560	04- -47	220	S	W-50
						04- -57	368.00		
						02-04-87	247.12		
US-54-09-301	Yates Estate	ET	--	135	2,386	02-05-87	124.14	U	--
US-54-09-5__	Holmes & Monroe	ET	1937	680	2,905	04- -47	635	S	GG-8
US-54-09-6__	John Monroe	ET	1920	250	2,410	04- -47	200	H	GG-12
US-54-09-7__	C.C. Cannon	ET	--	300	2,428	05-01-47	190.90	S	GG-5
US-54-09-901	T.G. Thigpen	ET	--	210	2,270	04-29-47	93.60	S,H	GG-40
						02-04-87	95.45		
US-54-10-1__	I.G. Yates Estate	ET	1939	90	2,187	04-23-47	57.10	S	W-39
US-54-10-704	Millard Holmes	ET	1936	135	2,217	03-25-57	124.60	S	GG-19
						02-04-87	130.42		
US-54-10-7__	Herbert Holmes	ET	1942	172	--	04- -47	147	S	GG-26
US-54-17-402	Don Slaughter	ET	--	400	2,520	1/04-29-87	--	H	--
US-54-17-901	Blackstone & Slaughter	ET	--	300	2,434	05-14-57	275.50	S	GG-97
						02-05-87	271.45		
US-54-18-101	M.B. Monroe	ET	--	210	2,210	03-20-57	56.80	S	--
						02-03-87	56.14		
US-54-18-1__	Mrs. Jerry Monroe	ET	--	125	2,131	03-21-57	73.20	S	GG-58

See footnotes at end of table.

Table 2.--Records of wells and springs in Pecos County and adjacent counties--Continued

Well no. (pl. 2)	Owner	Aquifer and spring	Year of well completion	Depth of well (ft)	Altitude of land surface (ft)	Water levels: Date of measurement	Water levels: Below land-surface datum (ft)	Use of water	Original well no.
US-54-18-401	H.C. Noelke, Jr.	ET	1953	255	2,178	01-29-59	108.25	I	--
						12-08-72	94.53		
						02-03-87	100.53		
US-54-18-4__	Mrs. H.C. Noelke, Jr.	ET	--	190	2,260	04-30-47	166.60	S	GG-87
US-54-18-502	Mrs. H.C. Noelke, Jr.	ET	1946	180	2,158	04-11-47	75.30	I	GG-82
US-54-18-503	City of Sheffield, well 1	ET	1967	227	2,170	09-28-67	105.00	P	--
						02-03-87	134.97		
						1/03-26-87	--		
US-54-18-506	Don Jackson	ET	1987	184	2,170	04-13-87	142.00	H	--
WD-52-05-601	--	ET	--	--	3,104	01-28-87	213.93	--	--

1/ Water-quality analysis only; water level not measured.
2/ Historical water-quality analysis.
3/ The following wells have been renumbered because of relocation on topographic maps:

Well number used in this report	Well number prior to relocation
US-45-44-7--	US-45-52-101
US-45-51-105	US-45-50-301
US-45-52-105	US-45-51-301
US-46-63-802	US-46-63-901
US-53-02-7--	US-53-10-101

4/ Used for geologic control (fig. 7).

Table 3.--Source and significance of selected properties and constituents commonly reported in water analyses 1/

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; SMCL, secondary maximum contaminant level; mg/L, milligrams per liter; >, greater than; MCL, maximum contaminant level]

Property or constituent	Source or cause	Significance
Specific conductance (µS/cm)	Specific conductance is a measure of the ability of water to transmit an electrical current and depends on the concentrations of ionized constituents dissolved in the water. Many natural waters in contact only with granite, well-leached soil, or other sparingly soluble material have a conductance of less than 50 µS/cm. The specific conductance of some brines exceeds several hundred thousand microsiemens per centimeter.	The specific conductance is an indication of the degree of mineralization of a water and may be used to estimate the dissolved-solids concentration in the water.
pH (standard units)	The pH of a solution is a measure of its hydrogen ion activity. By definition, the pH of pure water at a temperature of 25 °C is 7.0. Natural waters contain dissolved gasses and minerals, and the pH may deviate significantly from that of pure water. Rainwater not affected by atmospheric pollution generally has a pH of 5.6 resulting from the solution of carbon dioxide from the atmosphere. The pH range of most natural surface and ground waters is about 6.0 to 8.5. Many natural waters are slightly basic (pH >7.0) because of the prevalence of carbonates and bicarbonates, which tend to increase the pH.	The pH of a domestic or industrial water supply is important because it may affect taste, corrosion potential, and water-treatment processes. Acidic waters may have a sour taste and cause corrosion of metals and concrete. The National Secondary Drinking-Water Regulations (U.S. Environmental Protection Agency, 1990b) set a pH range of 6.5 to 8.5 as the SMCL for public-water systems.
Hardness (mg/L as $CaCO_3$)	Hardness of water is attributable to all polyvalent metals but principally to calcium and magnesium ions expressed as $CaCO_3$ (calcium carbonate). Water hardness results naturally from the solution of calcium and magnesium, both of which are widely distributed in common minerals of rocks and soils. Hardness of waters in contact with limestone commonly exceeds 200 mg/L. In waters from gypsiferous formations, a hardness of 1,000 mg/L is not uncommon.	Hardness values are used in evaluating water quality and in comparing waters. The following classification is commonly used by the Geological Survey. Hardness as $CaCO_3$ (mg/L) — Classification 0 - 60 — Soft 61 - 120 — Moderately hard 121 - 180 — Hard >180 — Very hard Excessive hardness of water for domestic use is objectionable because it causes incrustations on cooking utensils and water heaters and increased soap or detergent consumption. Excessive hardness is undesirable also in many industrial supplies. (See discussions concerning calcium and magnesium.)
Alkalinity (mg/L as $CaCO_3$)	Alkalinity is a measure of the capacity of a water to neutralize a strong acid, usually to a pH of 4.5, and is expressed in terms of an equivalent calcium carbonate concentration. Alkalinity in natural waters usually is caused by the presence of bicarbonate and carbonate ions and to a lesser extent by hydroxide and minor acid radicals such as borates, phosphates, and silicates. Carbonates and and bicarbonates are common to most natural waters because of the abundance of carbon dioxide and carbonate minerals in nature. Direct contribution to alkalinity in natural waters by hydroxide is rare and usually can be attributed to contamination. The alkalinity of natural waters varies widely but rarely exceeds 400 to 500 mg/L as $CaCO_3$.	Alkaline waters may have a distinctive unpleasant taste. Alkalinity is detrimental in several industrial processes, especially those involving the production of food and carbonated or acid-fruit beverages. The alkalinity in irrigation waters in excess of alkaline earth concentrations may increase the pH of the soil solution, leach organic material, decrease permeability of the soil, and impair plant growth.
Calcium (mg/L as Ca)	Calcium is widely distributed in the common minerals of rocks and soils and is the principal cation in many natural freshwaters, especially those that contact deposits or soils originating from limestone, dolomite, gypsum, and gypsiferous shale. Calcium concentrations in freshwaters usually range from zero to several hundred milligrams per liter. Larger concentrations are not uncommon in waters in arid regions, especially in areas where some of the more soluble rock types are present.	Calcium contributes to the total hardness of water. Small calcium carbonate concentrations combat corrosion of metallic pipes by forming protective coatings. Calcium in domestic water supplies is objectionable because it tends to cause incrustations on cooking utensils and water heaters and increases soap or detergent consumption in waters used for washing, bathing, and laundering. Calcium also is undesirable in some industrial water supplies, particularly in waters used by electroplating, textile, pulp and paper, and brewing industries and in water used in high-pressure boilers.
Magnesium (mg/L as Mg)	Magnesium ranks eighth among the elements in order of abundance in the Earth's crust and is a common constituent in natural water. Ferromagnesian min-	Magnesium contributes to the total hardness of water. Large magnesium concentrations are objectionable in domestic water supplies because they can

Table 3.--Source and significance of selected properties and constituents commonly reported in water analyses--Continued

Property or constituent	Source or cause	Significance
Magnesium--continued	erals in igneous rock and magnesium carbonate in carbonate rocks are two of the more important sources of magnesium in natural waters. Magnesium concentrations in freshwaters usually range from zero to several hundred milligrams per liter; but larger concentrations are not uncommon in waters associated with limestone or dolomite.	exert a cathartic and diuretic action upon unacclimated users and increase soap or detergent consumption in waters used for washing, bathing, and laundering. Magnesium also is undesirable in some industrial supplies, particularly in waters used by textile, pulp and paper, and brewing industries and in water used in high-pressure boilers.
Sodium (mg/L as Na)	Sodium is an abundant and widespread constituent of many soils and rocks and is the principal cation in many natural waters associated with argillaceous sediments, marine shales, and evaporites and in sea water. Sodium salts are very soluble and once in solution tend to stay in solution. Sodium concentrations in natural waters vary from less than 1 mg/L in stream runoff from areas of greater precipitation to more than 100,000 mg/L in ground and surface waters associated with the halite deposits in arid areas. In addition to natural sources of sodium, sewage, industrial effluents, oilfield brines, and deicing salts may contribute sodium to surface and ground waters.	Sodium in drinking water may impart a salty taste and may be harmful to persons suffering from cardiac, renal, and circulatory diseases and to women with toxemias of pregnancy. Sodium is objectionable in boiler feedwaters because it may cause foaming. Large sodium concentrations are toxic to most plants; and a large ratio of sodium to total cations in irrigation waters may decrease the permeability of the soil, increase the pH of the soil solution, and impair drainage.
Potassium (mg/L as K)	Although potassium is only slightly less common than sodium in igneous rocks and is more abundant in sedimentary rocks, the potassium concentration in most natural waters is much smaller than the sodium concentration. Potassium is liberated from silicate minerals with greater difficulty than sodium and is more easily adsorbed by clay minerals and reincorporated into solid weathering products. Potassium concentrations more than 20 mg/L are unusual in natural freshwaters, but much larger concentrations are not uncommon in brines or in water from hot springs.	Large potassium concentrations in drinking water may impart a salty taste and act as a cathartic, but the range of potassium concentrations in most domestic supplies seldom causes these problems. Potassium is objectionable in boiler feedwaters because it may cause foaming. In irrigation water, potassium and sodium act similarly upon the soil, although potassium generally is considered less harmful than sodium.
Sulfate (mg/L as SO_4)	Sulfur is a minor constituent of the Earth's crust but is widely distributed as metallic sulfides in igneous and sedimentary rocks. Weathering of metallic sulfides such as pyrite by oxygenated water releases sulfate ions to the water. Sulfate also is dissolved from soils and evaporite sediments containing gypsum or anhydrite. The sulfate concentration in natural freshwaters may range from zero to several thousand milligrams per liter. Drainage from mines may add sulfate to waters by virtue of pyrite oxidation.	Sulfate in drinking water may impart a bitter taste and act as a laxative on unacclimated users. According to the National Secondary Drinking-Water Regulations (U.S. Environmental Protection Agency, 1990b), the SMCL for sulfate in public-water systems is 250 mg/L. Sulfate also is undesirable in some industrial supplies, particularly in waters used for the production of concrete, ice, sugar, and carbonated beverages and in waters used in high-pressure boilers.
Chloride (mg/L as Cl)	Chloride is relatively scarce in the Earth's crust but is the predominant anion in sea water, most petroleum-associated brines, and in many natural freshwaters, particularly those associated with marine shales and evaporites. Chloride salts are very soluble and once in solution tend to stay in solution. Chloride concentrations in natural waters vary from less than 1 mg/L in stream runoff from humid areas to more than 100,000 mg/L in ground and surface waters associated with evaporites in arid areas. The discharge of human, animal, or industrial wastes and irrigation return flows may add substantial quantities of chloride to surface and ground waters.	Chloride may impart a salty taste to drinking water and may accelerate the corrosion of metals used in water-supply systems. According to the National Secondary Drinking-Water Regulations (U.S. Environmental Protection Agency, 1990b), the SMCL for chloride in public-water systems is 250 mg/L. Chloride also is objectionable in some industrial supplies, particularly those used for brewing and food processing, paper and steel production, and textile processing. Chloride in irrigation water generally is not toxic to most crops but may be injurious to citrus and stone fruits.
Fluoride (mg/L as F)	Fluoride is a minor constituent of the Earth's crust. The calcium fluoride mineral fluorite is a widespread constituent of resistate sediments and igneous rocks, but its solubility in water is negligible. Fluoride commonly is associated with volcanic gases, and volcanic emanations may be important sources of fluoride in some areas. Fluoride concentrations in fresh surface waters usually are less than 1 mg/L; but larger concentrations are not uncommon in saline water from oil wells, ground	Fluoride in drinking water decreases the incidence of tooth decay when the water is consumed during the period of enamel calcification. Excessive quantities in drinking water consumed by children during the period of enamel calcification may cause a characteristic discoloration (mottling) of the teeth. According to the National Primary Drinking-Water Regulations (U.S. Environmental Protection Agency, 1990a), the MCL for fluoride in drinking water varies from 1.4 to 2.4 mg/L, depending upon the annual

Table 3.--Source and significance of selected properties and constituents commonly reported in water analyses--Continued

Property or constituent	Source or cause	Significance
Fluoride--continued	water from a wide variety of geologic terranes, and water from areas affected by volcanism.	average of the maximum daily air temperature for the area in which the water system is located. Excessive fluoride also is objectionable in water supplies for some industries, particularly in the production of food, beverages, and pharmaceutical items.
Silica (mg/L as SiO_2)	Silica ranks second only to oxygen in abundance in the Earth's crust. Contact of natural waters with silica-bearing rocks and soils usually results in a concentration range of about 1 to 30 mg/L; but concentrations as large as 100 mg/L are common in waters in some areas.	Although silica in some domestic and industrial water supplies may inhibit corrosion of iron pipes by forming protective coatings, it generally is objectionable in industrial supplies, particularly in boiler feedwater, because it may form hard scale in boilers and pipes or deposit in the tubes of heaters and on steam-turbine blades.
Dissolved solids (mg/L)	Theoretically, dissolved solids are anhydrous residues of the dissolved substance in water. In reality, the term "dissolved solids" is defined by the method used in the determination. In most waters, the dissolved solids consist predominantly of calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, and silica with minor or trace amounts of other inorganic and organic constituents. In areas of greater precipitation and relatively insoluble rocks, waters may contain dissolved-solids concentrations of less than 25 mg/L, but saturated sodium chloride brines in other areas may contain more than 300,000 mg/L.	Dissolved-solids concentrations are used widely to evaluate water quality and to compare waters. The following classification, based on the dissolved-solids concentrations, commonly is used by the Geological Survey (Winslow and Kister, 1956). The Classification — Dissolved-solids concentration (mg/L) Fresh — <1,000 Slightly saline — 1,000 - 3,000 Moderately saline — 3,000 - 10,000 Very saline — 10,000 - 35,000 Brine — >35,000 National Secondary Drinking-Water Regulations (U.S. Environmental Protection Agency, 1990b) set a dissolved-solids concentration of 500 mg/L as the SMCL for public-water systems. This level was set primarily on the basis of taste thresholds and potential physiological effects, particularly the laxative effect on unacclimated users. Although drinking waters containing more than 500 mg/L are undesirable, such waters are used without any obvious ill effects in many areas where less mineralized supplies are not available. Dissolved solids in industrial water supplies can cause foaming in boilers; interfere with clearness, color, or taste of many finished products; and accelerate corrosion. Uses of water for irrigation also are limited by excessive dissolved-solids concentrations. Dissolved solids in irrigation water may adversely affect plants directly by the development of high osmotic conditions in the soil solution and the presence of phytoxins in the water, or indirectly by their effect in soils.
Nitrogen (mg/L as N)	A considerable part of the total nitrogen of the Earth is present as nitrogen gas in the atmosphere. Small amounts of nitrogen are present in rocks, but the element is concentrated to a greater extent in soils or biological material. Nitrogen is a cyclic element and may be present in water in several forms. The forms of greatest interest in water, in order of increasing oxidation state, include organic nitrogen, ammonia nitrogen (NH_4-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N). These forms of nitrogen in water may be derived naturally from the leaching of rocks, soils, and decaying vegetation; from precipitation; or from biochemical conversion of one form to another. Other important sources of nitrogen in water include effluent from wastewater-treatment plants, septic tanks, and cesspools, and drainage from barnyards, feed lots, and fertilized fields. Nitrate is the most stable form of nitrogen in an oxidizing environment and is usually the dominant form of nitrogen in natural waters and in polluted waters that have undergone self-purification or aerobic treatment processes. Substantial quantities of reduced nitrogen often are present in some	Concentrations of any of the forms of nitrogen in water substantially greater than the local average may suggest pollution. Nitrate and nitrite are objectionable in drinking water because of the risk to bottle-fed infants for methemoglobinemia, a sometimes fatal illness related to the impairment of the oxygen-carrying ability of the blood. According to the National Primary Drinking-Water Regulations (U.S. Environmental Protection Agency, 1990a), the MCL for nitrate (as N) in drinking water is 10 mg/L. Although an MCL for nitrite is not specified in the drinking-water regulations, Appendix A to the regulations indicates that waters with nitrite concentrations (as N) greater than 1 mg/L should not be used for infant feeding. Excessive nitrate and nitrite concentrations also are objectionable in water supplies for some industries, particularly in waters used for the dying of wool and silk fabrics and for brewing.

Table 3.--Source and significance of selected properties and constituents commonly reported in water analyses--Continued

Property or constituent	Source or cause	Significance
Nitrogen--continued	ground waters, deep unoxygenated waters of stratified lakes and reservoirs, and waters containing partially stabilized sewage or animal wastes.	
Phosphorus (mg/L as P)	Phosphorus is a major component of the mineral apatite, which is widespread in igneous rock and marine sediments. Phosphorus also is a component of household detergents, fertilizers, human and animal metabolic wastes, and other biological material. Although small phosphorus concentrations may be present naturally in water as a result of leaching from rocks, soils, and decaying vegetation, larger concentrations are likely to be present as a result of pollution.	Phosphorus stimulates the growth of algae and other nuisance aquatic plants, which may impart undesirable tastes and odor to the water, become aesthetically unpleasant, alter the chemistry of the water supply, and affect water-treatment processes.

1/ Most of the material in this table has been summarized from several references. For a more thorough discussion of the source and significance of these and other water-quality properties and constituents, the reader is referred to the following additional references: American Public Health Association and others (1975); Hem (1985); McKee and Wolf (1963); National Academy of Sciences, National Academy of Engineering (1973); National Technical Advisory Committee to the Secretary of the Interior (1968); and U.S. Environmental Protection Agency (1990a,b).

Table 4.--Summary of regulations for selected water-quality properties and constituents for public-water systems 1/

[mg/L, milligrams per liter; °C, degrees Celsius]

Property or constituent 2/	Maximum contaminant level 3/	Secondary maximum contaminant level 4/
	Inorganic chemicals and related properties	
pH (standard units)	--	6.5 - 8.5
Sulfate (SO_4)	--	250 mg/L
Chloride (Cl)	--	250 mg/L
Fluoride	4 mg/L	2 mg/L
Dissolved solids	--	500 mg/L
Nitrate (as N)	10 mg/L	--

1/ Public-water system.--A system for the provision of piped water to the public for human consumption, if such system has at least 15 service connections or regularly serves at least 25 individuals daily at least 60 days out of the year.

2/ Constituent.--Any physical, chemical, biological, or radiological substance or matter in water.

3/ Maximum contaminant level.--The maximum permissible level of a contaminant in water that is delivered to the free-flowing outlet of the ultimate user of a public-water system. Maximum contaminant levels are those levels set by the U.S. Environmental Protection Agency (1990a) in the National Primary Drinking-Water Regulations. These regulations deal with contaminants that may have a substantial direct impact on the health of the consumer and are enforceable by Federal law.

4/ Secondary maximum contaminant level.--The advisable maximum level of a contaminant in water that is delivered to the free-flowing outlet of the ultimate user of a public-water system. Secondary maximum contaminant levels are those levels proposed by the U.S. Environmental Protection Agency (1990b) in the National Secondary Drinking-Water Regulations. These regulations deal with contaminants that may not have a substantial direct impact on the health of the consumer, but their presence in excessive quantities may affect the aesthetic qualities of the water and may discourage the use of a drinking-water supply by the public.

Table 5.--Specific conductance and dissolved-solids concentrations in water from selected wells and springs in Pecos County and adjacent county

County prefix: BK, Brewster; US, Pecos
Aquifer: ET, Edwards-Trinity; CA, Cenozoic alluvium; K, Cretaceous rocks, undifferentiated; PR, Permian Rustler; PU, Permian undivided
Spring: SA, Santa Rosa; DIA, Diamond Y; COM, Comanche

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data or unknown]

Well no. (pl. 2)	Date of sample	Aquifer and spring	Specific conductance (μS/cm)	Dissolved-solids concentration (mg/L)			Original well no.
				Estimated	Analyzed	Change 1/	
2/BK-52-30-104	06-24-87	ET	605	--	409	--	--
US-45-41-7B	12-14-49	ET,SA	3,220	--	2,330	--	B-40
US-45-41-7B	01-29-87	ET,SA	9,600	7,224	--	4,894	B-40
US-45-50-602	05-08-50	ET	7,460	--	5,020	--	C-157
US-45-50-602	01-28-87	ET	5,600	4,176	--	-844	C-157
US-45-51-7__	01-29-87	CA,K	8,160	--	--	--	--
2/US-45-52-901	04-09-87	CA,K	8,740	--	6,580	--	J-16
US-45-57-201	02-03-87	ET	4,550	3,376	--	--	--
US-45-57-801	05-10-43	ET,DIA	10,600	--	7,210	--	G-30
2/US-45-57-801	04-09-87	ET,DIA	7,100	--	5,580	-1,630	G-30
US-45-58-301	01-28-87	--	4,660	--	--	--	H-32
US-45-58-502	01-28-87	PR	4,030	--	--	--	H-76
US-45-58-605	10-30-46	ET	6,190	--	4,360	--	H-47
US-45-58-605	01-28-87	ET	5,150	3,833	--	-527	H-47
US-45-58-802	02-03-87	ET	3,400	2,500	--	--	H-79
2/US-45-59-501	04-09-87	CA	10,700	--	8,330	--	J-37
2/US-45-61-607	04-09-87	ET	2,540	--	1,800	--	--
2/US-45-63-703	04-09-87	CA,K	11,300	--	8,020	--	L-59
2/US-46-48-701	04-07-87	CA	3,160	--	2,450	--	--
2/US-46-56-201	04-07-87	CA	1,380	--	990	--	A-86

See footnotes at end of table.

Table 5.--Specific conductance and dissolved-solids concentrations in water from selected wells and springs in Pecos County and adjacent county--Continued

Well no. (pl. 2)	Date of sample	Aquifer and spring	Specific con- duct- ance (μS/cm)	Dissolved-solids concentration (mg/L) Estimated	Analyzed	Change 1/	Orig- inal well no.
3/US-46-56-306	03-24-87	ET	2,880	--	1,510	--	--
2/US-46-63-802	04-07-87	ET	952	--	594	--	F-94
US-52-06-302	01-26-87	CA	2,280	--	--	--	--
US-52-06-502	06-18-42	ET	--	--	442	--	N-19
US-52-06-502	01-28-87	ET	829	540	--	98	N-19
2/US-52-06-503	06-23-87	ET	1,020	--	653	--	--
2/US-52-06-603	06-23-87	ET	770	--	434	--	--
3/US-52-06-604	03-24-87	ET	785	--	419	--	--
US-52-06-701	02-09-87	--	676	--	--	--	M-15
US-52-06-801	02-09-87	--	607	--	--	--	N-26
2/US-52-07-303	04-30-87	ET	943	--	572	--	--
2/US-52-07-902	04-29-87	ET	1,590	--	1,150	--	P-52
US-52-08-801	05-05-47	ET	3,670	--	2,640	--	P-62
US-52-08-801	02-18-87	ET	2,570	1,867	--	-773	P-62
US-52-13-302	06-24-87	ET	750	480	--	--	--
US-52-13-303	02-09-87	ET	574	346	--	--	M-16
US-52-13-901	05-13-47	ET	774	--	505	--	X-24
2/US-52-13-901	06-24-87	ET	670	--	346	-159	X-24
US-52-14-1__	05-12-47	ET	707	--	508	--	M-17
US-52-14-1__	02-08-87	ET	560	336	--	-172	M-17
US-52-14-3__	02-09-87	ET	670	419	--	--	N-27
US-52-14-801	01-29-87	ET	550	328	--	--	Y-15
US-52-15-201	05-05-47	ET	614	--	420	--	N-32
US-52-15-201	02-03-87	ET	612	375	--	-45	N-32
US-52-15-301	02-03-87	ET	1,150	785	--	--	P-137

See footnotes at end of table.

Table 5.--Specific conductance and dissolved-solids concentrations in water from selected wells and springs in Pecos County and adjacent county--Continued

Well no. (pl. 2)	Date of sample	Aquifer and spring	Specific con-duct-ance (μS/cm)	Dissolved-solids concentration (mg/L) Estimated	Analyzed	Change 1/	Orig-inal well no.
US-52-15-4__	02-03-87	ET	930	617	--	--	Y-5
US-52-15-501	02-03-87	--	1,040	--	--	--	Y-8
US-52-15-502	02-03-87	PR	2,540	--	--	--	Y-10
US-52-15-901	05-17-47	ET	2,800	--	2,470	--	Y-11
2/US-52-15-901	06-24-87	ET	2,550	--	2,090	-380	Y-11
US-52-16-101	05-05-47	ET	1,090	--	680	--	P-135
US-52-16-101	02-02-87	ET	2,110	1,517	--	837	P-135
2/US-52-16-611	04-30-87	PR	2,140	--	1,540	--	Z-34
3/US-52-16-904	03-25-87	ET	3,020	--	1,520	--	--
2/US-52-22-101	06-24-87	ET	560	--	386	--	X-27
US-52-23-3B	02-10-87	--	906	--	--	--	Z-59
US-52-23-501	02-10-87	ET	1,940	1,387	--	--	Y-21
2/US-52-24-101	06-24-87	ET	1,530	--	917	--	Z-64
US-52-24-1__	02-11-87	ET	1,880	1,341	--	--	Z-63
US-52-24-2B	05-27-47	ET	1,910	--	1,200	--	Z-72
US-52-24-2B	02-11-87	ET	1,780	1,265	--	65	Z-72
US-52-24-6__	02-11-87	--	1,180	--	--	--	Z-78
US-53-01-906	05-20-58	ET,COM	2,130	--	1,350	--	Q-216
2/US-53-01-906	04-08-87	ET,COM	6,050	--	4,640	3,290	Q-216
2/US-53-01-907	04-29-87	ET	1,950	--	1,340	--	--
US-53-05-902	01-27-87	ET	3,860	2,850	--	--	T-31
2/US-53-06-703	04-29-87	ET	2,990	--	2,130	--	--
3/US-53-08-103	03-25-87	ET	3,530	--	1,740	--	--
3/US-53-08-105	03-25-87	ET	661	--	352	--	--

See footnotes at end of table.

Table 5.--Specific conductance and dissolved-solids concentrations in water from selected wells and springs in Pecos County and adjacent county--Continued

Well no. (pl. 2)	Date of sample	Aquifer and spring	Specific con-duct-ance (µS/cm)	Dissolved-solids concentration (mg/L)			Orig-inal well no.
				Estimated	Analyzed	Change 1/	
3/US-53-08-404	03-25-87	ET	1,820	--	900	--	V-9
3/US-53-08-501	03-26-87	ET	684	--	374	--	--
3/US-53-08-601	03-26-87	ET	984	--	514	--	--
2/US-53-08-601	04-29-87	ET	780	--	450	--	--
3/US-53-08-602	03-26-87	ET	715	--	381	--	--
3/US-53-08-603	03-26-87	ET	679	--	358	--	--
2/US-53-12-204	04-28-87	--	1,530	--	1,020	--	--
US-53-13-201	05-09-47	ET	667	--	427	--	DD-2
US-53-13-201	04-10-87	ET	563	338	--	-89	DD-2
2/US-53-13-203	04-10-87	ET	597	--	361	--	--
US-53-14-501	01-31-87	ET	4,100	3,033	--	--	--
2/US-53-15-502	04-29-87	ET	574	--	330	--	--
US-53-16-101	08-07-48	ET	560	--	319	--	V-43
US-53-16-101	02-04-87	ET	545	324	--	5	V-43
US-53-18-6__	02-10-87	--	410	--	--	--	--
US-53-19-101	06-16-42	ET	--	--	304	--	BB-30
2/US-53-19-101	04-11-87	ET	643	--	405	101	BB-30
US-53-19-801	10-28-58	ET	640	--	392	--	LL-4
2/US-53-19-801	04-11-87	ET	597	--	375	-17	LL-4
US-53-19-902	02-09-87	ET	387	204	--	--	MM-5
US-53-20-401	02-11-87	ET	389	205	--	--	--
US-53-20-502	02-11-87	ET	580	351	--	--	CC-23
2/US-53-20-601	04-28-87	ET	630	--	369	--	--
US-53-22-101	02-15-87	ET	506	294	--	--	--
US-53-27-3__	02-04-87	ET	311	146	--	--	--

See footnotes at end of table.

Table 5.--Specific conductance and dissolved-solids concentrations in water from selected wells and springs in Pecos County and adjacent county--Continued

Well no. (pl. 2)	Date of sample	Aquifer and spring	Specific con- duct- ance (μS/cm)	Dissolved-solids concentration (mg/L)			Orig- inal well no.
				Estimated	Analyzed	Change 1/	
US-53-31-201	05-06-47	ET	1,010	--	667	--	PP-10
2/US-53-31-201	04-13-87	ET	1,070	--	704	37	PP-10
US-53-33-901	04-04-58	PU	957	--	600	--	RR-6
2/US-53-33-901	04-14-87	PU	1,560	--	1,050	450	RR-6
2/US-53-35-102	04-12-87	ET	470	--	299	--	SS-4
US-53-35-802	02-12-87	ET	757	486	--	--	--
US-53-41-101	02-07-87	PU	1,010	--	--	--	--
US-53-42-401	02-07-87	--	424	--	--	--	VV-13
2/US-53-42-901	04-12-87	--	426	--	264	--	VV-10
US-53-43-1__	02-12-87	--	573	--	--	--	S-17
US-53-45-2__	02-03-87	--	387	--	--	--	--
US-53-45-401	02-03-87	ET	388	204	--	--	UU-33
US-53-45-501	10-09-58	ET	384	--	224	--	UU-32
2/US-53-45-501	04-10-87	ET	375	--	251	27	UU-32
US-53-45-601	02-03-87	ET	387	204	--	--	UU-28
2/US-54-17-402	04-29-87	ET	498	--	289	--	--
3/US-54-18-503	03-26-87	ET	580	--	310	--	--
2/US-54-18-506	04-13-87	ET	584	--	368	--	--

1/ Change between historical and 1987 concentrations. Dissolved-solids concentrations for 1950 and 1958 were used for Comanche Springs and some wells in eastern Pecos County when historical data were not available.
2/ Collected and analyzed by U.S. Geological Survey.
3/ Collected and analyzed by Texas Water Development Board.

Table 6.--Water-quality data from selected wells and springs in Pecos County and adjacent county, 1987

County prefix: BK, Brewster; US, Pecos
Aquifer: ET, Edwards-Trinity; CA, Cenozoic alluvium; K, Cretaceous rocks, undifferentiated; PR, Permian Rustler; PU, Permian undivided
Spring: DIA, Diamond Y; COM, Comanche

[ft, feet; gal/min, gallons per minute; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; --, unknown or no data; mg/L, milligrams per liter; <, less than]

Well no. (pl. 2)	Date of sample	Time	Aquifer and spring	Depth of well, total (ft)	Pump or flow period prior to sampling (minutes)	Flow rate, instantaneous (gal/min)	Specific conductance (µS/cm)	pH (standard units)	Temperature, water (°C)
BK-52-30-104	06-24-87	1025	ET	--	10	1.7	605	7.7	22.5
US-45-52-901	04-09-87	1645	CA,K	100	10	10	8,740	7.1	22.0
US-45-57-801	04-09-87	0830	ET,DIA	--	60	450	7,100	7.1	18.0
US-45-59-501	04-09-87	1530	CA	--	10	10	10,700	7.0	20.0
US-45-61-607	04-09-87	1230	ET	256	60	110	2,540	6.9	21.0
US-45-63-703	04-09-87	1330	CA,K	199	30	800	11,300	6.9	20.5
US-46-48-701	04-07-87	1630	CA	654	60	40	3,160	7.2	20.0
US-46-56-201	04-07-87	1130	CA	865	60	700	1,380	7.4	23.5
US-46-63-802	04-07-87	0900	ET	372	60	1,000	952	7.1	23.0
US-52-06-503	06-23-87	1455	ET	290	10	5.0	1,020	7.6	--
US-52-06-603	06-23-87	1530	ET	597	10	175	770	7.6	23.5
US-52-07-303	04-30-87	1030	ET	500	10	50	943	7.0	23.0
US-52-07-902	04-29-87	1730	ET	650	10	100	1,590	7.1	--
US-52-13-901	06-24-87	1417	ET	240	10	1.0	670	7.3	23.0
US-52-15-901	06-24-87	0645	ET	400	10	2.8	2,550	7.5	22.5
US-52-16-611	04-30-87	1240	PR	483	10	850	2,140	6.9	26.0
US-52-22-101	06-24-87	1240	ET	469	10	.5	560	7.6	.0
US-52-24-101	06-24-87	0905	ET	252	10	1.7	1,530	7.6	22.5
US-53-01-906	04-08-87	0930	ET,COM	--	60	100	6,050	6.9	18.0
US-53-01-907	04-29-87	1330	ET	390	10	250	1,950	6.9	22.0
US-53-06-703	04-29-87	0915	ET	200	10	800	2,990	7.0	21.5
US-53-08-601	04-29-87	0930	ET	261	10	250	780	7.1	21.5
US-53-12-204	04-28-87	1110	--	685	10	15	1,530	6.9	21.0
US-53-13-203	04-10-87	0930	ET	372	60	105	597	7.1	21.0
US-53-15-502	04-29-87	1605	ET	360	10	2.0	574	6.9	21.5
US-53-19-101	04-11-87	1640	ET	450	10	40	643	7.1	23.0
US-53-19-801	04-11-87	0745	ET	700	10	4.0	597	7.3	18.0
US-53-20-601	04-28-87	1020	ET	600	10	140	630	7.2	22.5
US-53-31-201	04-13-87	1140	ET	135	10	8.0	1,070	7.1	21.0
US-53-33-901	04-14-87	1045	PU	220	10	1.0	1,560	7.1	20.0
US-53-35-102	04-12-87	1130	ET	550	10	3.0	470	7.1	23.0
US-53-42-901	04-12-87	1525	--	360	10	2.0	426	7.1	22.5
US-53-45-501	04-10-87	1030	ET	525	10	1.0	375	7.4	18.0
US-54-17-402	04-29-87	1405	ET	400	10	20	498	7.1	21.5
US-54-18-506	04-13-87	1600	ET	184	10	15	584	7.1	22.0

Table 6.--Water-quality data from selected wells and springs in Pecos County and adjacent county, 1987--Continued

Well no. (pl. 2)	Hardness, total (mg/L $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Alkalinity, field (mg/L $CaCO_3$)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)
BK-52-30-104	210	58	70	7.8	36	3.9	150	46	16
US-45-52-901	2,400	2,100	550	240	1,300	30	230	2,000	2,300
US-45-57-801	2,000	1,700	430	220	1,000	28	280	2,300	1,400
US-45-59-501	3,400	3,100	830	330	1,500	33	360	2,300	3,100
US-45-61-607	950	750	260	73	220	9.0	200	710	390
US-45-63-703	3,800	3,600	830	430	1,300	15	200	2,100	3,200
US-46-48-701	1,100	940	330	60	340	12	130	1,200	400
US-46-56-201	370	190	110	24	170	8.1	180	430	120
US-46-63-802	370	190	110	23	64	5.1	180	160	100
US-52-06-503	390	220	120	23	61	4.8	180	200	73
US-52-06-603	270	79	83	16	43	4.6	200	94	60
US-52-07-303	340	160	100	23	65	5.1	190	150	96
US-52-07-902	580	410	170	38	140	6.3	170	480	190
US-52-13-901	260	21	85	11	17	3.2	240	24	12
US-52-15-901	1,300	1,100	360	98	120	5.9	160	1,300	51
US-52-16-611	700	480	200	49	250	10	220	530	350
US-52-22-101	320	25	110	11	7.8	7.0	300	17	15
US-52-24-101	340	140	87	31	180	8.0	200	270	190
US-53-01-906	1,900	1,600	470	170	790	35	260	1,800	1,200
US-53-01-907	620	410	170	48	220	10	210	410	340
US-53-06-703	940	730	230	90	350	11	220	630	660
US-53-08-601	320	93	80	28	45	2.2	220	64	80
US-53-12-204	490	260	130	40	160	8.4	230	290	230
US-53-13-203	250	65	77	15	29	1.9	190	61	41
US-53-15-502	240	51	65	19	26	1.6	190	48	36
US-53-19-101	240	48	72	15	49	3.3	190	89	39
US-53-19-801	170	0	44	15	71	5.5	210	76	24
US-53-20-601	270	59	86	13	26	3.2	210	62	35
US-53-31-201	370	160	100	29	89	5.1	210	180	150
US-53-33-901	660	400	110	93	110	7.7	260	270	240
US-53-35-102	240	67	57	24	14	1.7	170	52	16
US-53-42-901	210	21	60	14	13	1.5	190	18	8.7
US-53-45-501	180	11	59	8.3	11	7.0	170	23	14
US-54-17-402	230	36	62	19	16	1.6	200	42	15
US-54-18-506	260	52	79	16	27	1.8	210	28	54

Table 6.--Water-quality data from selected wells and springs in Pecos County and adjacent county, 1987--Continued

Well no. (pl. 2)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, nitrite, total (mg/L)	Nitrogen, NO_2+NO_3, total (mg/L)	Nitrogen, ammonia, total (mg/L)	Nitrogen, ammonia + organic, total (mg/L)	Nitrogen, total (mg/L)	Phosphorus total (mg/L)
BK-52-30-104	0.5	43	409	--	--	--	--	--	--
US-45-52-901	2.5	21	6,580	0.01	2.7	0.16	2.1	4.8	0.01
US-45-57-801	2.4	30	5,580	.01	5.5	.16	.90	6.4	.01
US-45-59-501	1.8	21	8,330	<.01	<.10	.31	.50	--	<.01
US-45-61-607	2.2	12	1,800	<.01	1.0	.07	.50	1.5	<.01
US-45-63-703	1.4	23	8,020	<.01	12.	.26	2.3	14	.01
US-46-48-701	1.2	24	2,450	.02	1.2	.10	.60	1.8	<.01
US-46-56-201	1.3	17	990	<.01	.80	.03	.20	1.0	<.01
US-46-63-802	.9	21	594	<.01	5.6	.03	1.2	6.8	.01
US-52-06-503	.7	16	653	--	--	--	--	--	--
US-52-06-603	.8	16	434	--	--	--	--	--	--
US-52-07-303	.9	19	572	<.01	1.4	.06	.20	1.6	.01
US-52-07-902	.8	17	1,150	<.01	2.9	.08	.50	3.4	.01
US-52-13-901	.6	39	346	--	--	--	--	--	--
US-52-15-901	2.2	14	2,090	--	--	--	--	--	--
US-52-16-611	1.6	21	1,540	<.01	1.0	.08	.50	1.5	.01
US-52-22-101	.4	24	386	--	--	--	--	--	--
US-52-24-101	1.5	20	917	--	--	--	--	--	--
US-53-01-906	1.8	22	4,640	<.01	8.9	.16	1.3	10	.01
US-53-01-907	1.4	13	1,340	<.01	<.10	.07	.20	--	<.01
US-53-06-703	1.7	21	2,130	<.01	1.5	.10	.70	2.2	.01
US-53-08-601	1.1	17	450	<.01	1.3	.04	.80	2.1	.01
US-53-12-204	1.6	20	1,020	<.01	1.9	.06	.50	2.4	.01
US-53-13-203	1.1	16	361	--	--	--	--	--	--
US-53-15-502	1.3	19	330	<.01	1.9	.03	.60	2.5	.01
US-53-19-101	1.4	15	405	--	--	--	--	--	--
US-53-19-801	1.7	10	375	--	--	--	--	--	--
US-53-20-601	.7	17	369	<.01	2.6	.04	.40	3.0	.01
US-53-31-201	1.2	18	704	--	--	--	--	--	--
US-53-33-901	1.1	23	1,050	--	--	--	--	--	--
US-53-35-102	1.4	23	299	--	--	--	--	--	--
US-53-42-901	.3	22	264	--	--	--	--	--	--
US-53-45-501	.5	16	251	--	--	--	--	--	--
US-54-17-402	1.4	14	289	<.01	.80	.03	.60	1.4	.02
US-54-18-506	1.0	23	368	--	--	--	--	--	--

*U.S. GOVERNMENT PRINTING OFFICE: 1993-761-876