INTRODUCTION

The Edwards-Trinity aquifer system is a sequence of near-surface, hydraulically connected, Cretaceous carbonate and quartzose clastic rocks that underlie about 42,000 mi² of west-central Texas (fig. 1). The aquifer system is currently (1991) being studied as a part of the U.S. Geological Survey's Regional Aquifer-System Analysis (RASA) program, which is intended to describe the regional hydrogeology of important aquifer systems nationwide.

The purpose of this report is to present a potentiometric-surface map of the principal aquifers of the Edwards-Trinity aquifer system based on the earliest available data; to explain in general terms what the potentiometric surface represents relative to rainfall conditions and ground-water withdrawals; and to discuss the major factors that control the configuration of the potentiometric surface.

The map portrays regional water-level patterns over broad areas rather than precise water-level altitudes at specific sites. The water-level data used to construct the map span 6 decades. Therefore the data reflect a wide range of rainfall conditions and not a regional average, or a dry or wet condition that would likely characterize a synoptic map. Rainfall conditions during and preceding the dates of water-level measurements are qualitatively indicated to denote whether the potentiometric contours represent a normal, dry, or wet condition. The map includes contiguous units in areas where ground-water flow does not stop at the boundaries of the Edwards-Trinity aquifer system and where water-level data in units contiguous to the aquifer system are available.

As originally planned, the map was to represent the potentiometric surface as it existed prior to ground-water development (prior to withdrawal of substantial quantities of ground water, also referred to subsequently as predevelopment). As shown, the map represents the predevelopment condition in most areas of the system, because ground-water withdrawals were negligible when the water-level measurements used to construct the map were made. However, in some areas withdrawals caused measurable declines in water levels before many water levels were obtained.

Even if a potentiometric-surface map representing the predevelopment condition could be made, it probably would not represent conditions unaffected by human activities. According to Brune (1981, p. 35-36), vast cattle herds in the 19th century overgrazed and destroyed many native prairie grasses. This destructive process allowed the turf to become so compacted that infiltration of rainfall, and thus recharge to the aquifers beneath the prairies, was appreciably reduced. Replacement of the grasses by deep-rooted brush such as mesquite increased transpiration rates and correspondingly reduced recharge rates. Brune also states that in the mid-1800's, flowing wells could be drilled "nearly everywhere." So many were drilled and allowed to flow unrestricted that declines of potentiometric heads caused most of the wells to cease flowing. On the basis of Brune's observations, the original potentiometric surface of the Edwards-Trinity aquifer system would probably have been higher than the potentiometric surface shown in this report. Nevertheless, the potentiometric surface of this report is considered to be a suitable benchmark from which to measure past and future regional water-level changes.

Five regional hydrogeologic units compose the Edwards-Trinity aquifer system (fig. 2). Three aquifers--the Edwards, the Trinity, and the Edwards-Trinity--comprise the permeable parts of the system. These aquifers are laterally adjacent except in the southeastern part of the system where part of the Trinity aquifer is overlain by the Edwards aquifer. Two mappable confining units are part of the aquifer system. The Navarro-Del Rio confining unit directly overlies the downdip part of the Edwards aquifer, thereby confining the southeastern fringe of the aquifer system. Except locally, the remainder of the aquifer system is unconfined or nearly so. The Hammett confining unit is within the Trinity aquifer where the Trinity is not overlain by the Edwards, and within the southeastern part of the Edwards-Trinity aquifer. The westernmost extent of the Hammett confining unit currently (1991) is not accurately known.

The Edwards-Trinity aquifer system is hydraulically connected to contiguous units along the northern and southeastern boundaries (fig. 1). The principal contiguous hydraulically connected units are the High Plains aquifer to the north and the Cenozoic Pecos alluvium aquifer along the Pecos River (fig. 2). Several minor aquifers in rocks of pre- and post-Cretaceous age are between the aquifer system and the Colorado River. A freshwater/saline-water transition zone bounds the aquifer system along its southeastern margin.

For descriptive purposes, the aquifer system is divided into four geographic subareas named the Balcones fault zone, the Hill Country, the Edwards Plateau, and the Trans-Pecos (fig. 2). As used in this report, the Balcones fault-zone subarea coincides with the area where the Edwards aquifer is the principal aquifer. The Hill Country subarea coincides with the area where the Trinity aquifer is the principal aquifer. Although the Trinity aquifer exists beneath the Edwards aquifer in the Balcones fault zone, it is not the principal aquifer there. The Edwards Plateau and the Trans-Pecos subareas together coincide with the area of the Edwards-Trinity aquifer. The two subareas are separated by the Pecos River.

Various stratigraphic units compose the aquifers in each of the four subareas (fig. 3). Water-level data show that, in places heads within aquifers vary considerably--several tens of feet or more--with depth, depending upon the units tapped by a well. Vertical head differences are particularly prominent among stratigraphic units in the Hill Country. The Trinity aquifer in the Hill Country can be divided into three water-yielding zones: The upper Trinity (upper Glen Rose Limestone), the middle Trinity (lower Glen Rose Limestone, Hensel Sand, and Cow Creek Limestone), and the lower Trinity [Sycamore Sand (updip), Sligo Formation (downdip), and Hosston Formation]. In places, distinct potentiometric surfaces can be associated with each of the three zones. The potentiometric-surface map of this report reflects heads in the middle Trinity aquifer because that zone is the most widely used source of ground water in the Hill Country (Ashworth, 1983, p. 60).

Average annual rainfall on the Edwards-Trinity aquifer system during 1951-80 was about 20 in/yr. More rain falls on the eastern part than on the western part. For the 1951-80 period, the Balcones fault zone averaged about 28 in/yr; the Hill Country, about 30 in/yr; the Edwards Plateau, about 19 in/yr; and the Trans-Pecos, about 13 in/yr.

HISTORICAL POTENTIOMETRIC SURFACE

The historical potentiometric surface of the Edwards-Trinity aquifer system and contiguous hydraulically connected units (sheet 3) is based on water-level (or pressure-head) measurements made in 1,789 wells between December 1915 and November 1969. The largest number of measurements were made during two periods. Fifty-four percent of the measurements were made during 1934-41; 20 percent were made during 1961-64. For each county, the earliest recorded measurements were sought from published reports and unpublished data in the files of the U.S. Geological Survey in Austin and the Texas Water Development Board in Austin. If measurements in a given county were plentiful, an effort was made to select measurements from a single time period--for example, a month or group of months within a year--although in some instances, selecting a synoptic group of measurements meant excluding a few older measurements. The only water levels selected for use were those based on measured depths below (or above) land-surface altitudes obtained from instrument levels or 1:24,000-scale topographic maps. Water levels were not used if the stratigraphic units to which a well was open were unknown or could not be assumed with confidence, or if the date of measurement (year and month) were unknown.

Water levels in all areas of the aquifer system fluctuate in response to variations in rainfall. An early hydrograph of the water level in a well in the Edwards aquifer in the city of San Antonio shows a rise of 27 ft between the summer of 1913 and the end of that year, attributable to abundant rainfall in September and October 1913 (Livingston and others, 1936, p. 95). Although water levels in other aquifers of the system probably fluctuate less in response to variations in rainfall than those in the Edwards, the configuration of the potentiometric surface in a given area can be noticeably influenced by rainfall conditions preceding the water-level measurements. The well-location symbols on the map qualitatively indicate rainfall conditions associated with the historical potentiometric surface. Each symbol represents one of five categories of rainfall conditions--very dry, moderately dry, near normal, moderately wet, and very wet--that prevailed, on the average, during the 3-month season in which a measurement was made and the three preceding 3-month seasons. The rainfall categories represent ranges of seasonal total rainfall for areal climatic divisions based on frequency analyses of rainfall from 1895-1985 (Karl and Knight, 1985a, b, c, d). Karl and Knight defined the ranges of seasonal total rainfall such that the probability of occurrence of near normal conditions (that is, seasonal total rainfall in the near normal category) is 40 percent; the probability of occurrence of moderately dry or moderately wet conditions is 15 percent; and the probability of occurrence of very dry or very wet conditions is 10 percent. They also defined two additional categories--extremely dry and extremely wet--each with a probability of occurrence of less than 5 percent. None of the rainfall categories symbolized on the map were in either extreme range because four-season averaging attenuated the data.

Dry or wet rainfall conditions tend to be cyclic and fairly consistent across the area of the aquifer system, as shown by the five-season moving average of rainfall conditions in each of the four climatic divisions that together include the area of the aquifer system (fig. 5). During 1934-41, when more than one-half the water-level measurements were made, average rainfall conditions in each climatic division were variable, favoring neither dry nor wet periods. Average conditions during 1961-64, when another one-fifth of the measurements were made were generally drier than normal. Less than 5 percent of the measurements used for the map were made during the prolonged region-wide drought of 1951-56.

Assuming that rainfall conditions at the well locations are accurately represented by the four-season regional averages computed from the data of Karl and Knight (1985a, b, c, d), near-normal rainfall conditions preceded 55 percent of the 1,789 measurements upon which the historical potentiometric-surface map is based. Moderately dry conditions preceded 20 percent of the measurements; moderately wet conditions preceded 22 percent of the measurements; very dry conditions preceded less than 1 percent; and very wet conditions preceded about 3 percent. Thus, on a regional basis, the potentiometric surface does not disproportionately represent either wet or dry conditions.

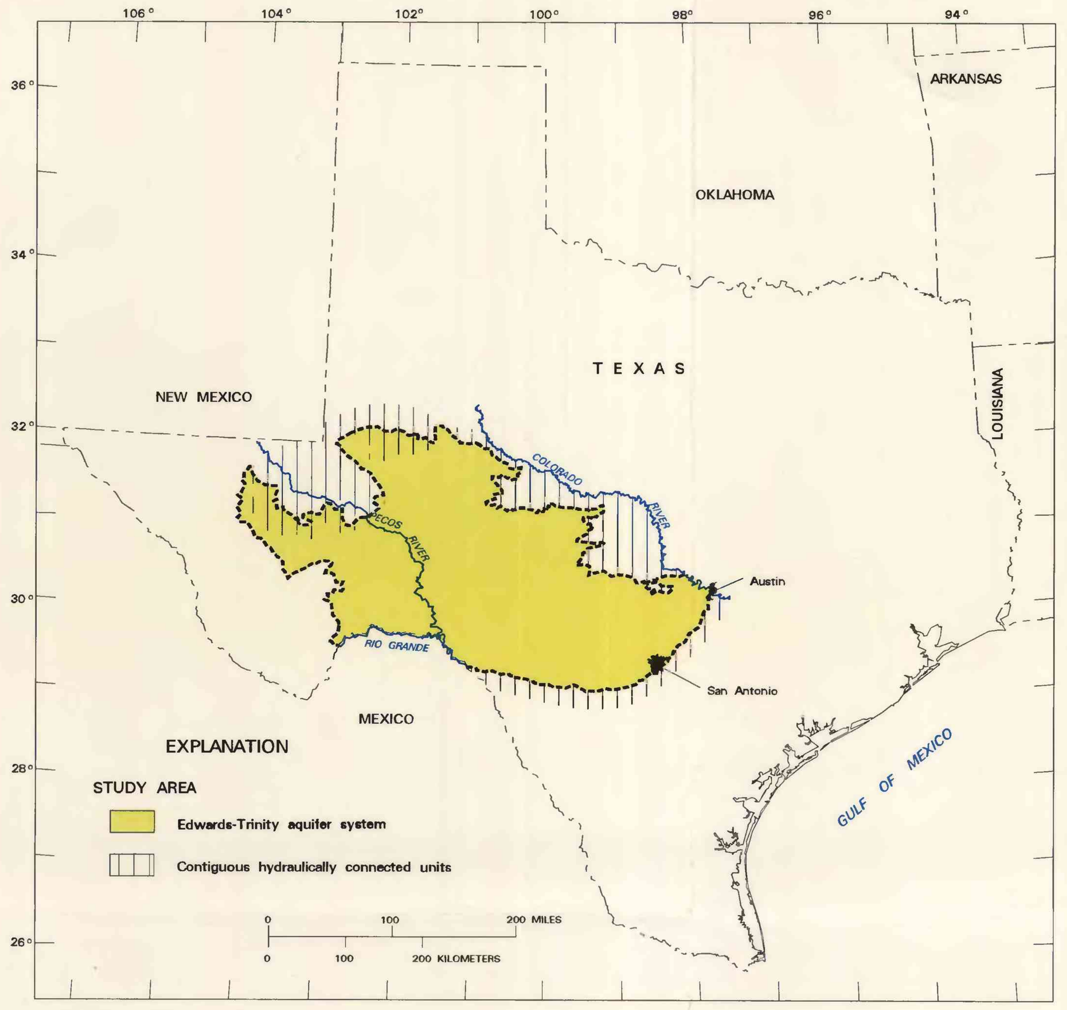


Figure 1. Study area of the Edwards-Trinity Regional Aquifer-System Analysis.

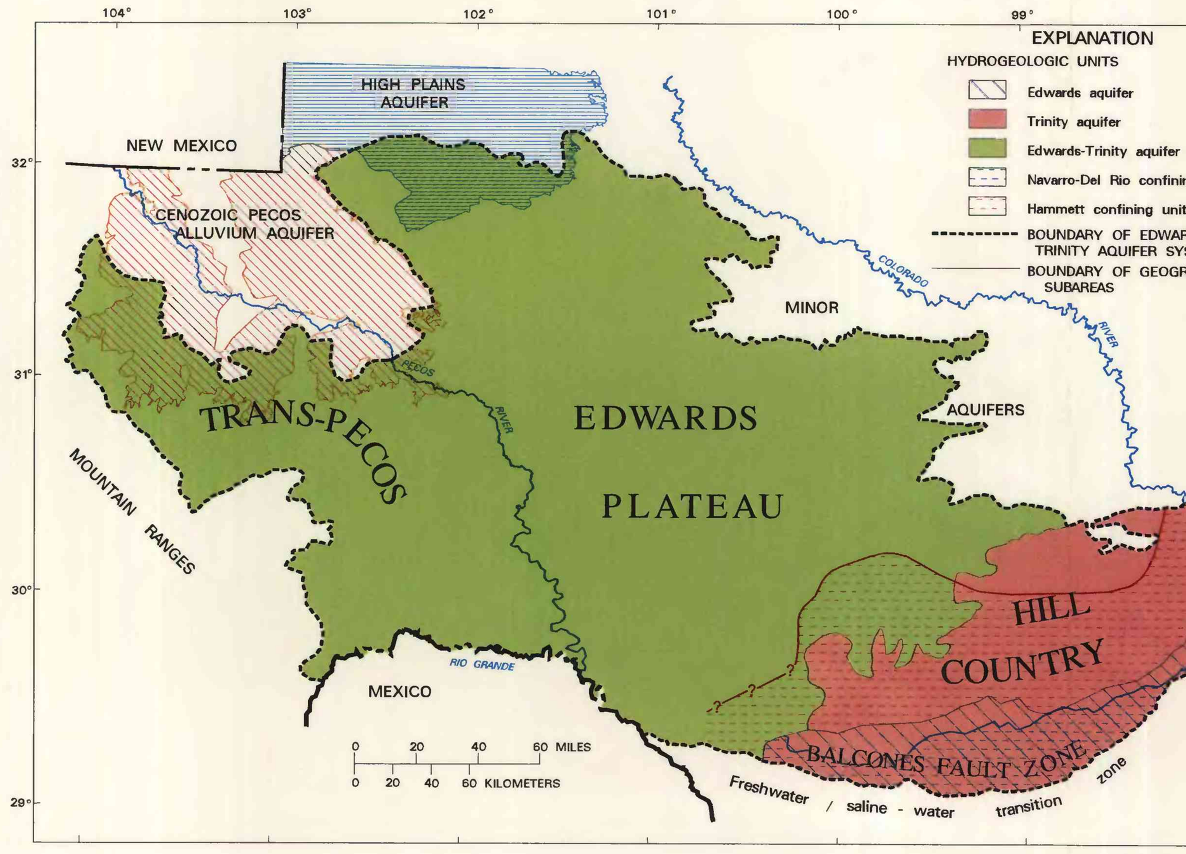


Figure 2. Regional hydrogeologic units and geographic subareas of the Edwards-Trinity aquifer system.

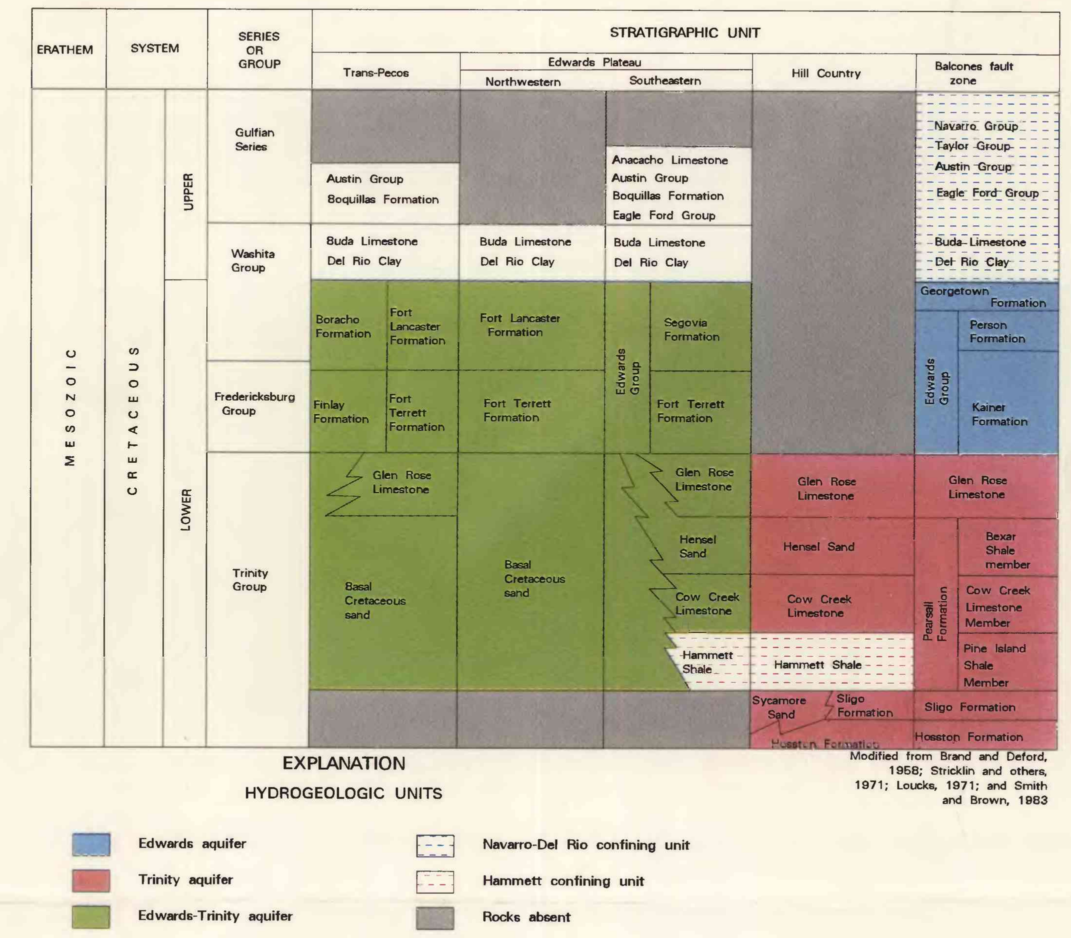
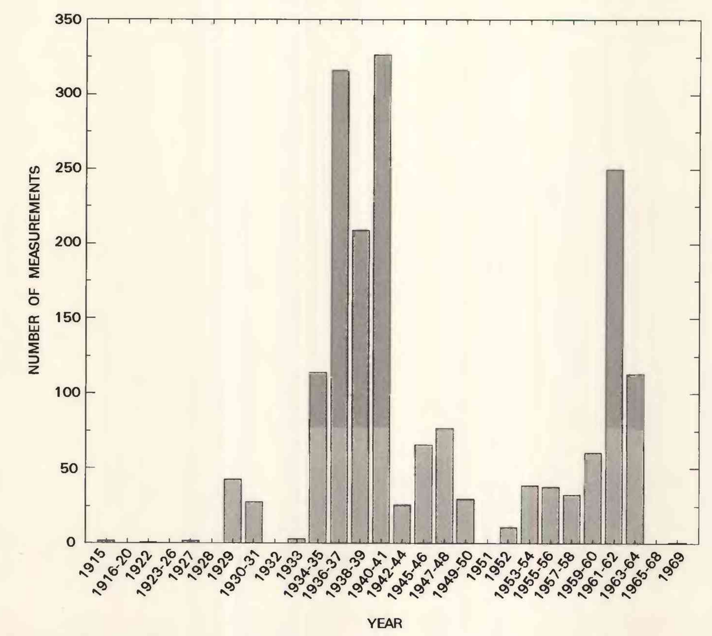


Figure 3. Generalized correlation chart of the rocks that compose or directly overlie the Edwards-Trinity aquifer system.



Time distribution of water-level measurements

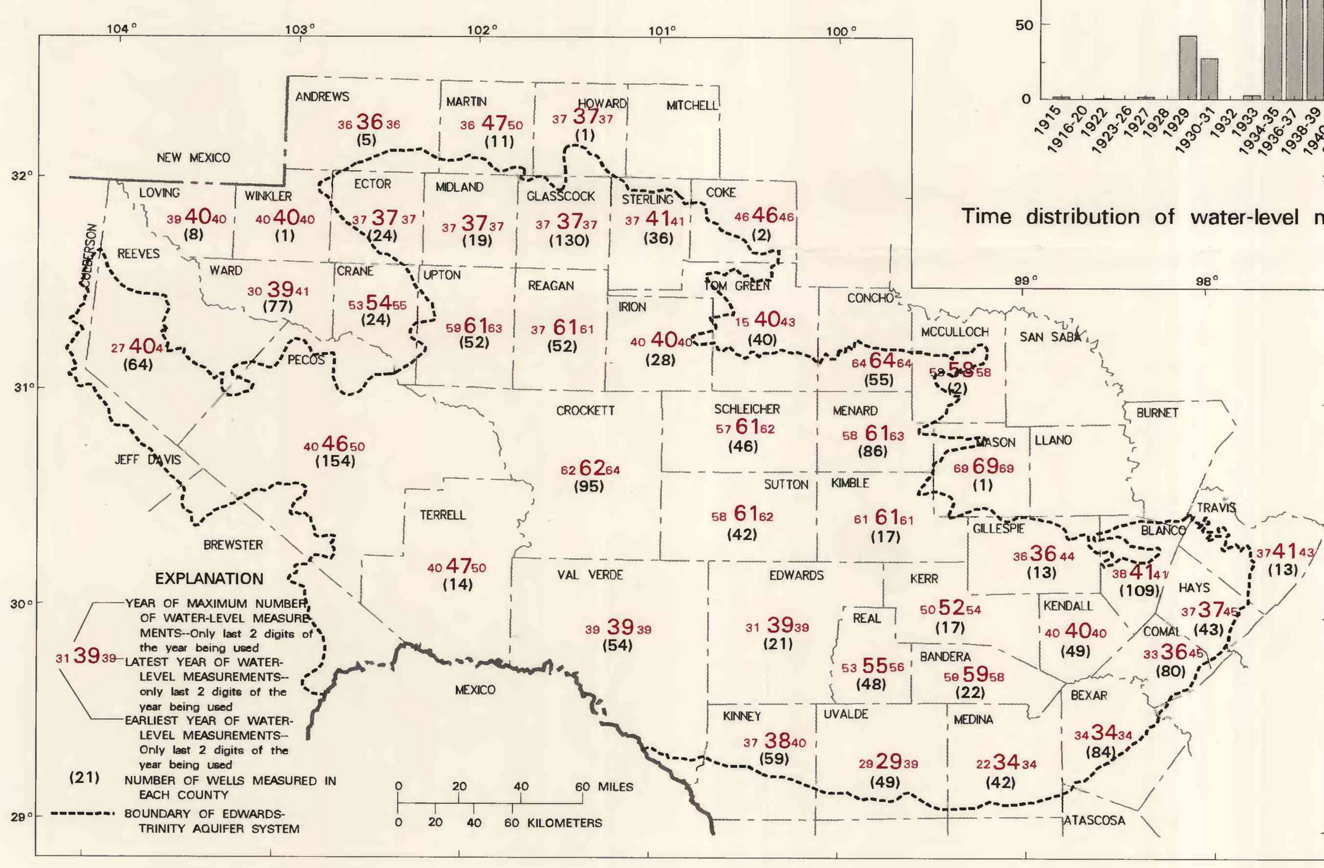


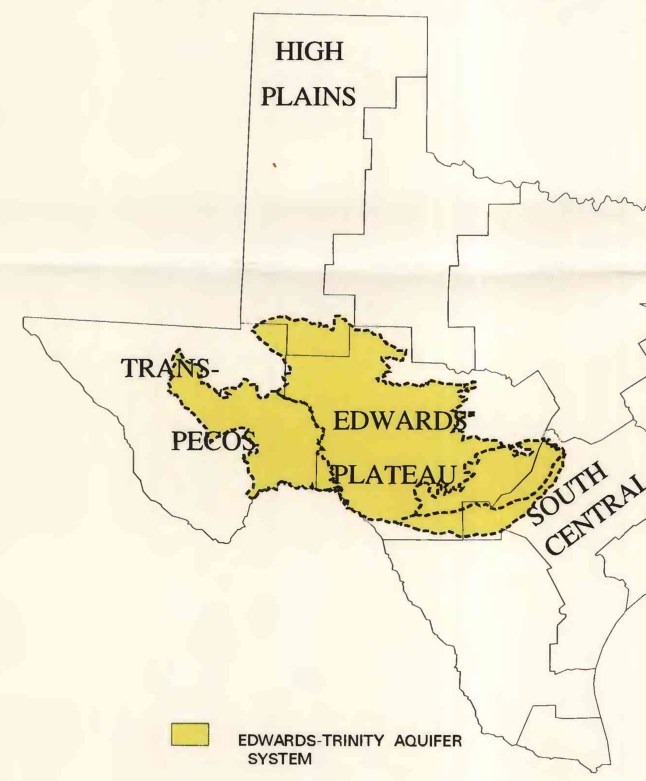
Figure 4. Years of water-level measurements used to construct the historical potentiometric-surface map.

EXPLANATION

RAINFALL CONDITION DESCRIPTOR	RAINFALL CONDITION INDEX NUMBER
Extremely wet	3
Very wet	2
Moderately wet	1
Near normal	0
Moderately dry	-1
Very dry	-2
Extremely dry	-3

The height of the bars represents departure from normal of total seasonal rainfall by year. Winter comprises December, January, February; spring comprises March, April, May; summer comprises June, July, August; and fall comprises September, October, November. The descriptors represent ranges of rainfall defined for each season and each climatic division based on frequency analyses of rainfall for the period 1895-1985 (Karl and Knight, 1985a, b, c, d).

The line through the bars shows the five-season moving average of rainfall conditions. The index numbers associated with the descriptors were arbitrarily assigned in order to make the bar and line graphs.



Climatic divisions associated with the Edwards-Trinity aquifer system (Modified from Riggio and others, 1987, fig. 12)

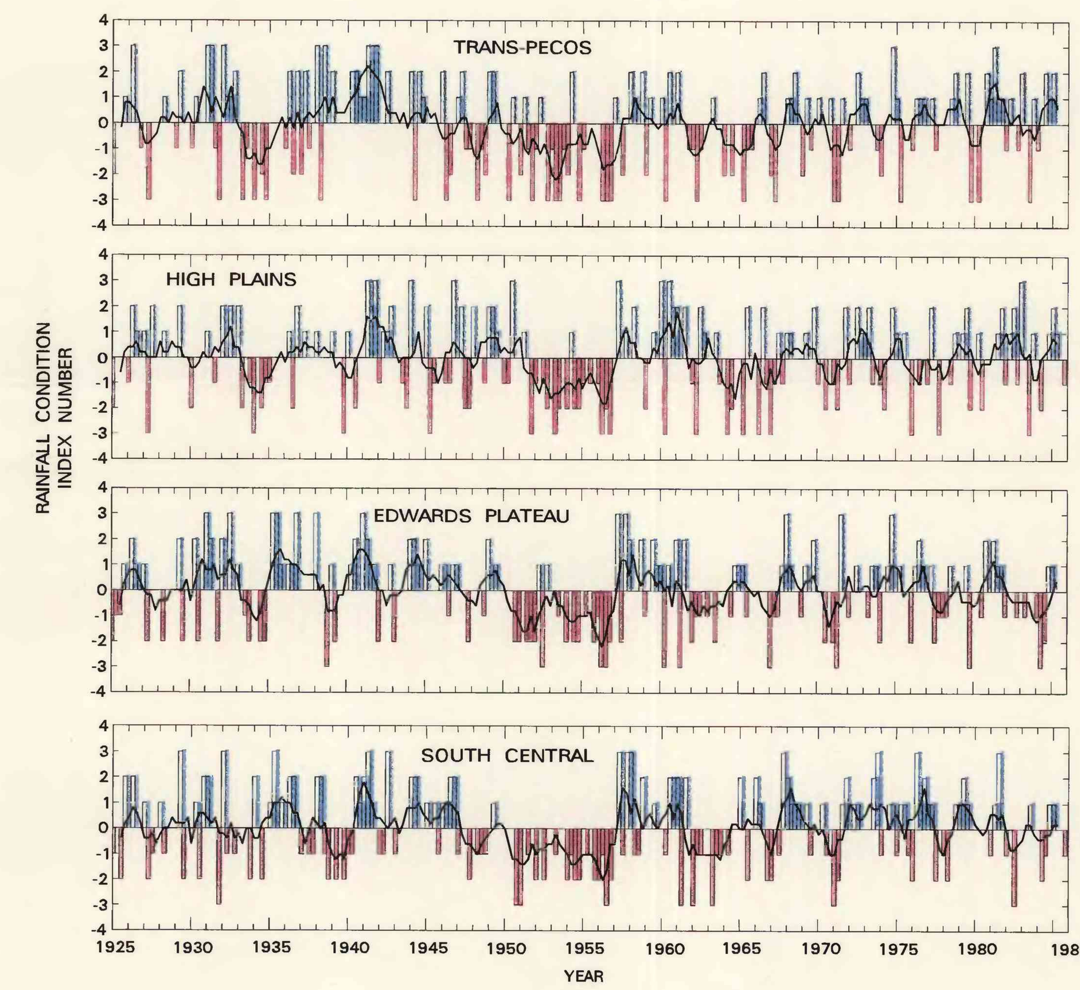


Figure 5. Rainfall conditions by season and climatic divisions, 1925-85.

HISTORICAL POTENTIOMETRIC SURFACE OF THE EDWARDS-TRINITY AQUIFER SYSTEM AND CONTIGUOUS HYDRAULICALLY CONNECTED UNITS, WEST-CENTRAL TEXAS

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